Sonoma Technology

Standard Operating Procedures for the CEREX AirSentry FTIR

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1. Scope and Application

This Standard Operating Procedure (SOP) document covers the use of the CEREX AirSentry Fourier Transform Infrared Spectroscopy (FTIR) analyzer in a fenceline monitoring application. This document addresses routine maintenance activities, including visual inspections, instrument checks, data management, quality assurance (QA) bump 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 IR 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.**

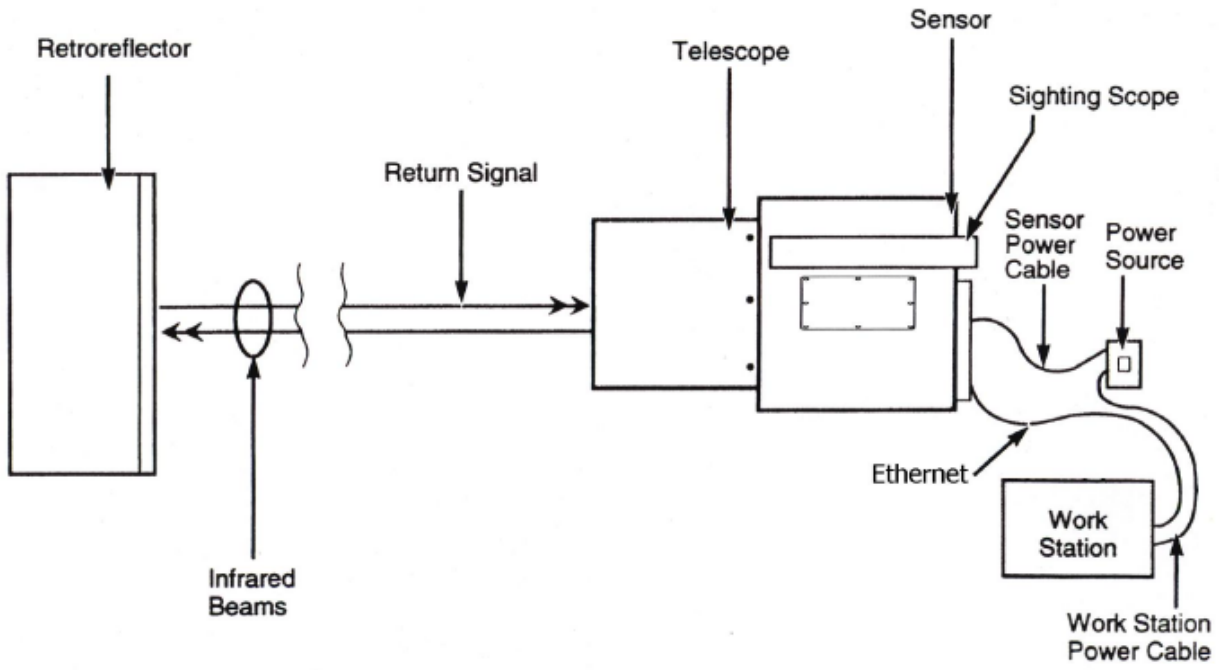


Figure 1. Schematic of the instrument.

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 rapidly converts the incident IR wavelengths into electrical currents. 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 go 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 for 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	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.
Coefficient of Determination (R^2)	The square of the correlation coefficient. R^2 ranges from 0 (not correlated) to 1 (perfect correlation).
Correlation Coefficient (r)	A coefficient that measures the linear correlation between two sets of data. In the case of the FTIR, 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 (i.e., $R^2 \times 100$).
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 Personal Protective Equipment (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. The operator should be fully trained and experienced in the use of compressed gas cylinders, one- and two-stage regulators used in conjunction with the cylinders, flow controllers, and tubing connections. The 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.

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 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 QA 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 are invalidated on the public website before proceeding with maintenance.
- ❒ When maintenance is complete check the public site for at least 15 min to ensure proper reporting (no missing data, no high values, etc.).
- ❒ Take the equipment 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 Continuous Monitoring Software (CMS) must be operating and the instrument must be aligned. These actions are detailed in the steps below.

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

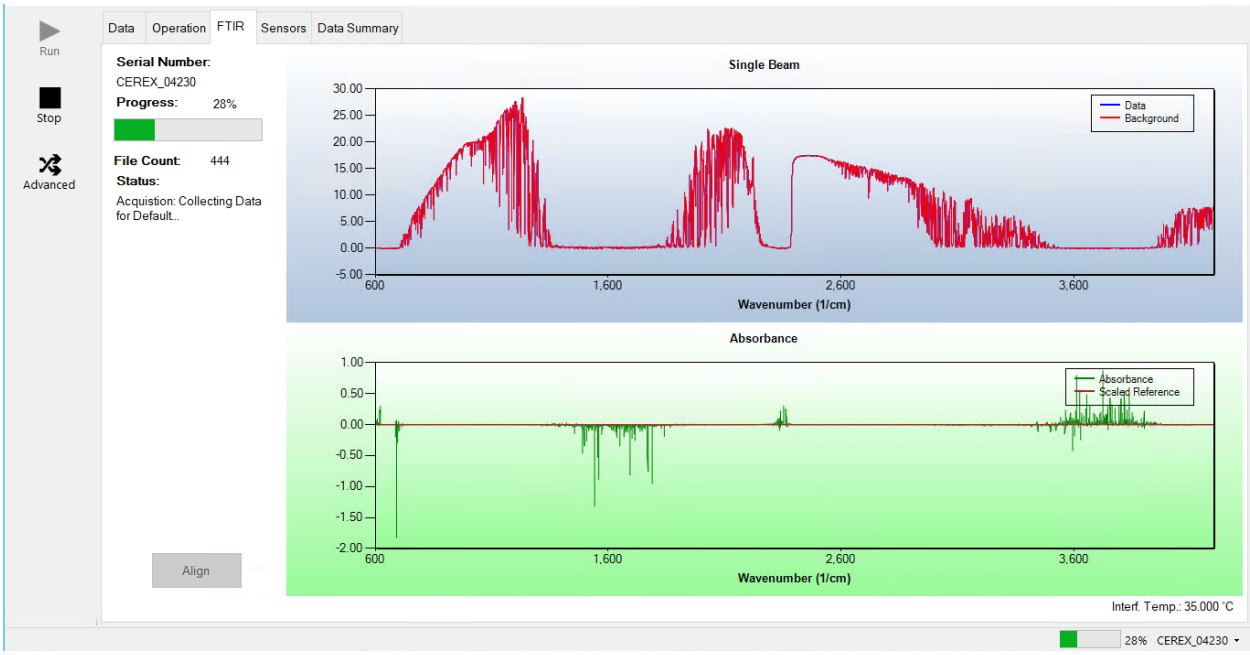
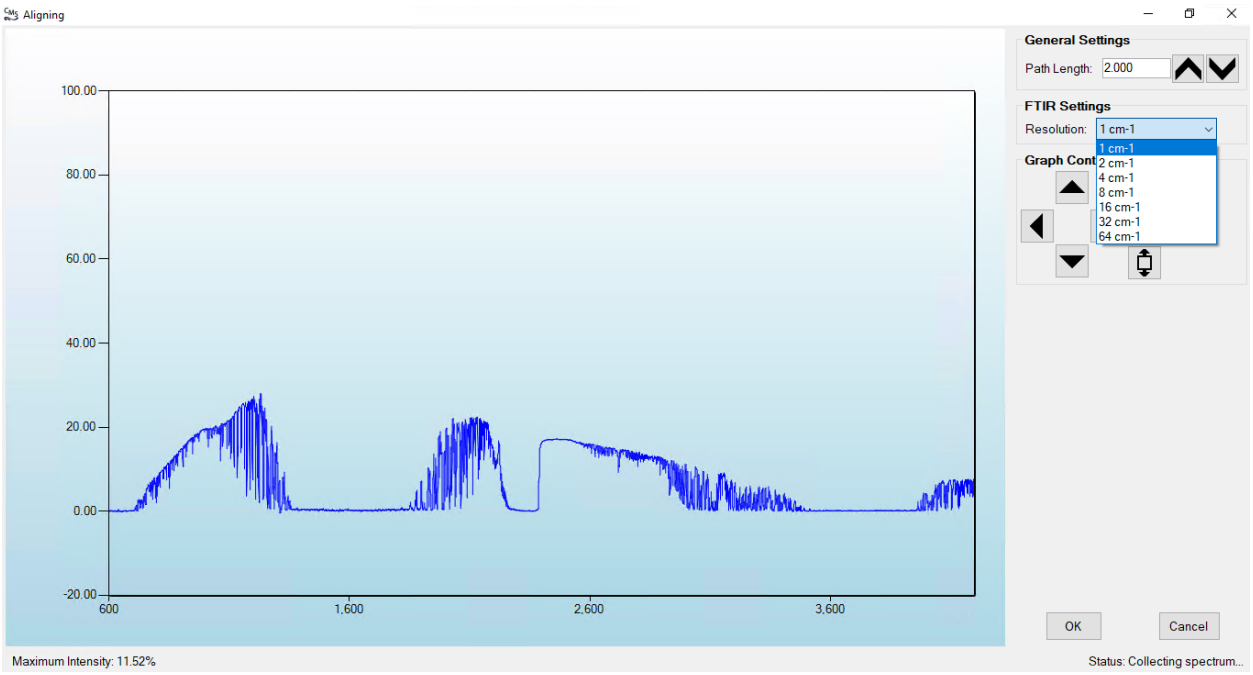


Figure 2. Screenshot showing the FTIR tab of the CMS software. Note that the Align and Run buttons are grayed out because the instrument is in run mode.

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



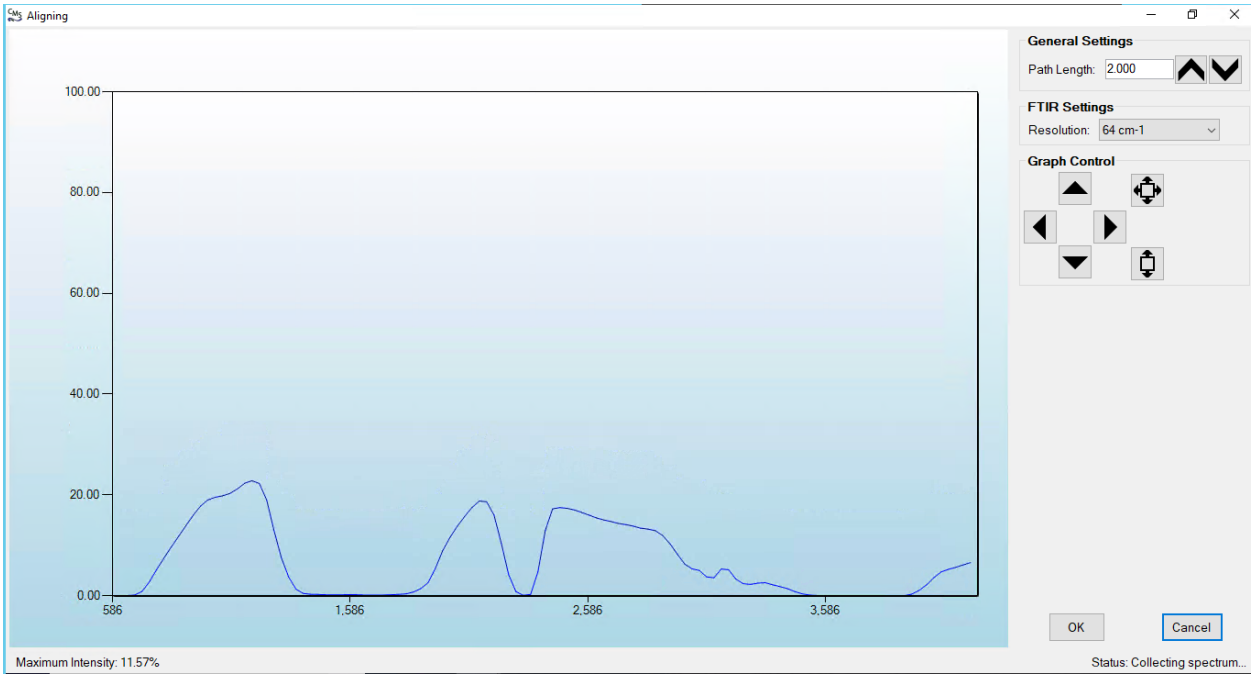


Figure 3. Screenshots of Align mode. The spectral resolution can be selected from the dropdown menu. In these particular screenshots, resolutions of 1 cm^{-1} (top) and 64 cm^{-1} (bottom) are selected.

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

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

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

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

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

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

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

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

6. Equipment and Supplies

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

9. Distilled water
10. Pressurized sprayers
11. Powder-free nitrile gloves
12. Cell bump test apparatus (including panels, regulators, valves, meters, etc.)
13. Tubing as required: 1/4" metal jacketed polytetrafluoroethylene 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 five 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 up space.
- Ensure there are no obstructions between the detector and the retroreflector.
- Check and replace air conditioner fans when needed.
- Change out the IR source.
- Re-align system after service.

- Check system response (bump test). Take corrective action if % error exceeds the level specified in the quality assurance project plan (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

In 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 a 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 as follows:

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

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 12 months should be deleted from the instrument each month to prevent the instrument from filling its 125GB 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 at regular intervals. 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 number of single-beam files is the same on both the external hard drive located on the brick PC and the internal hard drive 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

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

free disk space, the disk drive may need to be re-indexed (see Section 7.3.2).

7.3.2 Rebuilding the Instrument's Indexing Preferences

If deleting data from the instrument does not increase available storage sufficiently, you may need to re-index 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 instrument's ability to perform data collection. On the original indexing option screen, the magnifying glass in the upper right-hand corner will move and the number of items indexed will slowly increase. Take note of the available space on the instrument's internal drive once 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 buildup 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 buildup on the retroreflector.
4. Once the retroreflector has been cleaned and dried, repower the any electrical equipment you have powered down, and clean up 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 optics are not dirty, do not clean them. Excessive cleaning of optics can result in

scratches and wear over time. If the optics are obviously soiled and the soil is affecting their 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 on 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 optics.
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 min before placing it back on the instrument.

7.4.3 Replace AC Fans

Two AC fans are necessary to control the temperature 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.

1. Turn off MDAs and place the unit in Planned Maintenance mode.
2. Close the CMS and shut down the operating system.
3. Unplug the power to the unit.

4. Open FTIR lid.
    a. Note: A barrier should be placed to prevent screws from falling into the FTIR assembly.
5. Remove shroud fan cover on the underside of the FTIR lid.
6. Make a note of each fan's orientation (i.e., front facing before removing it.
    a. Unplug each fan, then remove the four screws holding each fan for removal.
7. Install new fans with screws, then plug the fans into a power source.
8. Close the FTIR lid.
9. Plug in the FTIR power source and begin operations.
10. Start the CMS and align the 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 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 reference gas 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 shown in **Figure 4**.

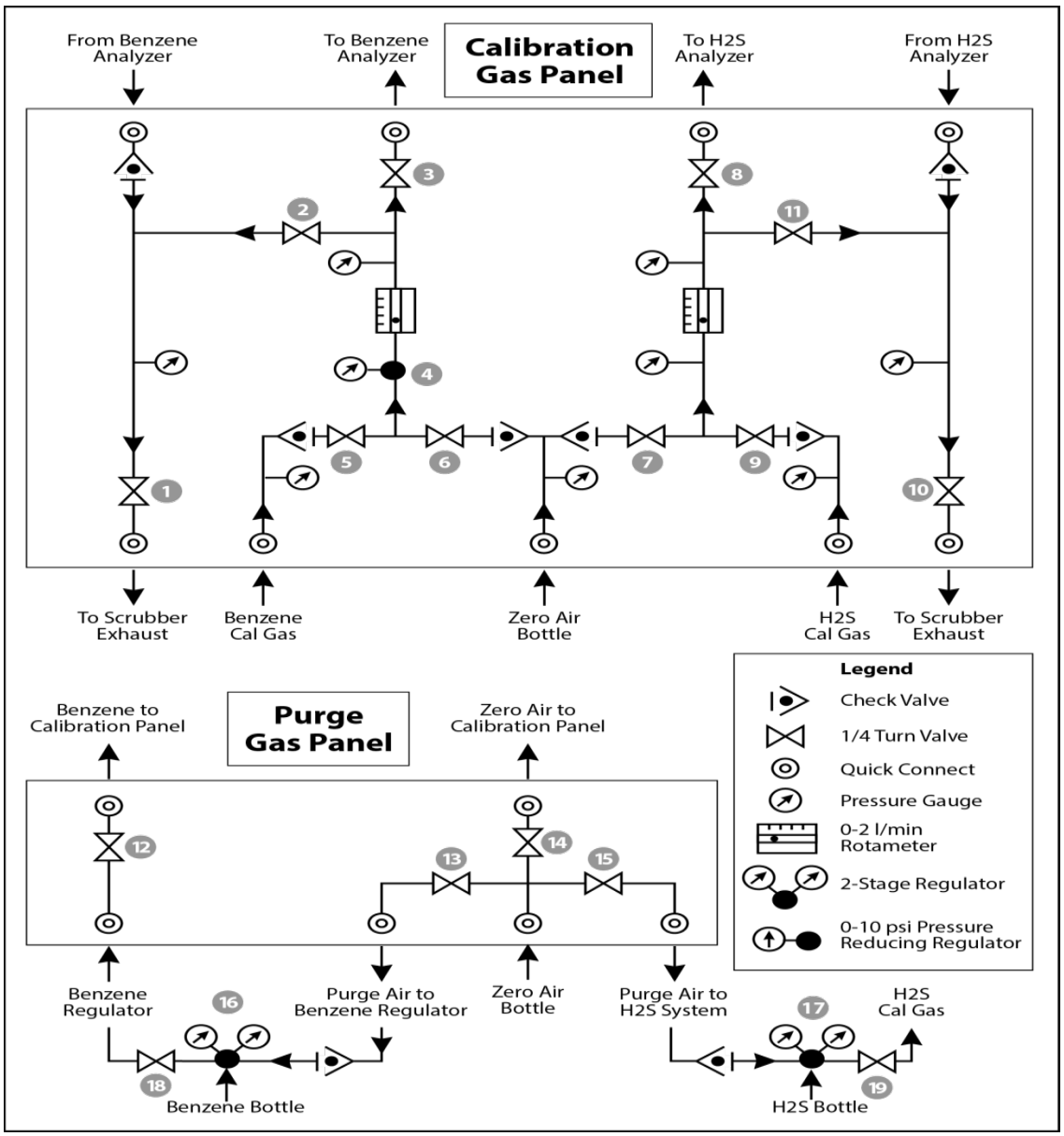


Figure 4. Diagram of the calibration gas panel (top) and purge gas panel (bottom) used for gas delivery. Note that the gas used will change depending on the instrument.

Materials Required

1. Operator-supplied SOP approved by the end user and in compliance with the 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 the calibration gas panel.

d. Flow regulation system capable of delivering gas at 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 five times the instrument's theoretical detection limit or higher.
5. All relevant PPE, hardware and procedural guidance per SOP, Safety Plan, and Safe Work Permit.
6. Local or remote network link device (as required).
7. External laptop computer with network interface device to the AirSentry FTIR unit (as required).

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

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

7.5.3 Gas Test System Setup

1. Connect the 1/4" reference cell line coming from the calibration 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 the spectral resolution to 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%. 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 path length 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 shown 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 the 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, as seen 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 on 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 5 min to ensure there is no drop in pressure and that 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 can be provided by the Field Staff Manager.
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 the valve 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 L/min) 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 three 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 10 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 L/min) 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 on 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 min to fill and condition the lines and cell.
6. After 10 min of calibration span gas flow, press **Start** in the 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 the 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 the 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 L/min) 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 on 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 a nondetectable R^2.

   NOTE If the concentration has not returned to 0 ppm, this means the 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 the 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 the CMS, you will see the file number located on the FTIR main menu of the 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 the** CMS.

   b. Click **Advanced** on the left side of the CMS software window; the password can be provided by the Field Staff Manager.

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

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

and the sample standard deviation (σ) as:

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

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

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

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

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

1. Concentration
    a. Average the concentration of 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:** the test is considered passing if below the acceptance criteria, but 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:** the test is not considered passing and 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:

- Re-aligning the system and performing the test again.
- Reviewing data for potential interferants, including a detailed check of absorbance spectra in the analysis regions configured for the analyte, and noting any excessive noise or unexpected absorbance features
- Consulting with the project technical lead to identify abnormal changes to the background
- Checking the 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.
- Reviewing and confirming 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**).

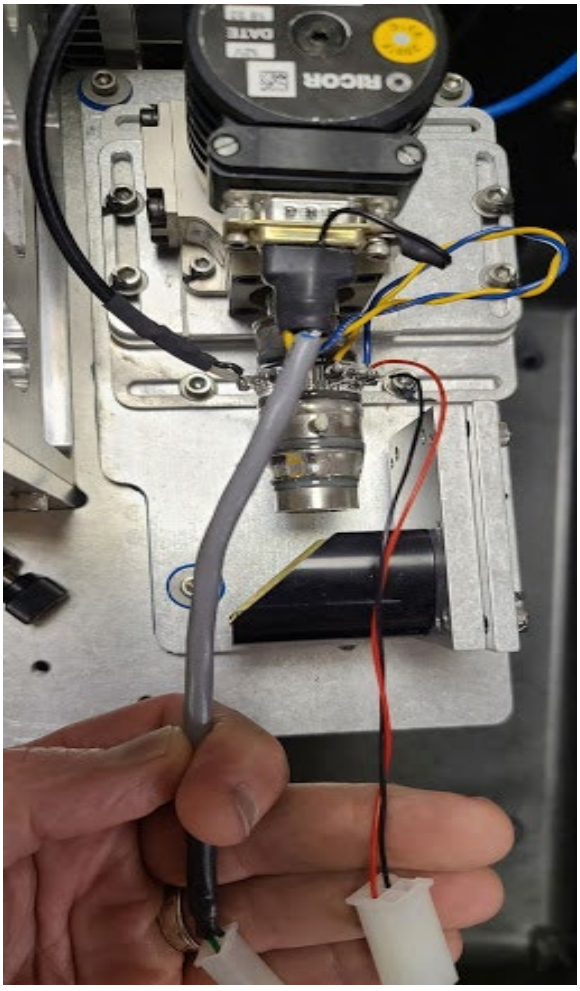


Figure 5. Detector assembly showing RICOR cryocooler, glass detector, DB9 connector, two white Molex connectors, and mirror.

    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 the 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 (Figure 6). Only remove three screws to release the entire assembly.

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

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

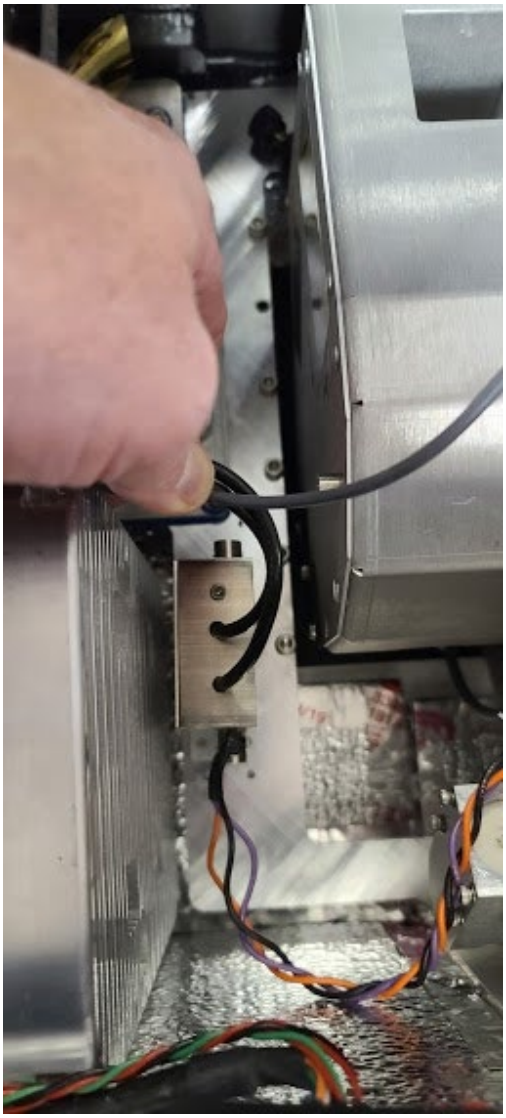


Figure 7. Preamp assembly (with orange, black, and purple wires) between the heatsink (left) and interferometer (right).

g. Disconnect power to the preamp—this is a four-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 with 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 a protective case to transport the entire assembly securely.

2. Re-install the cryocooler
    a. The installation process is the reverse of the removal process.
    b. Make sure all screws and connectors are secured and tightened.
3. Optics calibration
    a. After replacing or installing a new detector, optics optimization using a small test retroreflector array is required.
        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).

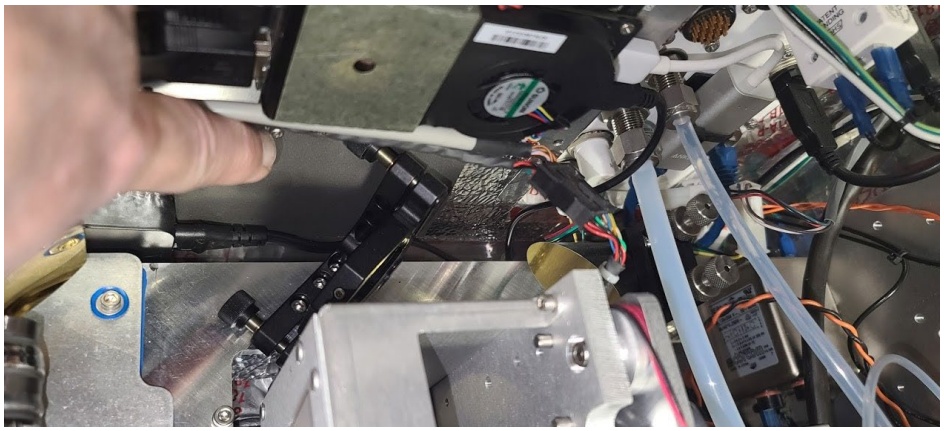


Figure 8. Beamsplitter (black object at 45-degree angle) with adjustment screws.

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).

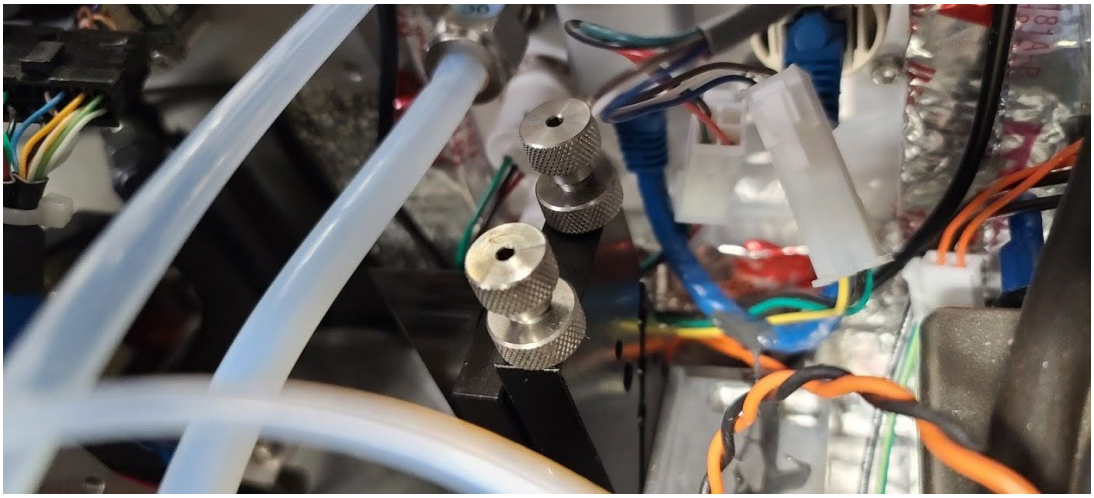


Figure 9. Beam-steering mirror with sliver adjustment screws.

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 are invalidated on the public website before proceeding with maintenance.
- ❒ When maintenance is complete check the public site for at least 15 min to ensure proper reporting (no missing data, no high values, etc.).
- ❒ Take the equipment 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 retroreflector (such as equipment, vegetation, or vehicles).	
Move data older than 1 week into an archive folder and note location.	
Ensure data are backed up on external drive. Delete files older than 12 months from the instrument computer.	
Re-align 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 Bump Test 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 (3 × Standard Dev) _____ ppm

Restore Normal Operation

Restore running data file _____ Init

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