KERN ENERGY
We Fuel the Future

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November 1, 2024

Mr. John Stagnaro
Director of Compliance
San Joaquin Valley Air Pollution Control District
1990 E. Gettysburg
Fresno, CA 93726

Subject: **Kern Energy (Facility No. S-37)**
Revised Fenceline Monitoring Plan

Dear Mr. Stagnaro,

Kern Energy (Kern) respectfully submits the enclosed document, "*Kern Energy Fenceline Monitoring Plan*," dated November 1, 2024, for your review and approval. Kern prepared this plan in accordance with San Joaquin Valley Air Pollution Control District (District) Rule 4460 amended October 20, 2022 and the associated guidance from the District.

Kern is prepared to implement the plan, including procuring equipment and commencing steps to install the monitoring system to meet the Rule 4460 requirement to have the system operational within 365 days of District approval of the plan.

If you have questions, please contact Gabe Castro at (661) 845-0761 or by email at gcastro@kernenergy.com.

Sincerely,

Melinda Palmer
Vice President – Regulatory & Public Affairs
Kern Energy

San Joaquin Valley
Unified Air Pollution Control District

CERTIFICATION OF TRUTH AND ACCURACY

Company Name:	**Kern Energy**	FACILITY ID:	**S - 37**

CERTIFICATION:
I declare, under penalty of perjury under the laws of the state of California, that, based on information and belief formed after reasonable inquiry, all information provided in this reporting package is true, accurate, and complete:

Signature of Responsible Official

November 1, 2024
Date

Melinda Palmer
Name of Responsible Official (please print)

Vice President- Regulatory & Public Affairs
Title of Responsible Official (please print)

Kern Fenceline Monitoring Plan for Rule 4460

KERN ENERGY
We Fuel the Future

Monitoring Plan Prepared for the
San Joaquin Valley Air Pollution Control District
Bakersfield, CA

November 1, 2024

Kern Fenceline Air Monitoring Plan for Rule 4460

Prepared by

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Air Monitoring Plan

November 1, 2024

STI-923014-7393

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1. Rule 4460 Summary

On December 19, 2019, the San Joaquin Valley Air Pollution Control District (SJVAPCD or District) adopted Rule 4460, "Petroleum Refinery Fenceline Air Monitoring."[1] Kern Energy (Kern) implemented the SJVAPCD-approved fenceline monitoring system on January 27, 2022, in accordance with the original requirements specified in Rule 4460. Kern continues to operate the fenceline monitoring system in accordance with the approved plan.

Subsequently, the rule was amended on October 20, 2022, with an expanded target compound list based on guidance from the California Air Resources Board (CARB) and California Air Pollution Control Officers Association (CAPCOA). Rule 4460 and its amendment requires petroleum refineries within the District to establish measurement systems at their facility fencelines (at or near the property boundary) and provide real-time air quality information to the public and to the District. Data must be collected by the monitoring systems in accordance with an approved fenceline monitoring plan (this document) that follows District guidelines. This version of the plan, dated July 1, 2024, has been updated in response to feedback from the District. Earlier versions were dated May 1, 2023, August 16, 2023, and July 1, 2024, which incorporated new Rule requirements and prior feedback from the District.

According to Rule 4460, the monitoring plan must provide detailed information on several elements to justify the measurement and data dissemination approach. Section numbers in the following list indicate where each element is discussed in this plan.

- A plan for monitoring pollutants based on an evaluation of routine emission sources at the refinery (Section 1). Given the refinery's processes and emissions, Kern Energy will monitor many of the required pollutants highlighted in the Rule 4460 guidelines, including sulfur dioxide (SO_2), hydrogen sulfide (H_2S), BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), acetaldehyde, ammonia, 1,3-butadiene, formaldehyde, naphthalene, and nitrogen dioxide (NO_2).
- A summary of fenceline air monitoring instruments proposed to continuously measure, record, and report air pollutant levels in real-time near the petroleum refinery facility perimeter (i.e., fenceline) (Section 2). *This plan relies on multiple open-path and point instruments to satisfy Rule 4460 requirements.*
- Proposed monitoring equipment siting and selected pathways for fenceline instruments, including the justification for selecting specific locations (Section 2). *This plan covers paths along the important refinery fencelines and has accounted for the measurements of all chemical species for which measurements have been deemed justified based on refinery processes and expected concentration levels.*

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[1] San Joaquin Valley Air Pollution Control District (2019) Rule 4460: Petroleum refinery fenceline air monitoring. Final rule adopted December 19, 2019. Available at https://www.valleyair.org/rules/currntrules/4460.pdf.

- A summary of equipment used to measure and continuously log wind speed and wind direction data within the facility boundaries (Sections 2 and 4).
- Procedures for maintenance of all fenceline monitoring equipment. These procedures include routine maintenance requirements and timelines of periodic maintenance; length of monitoring equipment downtime during maintenance (when equipment is not operational); and temporary air monitoring measures that will be implemented should equipment fail and be used until normal operating conditions are restored (Section 5).
- Procedures for implementing quality assurance including independent audits of the fenceline monitoring system (Section 6 and **Appendix A**). *This plan includes a detailed Quality Assurance Project Plan (QAPP).*
- Methods for the distribution of data collected by the fenceline monitoring system to the public, local response agencies, and the District. (Sections 7 and 8). *This plan provides the key content of a web system for disseminating information and an email-based public notification system.*

1.1 Summary of Kern Energy

Kern Energy is an independent refining and marketing company located at 7724 E. Panama Lane, Bakersfield, CA 93307. As shown in **Figure 1**, the area within several miles of Kern is flat, mostly agricultural land, with two main rural, residential communities of Lamont and Fuller Acres located to the south and northeast of Kern, respectively. This area of the Central Valley often has winds flowing from the northwest and less often flowing from the southeast; other flow directions are much less frequent.

Kern is an important producer and supplier of California-approved gasoline and diesel fuel. Kern employs about 190 people and is committed to providing a safe working environment while working diligently to provide cleaner fuels. Kern's crude oil refining capacity is approximately 26,000 bpd. Kern processes light, sweet crude oil, which is low in sulfur. In addition, it produces renewable diesel from biomass, and blends additional volumes of biodiesel. Kern also produces an intermediate fuel oil stream, and a small quantity of sulfur as a co-product.

The facility layout with major process and storage areas is shown in **Figure 2**. There are no residences immediately adjacent to the facility process or storage areas. The main process area is located in the north-central area of the facility. Storage tanks are located on the west side of the facility (product storage tanks are in the areas labeled 12 and 13 in Figure 2), across Weedpatch Hwy on the east side of the facility (crude oil storage tanks are in the area labeled 1 in Figure 2), and in the central area of the facility.

In response to the amended Rule 4460 monitoring requirements (compounds listed in Table 2), Kern will continue to monitor SO_2, H_2S, and BTEX compounds, and will add instruments to measure acetaldehyde, ammonia, 1,3-butadiene, formaldehyde, naphthalene, and NO_2. A summary of 2022 emissions inventory estimates for several of these compounds is provided in Table 1.

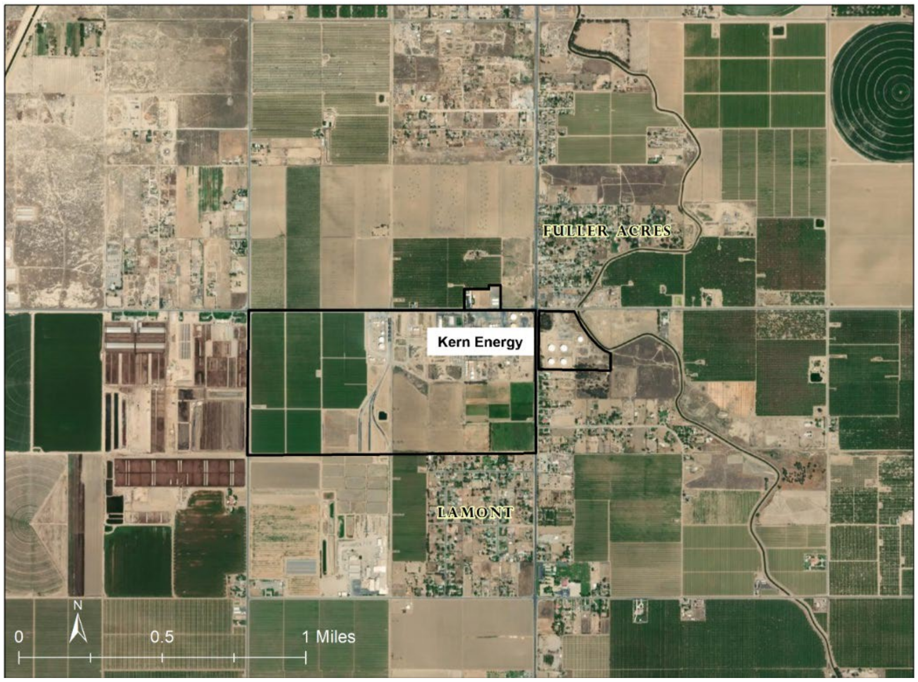

Figure 1. Location of the Kern Energy facility and surrounding communities.

Figure 2. Map of the Kern Energy facility showing the general layout. Neighboring residences are also visible to the northeast, east, and south.

Table 1. A summary of reported emissions that contain Rule 4460 compounds.

Compound	2022 Emissions (tons/year)
VOC	38.3
SO_x	6.1
NO_x	39.4
NH_3	729.5

1.2 Summary of Monitoring Plan for Kern Energy Refinery

Kern's monitoring and data reporting system will meet many important Amended Rule 4460 requirements. Key elements include:

- Kern will measure required species including acetaldehyde, ammonia, 1,3-butadiene, formaldehyde, naphthalene, BTEX, SO_2, and H_2S.
- Instruments that will be used to measure these species will include open-path Ultraviolet-Differential Optical Absorption Spectroscopy (UV-DOAS) instruments for BTEX, naphthalene, NO_2, and SO_2; open-path Fourier-Transform Infrared (FTIR) for the remaining non-methane hydrocarbons; and ultraviolet (UV) fluorescence point analyzers for H_2S. The instruments are capable of measuring these pollutants in real time. Meteorological parameters and visibility will also be measured.
- Kern will monitor concentrations across 4 open paths and 4 point monitor locations. These paths and point locations are shown in Figure 3. The monitoring will cover fenceline locations along the northeast, east, and south sides of the main facility, as well as the north and south sides of the adjacent crude tank farm. Kern selected these locations after analyzing wind patterns, sources of potential air emissions on the refinery property, nearby local receptors, and logistical feasibility. These locations will provide coverage for nearby downwind communities under typical and atypical wind patterns.
- Data will be collected and averaged as needed to produce a data point every 5 minutes.
- The data will be subjected to real-time automatic data quality control, and these preliminary data will be delivered to the public via a website within 10-15 minutes of collection. The data will also be used for any public notifications via an opt-in email notification system.
- Kern will perform more detailed quality control on a quarterly basis to produce final datasets and will make these data available within 45 days after the end of each calendar quarter.
- Kern will provide the District with quarterly data reports that will include a summary of periods when the instruments were inoperative, a list of routine maintenance periods, the

nature of any repairs and adjustments, a summary of the data and health thresholds, data completeness, and any special quality control efforts beyond those described in the QAPP. Hard copies of the report will be provided to the public at the refinery on an appointment basis.

- Kern's public website will provide real-time data, historic data for the most recent annual quarter, frequently asked questions (FAQs), links to additional resources, and a feedback mechanism for the public.
- Notifications will be issued when thresholds are exceeded or when major activities affect the monitoring or reporting system.
- Kern will operate and maintain equipment in accordance with a District-approved QAPP and associated standard operating procedures (SOPs).
- Kern will provide annual independent reviews of the instruments to validate instrument performance. Internal audits and system checks will occur as part of regular operations and maintenance.
- Kern will provide temporary monitoring only during extended equipment downtimes (>96 hours) using 24-hr volatile organic compound (VOC) canister sampling. Note, canister sample laboratory analysis is carried out using the U.S. EPA method TO-15, which can only quantify concentrations of BTEX compounds. Extended downtimes are not anticipated and attempts to avoid them will be made.
- Kern will maintain all data records and chain-of-custody information for 5 years, consistent with other data record-keeping requirements.

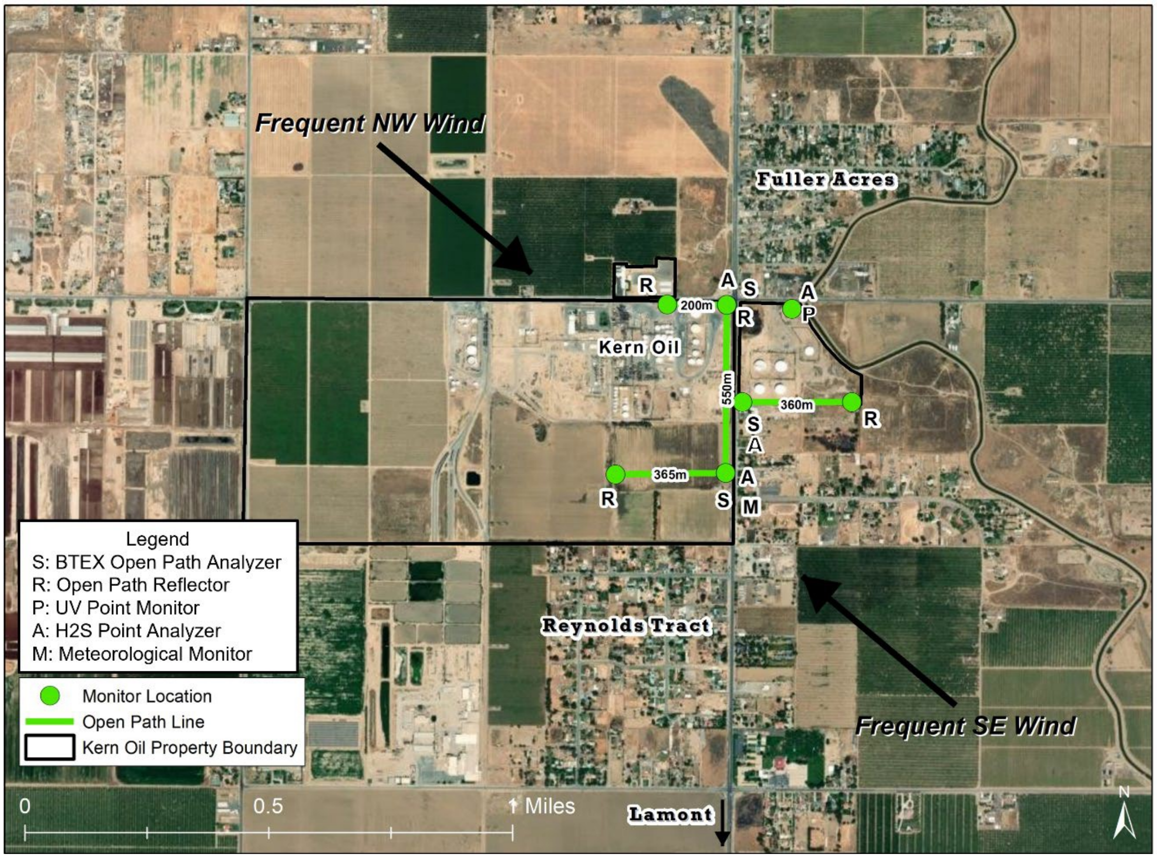

Figure 3. Monitoring paths for the Kern refinery in relation to the refinery equipment and property boundary. Note, instrument locations are not exact.

1.3 Justification for Pollutant Monitoring List

The list of pollutants required to be considered for monitoring as part of the Amended Rule 4460 is shown in Table 2. From the list of pollutants identified in Table 2, Kern proposes to add acetaldehyde, ammonia, 1,3-butadiene, and formaldehyde to the Kern fenceline monitoring network. The existing monitors for BTEX, SO_2, and H_2S will remain in service. The four additional compounds that will be added to the network can be measured by open-path FTIR analyzers. Kern will install three FTIR analyzers next to the existing UV-DOAS analyzers. Naphthalene and NO_2 will be measured by the existing UV-DOAS analyzers along each fenceline path.

In addition to the original fenceline monitors, Kern will install UV-DOAS and H_2S analyzers along the northern and southern edges of the crude tank farm. These will be used to monitor for BTEX, SO_2, and H_2S. Because the tanks are only used to store crude oil and no processing occurs on this side of the Kern Energy facility, no FTIR analyzers will be placed here to monitor for additional compounds.

The proposed monitoring actions to be taken by Kern for each of the compounds listed in Amended Rule 4460 are summarized in Table 2 below.

Table 2. List of pollutants included in Amended Rule 4460 and a summary of the fenceline monitoring approach proposed by Kern Energy.

Pollutant	Proposed Approach
Acetaldehyde	Add open-path FTIR analyzers
Ammonia	Add open-path FTIR analyzers
Benzene	Measure with UV open-path analyzers and point monitors
1,3-Butadiene	Add open-path FTIR analyzers
Cadmium	Not to be monitored given low health risk
Diethanolamine	Not to be monitored given lack of use at facility and absence of real-time monitoring capability
Ethylbenzene	Measure with UV open-path analyzers and point monitors
Formaldehyde	Add open-path FTIR analyzers
Hydrogen Fluoride	Not to be monitored given lack of use at facility
Hydrogen Sulfide	Measure with point monitors
Manganese	Not to be monitored given low health risk
Naphthalene	Measure with open-path UV analyzers
Nickel	Not to be monitored given low health risk
Nitrogen Oxides	Measure with open-path UV analyzers
Polycyclic Aromatic Hydrocarbons	Measure naphthalene with open-path UV analyzers
Particulate Matter	Not to be monitored; facility not a significant source
Sulfur Dioxide	Measure with UV open-path analyzers and point monitors
Sulfuric Acid	Not to be monitored given lack of use at facility and absence of real-time monitoring capability
Toluene	Measure with UV open-path analyzers and point monitors
Xylenes	Measure with UV open-path analyzers and point monitors

Kern’s proposed fenceline monitoring system has been tailored based on various factors deemed sufficient justification to provide appropriate monitoring of facility emissions specific to Kern’s operation. Compounds to be excluded from fenceline monitoring and their exclusion criteria are:

Diethanolamine – Kern does not use diethanolamine in its refining processes to remove H_2S from natural gas, and therefore would not have measurable emissions. Furthermore, the only currently known method for measuring and quantifying diethanolamine is through the use of offline filters, which then require laboratory-based analysis. Given that this monitoring does not meet the Rule

4460 requirements for continuous, real-time monitoring displayed on the public website, Kern cannot add this pollutant to the fenceline monitoring system.

Cadmium, Manganese, and Nickel – Kern used the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD)[2] and CARB HARP[3] air dispersion and risk modeling tool to estimate the maximum offsite metals concentrations and the health risks from the refinery operating under maximum operation conditions. The results of these analyses showed that the maximum predicted concentrations of cadmium, manganese, and nickel were well below the health-based standards for sensitive receptors downwind and near the fenceline of the facility (see Section 3.2). The modeled health risk was below one-in-a-million for residential cancer risk. Results also showed a Hazard Index value below 1.0 at both acute and chronic thresholds, meaning the results are below the levels of toxicity. Figure 4 contains maps showing the health risks in and around Kern Energy at various distances from the facility.

Further, the 1-hr maximum risk for these three metals were all at least one order of magnitude lower than chronic or 8-hr reference exposure levels (REL) set by the California Office of Environmental Health Hazard Assessment (OEHHA). In addition, for Cadmium specifically, the model results show a maximum concentration lower than the detection limit of the energy dispersive X-ray fluorescence (EDXRF) analyzer that is commercially available to provide continuous metals measurements.

Therefore, these metals are not expected to be emitted from the refinery at levels that would pose any risk to public health or be measurable in any significant or detectable quantities by the fenceline monitoring system, and will be excluded.

Hydrogen Fluoride (HF) – The Kern facility does not have any alkylation processes and does not use HF at the facility. Absent any source of HF, no emissions are expected to be emitted from the refinery or measurable by the fenceline monitoring system.

Polycyclic Aromatic Hydrocarbons (PAHs) – Kern is not aware of any commercially available analyzer that can provide real-time measurements of total PAHs with accuracy comparable to non-real-time quantification methods. A continuous photoelectric aerosol sensor for particle-bound PAH identification is not highly selective, cannot be easily calibrated,[4] and does not provide information on the more abundant, gas-phase PAHs.[5] It is therefore not well suited for this fenceline monitoring application.

Recent studies have shown an overall decrease in PAH concentrations in California, even in areas near refineries.[6] In addition, naphthalene has been reported as the most abundant PAH, and is most

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[2] https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod

[3] https://ww2.arb.ca.gov/resources/documents/harp-air-dispersion-modeling-and-risk-tool

[4] Wallace, Lance (2005) Real-Time Measurements of Black Carbon Indoors and Outdoors: A Comparison of the Photoelectric Aerosol Sensor and the Aethalometer, Aerosol Science and Technology, 39:10, 1015-1025, DOI: 10.1080/02786820500365363

[5] Masri S, Li L, Dang A, Chung JH, Chen JC, Fan ZH, Wu J. (2018) Source characterization and exposure modeling of gas-phase polycyclic aromatic hydrocarbon (PAH) concentrations in Southern California. Atmospheric Environment. Mar 1;177:175-86.

[6] http://www.aqmd.gov/docs/default-source/planning/mates-v/mates-v-final-report-9-24-21.pdf

frequently associated with refinery emissions compared to other PAHs.[7] Given this information, and the fact that the currently operating UV-DOAS systems are capable of providing continuous measurements of naphthalene, we propose to monitor for naphthalene and begin reporting these concentrations to the public. No additional PAHs will be monitored.

Particulate Matter (PM) – Because Kern does not operate fluidized catalytic cracking units (FCCU) or a coker unit at this facility, the refinery is not expected to be a significant source of PM concentrations in the region. To assess potential PM concentrations, Kern also performed AERMOD and HARP modeling analysis. The model assumed the same maximum operating conditions noted above for metals. Modeling analyses showed that 24-hour maximum PM concentrations from the Kern facility were much lower than regional background PM concentrations, and significantly lower than the 24-hour National Ambient Air Quality Standards (NAAQS). More specifically, the maximum daily PM_{10} concentration from the facility was 4 µg/m^3 (compared to regional background values of 121 µg/m^3), and the maximum $PM_{2.5}$ concentration was 4 µg/m^3 (compared to regional background values of 10 µg/m^3). Results are summarized in **Table 3**. A map showing the dispersion of PM concentrations moving further away from the facility is found in **Figure 5**. Based on these results, PM measurements will be excluded from the fenceline monitoring system.

Sulfuric Acid – The Kern facility does not have any alkylation processes that use sulfuric acid at the facility. Also, HARP analysis showed that the 1-hr maximum concentrations are several orders of magnitude below the acute REL for sulfuric acid. Furthermore, Kern is not aware of any monitoring methods that provide continuous measurements of sulfuric acid. Given the lack of use at this facility, the absence of a real-time measurement technique for monitoring, and minimal health impact, Kern will exclude sulfuric acid from the fenceline monitoring system.

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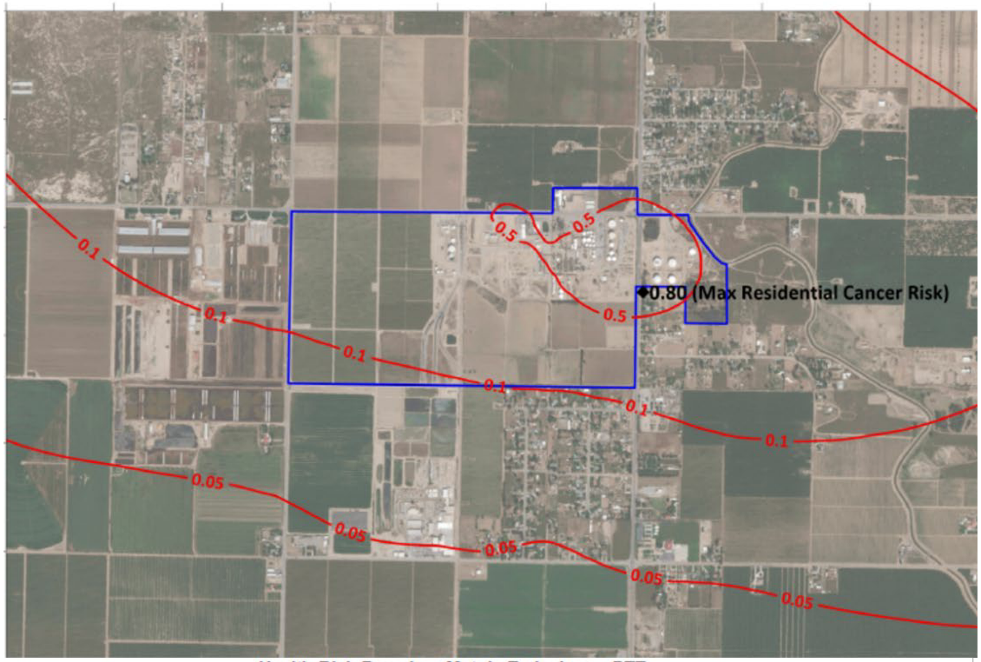
[7] https://oehha.ca.gov/media/downloads/faqs/refinerychemicalsreport032019.pdf

Health Risk Based on Metals Emissions - PTE
Residential Cancer Risk (per Million)



Health Risk Based on Metals Emissions - PTE
Chronic Risk (Hazard Index)

Figure 4. Maps showing AERMOD/HARP model results of health risks based on maximum metals emissions for sensitive receptors near the Kern Energy facility. The Kern facility is outlined in blue. For all residents and workers near the facility, the maximum potential residential cancer risk is less than one-in-a-million (top panel), and the Hazard Index is less than 1.0 (bottom panel).

Table 3. AERMOD/HARP model results of maximum PM_{10} and $PM_{2.5}$ concentrations from the Kern facility compared to regional PM concentrations and the NAAQS. Kern Energy is not predicted to be a significant source of PM concentrations in the region.

Pollutant	Modeled Max. 24-hr Concentration Emissions (µg/m^3)	Regional Background Concentration (µg/m^3)	24-hr NAAQS (µg/m^3)
PM_{10}	4	121	150
$PM_{2.5}$	4	14	35

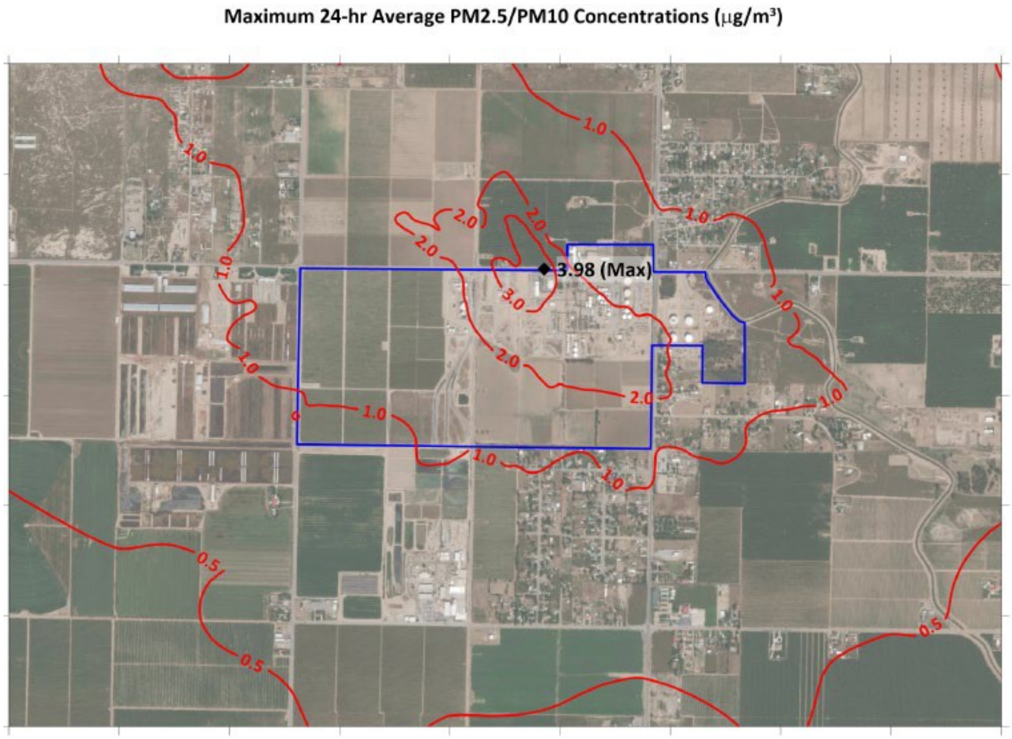


Figure 5. Map illustrating AERMOD/HARP model results of maximum PM concentrations at and near the Kern Energy facility. Estimated concentrations are well below the regional PM concentrations, as well as the NAAQS.

2. Summary of the Monitoring Network and Reporting System

This section describes the sampling locations, paths, and analyzer types selected for the fenceline monitoring system, and the specifications and maintenance requirements for each instrument. The compounds that will be monitored along each path/location are also provided. Point monitors were chosen for H_2S as open-path technology has not been proven to have a consistent minimum detection limit (MDL) below the California OEHHA acute exposure threshold of 30 ppb. Therefore, open-path technology will not be used to measure H_2S.

Kern will monitor concentrations across 4 open paths and 4 point monitoring locations (Figure 6). The Figure 6 legend indicates the type of monitor that will be placed at each location. The paths are described in Table 4, and specific monitor locations are listed in Table 5. The monitoring plan also includes a meteorological station equipped with sensors that measure visibility, wind speed and direction, temperature, and relative humidity.

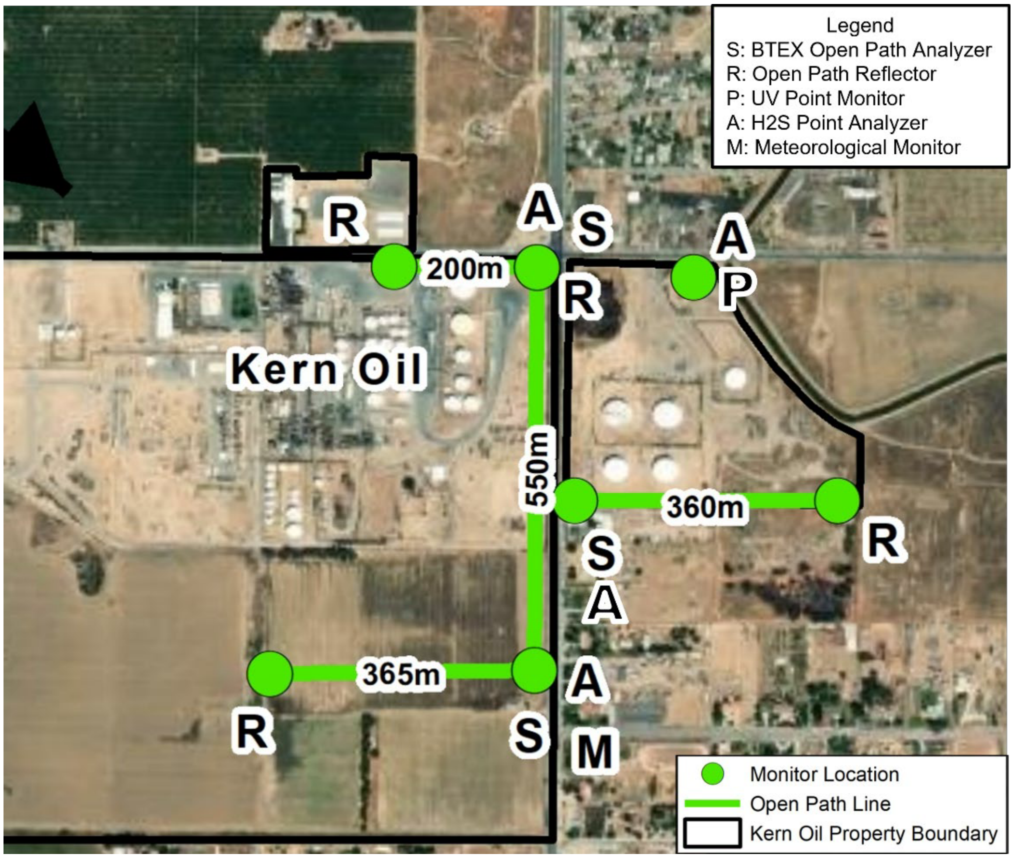


Figure 6. Locations of monitors covering the important fencelines around Kern.

Table 4. General monitoring locations, path lengths, and height above ground level where equipment is mounted.

Path #	Monitor Location Description	Path Length (m)	Analyzer Height (m)	Retroreflector Height (m)
1	Open path East-West along North boundary of main facility	200	2	7
P1	Point monitor in Northeast corner	-	-	-
2	Open path North-South along East boundary; Meteorological station	550	2	7
P2	Point monitor in Southeast corner	-	-	-
3	Open path East-West along South boundary of main facility;	365	2	7
4	Open path East-West along Southern boundary of crude tank farm	360	2	7
P3	Point monitor along northern boundary of crude tank farm	-	-	-
P4	Point monitor in the southwest corner of crude tank farm	-	-	-

Table 5. Specific monitor locations.

Position	Monitoring Equipment	Lat.	Long.
Northeast	• UV-DOAS open-path analyzer pointing west; another UV-DOAS analyzer pointing south • FTIR open-path analyzer pointing west; FTIR analyzer pointing south • UV fluorescence point analyzer	35.2959690	-118.9146818
Northwest	UV and FTIR open-path reflectors	35.2959670	-118.9168370
Southeast	• UV-DOAS open-path analyzer pointing west • FTIR open-path analyzer pointing west • UV fluorescence point analyzer • Meteorological monitor • Open-path reflector	35.2909736	-118.9146596
Southwest	UV and FTIR open-path reflectors	35.2909009	-118.9186648
Crude Tank North	• UV-DOAS point analyzer • UV fluorescence point analyzer	35.295929	-118.912380
Crude Tank Southwest	• UV-DOAS open-path analyzer pointing west • UV fluorescence point analyzer	35.293097	-118.914059
Crude Tank Southeast	UV open-path reflectors	35.293055	-118.909947

Fenceline monitoring paths were chosen after considering dominant wind patterns (most frequently from the northwest and from the southeast), sources of potential air emissions on the refinery property, and nearby local receptors. Transmitter-detectors/analyzers will be located at sites labeled "S" (identified in Figures 3 and 6), and retroreflectors (mirrors) will be placed at the sites labeled "R". Retroreflectors for UV analyzers consist of an array of 27 quartz cubes, while FTIR reflectors consist of arrays of 40-90 gold-plated corner cubes, depending on path length (longer paths require more cubes). Point analyzer locations are denoted with an "A." Analyzers and reflectors are mounted approximately 2 – 7 m above ground level. The following is Kern's rationale for selecting the monitoring locations identified in Figures 3 and 6.

- Overall, measurement locations cover the areas where nearby downwind receptors are located, and were chosen based on the analysis in Section 3.
- Paths along the northeast, east, and south sides of the refinery cover all nearby downwind communities, including Fuller Acres to the northeast, low-density rural housing to the east, and Lamont to the south. The nearest sensitive receptors west of the facility are several miles away.
- The north fenceline path is adjacent to the Crude and Cogen units and the Gasoline and Diesel tank farms and covers the main entrance into the refinery for truck and vehicle traffic. This path will include measurements from both UV-DOAS and FTIR open-path analyzers, and a point analyzer in the northeast corner will collect measurements of H_2S.
- The east fenceline path sits on the eastern side of Weedpatch Highway near the diesel tank farm and crude oil tanks. This path provides coverage of nearby low-density housing located southeast of Kern under the dominant northwesterly flow and Fuller Acres under infrequent southwesterly flow. Measurements will be provided from UV-DOAS and FTIR open-path analyzers, and a point analyzer in the northeast corner will collect measurements of H_2S.
- The south fenceline path provides coverage for the residential area at the southern edge of the refinery property and the community of Lamont. Measurements will be provided by UV-DOAS and FTIR open-path analyzers, and a point analyzer for H_2S measurements near the southeast corner of the refinery property boundary.
- Monitors in the crude tank farm, which sits to the east of the main refinery area, are being added to provide coverage for nearby receptors. Along the north side of the crude tank farm, point monitors for BTEX, SO_2, and H_2S provide coverage for the Fuller Acres neighborhood. On the southern edge of the crude tank farm, an open-path UV-DOAS and H_2S point monitor will provide coverage for the low-density housing area just to the south.
- A meteorological station will also be positioned at the southeast corner for wind flow that is unobstructed by trees or structures. Visibility measurements will be included here to identify instances of low-level Tule fog that will limit the ability of the open-path analyzers to detect transmitted light.

- Monitoring was not deemed necessary on the western property boundary because winds do not commonly originate from this direction and there are no downwind nearby sensitive receptors.

3. Local Topography, Meteorology, Local Communities, and Sensitive Receptors

To provide a fenceline monitoring network that best serves the community, the following factors were considered: (1) the characteristics of the refinery location, including topography and meteorology, (2) emissions types and source areas, (3) locations of nearby communities and sensitive receptors, and (4) spatial coverage of the monitors. Based on these considerations, monitoring along the northeast, east, and south boundaries of the main facility, and the north and south boundaries of the crude tank farm provide the measurements to capture potential impacts of facility emissions on nearby residences.

3.1 Topography and Meteorology

Kern is located in a rural area outside of Bakersfield at the southern end of the San Joaquin Valley. The San Joaquin Valley extends northwest several hundred miles to the Sacramento River Delta. About 30 miles to the west lies the Coast Range that divides the Central Valley and the Pacific Ocean. Several mountain passes exist through the Coast Range throughout the San Joaquin Valley. To the northeast and east is the Sierra Nevada mountain range that abruptly rises to several thousand feet, with peaks above 10,000 feet. Roughly 10 miles to the south, the Tehachapi Mountain range bounds the southern end of the San Joaquin Valley. These strong geographic features greatly influence the local weather patterns.

Two dominant wind flow patterns influence the transport of facility emissions with some seasonal variations. In the spring, summer, and early fall, winds most often blow from the northwest toward the southeast. These winds are driven by large-scale weather patterns, the channeling of flow by the regional topography, and strong temperature gradients between the coastal areas of California and the Central Valley. The winds blowing from the northwest are often strongest in the afternoon and evening and lighter overnight and in the morning hours. Sometimes, especially overnight and during morning hours, the winds reverse direction and come from the southeast. The reverse winds are typically driven by or reinforced by drainage flow from the Sierra Nevada. Occasionally in the winter, the southeast winds can be driven by winter storm systems. Calm or light and variable winds also occur and are most frequent in the overnight and morning hours and more often occur in the winter.

Radial histograms (wind roses) were prepared to provide the frequencies of wind speeds and directions (i.e., annual mean wind direction distributed by 30-degree arcs) by season using data from December 2016 through November 2019. **Figures 7 through 11** show the 3-yr average annual wind rose and seasonal wind roses using wind data recorded at the Bakersfield Municipal Airport, which is about 10 miles northwest of the refinery. Key findings are summarized as follows:

- **Northwest winds (winds blowing from the northwest to the southeast)**: Northwest winds occur about 40% of the time annually. Winds from these directions are most common in spring, summer, and early fall. The downwind receptors under these conditions include the eastern side of Lamont and scattered residences southeast of the facility.
- **Southeast winds (winds blowing from southeast to the northwest)**: Southeast winds occur about 15% of the time annually. There are no nearby receptors downwind of the facility during southeasterly wind flow.
- **Calm or light winds (0 to 1 mph speed)**: These conditions occur about 20% of the time. Under these conditions, it is possible that air could flow through the northeast corner of the facility toward Fuller Acres, given the community’s proximity to the facility.
- **All other wind directions**: Winds from other directions occur with lesser frequencies and account for the remaining 25% of the flow directions. Under northerly winds, scattered residences to the south of the facility are downwind. There are no other nearby receptors for other wind directions.

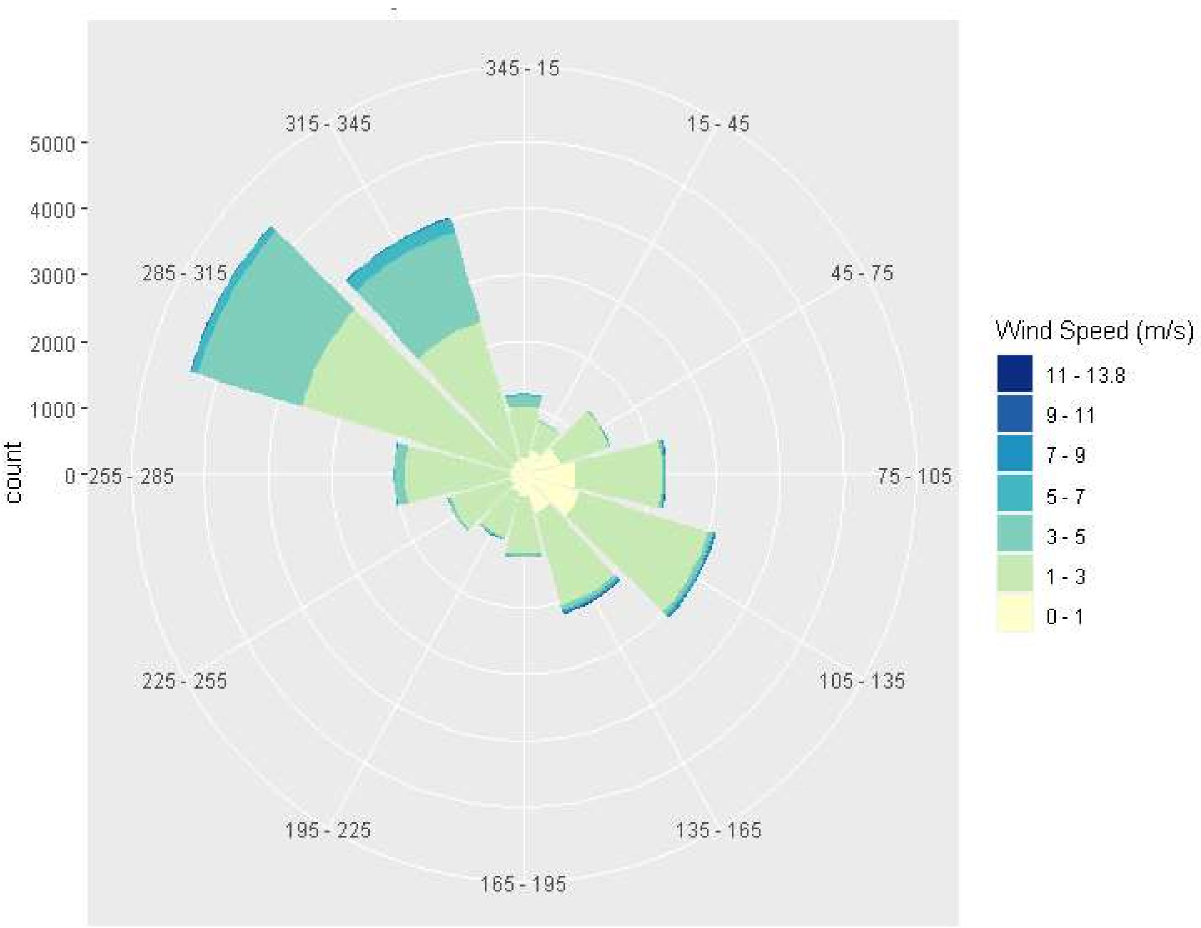


Figure 7. Annual (December 2016 through November 2019) wind rose for Bakersfield Municipal Airport. Source: U.S. Environmental Protection Agency's (EPA) AirNow-Tech.

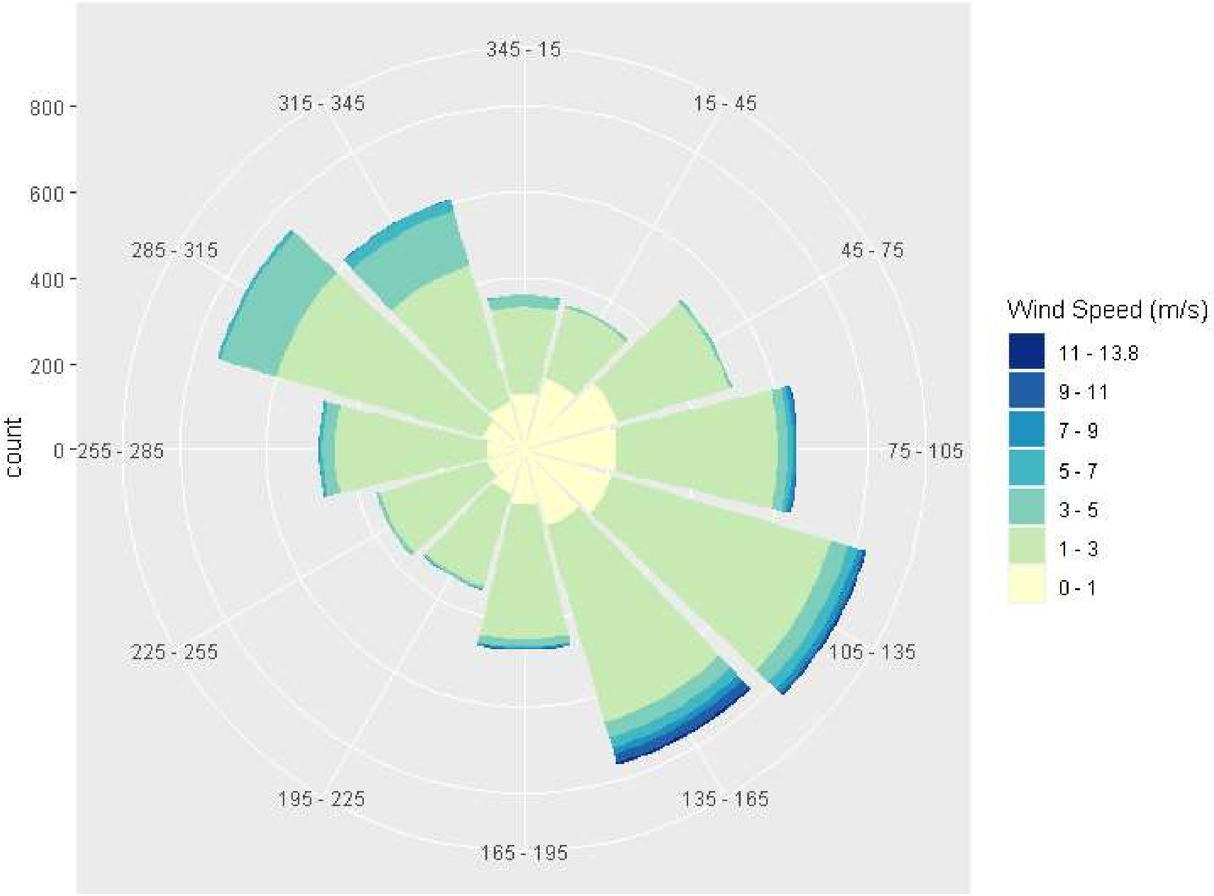


Figure 8. Winter (December through February) 2017-2019 wind rose for Bakersfield Municipal Airport. Source: EPA's AirNow-Tech.

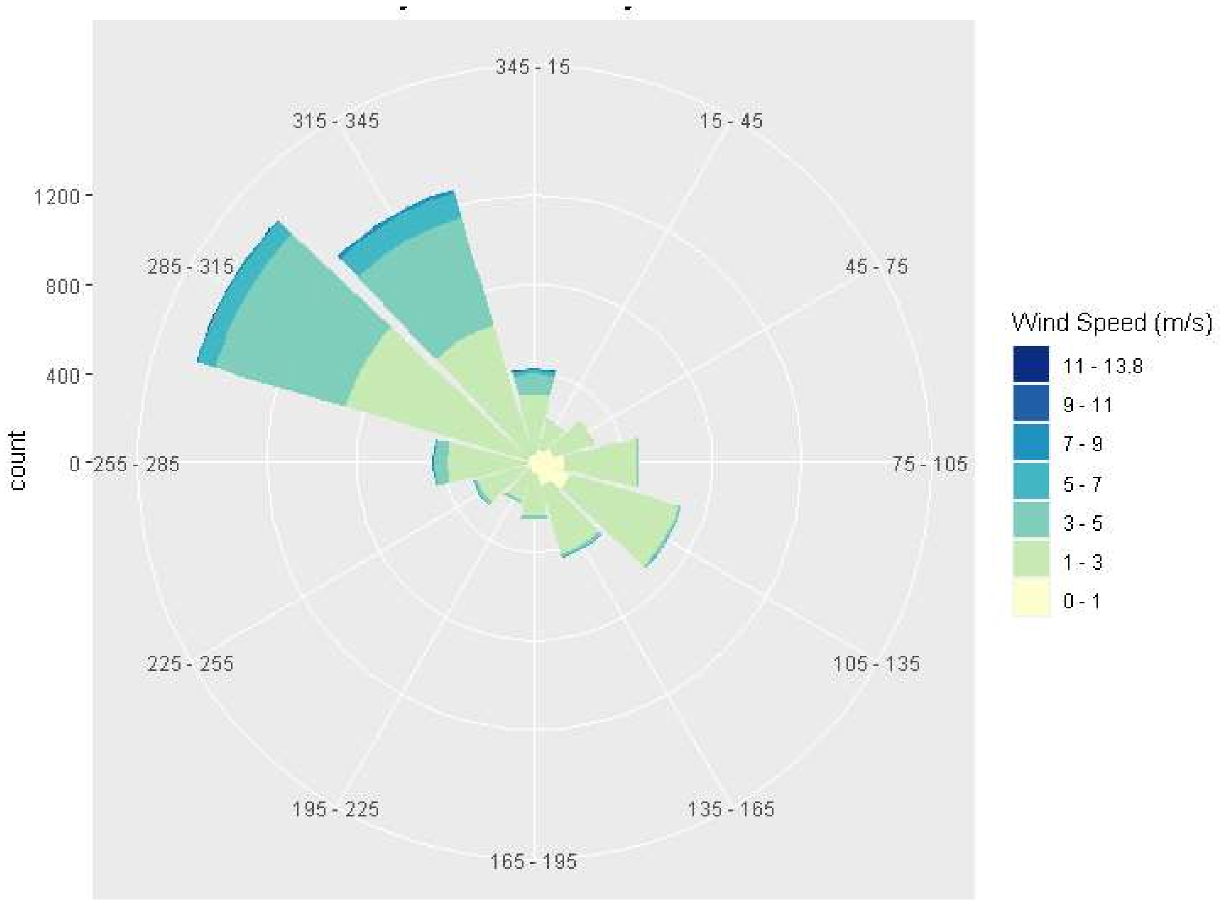


Figure 9. Spring (March through May) 2017-2019 wind rose for Bakersfield Municipal Airport. Source: EPA's AirNow-Tech.

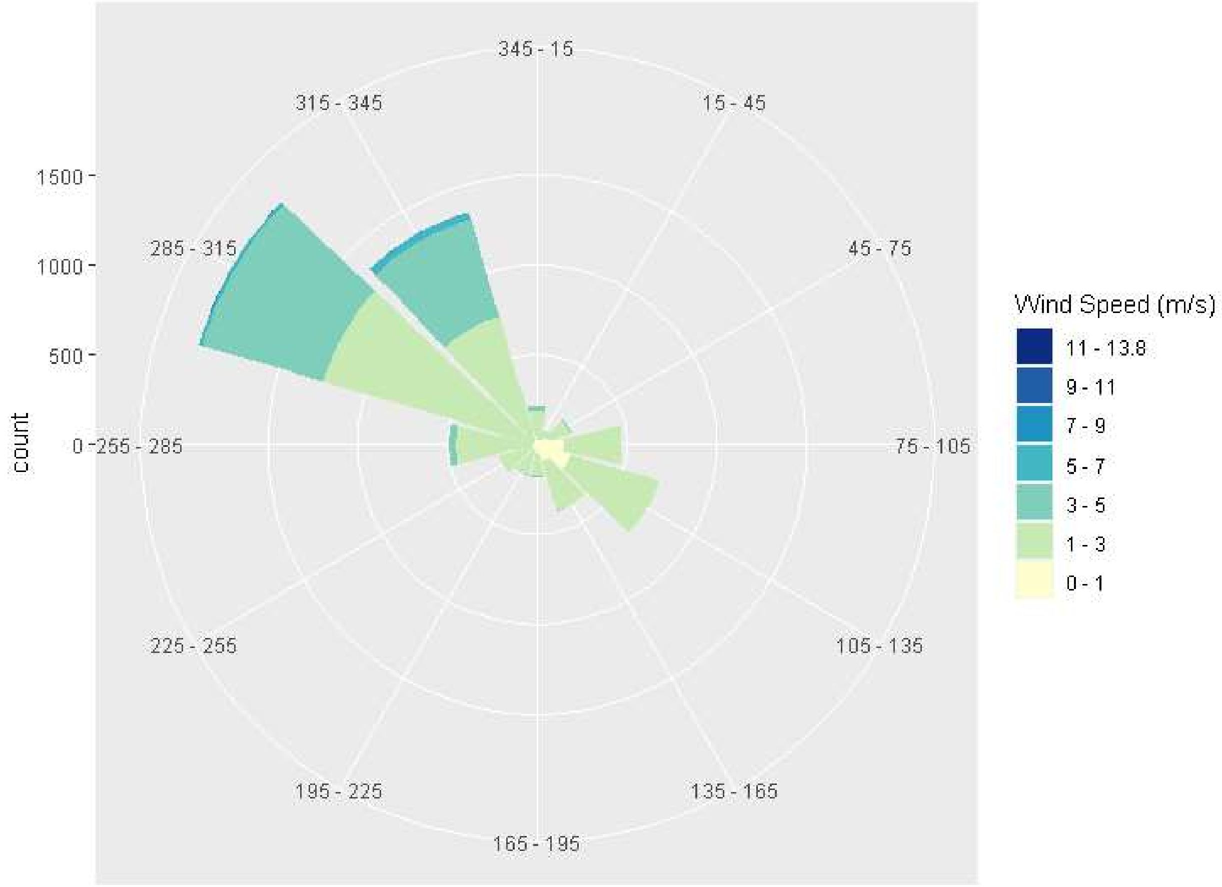


Figure 10. Summer (June through August) 2017-2019 wind rose for Bakersfield Municipal Airport. Source: EPA's AirNow-Tech.

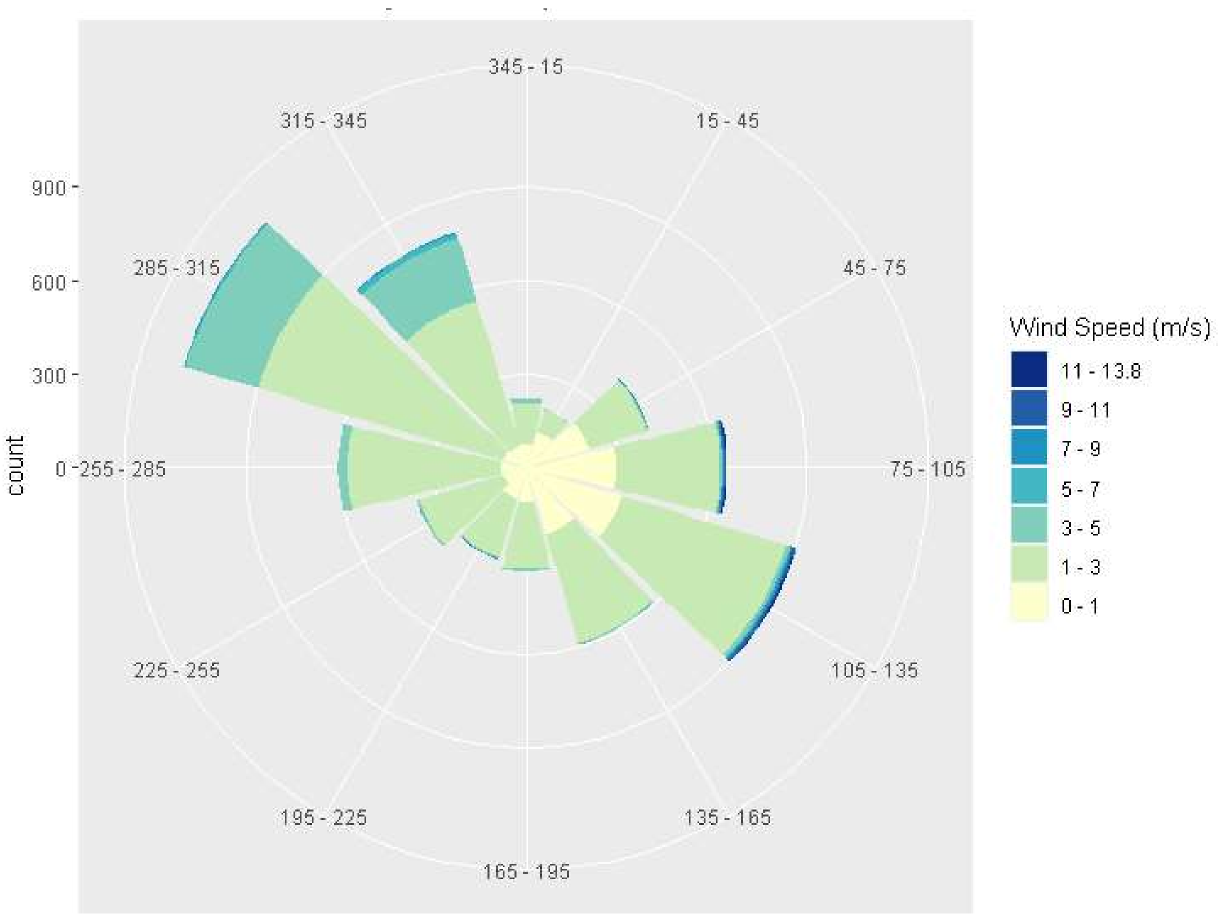


Figure 11. Fall (September through November) 2017-2019 wind rose for Bakersfield Municipal Airport. Source: EPA's AirNow-Tech.

3.2 Community and Sensitive Receptors

The nearby-populated public areas of Fuller Acres and Lamont represent air quality "receptor" communities that may be downwind from Kern. In addition to these areas, sensitive receptors were evaluated for all surrounding areas within about four miles of the facility. Sensitive receptors include daycare centers, youth centers, adult care facilities, hospitals, clinics, nursing homes, recreation areas, libraries, museums, and churches. Sensitive receptor data was collected from two main sources: https://www.infousa.com/ and the U.S. Geographic Names Information System (GNIS) via Esri Data and Maps for ArcGIS, 2018. Figure 12 shows the location of the nearby sensitive receptors with respect to the refinery. Few sensitive receptors are located within a mile of the facility. Most receptors are in Fuller Acres or Lamont, which are approximately two miles from the facility. There are no nearby sensitive receptors located to the west of the facility within about 4 miles.

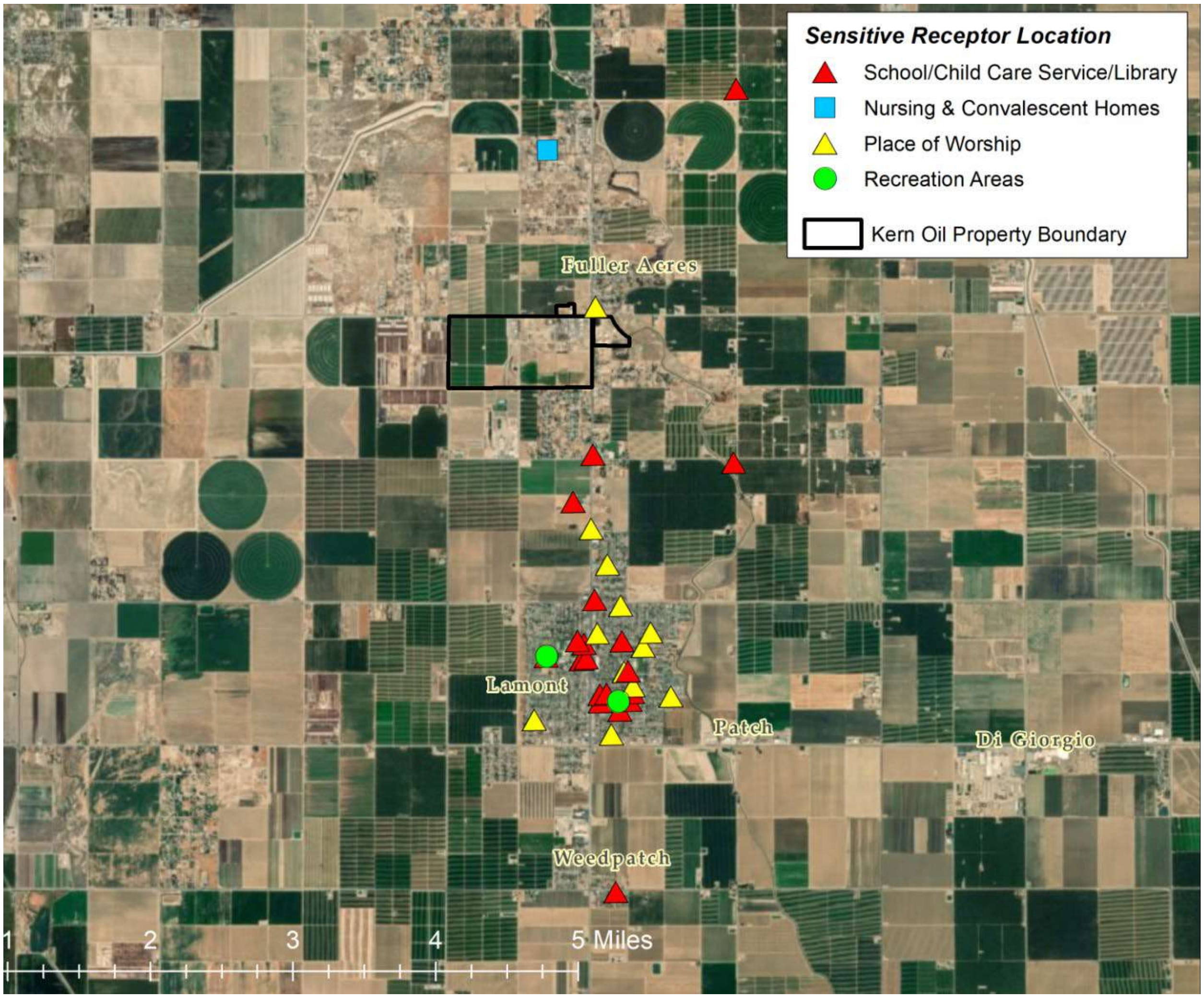


Figure 12. Locations of sensitive receptors near the Kern Refinery.

4. Details of Monitoring Equipment

Literature reviews, site surveys, and interviews with instrument manufacturers were performed to determine the instruments needed to meet the revised Rule 4460 requirements. Both fixed-site and open-path instruments were investigated. In light of the current state of measurement technology, Cerex UV-DOAS and FTIR open-path instruments, along with a UV-DOAS point monitor, were selected to measure hydrocarbons, ammonia, NO_2, and SO_2. Teledyne UV fluorescence point monitors were selected to measure H_2S.

4.1 Instrument Specifications

Along the measurement paths (see Section 2), BTEX, naphthalene, NO_2, and SO_2 will be measured by monostatic Cerex UV Sentry UV-DOAS instruments with a xenon light source. Acetaldehyde, ammonia, 1,3-butadiene, and formaldehyde will be measured by a monostatic Cerex Air Sentry FTIR open-path analyzer. Both analyzers can achieve measurements over paths that are about 300 to 600 meters long at adequate MDLs. For both systems, the principle of operation is similar. The analyzer records the intensity of UV or infrared (IR) light reflected back from a retroreflector array at discrete wavelengths. Any UV- or FTIR-absorbing gas that is present in the light beam absorbs at a specific wavelength of light. Each gas has a unique absorbance fingerprint (i.e., the ratios between the 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 and uses a classical least squares regression analysis to compare the measured and calibrated reference spectra. Beer's Law is used to report accurate gas concentrations. Although the approach specified in the U.S. Environmental Protection Agency's (EPA) TO-16 Methodology[8] was not written specifically for UV-DOAS (or was intended for FTIR), the approach is the same.

A schematic showing the light source/analyzer and the retroreflector array is shown in **Figure 13**. The figure also illustrates that the analyzers record a concentration across the entire path length. Monostatic (as opposed to bistatic) open-path instruments have been selected to reduce the need for substantial power at the retroreflector sites and improve minimum detection limits by increasing effective path lengths. Thus, only the light-source/detector end of the monitoring path requires substantial power, communications, and shelter. Limited power is needed for heaters at the retroreflectors. The retroreflector needs to be aligned at the other end of the path for maximum performance and will be cleaned regularly to ensure optimum performance. Retroreflectors arrays for UV analyzers contain 27 quartz cubes, and FTIR reflector arrays consist of between 40 and 90 gold-

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[8] 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.

plated corner cubes, depending on path length (longer paths require more cubes to achieve detection limits).

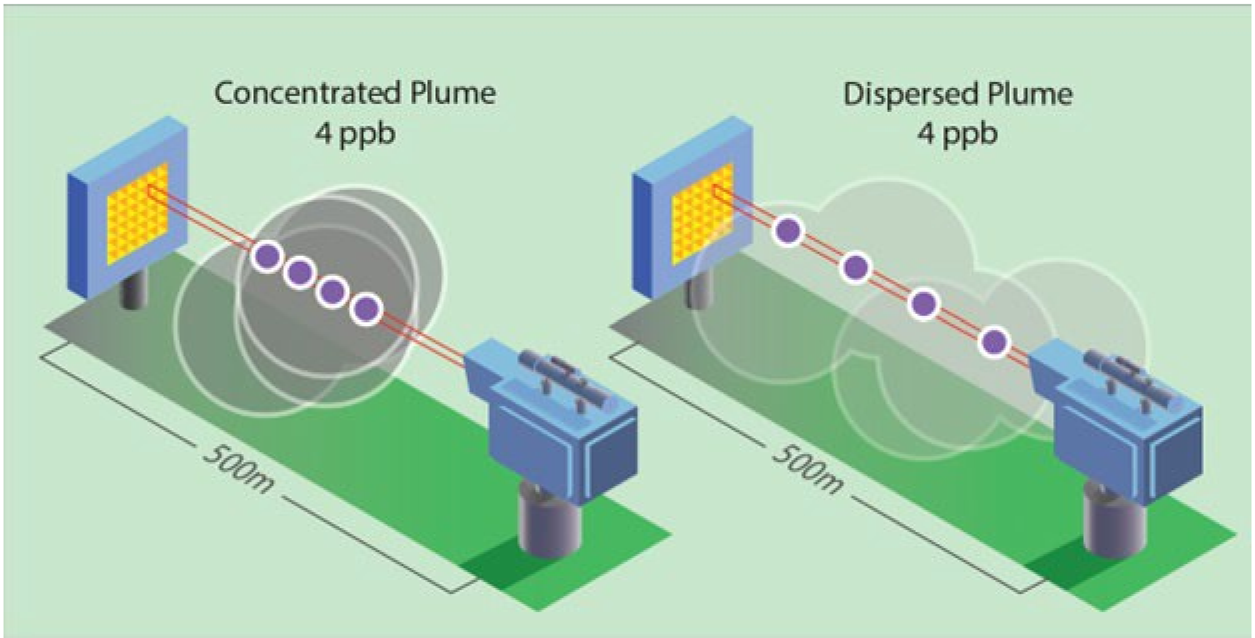


Figure 13. Schematic of an open-path monitoring system, depicting two types of path-integrated plumes measuring the gas concentration.

A point monitor version of the UV Sentry will be used to measure BTEX and SO_2 along the north side of the crude tank farm. This system operates similarly to the open-path UV-DOAS instrument; however, the optical path is shorter, at approximately 20 m, than the longer paths achieved by using a retroreflector.

For H_2S concentrations, a point analyzer will be used, providing concentration information at the instrument location. The analyzer is based on UV fluorescence principles to detect H_2S at levels typical of ambient air monitoring. In this method, UV radiation excites chemicals in an object and causes them to release visible light, which can then be detected.

4.2 Pollutant Detection Limits

Table 6 summarizes the instrument specifications, including detection limits. The detection limits listed are approximate and are based on the theoretical capabilities of the instruments; however, they are supported by manufacturers’ lab tests and real-world applications.

Actual detection limits will depend on atmospheric conditions and on the specific instrument brand used. Periods of poor visibility due to weather-related conditions (e.g., fog) are known to interfere with open-path measurements. Rule 4460 anticipates some data loss due to poor visibility and allows for such data loss if supported by visibility measurements. The Refinery will monitor visibility using a standard extinction measurement to identify periods of poor visibility that may cause data loss. For each of the meteorological sensors, operating ranges are provided. To provide context in relation to health benchmarks, the OEHHA chronic and acute Reference Exposure Levels (RELs) are also provided in Table 6. The analyzer detection limits are adequate for each of the gas species to be monitored as part of Rule 4460.

Table 6. Instrument specifications and the detection limit for each of the analyzer's detection methods compared to OEHHA health benchmarks.

Analyzer & Detection Method	Compounds Measured	Instrument Detection Limit*	OEHHA Chronic REL (ppb)	OEHHA Acute 1-hr REL (ppb)
Teledyne T101 - UV Fluorescence	H_2S	<0.5 ppb	7.2	30.1
Cerex UV Hound - UV-DOAS	Benzene	< 3.0 ppb	0.9	8.5
	Toluene	< 3.0 ppb	79.6	9812
	Ethylbenzene	< 10 ppb	460.6	-
	Xylenes	< 8.0 ppb (m); < 3.0 ppb (o); < 1.0 ppb (p)	161.2	5067
	SO_2	< 3.0 ppb	-	251.9
Cerex UV Sentry - UV-DOAS	Benzene	<0.5 ppb	0.9	8.5
	Toluene	<1.0 ppb	79.6	9812
	Ethylbenzene	<0.5 ppb	460.6	-
	Xylenes	<0.5 ppb (m/p); <4.0 ppb (o)	161.2	5067
	SO_2	<1.0 ppb	-	251.9
	Naphthalene	<0.5 ppb	1.7	-
	Nitrogen Dioxide	<4.0 ppb	-	250
Cerex Air Sentry - FTIR	Acetaldehyde	<1.0 ppb	77.7	261
	Ammonia	<0.5 ppb	287.1	4594
	1,3-butadiene	<1.0 ppb	0.9	298
	Formaldehyde	<0.5 ppb	7.3	45.5
Campbell Scientific CS120a - Infrared Forward-Scattering	Visibility	Range = <20 ft to 46 miles	-	-
RM Young - Resistance Thermometer Capacitive Polymer	Temperature	Temp range = -39.2 to 60°C	-	-
	Relative humidity	RH range = 0.8% to 100%		
RM Young - Wind Vane	Wind speed	Wind speed: 0-50 m/s	-	-
	Wind direction	Azimuth: 0-360 degrees		

*Open-path detection limits are based on a typical path length of 500 m.

5. Operations and Maintenance

Instrument operations, maintenance, and bump tests include daily checks to ensure that data are flowing consistently, as well as monthly, quarterly, and annual maintenance activities. Further details are provided in the following sections, which describe routine instrument and data management operations. Additional details and documentation, including standard operating procedures (SOPs) are included in the finalized Quality Assurance Project Plan (QAPP, Appendix A). Modest adjustments to the operating plans may be needed, depending on operational conditions.

5.1 Open-Path UV-DOAS

The UV-DOAS system requires only modest service and maintenance. Table 7 summarizes typical UV-DOAS maintenance activities as recommended by a manufacturer. Preventive maintenance frequency depends on the operating environment and may need to be adjusted beyond manufacturers' recommendations once the instruments are deployed in the field. System status alarms will alert operators to specific issues needing to be addressed. Bump tests will be performed on site.

Table 7. Schedule of routine maintenance activities for UV-DOAS open-path analyzers.

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

Activity	Monthly	Quarterly	Annually
Replace light source if diagnostics are outside the acceptable range		✓	
Replace ventilation exit and intake filters		✓	
Clean detector optics		✓	
Confirm the alignment of the light source and detector		✓	
Verify system settings			✓

5.2 Open-Path FTIR

The FTIR requires maintenance activities similar to the UV-DOAS and is also designed to require only modest service and maintenance. Table 8 summarizes the maintenance activities for an FTIR system, as recommended by a typical manufacturer. Preventative maintenance frequency depends on the operating environment and may need to be adjusted. System status alarms may alert operators to specific issues that need to be addressed. Bump tests will be performed on site.

Table 8. Schedule of routine maintenance activities for FTIR open-path analyzers.

Activity	Monthly	Quarterly	Annually	2 Yrs	5 Yrs
Visually inspect the system	✓				
Inspect detector and retroreflector optics; clean if necessary	✓				
Confirm the alignment of the light source/detector and retroreflector	✓				
Ensure that there are no obstructions between the light source/detector and retroreflector (e.g., refinery equipment, vegetation, or vehicles)	✓				
Archive historical data and remove from analyzer computer	✓				
Perform bump test		✓			
Inspect and clean exterior heat sink for AC system		✓			
Test and document signal levels to establish a baseline for light source and retroreflector replacement frequency			✓		
Replace cryocooler or swap detector module assembly				✓	
Replace the light source					✓

5.3 UV Fluorescence H_2S Analyzer

Table 9 describes typical maintenance actions for an H_2S point analyzer, such as cleaning and inspections, as well as their required frequencies for routine system management. Preventive maintenance ensures operational integrity and is strongly urged by the manufacturer. Frequency of maintenance checks may need to be adjusted beyond manufacturers' recommendations once operations begin.

Table 9. Schedule of maintenance activities for an H_2S UV fluorescence analyzer.

Activity	Monthly	Quarterly	Annually
Inspect sample line tubing	✓		
Inspect particle filter at inlet and replace as necessary	✓		
Perform zero/span check	✓		
Inspect particle filter inside analyzer and replace as necessary		✓	
Perform flow check		✓	
Perform gas test for analyzer response		✓	
Replace pump diaphragm			✓

5.4 UV-DOAS Point Analyzer

The UV-DOAS point monitor also requires only modest service and maintenance. **Table 10** summarizes typical maintenance activities as recommended by the instrument manufacturer. Preventive maintenance may need to be adjusted beyond manufacturers' recommendations once the instruments are deployed in the field. System status alarms will alert operators to specific issues to address. Bump tests will be performed on site.

Table 10. Schedule of maintenance activities for the UV-DOAS point monitor.

Activity	Monthly	Quarterly	Semi-Annually
Visually inspect the system	✓		
Inspect optics on analyzer; clean if necessary	✓		
Inspect system filters; replace as necessary	✓		
Confirm the alignment to verify sufficient signal	✓		
Archive historical data and remove from analyzer computer	✓		
Verify system signal after service		✓	
Check system performance indicators		✓	
Perform bump test 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		✓	
Change out the UV source			✓
Verify system settings			✓

5.5 Meteorological and Visibility Sensors

Meteorological sensors provide information about wind direction and speed to help determine sources of any air contaminants. The meteorological sensors will be maintained on a monthly and biannual basis. Table 11 lists the maintenance activities that will be performed.

Table 11. Schedule of maintenance activities for the meteorological tower.

Item	Activity	Monthly	Biannually
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	✓	

Item	Activity	Monthly	Biannually
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	✓	
All Sensors	Audit and calibrate		✓

Fog events may affect open-path measurements especially during the nighttime and early morning hours. Visibility measurements will be made to verify fog events. Maintenance activities for the visibility sensor are included in Table 12. Monthly maintenance includes inspecting the sensor for dirt, spiderwebs, birds' nests, or other obstructions and cleaning if necessary. There are no major serviceable components in the sensor. The sensors are calibrated annually in the field using a manufacturer-specific calibration kit.

Table 12. Schedule of routine maintenance activities for visibility sensors.

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

5.6 Additional Maintenance and Failure Activities

Normal routine scheduled maintenance for open-path instruments occurs once per month (at least). Instrument downtime for routine maintenance is expected to be less than four hours per month. During those maintenance visits, the operator will carry normal repair parts to the site.

If, between routine visits, monitors fail to report data or appear to report erroneous data, both remote diagnosis and, if necessary, a site visit will be conducted. If the problem cannot be resolved with the equipment or parts on hand, then Kern will obtain replacement parts from the vendor. Kern will keep some spare parts available for emergency repairs. It is expected that with these measures, the problem can be resolved by the next business day. If downtime exceeds more than 96 hours, integrated 24-hr canister samples of VOCs will be taken once per day on the predominant upwind/downwind directions. Laboratory analysis is expected to only report concentrations for BTEX compounds. Canister data will be reported to the District within 45 days after collection.

6. Data Quality

All data values not associated with bump tests or other instrument maintenance will be displayed to the public in near-real time (i.e., in about 10 minutes or less). If data are subsequently proven to be invalid, they will be removed from the public display, and the rationale for data removal will be provided. Common reasons for invalidation include instrument malfunction, power failure, and bump test data not identified as such.

6.1 Data Quality Objectives and Criteria

To ensure quantitative accuracy of field measurements, measurement performance criteria are established as part of the monitoring design. These criteria specify the data quality needed to minimize decision errors based on the data. The quantitative performance criteria for the data collected by the fenceline measurement systems are provided in this section. The principal quantitative indicators of data quality for this study are data completeness, precision, and accuracy. The objective of these measurements is to achieve 75% data completeness for all measurements at 1-hr and 24-hr intervals and 90% completeness of daily values for each annual quarter, excluding instrument downtime due to weather conditions.

In the field, a bump test simulates system-observed gas content at the required path average concentration and is used to verify that the system can detect concentrations at or below a set level of concern. Instrument bump tests (done quarterly) are used to evaluate performance regarding precision and accuracy. These will be done in adherence to the approved QAPP. **Table 13** shows the performance criteria for the monitoring systems.

Table 13. Performance criteria for the fenceline monitoring systems.

Sensor	Test	Acceptance Criteria for Precision and Accuracy
UV-DOAS	100 ppm benzene; internal flow-through QA cell	±25%
FTIR	100 ppm ammonia; internal flow-through QA cell	±25%
UV Point Monitor	100 ppb benzene; internal flow-through QA cell	±25%
H_2S Point Monitor	0, 200, 100, 50 ppb	±20%
Temperature	Two-point test	±0.5°C
Relative Humidity	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%

6.2 Data Quality Control Overview

In addition to the quarterly verification of instrument operations by conducting gas audits, more frequent review of the data will be conducted. The three levels of data quality control that will be performed are:

- QC1: Automated quality control of data
- QC2: Daily checks by analyst
- QC3: Quarterly review and reporting

6.2.1 QC1: Automated Quality Control

The first level of quality control checks are conducted automatically on the real-time data, using the data management system (DMS). The DMS can handle the large volumes of data that will be generated in this project. This allows data to be displayed within approximately 10 minutes of collection. Real-time data will be subjected to these tests:

- **MDL.** Values below the MDL will be flagged accordingly.

- **Range.** Ensure the instrument is not reporting values outside of reasonable minimum and maximum concentrations.
- **Sticking.** If values are repeated for several sampling intervals, data will be reviewed for validity. Typically, four or more intervals of sticking values are a reasonable time span to indicate that investigation is needed. Sticking checks will not be applied to data below the instrument detection limit.
- **Rate of Change.** Values that change rapidly without reasonable cause will be flagged as suspect and reviewed.
- **Missing.** If data are missing, data collected during those periods will be marked as missing.
- **Sensor OP Code.** If the instrument assigns operation (OP) codes to data automatically (e.g., for bump tests, internal flow rate checks, light extinction criteria, integration time criteria), the data will be reviewed, op codes confirmed, and data flags checked.
- **Visibility.** If visibility drops below threshold value, data will be marked as invalid.

Data that fail checks will be flagged in the DMS and brought to the attention of data reviewers. Data are invalidated only if a known 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 as suspect. Additional analysis may be needed to deem data valid or invalid. Screening checks are typically specific to the site, instrument, time of day, and season, and adjusted over time as more data are collected.

6.2.2 QC2: Daily Checks by Analyst

A non-public field operations website will be used for daily graphical review of the data (an example is provided in Figure 14). Common data problems include flat signal/constant values, no signal/missing data, extremely noisy signal, rapid changes (spikes or dips), and negative concentrations. An initial review, typically of a three-to five-day running time-series plot of selected parameters for each instrument, allows the analyst to see common problems and verify instruments are operational.

Types of items checked based on results of initial review of concentration data include:

- Instrument alignment.
- Spectral data if several acquisitions of compounds of concern are above detection.
- Signal intensity and integration time.
- Meteorology measurements.

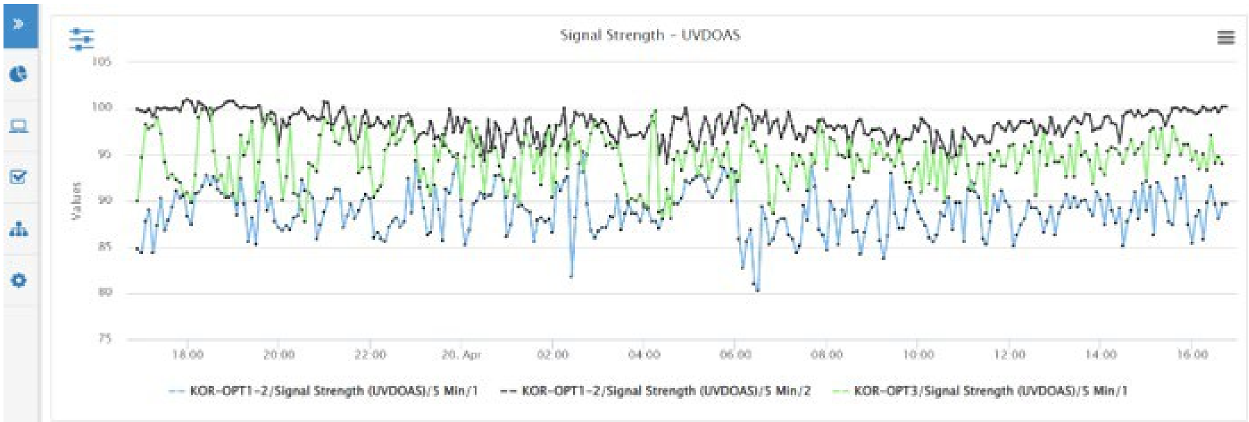


Figure 14. Example of a non-public field operations website used for daily review of open-path instrument operations.

The DMS will be used to automatically quality control data and detect outliers and problems, but will also create alerts. The DMS will feed auto-screened data to the field operations website and notification system to inform project and facility staff. These non-public, real-time auto alerts to the project team may be used to indicate any issues (e.g., missing data). If it appears that an instrument is not operating properly or the data are missing, the field operator will be notified and, if needed, further investigation and corrective action will be taken. DMS data will be backed up daily.

6.2.3 QC3: Quarterly Review and Reporting

In addition to auto-screening and daily visual checks, data will be subjected to more in-depth review on a quarterly basis and when data fail screening. Final data sets will be compiled quarterly, 30 days after each quarter's end. Kern will maintain a data record for five years.

These in-depth analyses typically require data that are not available in real time and ensure that the data on the website are updated. Validation checks will include:

- Looking for statistical anomalies and outliers in the data.
- Inspecting several sampling intervals before and after data issues, bump tests, or repairs.
- Evaluating monthly summaries of minimum, maximum, and average values.
- Ensuring data reasonableness by comparing to remote background concentrations and average urban concentrations.
- Referring to site and operator logbooks to see whether values may be unusual or questionable based on observations by site operator.
- Ensuring that data are realistically achievable, i.e., not outside the limits of what can be measured by the instrument.
- Confirming that bump tests were conducted and were within specifications.

On a quarterly basis, analysts will subject the data to final QC including:

- Verify routine instrument checks were acceptable and appropriate QC checks were applied.
- Review instrument bump test results for consistency.
- Fill in missing records with null values and add Null Codes.
- Inspect data consistency over three months.
- Review manual changes to operations/data and verify changes were logged and flagged appropriately.
    - Review ranges of values for consistency—ranges should remain consistent over months of monitoring.
    - Review data completeness.

6.3 Independent Quality Oversight

Kern will work with qualified independent contractors to perform annual systems and performance checks. These include fenceline monitoring component inspections, review of analyzer data and independent calibration checks, review of quality assurance procedures, and verification of data flow. More detailed performance review information is provided in Section 4.6 of the attached QAPP.

All field observations will be documented, and findings summarized in a technical memo, along with any recommendations for system optimization. These will be provided to Kern Energy within 3 months of system review completion for submission to SJVAPCD as needed.

6.4 Quality Assurance Project Plan

The QAPP is provided in Appendix A and contains the following key elements:

1. Project background and management
2. Technical approach
3. A description of the analytical equipment
4. Data quality objectives
5. Quality control procedures
6. Data management (QC, verification, validation)
7. Documentation and records (QA/QC, training)
8. SOPs (these will be provided once Kern selects the instrument make and model).

The QAPP will be reviewed annually and updated as needed.

6.5 SOPs for Equipment

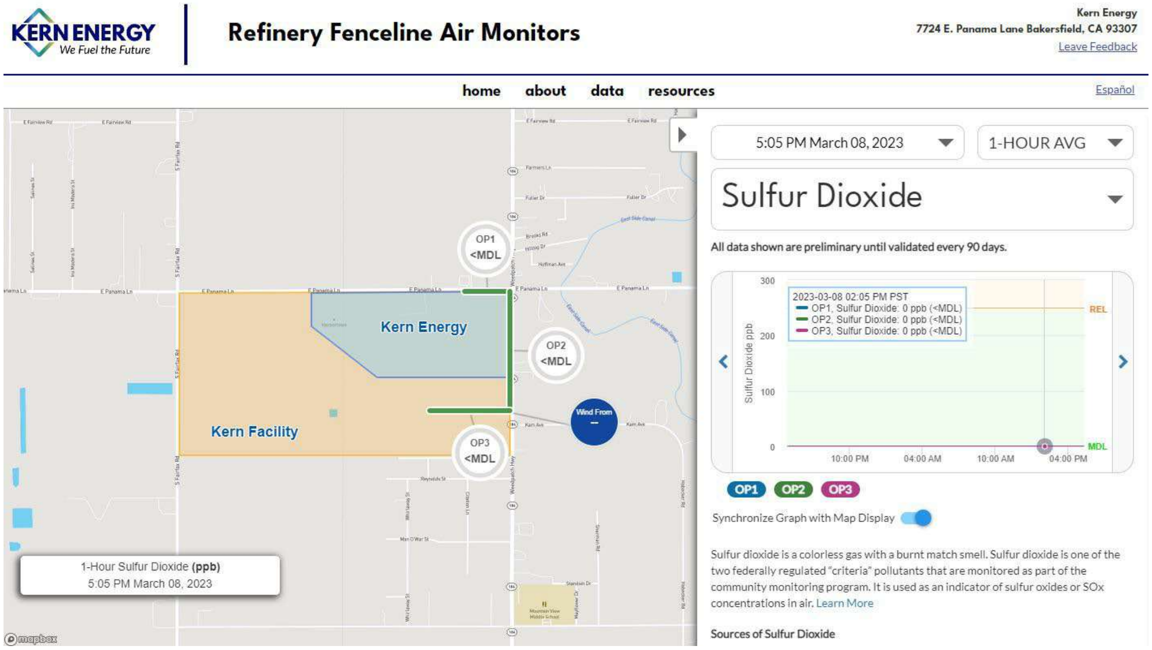
Instrument SOPs are included as attachments to the QAPP. SOPs will be reviewed and updated as needed.

7. Public Data Display

A public website will provide the data to the public, the District, and local response agencies in real time, in addition to other supporting information. Figure 15 is an image of the public-facing website. Key features on the website include:

- A summary of the program goals on the home page
- A visual display of data in near-real time; historical data for the prior quarter will also be provided
- Information for the public to better understand the concentrations displayed
- A mechanism for public feedback on the website
- A description of monitoring techniques
- A description of monitored pollutants
- A discussion of typical background levels of each pollutant to provide context
- A description of QA/QC procedures
- Documentation of QC flags (valid, invalid, suspect, missing) for each data point displayed
- Hyperlinks to related information from publicly available websites
- FAQs

The preliminary quality-controlled data will be presented as time-series and spatial plots of species concentrations and wind speed and direction. Data will be provided as 5-min averages and running hourly averages and will be available within 10 minutes after data collection. All real-time data will be preliminary until made final after quarterly data quality control is completed. At this point, the website will be updated with the finalized dataset. Data will be color-coded to represent concentration levels and annotated for quality (valid, invalid, suspect, missing).



Refinery Fenceline Air Monitors

Kern Energy
7724 E. Panama Lane Bakersfield, CA 93307

5:05 PM March 08, 2023

1-HOUR AVG

Sulfur Dioxide

All data shown are preliminary until validated every 90 days.

2023-03-08 02:05 PM PST
OP1, Sulfur Dioxide: 0 ppb (<MDL)
OP2, Sulfur Dioxide: 0 ppb (<MDL)
OP3, Sulfur Dioxide: 0 ppb (<MDL)

Synchronize Graph with Map Display

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 SOx concentrations in air. Learn More

Sources of Sulfur Dioxide

1-Hour Sulfur Dioxide (ppb)
5:05 PM March 08, 2023

Figure 15. Example of a public data display of fenceline air monitoring data.

Information will be written at a public-friendly level with links to additional resources for members of the public who want to delve deeper into the science. Clarity and thoroughness will help to reduce the number of questions that arise.

The home page of the public-facing website will be dedicated to providing background on reasons the monitoring is taking place and the technology being used in the monitoring system. From the home page, a "Resources" page will be provided. The "Resources" page will include a frequently asked questions (FAQ) page, a definitions page, and other educational material.

To facilitate public feedback, a feedback button will be provided on the web page. When a user clicks on the button, an email form will pop up for the user to submit comments about the website. The email will be delivered to a Kern contact responsible for deciding how to respond to the public comments. The emails received through the website will be archived. Some comments may aid in creating additional FAQs.

8. Notification System

Kern will maintain a notification system in accordance with Rule 4460. The website will provide an opt-in sign-up for the public and agencies to receive notifications. The public, the District, and local response agencies will be notified via email when values exceed thresholds or when activities may have a major effect on the monitoring system, and may be notified in the event of a false alarm.

Notifications will be triggered automatically when concentrations exceed threshold levels listed in Table 14. The concentrations will be calculated as 1-hr rolling averages that are updated every five minutes. These notifications will come with a message on the home page of the public website. Concentration thresholds correspond to the OEHHA acute relative exposure limits (RELs).[9]

Table 14. Thresholds for triggering automated notifications. Values for gaseous species in this table are acute 1-hr RELs from OEHHA.

Measurement	Threshold Level (ppb)
Acetaldehyde	261
Ammonia	4,594
Benzene	8.5
1,3-Butadiene	298
Ethylbenzene	460
Formaldehyde	45.5
Hydrogen Sulfide	30
Naphthalene	1.7*
Nitrogen Dioxide	250
Sulfur Dioxide	250
Toluene	9,800
Total Xylene	5,067

*A potential notification threshold for naphthalene is the chronic REL, as no hourly REL value has been set.

In the event that an hourly concentration exceedance notification is issued to the public, trained data reviewers will investigate the concentration data and determine the validity of the event. As part of

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[9] California Office of Environmental Health Hazard Assessment (2017) https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary

that review and verification process, information about the pollutant detected, the health notification threshold exceeded, event time and date (including start and stop time), wind speed and direction during the event, and whether or not the exceedance source is suspected of stemming from within the refinery can be ascertained. Data reviewers, field technicians, and refinery operations personnel will work together to determine the best course of action needed to address the concentration exceedance event as appropriate. A brief report containing the aforementioned exceedance event data, the likely source of concentrations, and all corrective actions taken can be generated for submission to the District within 10 calendar days of the event.

Contents of the exceedance event report will also be included in the quarterly reports submitted to the District, within 45 days of the end of the calendar quarter.

9. Implementation Elements and Schedule

Once this monitoring plan is approved, Kern will proceed with the implementation of the amended monitoring and reporting system following the plan. An implementation schedule detailing the key milestones for implementation of the FTIR monitoring systems is shown in Table 15, which assumes approval of the AMP in winter 2024/2025. If there are significant delays in getting the plan approved, the schedule may change.

Table 15. Approximate implementation schedule for Kern Rule 4460 monitoring expansion.

Project Element	Completion Date
Acquire additional instruments	Spring 2025
Install analyzers and associated equipment	Fall 2025
Update data management system	Fall 2025
Update internal and public-facing websites and notification system	Fall 2025
Conduct final monitoring system checks for additional pollutants (including gas testing and confirming data flow)	Fall 2025
Start monitoring and reporting for additional pollutants	Winter 2025/2026 (1 year from approval)
Operate, maintain, and audit equipment, data system, website, and notification system; perform daily data checks	Winter 2025/2026; continuous

Appendix A. Quality Assurance Project Plan

Appendix A.
Quality Assurance Project Plan

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November 1, 2024

STI-923014-7393

Approvals

Quality Assurance Project Plan
Fenceline Monitoring for the Kern Energy

Signature	Date

Name Kern Energy	Title

Signature	Date

Name Kern Energy	Title

Will be signed upon plan acceptance

Signature	Date

Name Sonoma Technology	Title

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1. Project Background and Management

1.1 Background

1.1.1 Purpose

Kern Energy (Kern) has been conducting air quality monitoring at its Bakersfield, California, refinery in response to the San Joaquin Valley Air Pollution Control District's (SJVAPCD) Rule 4460.[1] The rule was adopted in December 19, 2019, and amended on October 20, 2022. The monitoring follows a facility-specific air monitoring plan consistent with the SJVAPCD's Refinery Fenceline Air Monitoring Plan requirements. Rule 4460 requires routine monitoring near the fencelines of all San Joaquin Valley refineries for specific air pollutants, with data reported to the public. Monitoring operations began on January 28, 2022, with data flowing to a public-facing website on the same date.

1.1.2 Rationale

Rule 4460 requires real-time fenceline monitoring systems that provide air quality information to the public regarding concentrations of various air pollutants at or near property boundaries of petroleum refineries. The list of all pollutants to be monitored as part of the rule was amended in 2022 based on guidance from the California Air Resources Board (CARB) and California Air Pollution Control Officers Association (CAPCOA). The list includes criteria air pollutants and toxic air contaminants, including gases and particulates.[1] As outlined in its monitoring plan, Kern will conduct open-path and point monitoring of pollutants and meteorological measurements to meet the regulations.

This quality assurance project plan (QAPP) documents the measures that the project team will take to ensure that the data collected are of the highest quality. This document will be reviewed annually and updated as needed.

1.2 Roles and Responsibilities

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

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[1] San Joaquin Valley Air Pollution Control District (2019) Rule 4460: Petroleum refinery fenceline air monitoring. Final rule adopted December 19, 2019; amended on October 20, 2022. Available at https://www.valleyair.org/rules/currntrules/4460.pdf.

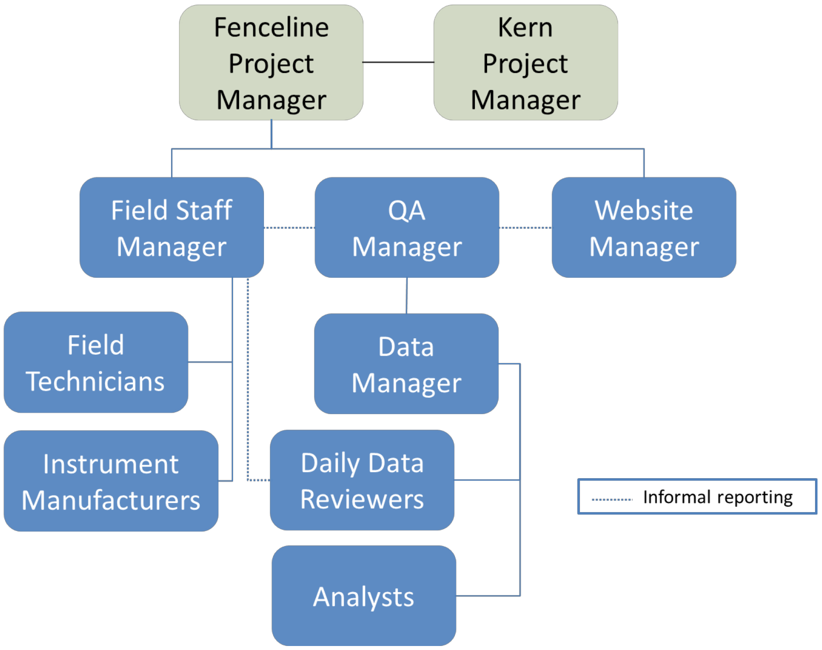

Figure 1. Organizational chart showing key roles for the Kern refinery monitoring project.

The overall project will be run by a **Fenceline Project Manager** (PM) appointed by the refinery. The Kern PM acts as the central point of contact for the SJVAPCD. The Fenceline PM is responsible for overseeing the project and reporting to the Kern PM.

The **QA Manager** is responsible for ensuring the quality of data collected in this project. The QA Manager oversees data collection and review, provides QA oversight during the study, and oversees and reports on QA activities to the Fenceline Project Manager and SJVAPCD 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 of high quality.

The **Field Staff Manager** ensures that field technicians (site operators) are meeting the requirements of the project. The Field Staff Manager coordinates staff coverage and serves as a technical resource for site measurements.

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

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

The **Data Manager** is responsible for ensuring that daily data review is conducted, that data that fail auto-screening are inspected, and that data validation follows the proper schedule and procedures. The Data Manager is also responsible for delivering the validated data to the PM.

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

The **Website Manager** is responsible for properly displaying data on the website, managing inquiries from the public, and ensuring that validated data are available for download on a quarterly basis. Automated alerts will notify the Website Manager when the real-time data are not available on the website. This manager will be responsible for assessing and fixing data communication and other information technology–related issues concerning the website and data system.

2. Measurements

2.1 Instrument Selection and Descriptions

The list of compounds to be measured, including pollutants added as part of the Amended Rule 4460, is presented in Table 1. These compounds will be measured at a 5-min resolution. 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 Ultraviolet-Differential Optical Absorption Spectroscopy (UV-DOAS) and Fourier Transform Infrared (FTIR) instruments were selected for measuring most compounds. The exception is hydrogen sulfide (H_2S), which will be measured by ultraviolet (UV) fluorescence point instruments.

Table 1. Pollutants to be monitored as part of Rule 4460.

Air Pollutants
Criteria Air Pollutants
Sulfur Dioxide (SO_2)
Nitrogen Dioxide (NO_2)
Volatile Organic Compounds (VOCs)
Acetaldehyde
Formaldehyde
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)
Naphthalene
1,3-butadiene
Other Compounds
Ammonia
Hydrogen Sulfide (H_2S)

The fenceline network will consist of both open-path and point monitoring locations. For long path measurements, naphthalene, NO_2, SO_2, and benzene, toluene, ethylbenzene, and xylenes (collectively referred to as BTEX) will be measured by monostatic Cerex UV Sentry UV-DOAS instruments with a xenon light source. Acetaldehyde, ammonia, 1,3-butadiene, and formaldehyde will be measured by a monostatic Cerex Air Sentry FTIR instrument. For both open-path systems, the UV or infrared (IR) light shines over a long path to a retroreflector and back to the instrument for analysis. The analyzers can take measurements over paths that are about 300 to 600 meters long and are able to achieve appropriate minimum detection limits (MDL). The analyzers record the intensity of light at discrete wavelengths, and any UV- or IR-absorbing gas that is present in the beam absorbs at a specific wavelength of light. The analyzer compares regions within the sample absorbance spectra to the same regions within the reference absorbance spectra, using least squares regression analysis. Beer's Law is used to report gas concentrations. Closeness of fit is indicated by the correlation coefficient (R^2) 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. The selection of regions of analysis that are free of absorbance due to 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.

A point monitor version of the UV-DOAS analyzer will be implemented along the northern edge of the crude tank farm. This analyzer operates similarly to the open-path instruments described above, but with a shorter internal optical path length, closer to about 20 m.

Heavy fog may entirely block the signal from an open-path instrument and prevent data collection. Even light fog can absorb the signal partially and interfere with measurements. Given that the refinery is in an area prone to Tule fog, fog events may impact open-path measurements at times, especially during nighttime and early morning hours. Visibility measurements will be made in the southeast corner of the refinery to provide operational verification of low atmospheric visibility events.

Four UV fluorescence point analyzers will be used to measure H_2S in the northeast and southeast corners of the main refinery and along the northern and southern edges of the crude tank farm.

Table 2 summarizes the estimated MDL for each species monitored by a typical UV or FTIR open-path analyzer or point UV instrument. For the open-path analyzers, the MDL is the lowest path-average concentration that can be measured at the path length. A 500-m path length was used in MDL calculations. Detection limits are approximate and are based on the theoretical instrument capabilities; however, they are supported by manufacturers' lab tests and real-world applications. Actual detection limits depend on atmospheric conditions and on the specific instrument used.

Table 2. Range of approximate instrument minimum detection limits (MDL) in parts per billion (ppb) by technology and species. Actual detection limits depend on atmospheric conditions.

Analyzer Detection Method	Compounds Measured	Instrument Detection Limit*
Teledyne T101 - UV Fluorescence	H_2S	<0.5 ppb
Cerex UV Hound - UV-DOAS	Benzene Toluene Ethylbenzene Xylenes SO_2	<3.0 ppb < 3.0 ppb < 10 ppb < 8.0 ppb (m); <3.0 ppb (o); < 1.0 ppb (p) < 3.0 ppb
Cerex UV Sentry - UV-DOAS	Benzene Toluene Ethylbenzene Xylenes SO_2 Naphthalene NO_2	<0.5 ppb <1.0 ppb <0.5 ppb <0.5 ppb (m/p); <4.0 ppb (o) <1.0 ppb <0.5 ppb <4.0 ppb
Cerex Air Sentry - FTIR	Acetaldehyde Ammonia 1,3-butadiene Formaldehyde	<1.0 ppb <0.5 ppb <1.0 ppb <0.5 ppb
Campbell Scientific CS120a - Infrared forward-scattering	Visibility	Range = <20 ft to 46 miles
RM Young - Resistance thermometer Capacitive polymer	Temperature Relative Humidity	Temp range = -39.2 to 60°C RH range = 0.8% to 100%
RM Young - Wind vane	Wind speed Wind direction	Wind speed: 0-50 m/s Azimuth: 0-360 degrees

*Open-path detection limits are based on a typical path length of 500 m.

2.2 Monitor Siting Overview

Kern will monitor concentrations across 4 open paths and 4 point locations (detailed in Table 3 and shown in Figure 2). The type of measurement for each path is indicated by the legend in Figure 2: transmitter-detectors/analyzers denoted with an “S”, retroreflectors denoted with an ”R”, and point analyzers denoted with an “A”. All instruments and reflectors will be located between 2 m and 7 m above ground level depending on site logistics.

Fenceline monitoring paths were chosen after considering dominant wind patterns (most frequently from the northwest and southeast), sources of potential air emissions on the refinery property, and nearby local receptors. A meteorological station, mounted on a tower approximately 10 m tall, will be installed. The station also includes a visibility sensor and sensors for measuring wind speed and direction, temperature, and relative humidity.

Table 3. Locations of equipment to be used in fenceline monitoring program at Kern refinery.

Path #	Description	Approximate Path Length (m)	Instrument(s)
1	Open path East-West along North boundary of main facility	200	UV-DOAS, FTIR, UV Fluorescence
P1	Point monitor in Northeast corner	-	UV Fluorescence
2	Open path North-South along East boundary of main facility; Meteorological station in Southeast corner	550	UV-DOAS, FTIR, Met. Station
P2	Point monitor in Southeast corner	-	UV Fluorescence
3	Open path East-West along South boundary of main facility	365	UV-DOAS, FTIR
4	Open path East-West along Southern boundary of crude tank farm	360	UV-DOAS
P3	Point monitors along northern boundary of crude tank farm	-	UV Fluorescence, Point UV-DOAS
P4	Point monitor in the southwest corner of crude tank farm	-	UV Fluorescence

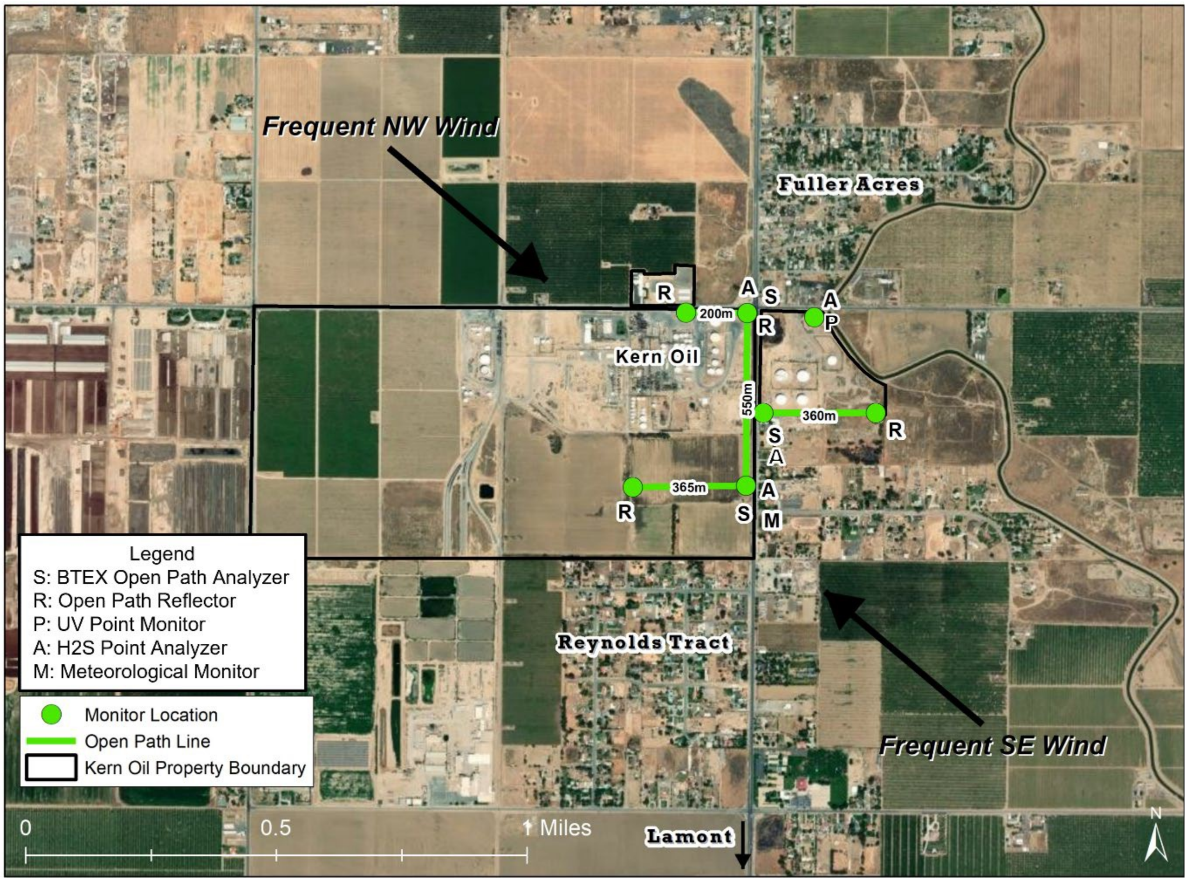

Figure 2. Location of sensors and measurement paths at the Kern Refinery. Each path consists of a transmitter-detector (S) and a retroreflector (R). Point analyzer locations (A) are in the northeast and southeast corners. The meteorology station is also shown (M).

2.3 Instrument Operations and Maintenance

The fenceline monitoring system includes open-path and point UV-DOAS analyzers, open-path FTIR analyzers, UV fluorescence analyzers, and meteorological instruments, including a visibility sensor. Quality assurance is built into instrument operation and maintenance. For all instruments, scheduled maintenance will occur monthly, quarterly, and/or annually. Daily checks will be made to (1) ensure data are flowing consistently to the data management system and public website, and (2) verify that data are reasonable. Emergency maintenance will occur as needed when problems are identified during daily data review and auto-screening of real-time data.

2.3.1 Open-Path UV-DOAS

The UV-DOAS system is designed to require only modest service and maintenance. Table 4 summarizes typical UV-DOAS maintenance activities as recommended by a manufacturer. Preventive maintenance frequency depends on the operating environment and may need to be adjusted beyond the manufacturers' recommendations once the instruments are deployed in the field. System status alarms will alert operators to specific issues that need to be addressed. Bump tests will be performed on site.

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

Activity	Monthly	Quarterly	Annually
Visually inspect the system	✓		
Inspect detector and retroreflector optics; clean if necessary	✓		
Inspect and clean system filters	✓		
Inspect all electrical cables for wear; replace as needed	✓		
Confirm the alignment of the light source and detector	✓		
Ensure that there are no obstructions between the light source and detector (e.g., refinery equipment, vegetation, or vehicles)	✓		
Document signal levels to establish a baseline for light source replacement frequency	✓		
Archive historical data and remove from analyzer computer	✓		
Perform bump test		✓	
Replace light source if diagnostics are outside the acceptable range		✓	
Replace ventilation exit and intake filters		✓	

Activity	Monthly	Quarterly	Annually
Clean detector optics		✓	
Confirm the alignment of the light source and detector		✓	
Verify system settings			✓

2.3.2 Open-Path FTIR

The FTIR requires maintenance activities similar to those for the UV-DOAS, and is also designed to require only modest service and maintenance. Table 5 summarizes the maintenance activities for an FTIR system, as recommended by a typical manufacturer. Preventative maintenance frequency depends on the operating environment and may need to be adjusted. System status alarms may alert operators on an as-needed basis to specific issues that need to be addressed. Bump tests will be performed on site.

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

Activity	Monthly	Quarterly	Annually	2 Yrs	5 Years
Visually inspect the system	✓				
Inspect detector and retroreflector optics; clean if necessary	✓				
Confirm the alignment of the light source/detector and retroreflector	✓				
Ensure that there are no obstructions between the light source/detector and retroreflector (e.g., refinery equipment, vegetation, or vehicles)	✓				
Archive historical data and remove from analyzer computer	✓				
Perform bump test	✓				
Inspect and clean exterior heat sink for AC system		✓			
Test and document signal levels to establish a baseline for light source and retroreflector replacement frequency			✓		
Replace cryocooler or swap detector module assembly				✓	
Replace the light source					✓

2.3.3 UV Fluorescence H_2S Analyzer

Table 6 describes typical maintenance actions for a H_2S UV fluorescence point analyzer, such as cleaning and inspections, as well as their required frequencies for routine system management. Preventive maintenance ensures operational integrity and is strongly urged by the manufacturer. The frequency of maintenance checks may need to be adjusted beyond the manufacturers' recommendations once operations begin. On an as-needed basis, system status alarms will alert operators to specific issues needing to be addressed.

Table 6. Schedule of maintenance activities for an H_2S UV fluorescence analyzer.

Activity	Monthly	Quarterly	Annually
Inspect sample line tubing	✓		
Inspect particle filter at inlet and replace as necessary	✓		
Zero/span check	✓		
Inspect particle filter inside analyzer and replace as necessary		✓	
Perform flow check		✓	
Perform gas test for analyzer response		✓	
Replace pump diaphragm			✓

2.3.4 UV-DOAS Point Analyzer

The UV-DOAS point monitor system also requires only modest service and maintenance. Table 7 summarizes typical maintenance activities as recommended by the manufacturer. Preventive maintenance frequency may need to be adjusted beyond manufacturers' recommendations once the instruments are deployed in the field. System status alarms will alert operators to specific issues that need to be addressed. Bump tests will be performed on site.

Table 7. Schedule of maintenance activities for the UV-DOAS point monitor.

Activity	Monthly	Quarterly	Semi-Annually
Visually inspect the system	✓		
Inspect optics on analyzer; clean if necessary	✓		
Inspect system filters; replace as necessary	✓		
Confirm the alignment to verify sufficient signal	✓		
Archive historical data and remove from analyzer computer	✓		
Verify system signal after service		✓	
Check system performance indicators		✓	
Perform bump test 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		✓	
Change out the UV source			✓
Verify system settings			✓

2.3.5 Meteorological and Visibility Sensors

Meteorological sensors provide information about temperature, relative humidity, and wind direction and wind speed to help determine sources of any air contaminants. The meteorological sensors will be maintained on a monthly and biannual basis. Table 8 lists the maintenance activities that will be performed.

Table 8. Schedule of maintenance activities for the meteorological tower.

Item	Activity	Monthly	Annually
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	✓	
All sensors	Audit and calibrate		✓

Visibility measurements will be made in order to provide operational verification of fog events. Maintenance activities for the visibility sensor are included in Table 9. Monthly maintenance includes inspecting the sensor for dirt, spider webs, birds' nests, or other obstructions, and cleaning the sensor if necessary. The sensors are calibrated in the field annually using a manufacturer-specific calibration kit.

Table 9. Schedule of routine maintenance activities for visibility sensors.

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

2.3.6 Overview of Spectrum Generation, and Quality Control Parameters for Open-Path Instruments

This section provides context for some parameters used in QA/QC procedures for open-path systems. Generation of spectra using UV-DOAS and FTIR is a distinctly different process that is dependent on the hardware used. However, in all cases, the result is a spectral file containing absorbance as a function of wavelength. To generate absorbance using FTIR or UV-DOAS, the logarithm of the ratio of two "single beam" transmission spectra is calculated (one spectra 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." In practice, the single gas MDL for one analyte in otherwise clean air will be lower than that for air that contains interfering species (species that absorb in the same spectral region as the analyte). Also affecting the MDLs is the total averaging time. The greater the number of scans averaged, the lower the MDL due to the reduction of noise.

For UV-DOAS measurements, light is collected for a period of time (the so-called "integration time"). The instrument software determines the integration time, based on a minimum amount of light needed. 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). For example, each manufacturer specifies a range of acceptable integration times for their system. A related metric that is applicable to all open-path measurements is the overall intensity of the light received at the analyzer; this is termed "signal strength." For certain UV-DOAS measurements, signal strengths greater than 80% are generally acceptable. For typical FTIR measurements, the values are generally lower because of absorption by atmospheric gases (CO_2, H_2O, etc.). For example, acceptable values for a manufacturer's FTIR system may be between 2% and 100%.

In order to derive concentrations, spectra must be fit using a least squares procedure. A "library" spectra of known compounds is used to best fit the experimental 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. For example, the fit to methane might have an R^2 of 0.70 or greater to be considered a valid detection.

Acceptance criteria for UV-DOAS and FTIR measurements are listed in Section 3.

2.4 System Corrective Actions

When a major problem is discovered with the fenceline monitoring system, corrective actions and maintenance procedures are required. Because the fenceline monitoring system is composed of two major components—field hardware and the website software—two integrated rotating on-call teams will work to respond to any issues. Corrective action will be taken to ensure that data quality objectives are met. Table 10 lists the types of issues that require corrective actions. This table is not all-inclusive, and additional checks may be added as the project progresses. The daily data reviewers will review data to identify issues and will work with the field technicians and instrument contractors to resolve issues that need to be addressed on site.

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

Item	Problem	Action	Notification	Person Responsible
Failed acceptance criterion	Instrument malfunction	Execute corrective action plan, conduct root cause analysis, flag data	Field Staff Manager, Refinery Project Manager, QA Manager	Field Staff Manager
Erratic data	Possible instrument malfunction	Contact Field Manager and Instrument Contractor	Document in logbook, notify Field Manager	Field Technician
Power	Power interruptions	Check line voltage, reset or restart instruments	Document in logbook, notify Field Manager	Field Technician
Data downloading	Data will not transfer to the DMS	Contact Field Manager and Instrument Contractor	Document in logbook, notify Field Manager and Website/Data System Manager	Field Technician
Supplies and consumables	Essential supplies run low	Contact Field Manager	Document in logbook, notify Field Manager	Field Technician
Access to sites	Technician cannot access the sites	Contact Project Manager	Document in logbook, notify Project Manager	Field Technician
Instrument Light level	A low light level alert is observed	Site visit for realignment or source replacement - possible manufacturer support	Document in logbook, notify Field Manager	Field Technician
Website	Website is down	Contact Website Manager	Notify Project Manager	Website Manager

3. Quality Objectives and Criteria

3.1 Data and Measurement Quality Objectives

3.1.1 Discussion

To ensure success of field measurements, measurement performance criteria are established as part of the monitoring design. These criteria, referred to as measurement quality objectives (MQOs) and data quality objectives (DQOs), specify the data quality needed to minimize errors in decisions made that are based on the data. Data quality is defined in terms of the degree of precision, accuracy, representativeness, comparability, and completeness needed for the monitoring. Of these five data quality indicators, precision and accuracy are quantitative measures (Section 3.2), representativeness and comparability are qualitative measures, and completeness is a combination of quantitative and qualitative measures.

The quantitative performance criteria for the data collected by the fenceline measurement systems are provided in the following tables. The principal quantitative indicators of data quality for this study are data completeness, precision, and accuracy. Table 11 shows the data completeness objectives for all collected data for several time intervals. For communication purposes, the Percent Data Valid—the percentage of data values that are valid divided by the number of captured data values (corrected for low-visibility conditions and scheduled maintenance as outlined in this QAPP)—will also be computed and included in quarterly reports.

Table 11. Measurement quality objectives, including data completeness targets.

Measurement Method	Pollutant	Reporting Unit	Completeness Target, 1-hr	Completeness Target, Quarterly
Open-Path UV-DOAS	BTEX, Naphthalene, NO_2, SO_2	ppb	75% (of 5-min values)	90%
Point UV-DOAS	BTEX, SO_2	ppb	75% (of 5-min values)	90%
Open-Path FTIR	Acetaldehyde, Ammonia, 1,3-Butadiene, Formaldehyde	ppb	75% (of 5-min values)	90%
Point Monitor (UV Fluorescence)	H_2S	ppb	75% (of 5-min values)	90%
Meteorological Sensors	Wind Speed, Wind Direction, Visibility	m/s, Degrees, Miles	75% (of 1-min values)	90%

Other factors that affect data availability include instrument bump tests (approximately every quarter for a few hours), annual maintenance, and other maintenance (e.g., UV light source replacement on the UV-DOAS roughly every 2,000 hours of use, and FTIR cryocooler refurbishment every 18-24 months). Regular maintenance and careful, responsive operation will minimize instrument downtime. Table 12 highlights additional measurement quality objects (precision and accuracy) for the fenceline monitoring systems. National Institute of Standards and Technology (NIST)-traceable certified gases will be used for bump tests and calibrations where possible. Bump-test levels for open-path analyzers are 5-10 times above the compound MDL and 2-5 times above compound MDL for the point analyzer; calibration levels for the H_2S point monitors cover the range from zero to about 8 times the REL. Meteorological checks are to be completed in accordance with the U.S. Environmental Protection Agency's (EPA) benzene fenceline monitoring requirements.

Table 12. Additional measurement and data quality objectives for the fenceline monitoring systems.

Sensor	Testing Method	Testing Frequency	Acceptance Criteria for Precision	Acceptance Criteria for Accuracy
UV-DOAS	100 ppm benzene; internal flow-through QA	Quarterly	±25%	±25%
FTIR	100 ppm ammonia; internal flow-through QA cell	Quarterly	±25%	±25%
UV Point Monitor	100 ppb benzene; internal flow-through QA	Quarterly	±25%	±25%
H_2S point analyzer	0, 250, 100, 50 ppb	Quarterly	±20%	±20%
Temperature	Two point test	Annually	--	±0.5°C
Relative Humidity	Hygrometer	Annually	--	±7%
Wind Speed	Starting threshold test; transfer function test	Annually	--	±0.25 m/s below 5 m/s and ±5% above 5 m/s
Wind Direction	Angle verification	Annually	--	±5 degrees
Visibility	Extinction	Annually	±10%	±10%

3.2 Precision Checks, Bump Tests, and Verification

All measurements outlined here are subjected to precision and accuracy tests. 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 if trials will be defined as 7≤ N ≤15. The average value of these measurements is calculated as

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

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:

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

3.2.1 Open-Path Instruments

To gauge precision and accuracy for the Cerex UV-DOAS and FTIR open-path systems, bump tests will be performed quarterly using NIST-traceable standards (where possible) passing continuously through a flow-through cell. The flow cell exhaust will be scrubbed with activated carbon appropriate to the gas being used. Temperature control for both instruments is accomplished by systems within the instrument enclosure itself. During the measurements, the light beam passes from the source, through the cell, and across the entire atmospheric path length to the retroreflector. From 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, this is a realistic test of the instrument's capabilities. These bump tests are used to verify that the system can reliably detect concentrations near the level of concern. Concentrations are selected such that they are well above the level of quantitation (LOQ = 5*MDL) but are near or below the alert thresholds for select species. For both the UV-DOAS and FTIR systems, a bump test will be performed quarterly.

For the open-path systems, precision will be measured by evaluating the variance of pollutant concentrations during a period of low variability, when atmospheric influence on variability is assumed to be minimal. Five-min data will be selected during periods of low variability, but when concentrations are well above the MDL. The precision can then be evaluated by calculating the coefficient of variation (CV) during the period of low variability, as shown in **Equation 4** above. If there are no periods of low variability with concentrations above the MDL, bump test data will be used to calculate precision.

3.2.2 UV-DOAS Point Analyzer

Bump tests will be performed to gauge precision and accuracy for the UV-DOAS point analyzer similarly to the open-path systems. The bump tests will be performed quarterly using NIST-traceable standards (where possible) passing through the analyzer flow-through cell. The flow cell exhaust will be scrubbed with activated carbon appropriate to the gas being used. Target concentrations will be selected such that they are well above the level of quantitation (LOQ = 5*MDL) but near or below the alert thresholds for select species.

3.2.3 H_2S Point Analyzer

A gas dilution calibrator is used to deliver calibration gas to the UV fluorescence H_2S analyzer. A certified gas cylinder of H_2S and source of zero air (cylinder or generator) will be connected to the dilution calibrator to generate a range of concentration set points. On a monthly basis, the analyzers will be checked against a zero set point and a span (concentration of about 150 – 200 ppb). Full calibration checks will be done quarterly and include a range of concentrations: 0 ppb, 50 ppb, 100 ppb, and 200 ppb. The acceptance criteria for these bump tests are ±20% accuracy.

3.2.4 Meteorological Equipment

Annual audits will be conducted for the meteorological stations. 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), Volume IV.*[2]

As part of the calibration process, each instrument will be first 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, the instrument would 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.

Wind Speed

An anemometer drive will be used to simulate known wind speeds. The propeller torque disc will be used to determine the anemometer starting threshold. Sensor starting threshold is a shaft-bearing efficiency measurement only.

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[2] U.S. Environmental Protection Agency (2008) 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.

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

Wind Direction

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

Ambient Temperature

A NIST-traceable thermometer will be used as the calibration transfer standard. The ambient temperature sensor will be tested by comparing the current ambient temperature, as measured by the digital thermometer, to the temperature reading from the RPU. The transfer standard will be placed near the temperature probe in a shaded location. Both sensors will be allowed to reach equilibration before the respective sensor responses are recorded.

Relative Humidity

A NIST-traceable psychrometer will be used as the calibration transfer standard. The relative humidity sensor will be tested by comparing the current relative humidity as measured by the psychrometer to the relative humidity reading from the RPU. The psychrometer will be placed near the temperature probe in a shaded location. Both sensors will be allowed to reach equilibration before their responses are recorded.

Visibility Sensors

An appropriate manufacturer-specific calibration kit will be used to test the visibility sensors. The calibration fixtures are instrument-specific. 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 (ECO) used to calculate the expected values during calibrations.

3.2.5 Instrument or Standards Certifications

For factory calibrations, a certification of the standard gases used will be requested from the manufacturer. Standards will not be used past their expiration date. If an expired standard is used, it shall be recertified by the manufacturer. The spectral file numbers generated during tests will be documented and archived.

4. Data Management, Quality Control, and Verification

Data quality criteria are evaluated through (1) automatic data checks conducted through the data management system and (2) data review by trained analysts (daily data review 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. In near-real time, data are transferred from in-field instruments through a data acquisition system (DAS) to a Data Management System (DMS) using cellular modems. Data are also stored onsite on instrument computers in case of cellular modem failure. The DAS performs data averaging to 5-min values and assigns initial quality control (QC) and operational (OP) codes to each data value based on operating characteristic information collected from the analyzers at the same time as the data. Trained analysts can access QC and OP codes in the password-protected DMS during validation, which does not happen in real time. The DMS keeps track of any changes in QC and OP code. The DMS uses a Microsoft SQL relational database with stored procedures. These raw data are not yet intended for the public website. Data are displayed on the website only after they undergo automated QC (described in Section 4.2) and are aggregated to 5-min and running 1-hr values, which occurs within 10 minutes of data collection. Any 1-hr average values that do not meet 75% completion criteria are considered invalid, due to insufficient data being collected.

4.1.1 QC and QA Processes

All data produced by the instruments are initially considered **Level 0**. All **Level 0** data values that are not associated with bump tests, other instrument maintenance, or instrument problems will be displayed to the public in near-real time. If data are subsequently proven to be invalid, they will be removed from the public website display.

As described in Section 4.2, the DMS automatically quality-controls data, detects outliers and problems, generates reports, and creates alerts. The DMS auto-screening capabilities will be used for continuous examination of data quality. As part of the auto-screening process, quality control flags are assigned as follows:

- **Valid (QC flag 0)** – data are within normal operating parameters.
- **Invalid (QC flag 9)** – data do not meet quality control criteria.

- **Missing (QC flag 8)** – data have not been received by the DMS for a time period greater than 10 minutes since the last data was received.
- **Suspect (QC flag 5)** – operating parameters are marginal and should be reviewed further.

The automatically quality-controlled air quality data will be 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 data review 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 SJVAPCD. Data from all stages of validation are retained in the DMS.

4.1.2 Data Storage and Backup

On-site, raw analyzer backup files will be copied to offsite storage on a regular basis. The DMS data will be backed up on a daily basis. Stored and retained information includes raw and validated data; QC codes, OP codes, and metadata associated with each data value; metadata associated with each analyzer; and change-of-custody logs. The data will be stored for a period of five years after sampling.

Access to the DMS data is controlled by username and password (with strong encryption), and is restricted to the Field Staff Manager and those designated to perform data validation and analysis. As protection against incorrect modification or deletion, a chain-of-custody record is kept of all changes to the database, and backups are performed frequently.

4.1.3 Data Delivery and Reporting

Final data sets (Level 2.0 data) will be compiled quarterly, within 45 days after the close of each quarter, and made available to the public on the website in graph format. Validated data will be provided to the SJVAPCD quarterly. Each quarter, a report will be prepared and delivered to the SJVAPCD. These quarterly reports will provide a summary of measured data, threshold exceedances, quarterly and monthly statistics, accuracy and precision of instruments, outliers, anomalies, and data quality control. The quarterly reports will be written at a public-friendly level, but still reflect a high level of data validation and quality control.

Data graphs will be stored and available on the website for 90 days. Kern will maintain a data record for five years consistent with Rule 4460.

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 for public display and are helpful to focus the data reviewer's efforts on the data that need the most attention. Initial screening checks, along with actions to be taken, are summarized in Table 13. 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 will be refined during the project based on actual observations. The DMS auto-screening checks that will be used include:

- **MDL**. Set up to check if data collected are above the analyzer's reported detection limit. If data are below the detection limit, it will be flagged as such.
- **Range.** These checks will 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 will be reviewed for validity. Typically, four or more intervals of sticking values are a reasonable time span to indicate that investigation is needed. Sticking checks will not be applied to data below the instrument detection limit.
- **Rate of Change.** Values that change rapidly without reasonable cause will be flagged and reviewed.
- **Missing.** If data are missing, data during those time periods will be coded as missing.
- **Sensor OP codes and alarms**. If the instrument assigns OP codes to data automatically (e.g., for bump tests, internal flow rate checks, light extinction criteria, integration time criteria), the data will be 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 the twice the path length (two times the path length is used because the open-path sensor light travels to the mirror and back to the analyzer).

Additional parameters that may be monitored as indicators of data quality include data quality value for each concentration as reported by the instrument (i.e., correlation between measured and reference spectra), signal strength, wavelength versus intensity, and visual review of peaks.

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

Table 13. Initial screening checks for 5-min data. All valid and suspect data values will be 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) are preliminary and will be refined during the project. During data validation, flagged data will be further investigated.

Measurement Species (units)	Checks						
	Minimum Detection Limit (MDL): If concentration is below MDL, flag as below MDL	**Range:** If concentration is above value listed, flag as suspect and conduct investigation	**Sticking:** If same value is 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
Acetaldehyde (ppb)	Same For All Pollutants	780	Same For All Pollutants	260	Same For All Pollutants	Same For All Pollutants	Same For All Pollutants
Ammonia (ppb)		1,380		460			
Benzene (ppb)		27		9			
1,3-butadiene (ppb)		900		300			
Ethylbenzene (ppb)		1,380		460			
Formaldehyde (ppb)		135		45			
H_2S (ppb)		90		30			
Naphthalene (ppb)		6		2			
NO_2 (ppb)		750		250			
SO_2 (ppb)		750		250			
Toluene (ppb)		29,400		9,800			
Total Xylenes (ppb)		15,000		5,000			
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 the analyst to see common problems and verify instruments are operational. If it appears that an instrument is not operating, or the data are missing, the field operator will be notified and further investigation and corrective action, if needed, will be taken.

In addition to daily checks of the field website, an automated alerting system will let 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 period allowed for missing data will be set for six 5-min values (30 minutes).

4.3.2 Assess Data Reasonableness

Also operationally, the data reviewer quickly assesses whether the pollutant concentrations are reasonable with respect to the time of day, season, meteorology, and concentrations expected and observed along other paths. If anomalies are observed, additional analysis will be 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 will validate data by building on the processes leading to Level 1.0 data. This process starts with an in-depth data review, which includes statistical tests to ensure the data are valid for the intended end use. The QA Manager will evaluate QA/QC procedures and ensure the methods for meeting data quality objectives are adhered to. Data validation activities will be 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-min averages of the same number.
- Evaluating monthly summaries of 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.
- 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 (see Section 4.5).
- Verify that daily instrument checks were acceptable.
- Review manual changes to operations/data, and verify that the changes were logged and appropriately flagged.
- Ensure that instrument checks have the appropriate QC codes applied.

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

- Assign invalid data a Null Code, which are assigned to give data a reason for being invalid.
- If a record is not created for a particular site/date/time/parameter combination, create a null record for data completeness purposes.
- Inspect data consistency over three months.
- Review ranges of values for consistency – ranges should remain consistent over months of monitoring.
- Check bump test values for consistency.
- 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 malfunction, power failure, and bump test data that were not identified as such. As the measurements progress, screening checks will be updated and refined. Screening checks are typically specific to the site, instrument, time of day, and season, and will be 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 will be flagged as invalid in the database. A summary of issues leading to invalidated data will be documented in the data file.

All actions will be 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.

4.5 Instrument QC Checks

Additional QC checks for the instruments are summarized in **Table 14**. Data that fail checks will be flagged in the DMS and brought to the reviewer's attention by color coding the graphic summaries.

On roughly an annual basis, the refinery or its designated contractor will review network performance by (1) reviewing the data completeness by monitoring path, instrument, and species; (2) reviewing results of bump tests; (3) analyzing the reported values in context of refinery operations; and (4) analyzing the data with meteorological context. The contractor will also use analyses similar to those used to support the network design to evaluate the overall network performance and ensure it is meeting overall objectives. The results will be summarized in a technical memorandum and provided to the SJVAPCD upon request.

Table 14. Typical instrument QA/QC checks.

QA/QC Checks	Frequency	Acceptance Criteria
UV-DOAS (Open-Path and Point Monitor)		
Bump test (accuracy)	Quarterly and after major service	±25%*
Baseline stability	Continuous	±5%
Measurement quality (R^2)	Continuous	0.8 to 1.0
Integration time	Continuous	20-150 msec *300 msec integration time results in a warning notification*
Signal intensity	Continuous	> 20% (point monitor) >80% (open-path) *Signal intensity below 30 results in a warning notification*
FTIR		
Bump test	Quarterly and after major service	±25%*
Measurement quality (R^2)	Continuous	0.7 to 1.0
Signal Intensity	Continuous	>2% *Signal intensity below 2% results in a warning notification*
UV Fluorescence H_2S Analyzer		
Bump test	Quarterly	20%
Meteorology		
Two point temperature test	Annually	±0.5°C
Relative humidity	Annually	±7%
Wind speed starting threshold and transfer function	Annually	±0.25 m/s below 5 m/s and ±5% above 5 m/s
Wind direction angle verification	Annually	±5 degrees
Visibility – extinction coefficient check	Annually	±10%

*Based on flow-through calibration system.

4.6 Independent Quality Oversight

As part of implementing quality assurance, Rule 4460 requires independent review of the fenceline monitoring system. Kern will work with contractors to perform annual systems performance checks that include the following elements:

- Inspect the condition of analyzers, analyzer shelters, point monitor cabinets and sample lines, and retroreflector arrays.
- Review quality assurance procedures in the QAPP and SOPs.
- Observe routine instrument checks performed by normal field staff on each instrument type and review of maintenance logs.
- Verify analyzer signal response and instrument alignment.
- Inspect analyzer optics and instrument configuration.
- Review quarterly bump test results as carried out by field technicians for the previous 12 months.
- Independently perform calibration checks or bump tests of instruments as needed, following the criteria outlined in Section 3.1.
- Audit data flow from the instruments through the data logger and database system to the public website.
- Review data validation procedures used for the latest quarterly report.

All field observations will be documented and findings will be summarized in a technical memo, along with any recommendations for system optimization. These will be provided to Kern Energy within 3 months of system review completion for submission to SJVAPCD as needed.

5. Standard Operating Procedures

Standard Operating Procedures for maintenance and routine performance checks of the Cerex UV Sentry analyzer, Cerex AirSentry FTIR analyzer, Teledyne T101 H_2S analyzer, and meteorological sensors are attached.

Standard Operating Procedures for the CEREX UV Sentry UV-DOAS

February 21, 2024

STI-7024

APPROVED:

Sonoma Technology date

Fenceline Monitoring Refinery Representative date

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.

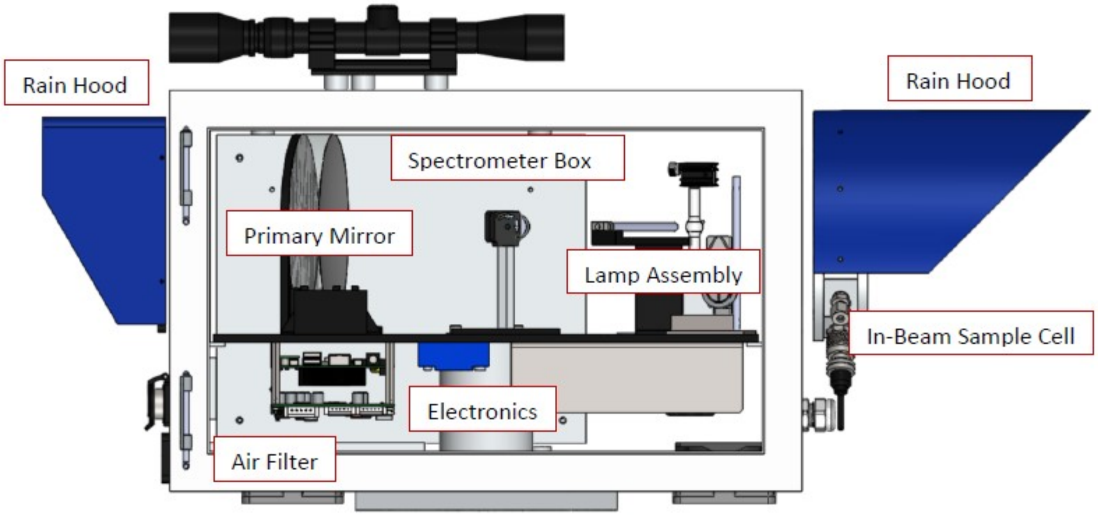


Figure 1. Schematic of the monostatic UV Sentry UV-DOAS analyzer.

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
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).
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

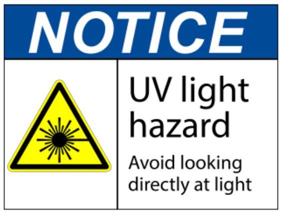
The following information is intended to provide guidance in ensuring a safe work environment.

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

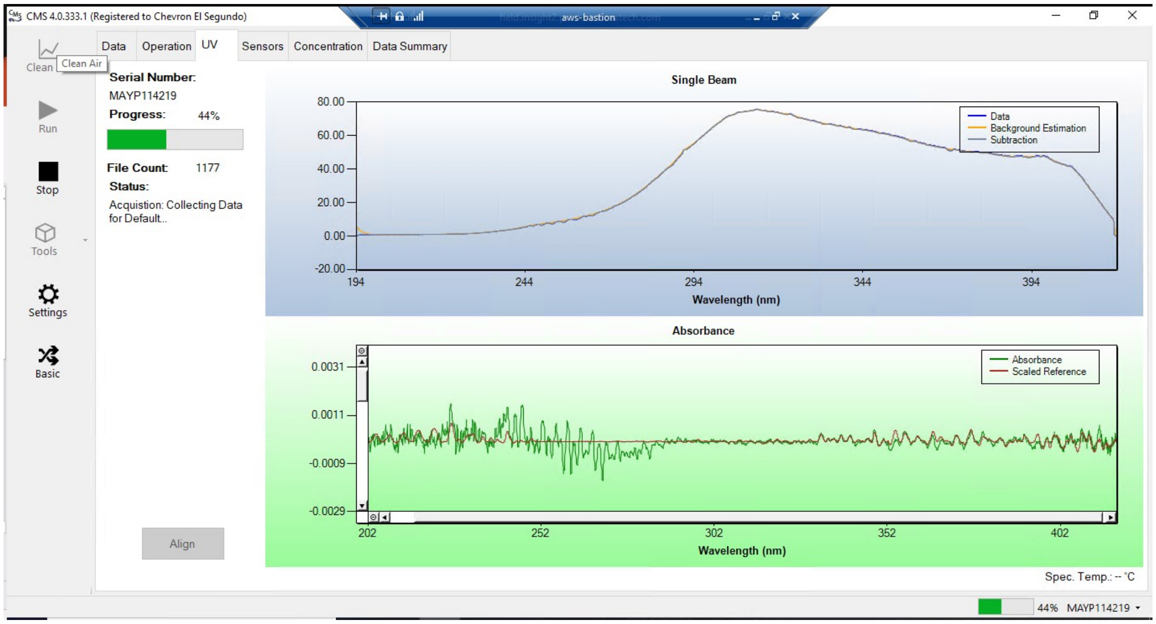
Please check off the following steps before conducting maintenance. Doing so reduces the chances of false notifications to the public and clients.

- ☐ 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 for at least 15 min to ensure proper reporting (no missing data, no high values, etc.).
- ☐ Take out of maintenance mode
- ☐ Notify the project manager and client when maintenance is complete.

5. Routine Operations

To set the 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).

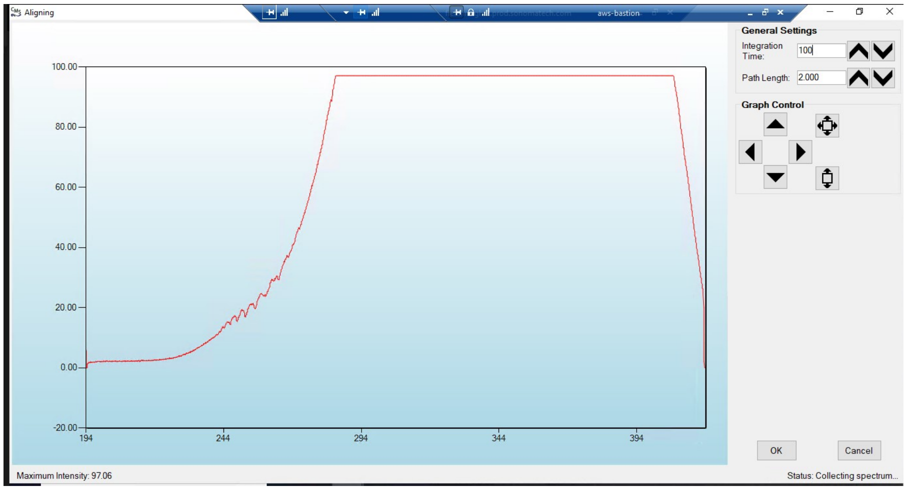
2. Under the **UV** tab, left-click on the **Align** button. This action brings up a new screen showing the instantaneous single beam plot (intensity vs wavelength). If the **Align** button is not active, you may need to press **Stop**. The **Align** mode is shown in Figure 3.

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.

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

        - Single Data Folder: **OFF**
        - Primary Summary File Logging: **ON**
            - C:\Users\CMS-USER\Documents\Cerex\Data
        - Secondary Summary File Logging: **ON**
            - \\OPT1-PC1\VLOData\OPT1_Path1\UVSentry_POC1
                - Note this path will change based on the different computer and path you are working on. This is just a basic file writing path to show you what it should look like
        - Single Summary File: **OFF**
    - Library
        - Library File: C:\Users\CMS-USER\Documents\Cerex\Library\
    - UI
        - Sort Column: Compound Name
        - Data Summary Chart: **OFF**
        - Concentration Chart: **OFF**
        - Password Protection Settings: **ON**
        - Pump Control: **OFF**
        - Status Control: **OFF**
        - Testing Control: **OFF**
- Analysis
    - General
        - Moving Average Interval: **12**
        - Display Units: **PPM**
    - Concentration
        - Zero Readings on Non-Detect: **OFF**
        - Zero Readings on Negative concentrations: **OFF**
        - Display BDL: **OFF**
        - Quick Analysis MDL Wave length Range: **276-280 (The range doesn’t matter)**
        - Temperature/ Pressure Concentration: **OFF**
    - Filters
        - Absorbance Savitzhy-Golay: **ON**
        - Baseline Correction Savitzky-Golay: **OFF**

- Instruments
    - UV
        - Operation
            - UV: **ON**
            - Acquisition Time (s): **30 (this is the “averaging time” of the instrument)**

      - Integration Time (ms): **Always will change if Auto integration is turned on**. This is the amount of time that the instrument will collect light.
      - Path Length (m): **2 (2 for monostatic, 1 for bistatic)**
      - Trigger Mode: **Normal**
    - Auto Routine
      - Auto Integration: **ON** **(the software will determine the integration time)**
      - Intervals (s): **300**
      - Wavenumber Range: **300-310 (This is the range where the intensity will be measured for autointegration determination. This is different on all instruments due to Spectral Background and Intensity Range)**
      - Intensity Range **75-85 (This is the target intensity range for the autointegration routine)**
      - Maximum Integration: **300**
      - Auto Background: **ON**
      - Interval (Acquisitions): **5**
      - Wavenumber Range: **266-270**
    - Verification
      - Verification: **OFF** **(This inactivates all inputs)**
- <u>Controller</u>
  - General
    - Serial Port: **n/a**
    - Sensor Refresh Interval (s): **15**
  - Sensors
    - **Don't Touch Anything**
  - Alarms
    - **Don't Touch Anything**
- <u>Email</u>
  - 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 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

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

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.

SAFETY WARNING

- Lamps emit ultraviolet radiation. Never stare directly into the operating lamp.
  - Ultraviolet radiation will irritate the eyes and might impair eyesight.
- Do not allow skin to be exposed to ultraviolet radiation.
  - Ultraviolet radiation may cause skin inflammation.
- Do not bring the lamp close to any flammable materials such as cloth or paper.

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**).

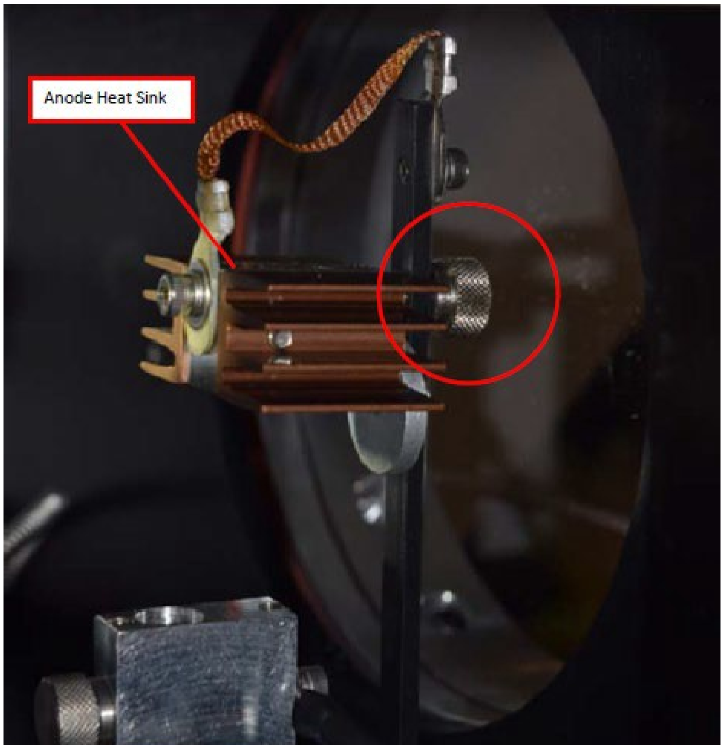


Figure 10. Anode heatsink at the top of the UV source.

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**).

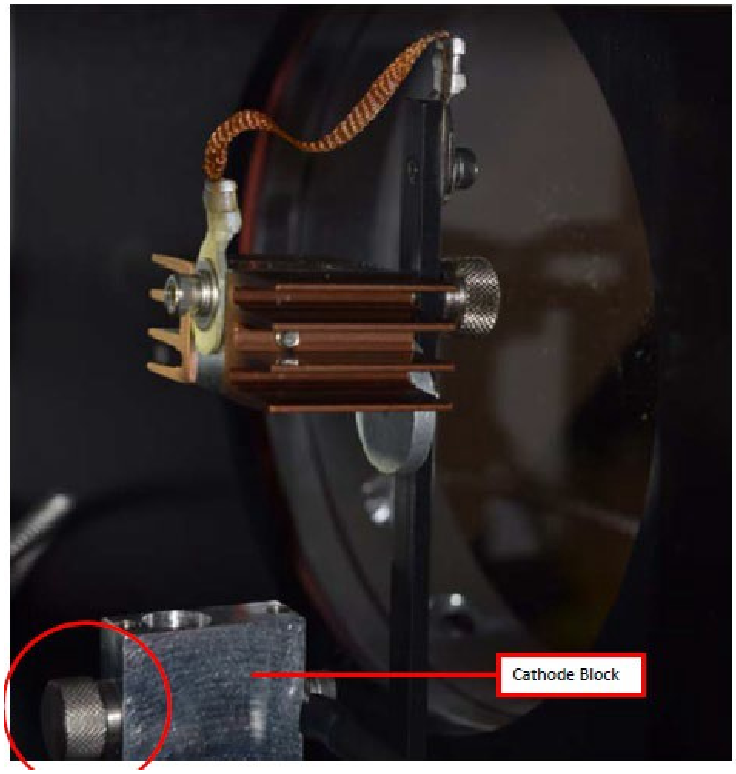


Figure 11. Loosen the thumbscrew on the Cathode block at the bottom of the UV source.

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 (-).

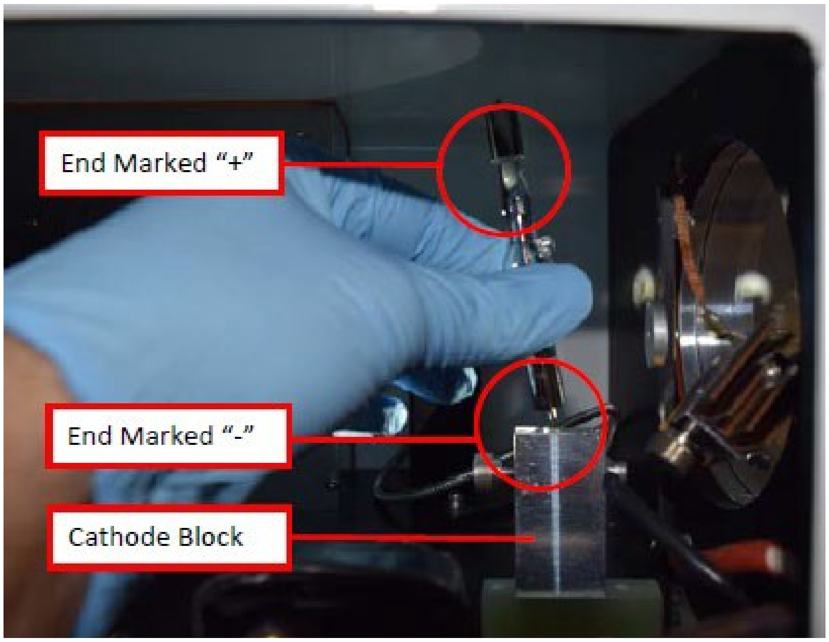


Figure 12. Inserting the Xenon UV Source into the Cathode block.

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.

Verify the system is set up (minus the instrument connections) as depicted in Figure 13.

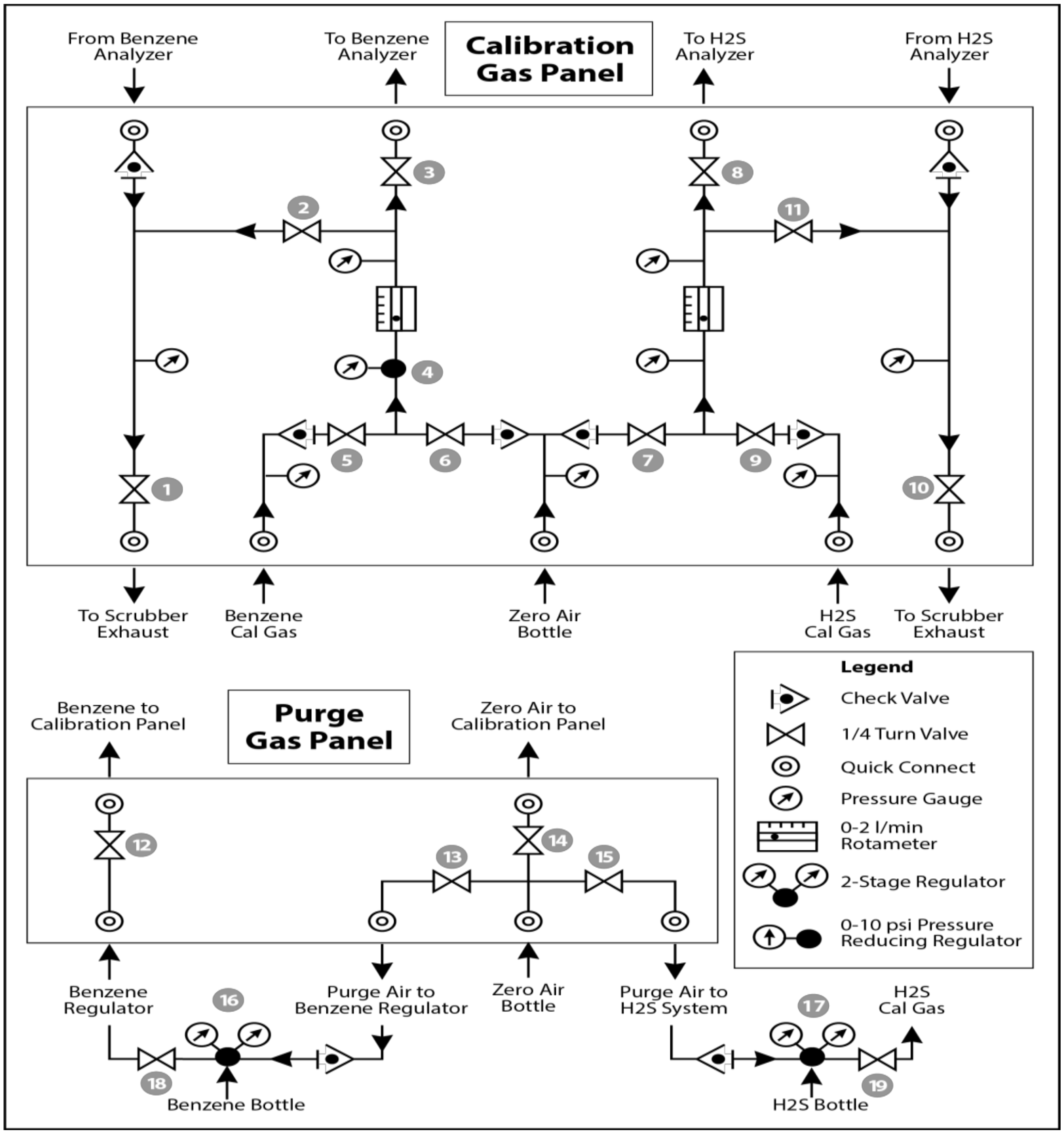


Figure 13. Diagram of the calibration gas panel (top) and purge gas panel (bottom) used for gas delivery.

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

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

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.

7.8.7 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).**

7.8.8 Completion of Test and Purge of Benzene Regulator

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.

7.8.9 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.

7.8.10 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.

7.8.11 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
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________
____________________	__________	_________

Verify Client ______________________ Init
Stop Time ______________________ Init
Open the **PURGE** gas Time ______________________
Reference Concentration __________ ppm
Average Concentration __________ ppm
% error __________ %
Std Deviation __________ ppm
% CV __________ ppm

Restore Normal Operation

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

Standard Operating Procedures for the CEREX AirSentry FTIR

February 21, 2024

STI-7036

APPROVED:

Sonoma Technology date

Fenceline Monitoring Refinery Representative date

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.**

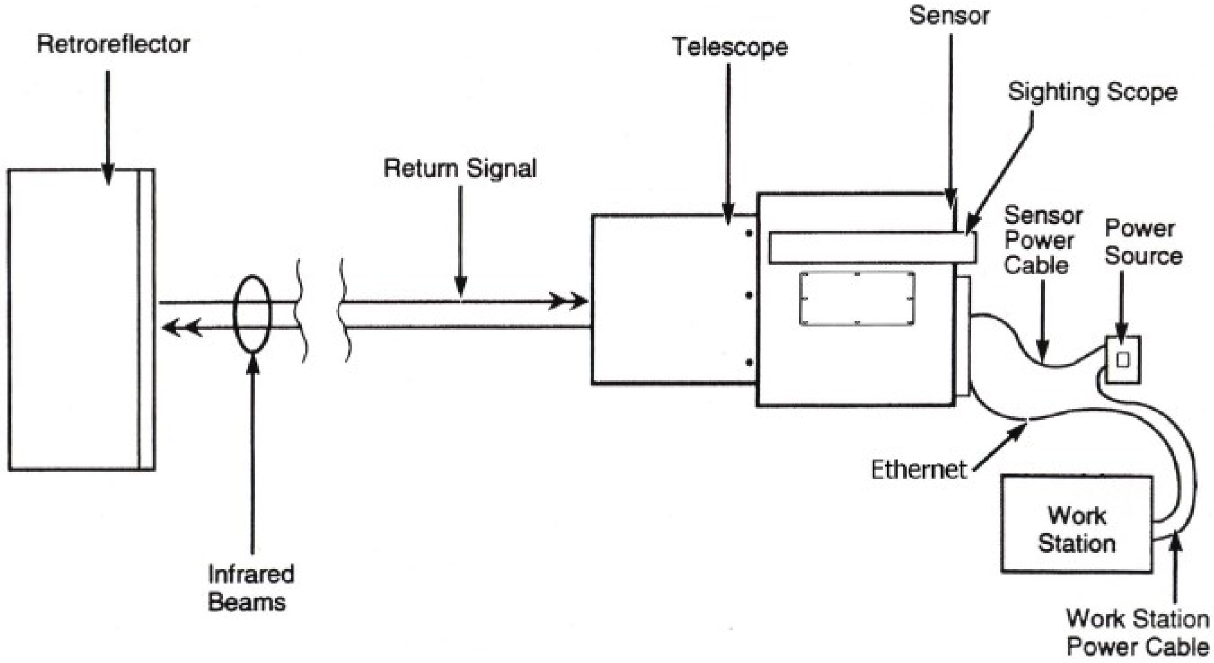


Figure 1. Schematic of the instrument.

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.

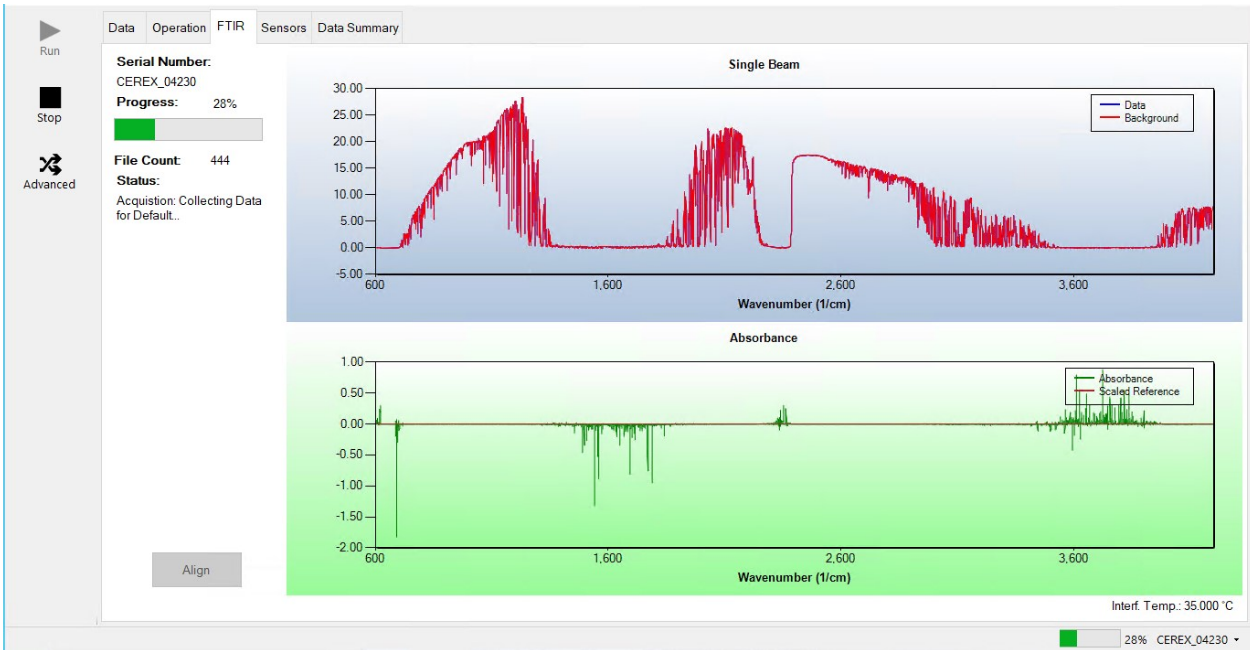
- ☐ Notify the client and project manager of maintenance tasks.
- ☐ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.

- ☐ 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.

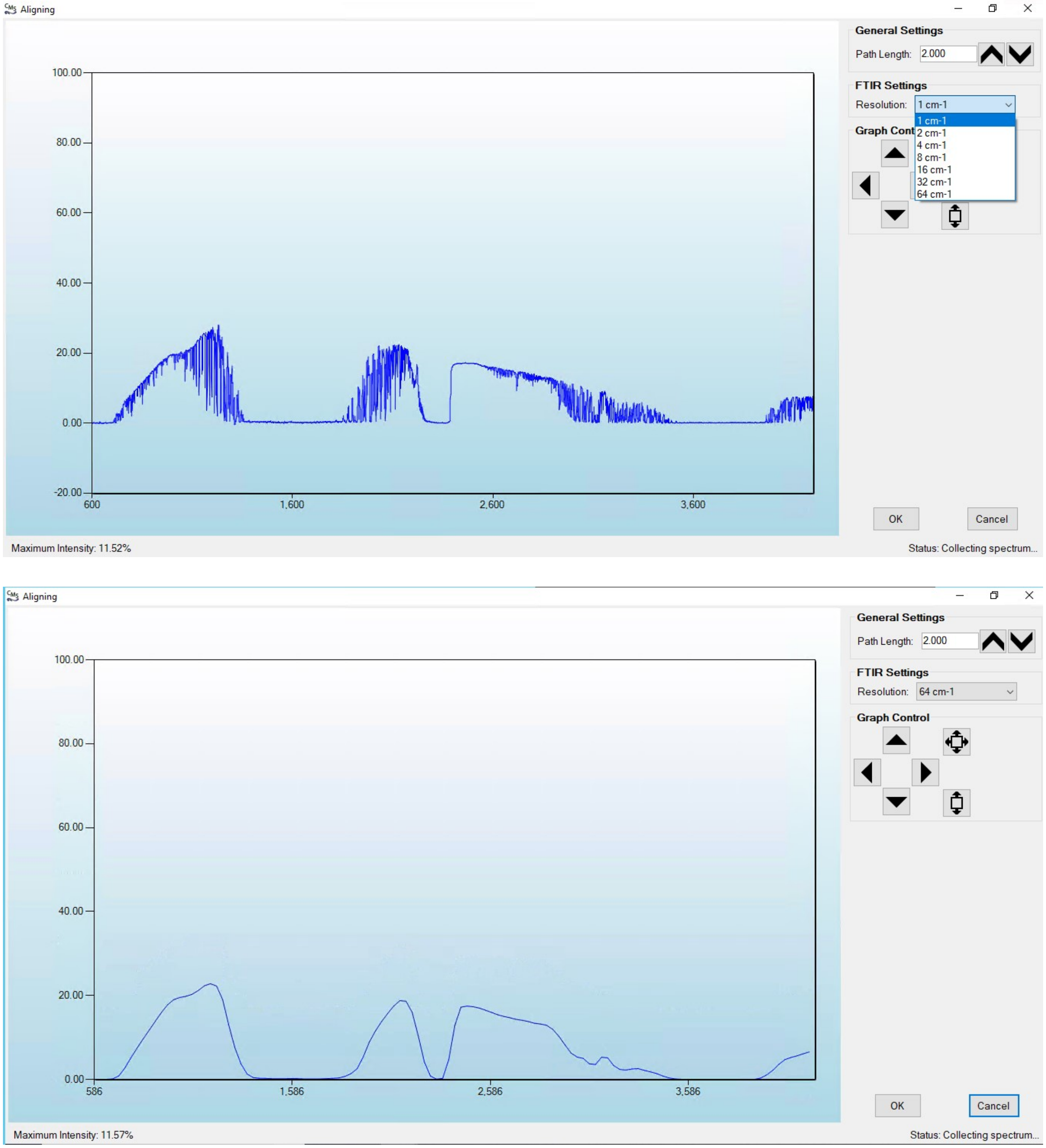
1. Start the CMS software (if not already initiated). You should see a window similar to the one shown in **Figure 2**.



Serial Number: CEREX_04230
Progress: 28%
File Count: 444
Status: Acquistion: Collecting Data for Default...
Interf. Temp.: 35.000 °C

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**.



Path Length: 2.000
Resolution: 1 cm-1
Maximum Intensity: 11.52%
Status: Collecting spectrum...

Path Length: 2.000
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**
- <u>Analysis</u>
    - General
        - Moving Average Interval: **12**
        - Display Units: **PPM**
    - Concentration
        - Zero Readings on Non-Detect: **OFF** (zeros reading below threshold % match)
        - Zero Readings on Negative concentrations: **OFF** (zeros reading less than zero)
        - Display BDL: **OFF**
        - Quick Analysis MDL Wave length Range: **276-280** (not typically used)
        - Temperature/ Pressure Concentration: **OFF**
    - Filters
        - Absorbance Savitzky-Golay: **OFF**
        - Baseline Correction Savitzky-Golay: **OFF**
    - Background
            - Auto Background: **ON** (typically ON for fenceline monitoring projects reporting concentration above background)
            - Interval (Acquisitions): **5** (How far back the routine will search for a background)
            - Depth: **4**

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

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

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

6. Equipment and Supplies

1. Field notebook
2. Tool kit, especially including: 7/64 hex driver, complete set of combination wrenches, adjustable wrenches, screwdrivers, etc.
3. Cleaning supplies designated to be safe for use on a Cerex FTIR
4. All relevant PPE, hardware, and procedural guidance per SOP, Safety Plan, and Safe Work Permit
5. Local or remote network link device (as required)
6. External laptop computer with network interface device to the Sentry unit (as required)
7. Cerex FTIR Sentry Unit equipped with CMS software
8. Isopropyl alcohol (≥80%)

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

7. Maintenance Activities

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

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

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

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

7.1 Monthly Visual Inspections

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

7.2 Light Level Check

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

Check for Stray Light

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

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

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

7.3 Data Management

7.3.1 Archiving and Deleting Older Data

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

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

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

   Note: This procedure excludes the Bump Test folder, which should always remain on the instrument computer.
4. Log into the brick PC located in the instrument shelter and locate the data files written from the instrument onto the external hard drive.
5. Confirm all Complete Data Summary files and Simple Data Summary files for the desired month have transferred over completely to the external hard drive attached to the brick PC.
6. Once you have confirmed that those files have been transferred over to the external hard drive, delete those exact Complete Data Summary and Simple Data Summary files from the instrument data folders.
7. For each individual day of single beam folders, ensure that the amount of single beam files are the same on both the external hard drive located on the brick pc and the internal hard of the instrument.
8. If both folder locations match and you have ensured proper file download, you may permanently delete the Single Beam folders from the instrument computer.
9. After all data older than 12 months have been deleted, note how much free space is now

---

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

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.

Verify system is set up (minus the instrument connections) as depicted in **Figure 4**.

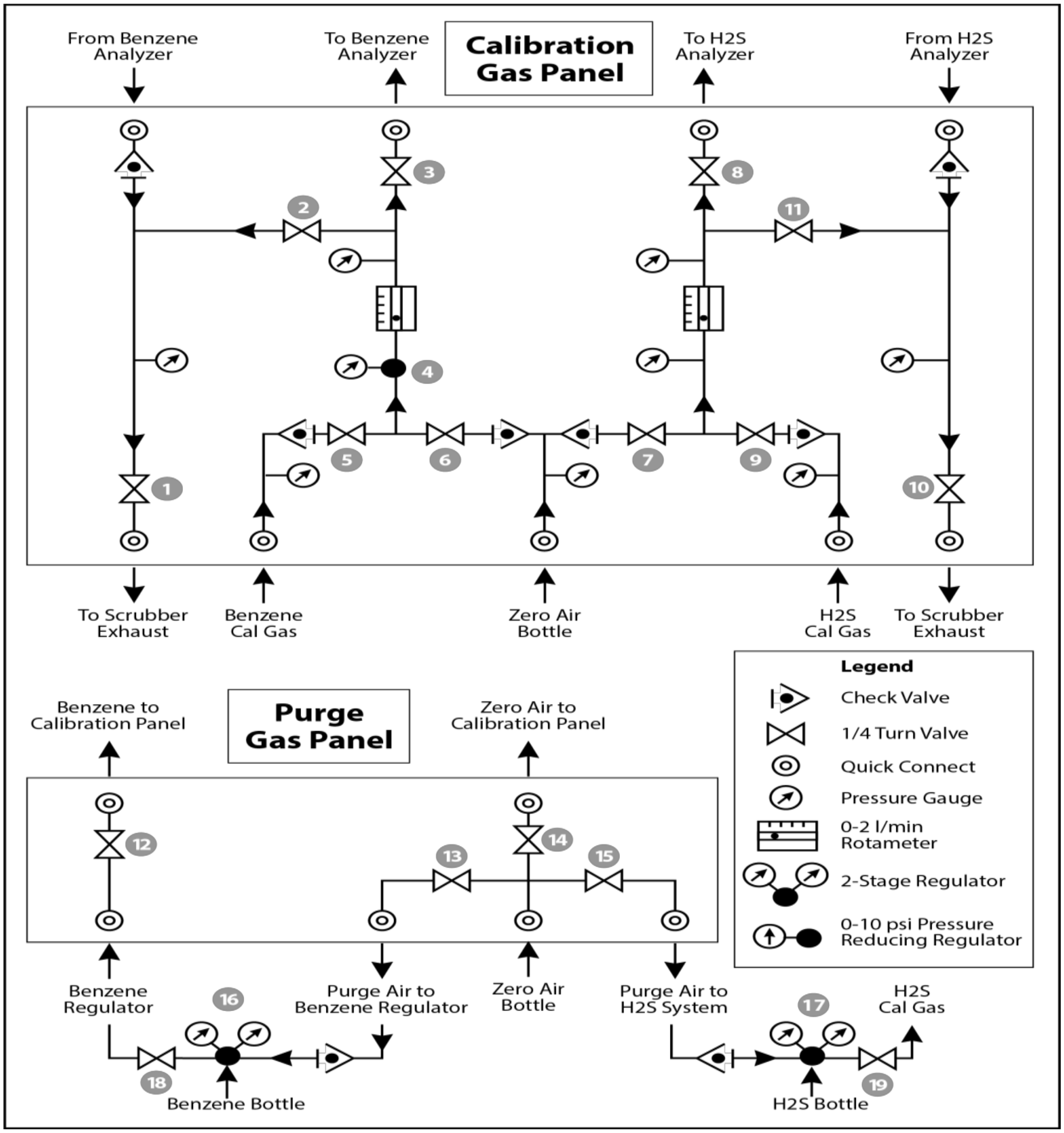


Figure 4. Diagram of the calibration gas panel (top) and purge gas panel (bottom) used for gas delivery. Note that the gas used will change depending on the instrument.

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 gas panel.
  c. All necessary tubing for supplying calibration and zero reference gas to calibration gas panel.
  d. Flow regulation system capable of delivering gas 0.1 to 5 L/min at a total system pressure of 3 psig or less.
3. Purge gas; typically, Zero Air.
4. Reference standard traceable gas blend in nitrogen for detection at about 5 times the instrument’s theoretical detection limit or higher.
5. All relevant PPE, hardware and procedural guidance per SOP, Safety Plan, and Safe Work Permit.
6. Local or remote network link device (as required).
7. External laptop computer with network interface device to the AirSentry FTIR unit (as required).

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

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

7.5.3 Gas Test System Setup

1. Connect the 1/4” reference cell line coming from the calibration panel 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 panel 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 panel are in the closed position.
4. Make all necessary connections from Zero Air and calibration gas standard cylinders to the Gas Calibration Panel.

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

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 left!**) 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 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.

7.5.8 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.

7.5.9 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.

7.5.10 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.

7.5.11 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:

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

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 (0.047 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 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**).

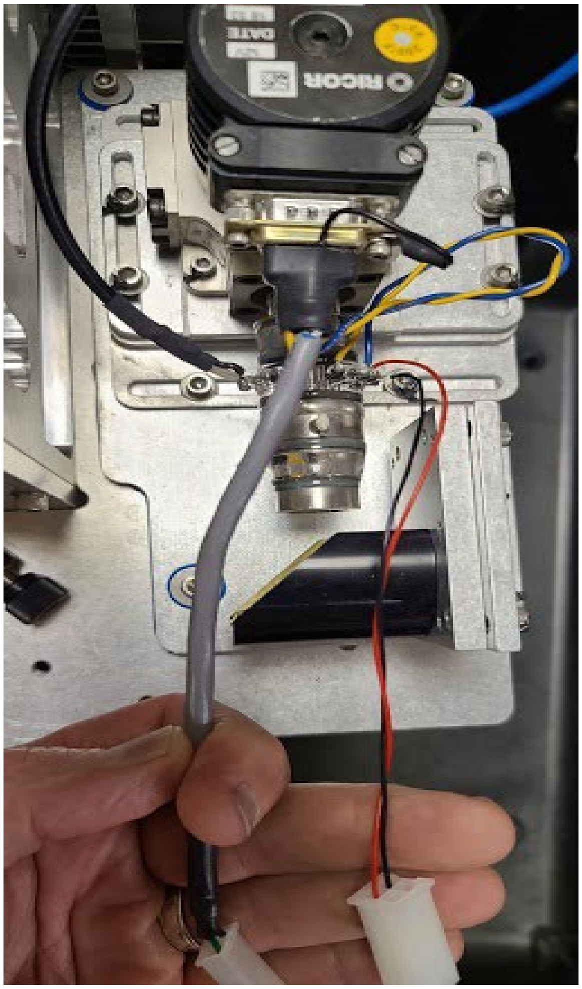


Figure 5. Detector assembly showing RICOR cryocooler, glass detector, DB9 connector, two white Molex connectors, and mirror.

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**).

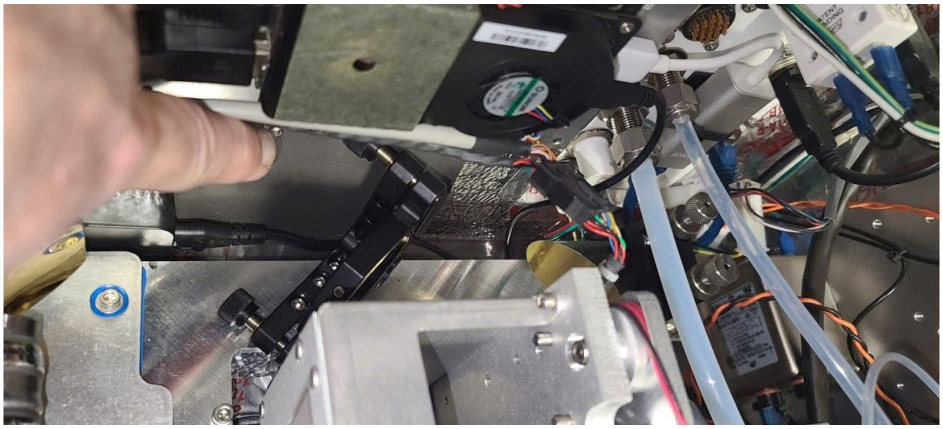


Figure 8. Beamsplitter (black object at 45-degree angle) with adjustment screws.

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**).

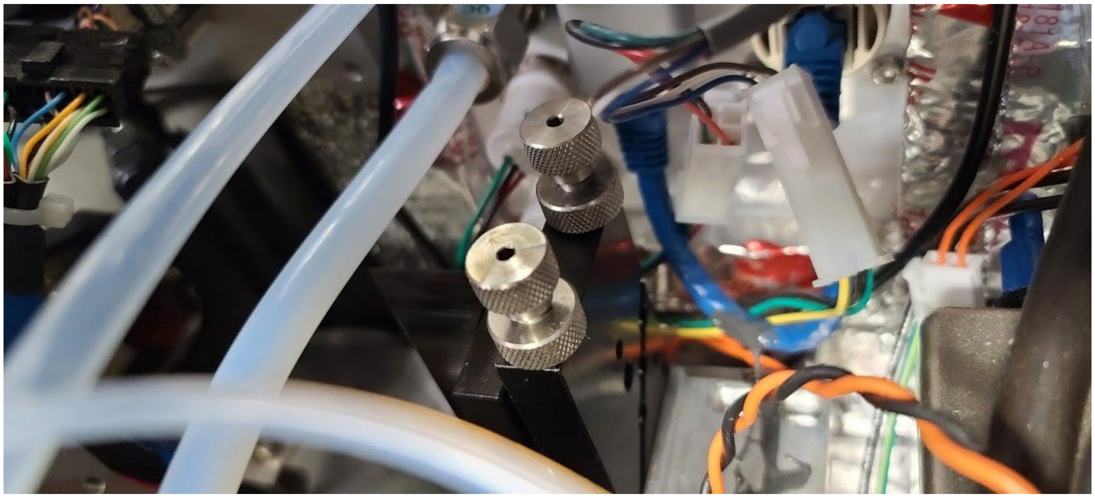


Figure 9. Beam steering mirror with sliver adjustment screws.

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

Verify Client ________________________ Init

Stop Time ________________________ Init

Open the PURGE Gas Time ________________________

Reference Concentration __________ ppm

Average Concentration __________ ppm

% error __________ %

% Spectral Match __________ %

Standard Deviation __________ ppm

Estimated MDL (3X Standard Dev) __________ ppm

Restore Normal Operation

Restore running data file ________________________ Init

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

Standard Operating Procedure for H_2S Point Monitors

June 24, 2024

STI-8094

APPROVED:

Sonoma Technology	date
Fenceline Monitoring Refinery Representative	date

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1. Scope and Application

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

2. Safety

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

3. Method Overview

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

4. Equipment and Supplies

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

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

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

5. Maintenance Schedule

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

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

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

6. Field Operation and Maintenance

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

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

6.1. Perform Zero/Span or Multi-Point Check

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

6.1.1. Manual Verification

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

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

6. From the dilution calibrator, select one of the following options:
    a. **Span Check:** Set the target H_2S span gas on. The target value should be at least 80% of the full measurement range.
    b. **Multi-Point Check:** Set the target H_2S concentrations appropriate for the monitoring project. An example of multi-point check concentrations is shown in Table 2.

Table 2. Example of multi-point check concentrations.

Multi-point check concentration (ppb)
450
225
120

7. Wait at least 45 minutes until the analyzer stability (STAB) is below 0.5 ppb for each concentration level (wait longer than 15 minutes if more time is needed for STAB to be < 0.5 ppb at each level). Record the readings. If the stability threshold cannot be achieved, contact the Project Manager and proceed to additional troubleshooting steps.
8. Refer to the facility's QAPP for the test acceptance criteria.
9. Purge the sampling line and the analyzer by generating a high flow of zero air for at least 5 minutes. This step helps the analyzer return to sampling ambient conditions.
10. At the conclusion of the check, put the calibrator into STANDBY Mode.

    IMPORTANT: Failing to change the calibrator to STANDBY Mode means the analyzer will continue to detect zero air or span gas fed to the inlet, resulting in INVALID ambient data.
11. Verify the T101 status remains in SAMPLE Mode at the lower right corner of the display.
12. Observe and make sure the H_2S reading has returned to ambient concentrations **before** putting the channel back to Normal Operations from the Field Tech Tool.

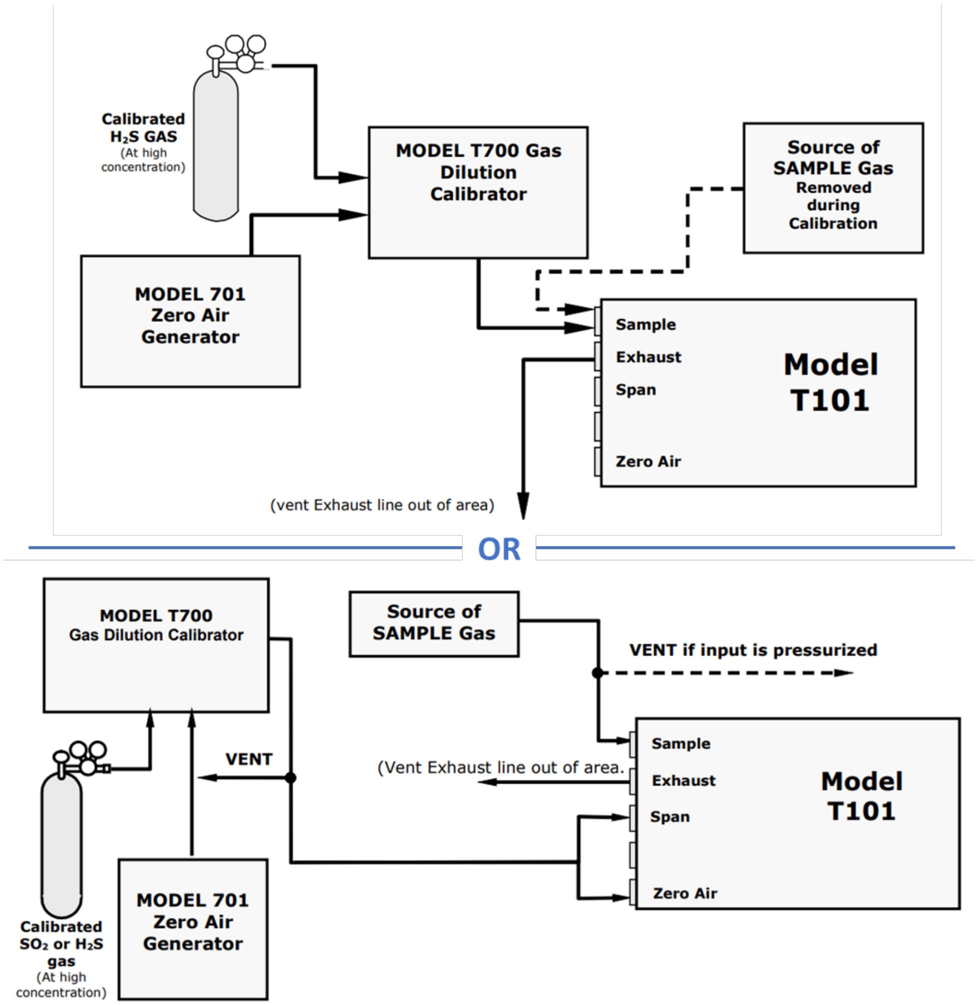


Figure 1. Connection setup for verification and calibration with basic configuration (top) or zero/span valves option (bottom).

6.1.2. Automated Verification

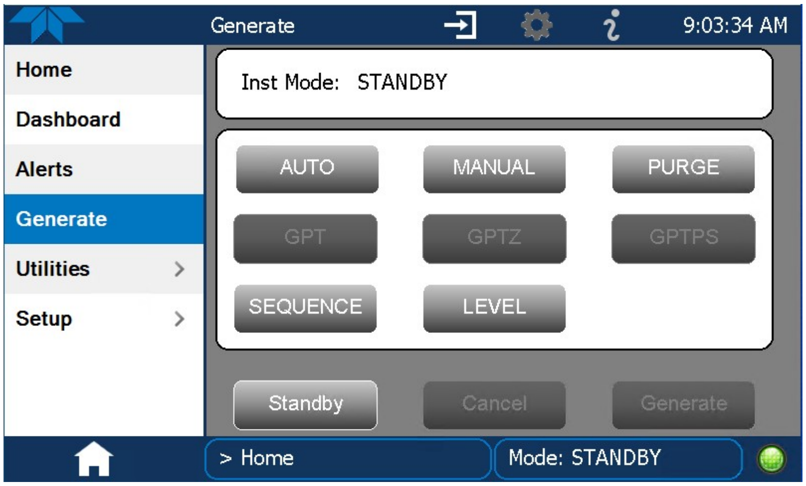
For some monitoring sites, automated verification may be configured and initiated manually. Note the following procedure is only applicable when the Teledyne T101 analyzer and T700 dilution calibrator are used together.

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

1. Verify the ambient conditions are acceptable (H_2S < 10 ppb) to proceed with gas verification. Put the H_2S channel into Maintenance Mode from the Field Tech Tool.
2. Connect the zero and span gas sources as shown in Figure 1, depending on instrument configuration. The zero air generator can be replaced by a zero air cylinder. Make sure the

T700 dilution calibrator contains the accurate gas standard concentration under cylinder setup menu.

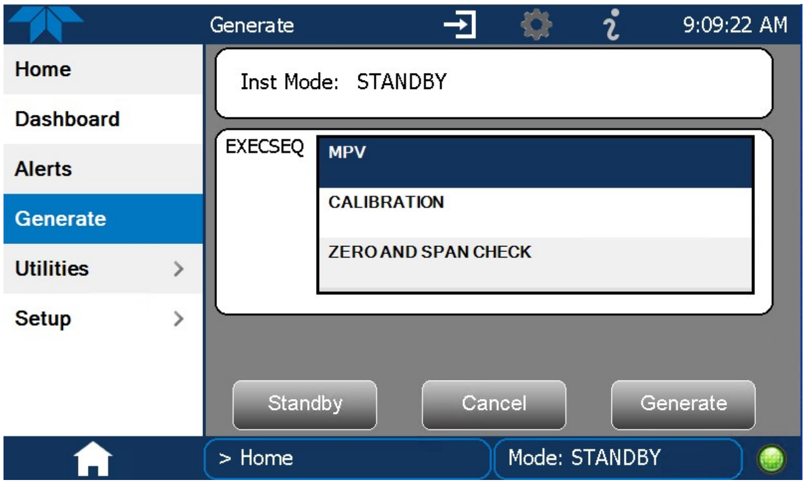
3. If the verification is to be initiated remotely via the NumaView Remote Software, open the software, and launch the analyzer and calibrator of interest.
4. From the T700 dilution calibrator, go to Generate > Sequence to view a selection of preset sequences, as shown in Figures 2 and 3.
5. Select the sequence to be initiated and click Generate.
6. Verify the calibrator begins the steps by observing the Instant Mode in the Generate menu or Mode at the lower right corner of the display.



Inst Mode: STANDBY

Mode: STANDBY

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



Inst Mode: STANDBY

EXECSEQ

Mode: STANDBY

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

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

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

6.2. Review and Verify Test Functions

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

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

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

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

6.3. Inspect Sample Lines

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

6.4. Change Sample Particulate Filter

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

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

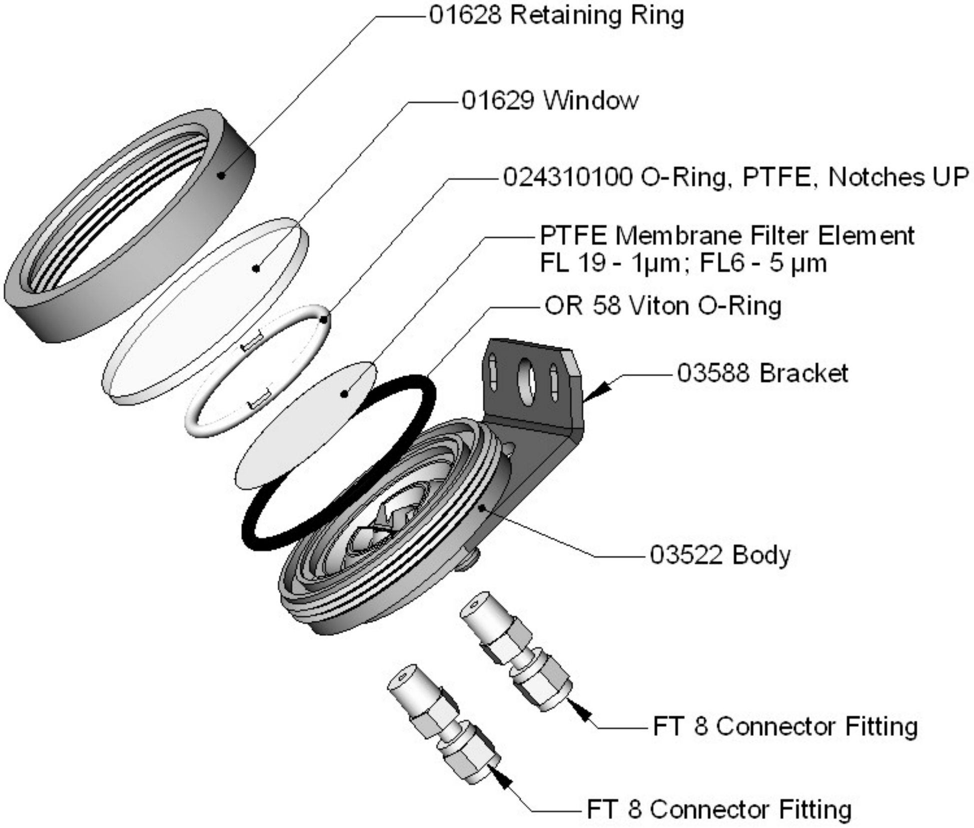


Figure 4. Particulate filter assembly.

6.5. Perform Flow Check

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

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

6.6. Change the SO_2 Scrubber (Activated Charcoal)

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

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

6.7. Check for H_2S -> SO_2 Converter Efficiency

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

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

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

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

6.8. Change H_2S -> SO_2 Converter Catalyst Material

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

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

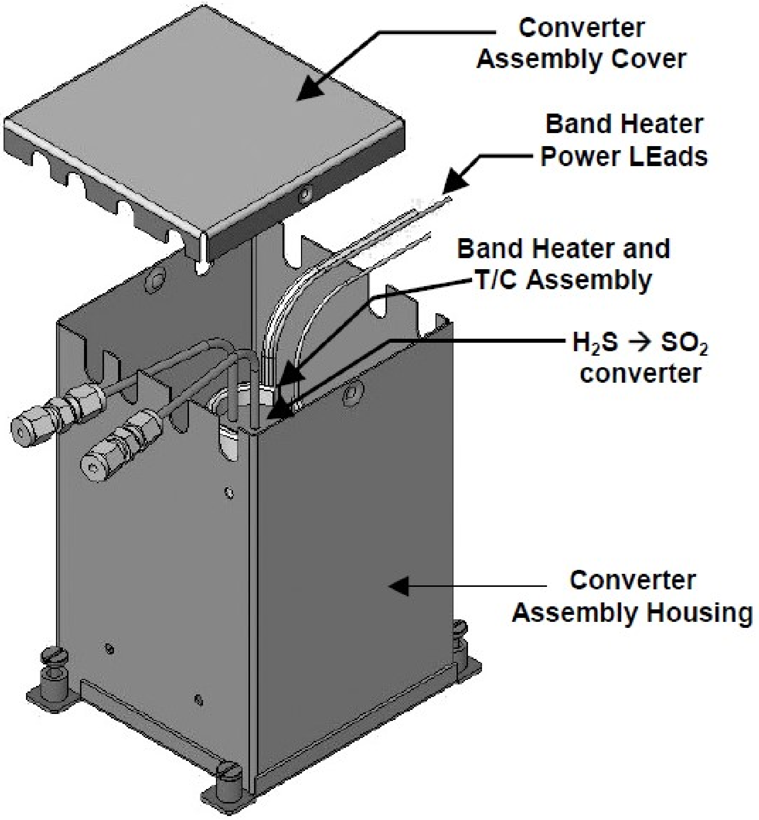


Figure 5. H_2S -> SO_2 converter assembly.

6.9. Service the Critical Flow Orifice Assembly

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

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

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

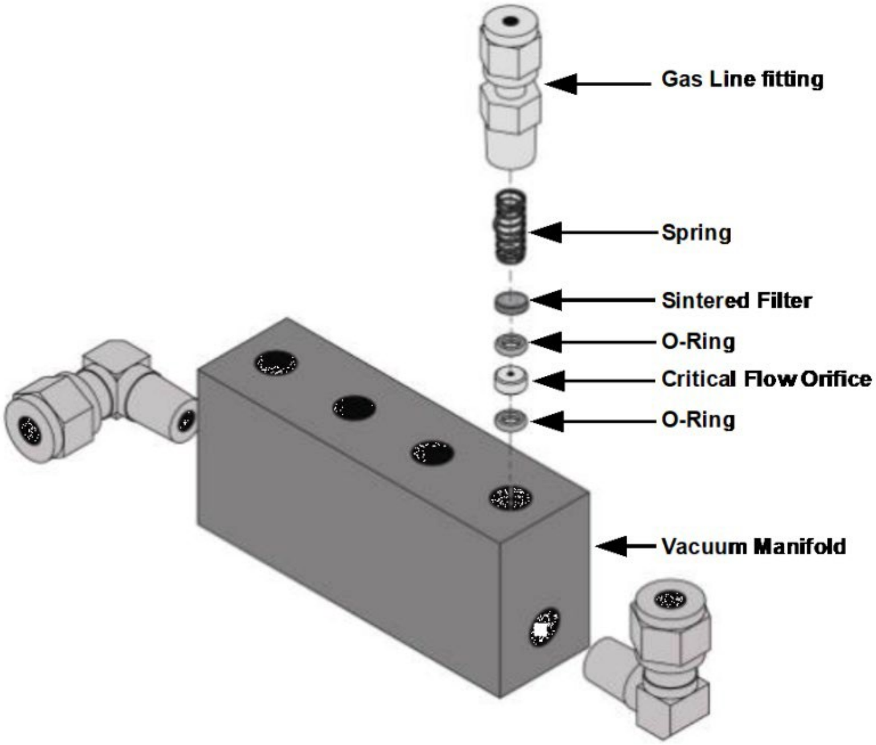


Figure 6. Critical flow orifice assembly.

6.10. Perform Leak Check/Pump Check

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

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

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

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

6.11. UV Lamp Adjustment and Calibration

The UV lamp output can be affected by line voltage change, aging lamp, or lamp position. Two metrics need to be considered when assessing the lamp life: UV lamp intensity and lamp ratio. Lamp intensity should be 2,000-4,000 mV and the lamp ratio should be 30-120%. These values will decrease over time. To optimize signal intensity, perform the following steps.

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

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

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

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

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

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

6.12. PMT Sensor Hardware Calibration

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

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

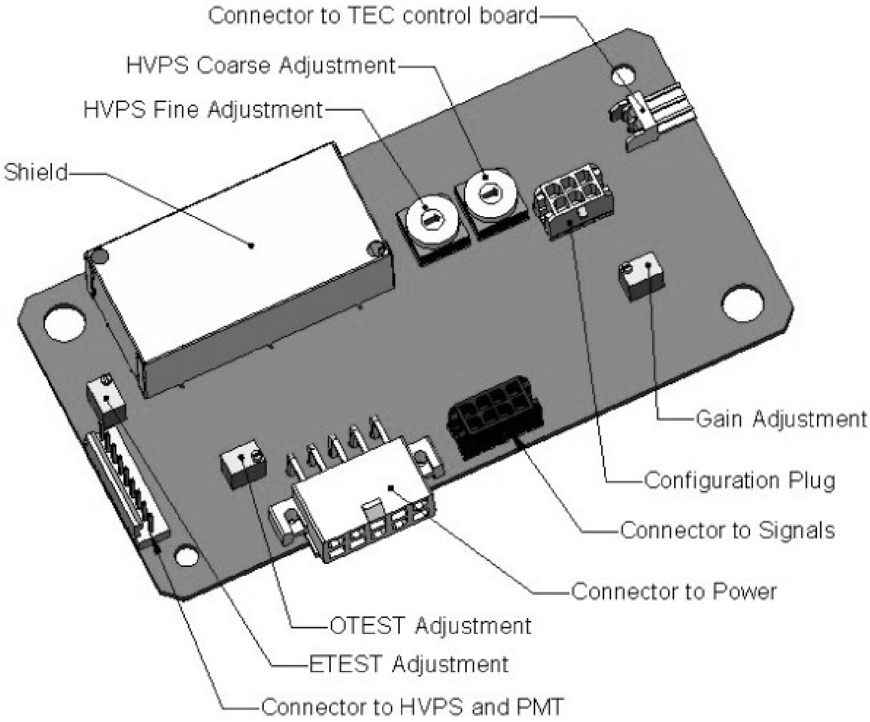


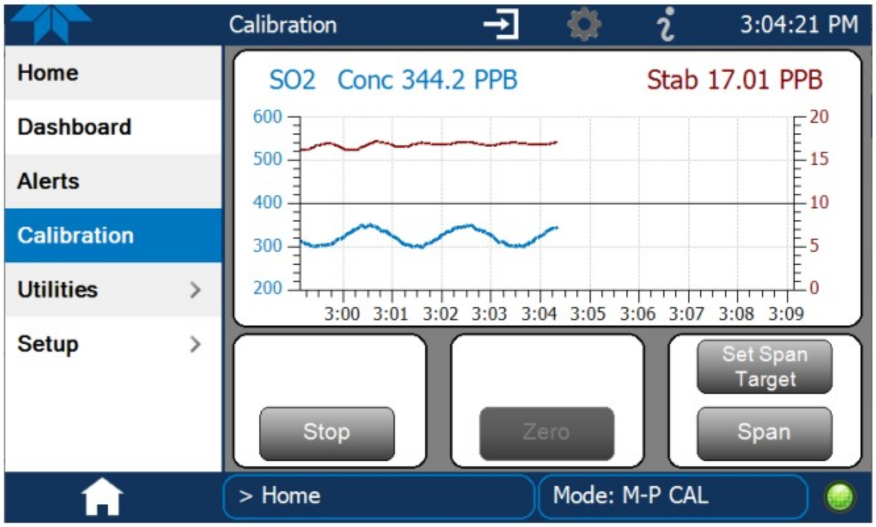
Figure 7. Pre-amplifier board layout.

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

6.13. Calibrate Offset and Slope

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

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



SO2 Conc 344.2 PPB

Stab 17.01 PPB

Mode: M-P CAL

Figure 8. Calibration page.

6.13.1. Manual Calibration

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

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

Zero calibration:

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

Span calibration:

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

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

6.13.2. Automated Calibration

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

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

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

- Before any calibration, record the as-found slope and offset in the maintenance form. <u>You will NOT be able to retrieve the values once the analyzer is calibrated.</u>
- Make sure the T700 dilution calibrator contains the accurate gas standard concentration information in the cylinder setup menu.
- Once the calibration sequence is initiated, verify the calibrator begins the steps by observing the Instant Mode in the Generate Menu or Mode at the lower right corner of the display.

- At the conclusion of Zero and Span calibration, verify the new slope and offset are within the acceptable range shown in Table 3. If not, some parts may be causing the slope and offset to over-compensate and corrective action is needed.
- Record the new slope and offset in the maintenance form.
- Proceed to Section 7.5 to perform a post-calibration multi-point check.

7. Teledyne T101 H_2S analyze Maintenance Forms

7.1. Maintenance Checklist

Activity	Monthly
Any active alerts for EITHER Analyzer or Calibrator? If yes, investigate the root cause of alerts. Record the time, date, and alert description below.	
Verify analyzer diagnostics. Complete Table 4 below.	
Inspect sample line tubing and inlet.	
Inspect and empty out water trap.	
Replace fine particulate filter at analyzer inlet.	
Perform the monthly gas test for analyzer response. If the test fails, investigate the root cause, and calibrate as needed.	
Activity	**Quarterly**
Perform multi-point gas test for analyzer response. If the test fails, investigate the root cause, and calibrate as needed. Acceptance Limits - Zero: ≤ ±1.5 ppb Span: ≤ ±20%	
Activity	**Annually**
Replace SO_2 scrubber media.	
Perform analyzer hardware calibration (Factory Cal).	
Perform zero air generator and dilution calibrator maintenance (refer to T101 SOP).	

Alert notes, if any:

7.2. Analyzer Diagnostics

Diagnostics	Acceptable Value Range	Value
H_2S slope	1 ± 0.3	
H_2S offset (mV)	< 250 mV	
Converter Temp (°C)	315 ± 1 °C	
Sample Flow (ccm)	585-715 ccm (650 ccm ± 10%)	
Pressure (inHg)	Ambient ± 2 inHgA	
UV Lamp Signal (mV)	2,000 – 4,000 mV	
UV Lamp Ratio (%)	30-120%	

7.3. Analyzer Response Summary

Date: ______________________ Technician: ______________________

Site: ______________________ Start Time: ______________________

Analyzer Serial Number: __________________ End Time: ______________________

Calibration Systems

Calibrator Model: ______________________ Calibrator Serial Number: ______________________

Zero Air Generator (ZAG) Model: ____________________ ZAG Serial Number: ______________________

Gas Cylinder Concentration: ____________________ Gas Cylinder Number: ______________________

Gas Cylinder Expiration Date: ____________________ Gas Cylinder Pressure (psi): ____________________

H_2S Gas Verification Type: ☐ Monthly ☐ Quarterly ☐ Annual/Factory Cal

7.4. Monthly Performance Verification Results

Point	Concentration Set Point (ppb)	Measured Concentration (ppb)	Stability (ppb)	Percent Error (%)
1	0			-
2	200			

7.5. Quarterly or Post-Calibration Performance Verification Results

Point	Concentration Set Point (ppb)	Measured Concentration (ppb)	Stability (ppb)	Percent Error (%)
1	0			-
2	200			
3	100			
4	50			

Notes for H_2S Analyzer:

Average %: ________________
As-left Slope: ________________
As-left Offset: ________________

Standard Operating Procedures for Meteorological Instruments

June 24, 2024

STI-7179

APPROVED:

Sonoma Technology date

Fenceline Monitoring Refinery Representative date

Contents

1. Scope and Applicability

This standard operating procedure (SOP) provides instructions for servicing a standard 10-m meteorological tower equipped with sensors that will measure wind speed, wind direction, temperature, relative humidity, and visibility. Table 1 lists the equipment make and model that will be 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	RM Young, Model 41341 and 41382
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 four weeks. If no problems are encountered, the site visit will take about one 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.

[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.

3. Calibration and SOPs for Meteorological Sensors

Semi-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 sensor 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 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	±0.25 m/s	0.2 m/s
Wind Direction	±5°	3°
Ambient Temperature	±0.5°C	0.3°C
Relative Humidity	±7% RH	1.0% RH
Vertical Temperature Difference	±0.1°C	0.1°C

3.1 Wind Direction Calibration

The wind direction calibration will be 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 will be verified using a calibration fixture, assigned compass reference points, or established distant sighting targets. Differences between reference and sensor measured directions will be recorded. The starting threshold for the direction vane will be 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.
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 will be rotated sequentially through the increments clockwise and counter-clockwise, and the DAS readouts will be recorded. The tip and the tail of the vane may also be pointed at established distant sighting targets.
4. The difference between the station and calibration wind directions is calculated using the following equation:

   Difference = Station Wind Direction - Reference Wind Direction

   The differences calculated above will be 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 will be 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 will be 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 will be 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 will be tested at zero and at least two speeds within the operational range of the sensor. The RM Young Model 18810 selectable speed anemometer drive will be 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 will be 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

- One 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 will be 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 will be immersed in a common stirred water bath.

   b. Readings will be compared at 3 points over the expected temperature range.

3. If delta-temperature is measured, simultaneously insert both temperature sensors in the same medium and compare the outputs.
4. Calculate the difference between the station and audit temperatures using the following equation:

   Difference = Station Temperature - Reference Temperature

5. The differences calculated above will then be compared against 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 against 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 will be performed by collocating the calibrated RH sensor or motor-aspirated psychrometer adjacent to the site sensor. The sensors will be placed in a shaded location and allowed to equilibrate.
2. Multiple readings will be taken over several hours.
3. Calculate the difference between the station and reference relative humidity readings using the following equation:

   % RH Difference = Station % RH - Reference % RH

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

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 will be 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
```

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
```

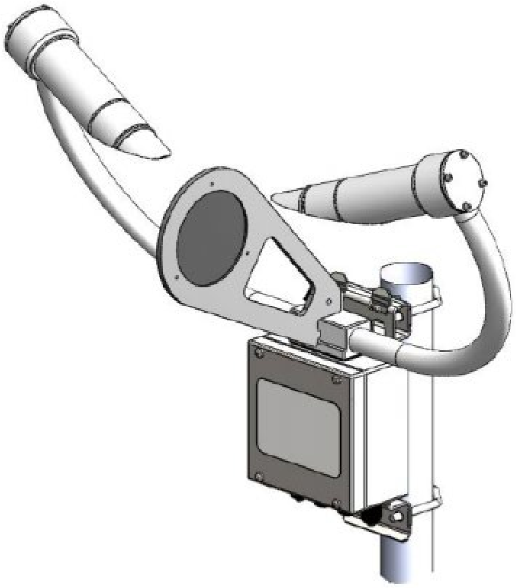
This part of the test will take approximately two minutes. Every ten seconds, a dot should appear indicating that the test is progressing as normal.

```
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 will be 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**.

U.S. Environmental Protection Agency (2008b) Quality assurance handbook for air pollution measurement systems, Volume IV: meteorological measurements version 2.0 (final). Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-08-002, March. Available at **https://www3.epa.gov/ttn/amtic/qalist.html**.

U.S. Environmental Protection Agency (2016) Technical assistance document for the National Air Toxics Trends Stations Program, Revision 3. Prepared for the Office of Air Quality Planning and Standards, Research Triangle Park, NC, by Battelle, Columbus, OH, October. Available at **https://www3.epa.gov/ttnamti1/files/ambient/airtox/NATTS%20TAD%20Revision%203_FINAL%20October%202016.pdf**.

U.S. Environmental Protection Agency (2017) Quality assurance handbook for air pollution measurement systems, Volume II: ambient air quality monitoring program. Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-17-001, January. Available at **https://www3.epa.gov/ttnamti1/qalist.html**.

5. Maintenance Form: Meteorology Station Checklist

Date: ____ Location: ____

Meteorological Checklist

Activity	Monthly
Visually inspect site conditions, including: • Cables and wires • Temp/RH radiation shield • Met tower and tower base • Anemometer heading	
Verify measurements in Public table on LoggerNet	
Wind speed (m/s) and wind direction (degree)	WS: WD:
Ambient 2M and 10M Temperature (°C)	2M: 10M:
Delta temperature between 2M and 10M (°C)	
Relative Humidity (%)	
Activity	**Semi-Annually**
Perform met QC check (WS, WD, Temp, and RH). Take corrective actions if any QC check fails.	

Notes for Met Sensors:

Campbell Scientific Visibility Sensor Checklist

Activity	Monthly
Visually inspect the system, including all cables.	
Inspect and clean optics on detector.	
Activity	**Quarterly**
Obtain visibility sensor status, check for faults, and clean and/or calibrate.	

Notes for Visibility Sensor:

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: