# PICARRO

# A0601 Zero Reference Module (ZRM)
# User Manual

# Notices

Thank you for purchasing a Picarro product. It has been designed and manufactured to provide reliable performance. This manual is an important part of your purchase as it will help familiarize you with the product and explain the features that have been designed into it. Please read this manual thoroughly before using it. Please contact Picarro or your authorized Picarro distributor if you have questions regarding specific applications or if you require additional information.

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## TRADEMARKS

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              Select Option 3

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# 1. Introduction

## 1.1 Intended Use

The Picarro Zero Reference Module (ZRM) is an optional peripheral for the Picarro G2920 Ambient Ethylene Oxide (EtO) analyzer. It has been designed to further improve the long-term stability of the G2920, enabling continuous monitoring of part-per-trillion (ppt) levels of ethylene oxide in ambient air over several days and months.

The core principle that enables this capability is the collection of a 'zero reference'; a measurement of ambient air in which ethylene oxide has been removed while preserving the concentrations of all other major components (carbon dioxide, methane, water vapor, oxygen, etc.). This 'zero reference' measurement is used to correct the direct ethylene oxide measurement in air, correcting for any effects of atmospheric variability, effectively improving the method detection limit (MDL) of the G2920. The details of this correction as well as a detailed breakdown of the ZRM's function and operation are explored in the various chapters within this manual.

The ZRM was designed to be used in ambient monitoring applications where low ppt and part-per-billion (ppb) levels of ethylene oxide are likely to be encountered and where low ppt detection limits are a requirement. The ZRM was not optimized to be used in applications where high ppb and part-per-million (ppm) levels of ethylene oxide are likely to be encountered. The standalone detection limits of the G2920, and G2910 Source EtO analyzers are sufficient for those applications.

## 1.2 Hardware Overview

### Front Panel

The front panel of the Zero Reference Module (ZRM) has a status LED light. The light indicates the communication and health status of the ZRM.
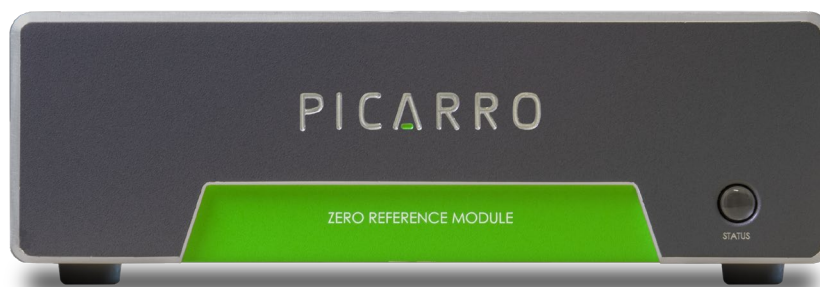


*Figure 1: ZRM Front Panel*

## Back Panel

The back panel of the module contains all available gas connections, as well as pump exhaust, USB communications, cooling fan exhaust, the module power connection, power switch and external ground.



*Figure 2: ZRM Back Panel*

## Top Panel and Service Layout

The top panel of the module has two sections. The front section has a handle that provides access to the service area when pulled. The service area allows easy access to the scrubber cartridges, particle filters, and the tools used for their removal. These same tools can be used for general peripheral service. The service tools include a 9/16" and 1/2" open-ended wrench and a 2.5 mm hex wrench. The rear section can be removed by removing the cover fastening screws. This provides access to all other internal hardware in the module.
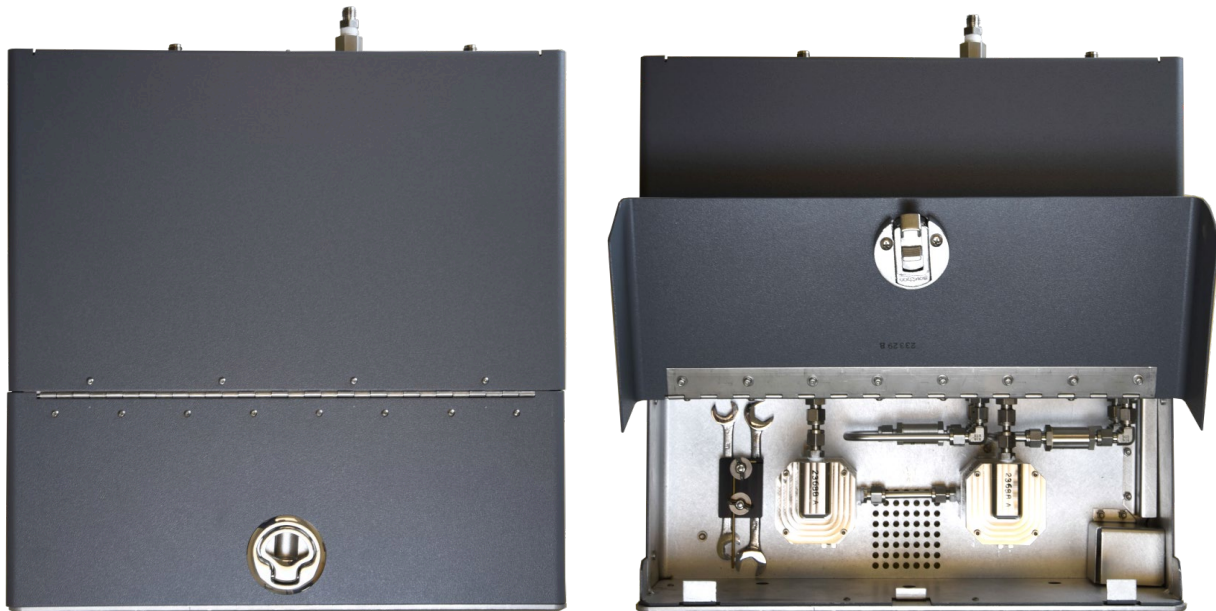


*Figure 3: ZRM Top Panel with Service Access*

## 1.3   Theory of Operation

### The Zeroing Correction

The Zero Reference Module (ZRM) has two basic operational states. The **Sample State** allows sampled gas to flow directly from the sample input to the gas analyzer. The **Zero State** flows sampled gas from the sample input through a scrubbing media which removes Ethylene Oxide from the stream. This "zeroed" gas then flows to the analyzer.
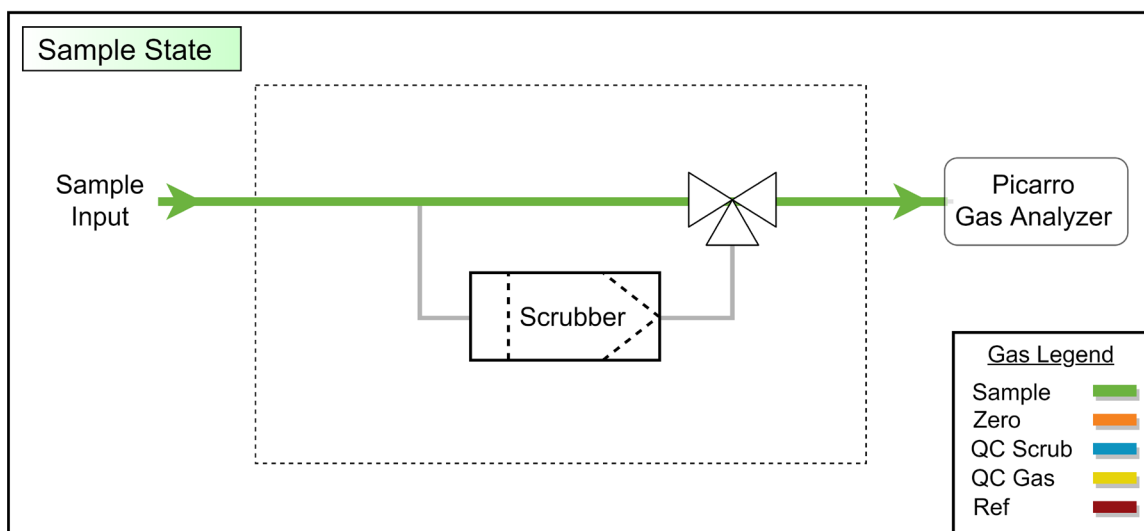


**In sample state, gas sampled at input passes directly to analyzer**

*Figure 4: Sample State*
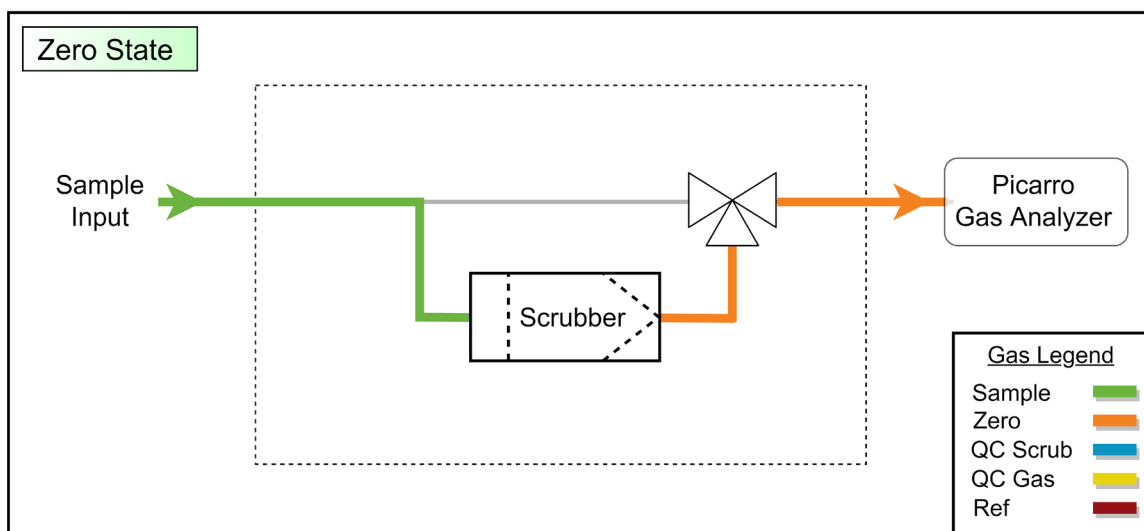


**In zero state, gas from input passes through scrubber which removes any Ethylene Oxide**

*Figure 5: Zero State*

Gas concentration measurements taken during the Zero State ($Conc_{ZERO}$) are then used as a baseline for subsequent Sample State measurements ($Conc_{SAMP}$) yielding a corrected concentration ($Conc_{CORR}$) via the following equation:

$$Conc_{CORR} = Conc_{SAMP} - Conc_{ZERO}$$

This correction eliminates concentration drift due to factors external to the measurement of the gas of interest such as aging and environmental changes. The time duration of the sample and zero states, as well as the settle time in between can be adjusted in the ZRM software.

## The Scrubber Verification

The efficiency of the gas scrubber can be tested via the Scrubber Health Check (QC) option. An external tank of gas is used to challenge the scrubber. The scrubbed output is measured against a previous zero to assure no gas from the tank passes through. A scrubber verification routine can be scheduled at desired time intervals in the ZRM software. Gas delivered from the QC tank is diluted with gas being pulled through the sample input. This is done to prevent any possibility of QC gas flowing out the sample input.
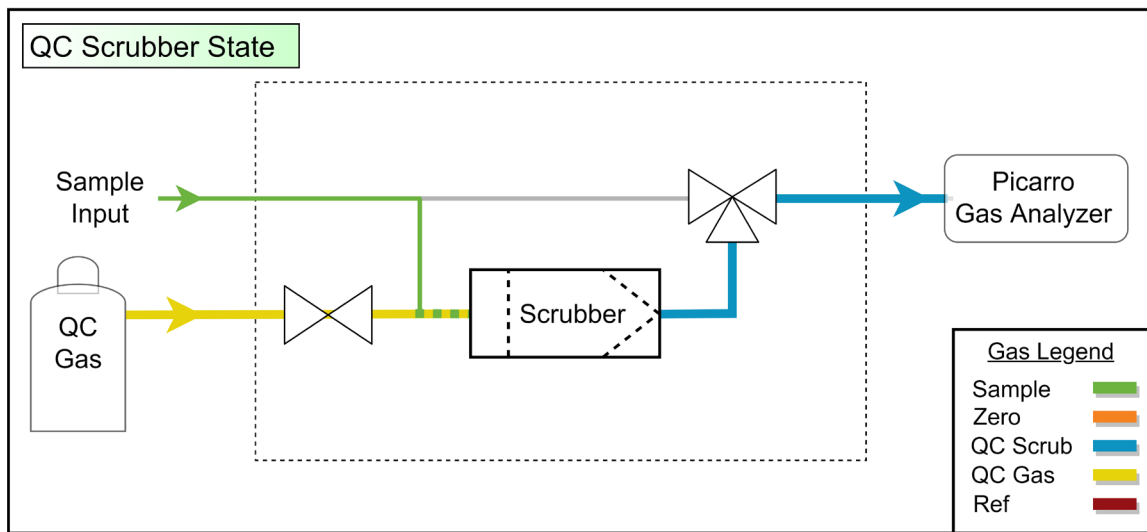


*Figure 6: QC Scrubber State*

## The Reference Measurement

A tank of reference gas can be connected to the ZRM. This gas can be used to verify the analyzer is reading concentration correctly or may be used for diagnostic purposes. During the reference state, gas flows directly to the analyzer without dilution. A reference measurement routine can be scheduled at desired time intervals in the ZRM software.

**Reference State**

Picarro Gas Analyzer

Scrubber

Ref Gas

**Gas Legend**

| | |
|---|---|
| Sample | |
| Zero | |
| QC Scrub | |
| QC Gas | |
| Ref | |
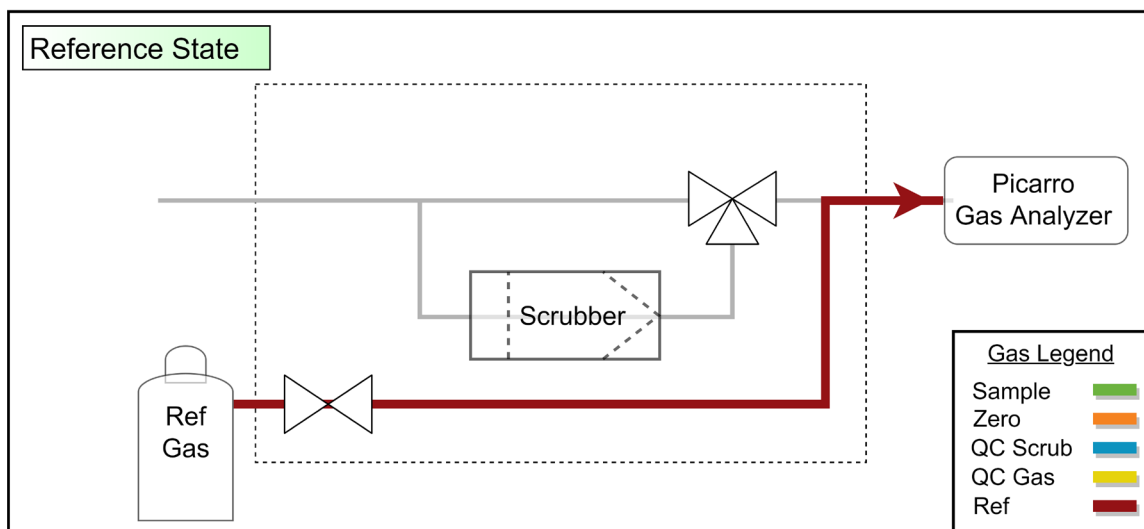
*Figure 7: Reference State*

## 1.4   ZRM Specifications

| Parameter | Specification |
|---|---|
| Analyzer Compatibility | Picarro G2920 Ambient Ethylene Oxide analyzer |
| Sample Temperature | –10 to 80 °C |
| Sample Flow Rate and Pressure | ~ 1 slpm at 760 Torr (101 kPa); 600 to 1000 Torr (80 to 133 kPa) |
| Sample Humidity | <99% R.H. non-condensing @40°C, no drying required |
| Connections | 1/4" Swagelok SS fittings |
| Ambient Temperature Range | 10 to 35°C (operating); -10 to 50°C (storage) |
| Ambient Humidity | <85% R.H. non-condensing |
| Maximum Altitude | See details for relevant paired instrument |
| Dimensions: (Width x Height x Depth) Height including feet Height with service cover open | 17 x 5-3/4 x 17 in. (43.2 x 14.6 x 43.2 cm) 5-3/4 in (14.6 cm) 11-1/2 in. (29.3 cm), 12 in. (30.5 cm) with feet |
| Weight | 25.7 lbs (11.7 kg) |
| Power Requirements | 100-240 VAC, 50/60 Hz, 100 VA |

| Parameter | Specification |
|---|---|
| Additional Gas Inputs | Scrubber QC gas (optional)<br>Reference Gas (optional) |
| Operating System Requirements | Windows 10 OS running on Picarro G2920 analyzer |
| Liquid Ingress Protection | None |

## 1.5    Acronyms

This manual includes various acronyms.

*Table 1: Acronyms, Formulas, Units, and Symbols*

| Acronym | Definition |
|---|---|
| ” (as in 1/4”) | Length in Inches |
| ’ (as in 10’) | Length in Feet |
| °C | Degrees Celsius |
| cm | Centimeters |
| $CH_4$ | Methane |
| $CO_2$ | Carbon Dioxide |
| CRDS | Cavity Ring-Down Spectroscopy |
| DAS | Data Acquisition System (the Analyzer) |
| EtO | Ethylene Oxide ($C_2H_4O$) |
| $H_2O$ | Water |
| mm | Millimeters |
| PAIAC | Phosphoric Acid Impregnated Activated Charcoal |
| ppb | Parts Per Billion |
| ppm | Parts Per Million |
| ppt | Parts Per Trillion |
| UM | User Manual |
| ZRM | Zero Reference Module |

## 1.6 Text Conventions

The following conventions are used in the manual.

- *Italic* text identifies screen names and emphasizes important text or certain features.

- ***Bold Italic*** text identifies section reference links.

- **Bold** text is for actions to take (such as clicking on a button in the user interface), caution and warning statements, and text you should type or select in screens.

# 2. QUICK START

| |
|---|
| **NOTE** |

**These quick start directions do not include set up of the Scrubber QC and Reference options. See section** *5, ZRM Pre-Installation Requirements* **and section** *6, Hardware Setup and Configuration* **for more detailed setup information.**

## 2.1 Initial Power Up Test and Software Installation

Before connecting gas lines, the ZRM is connected to the analyzer via USB and turned on to ensure it functions properly and is communicating with the analyzer.
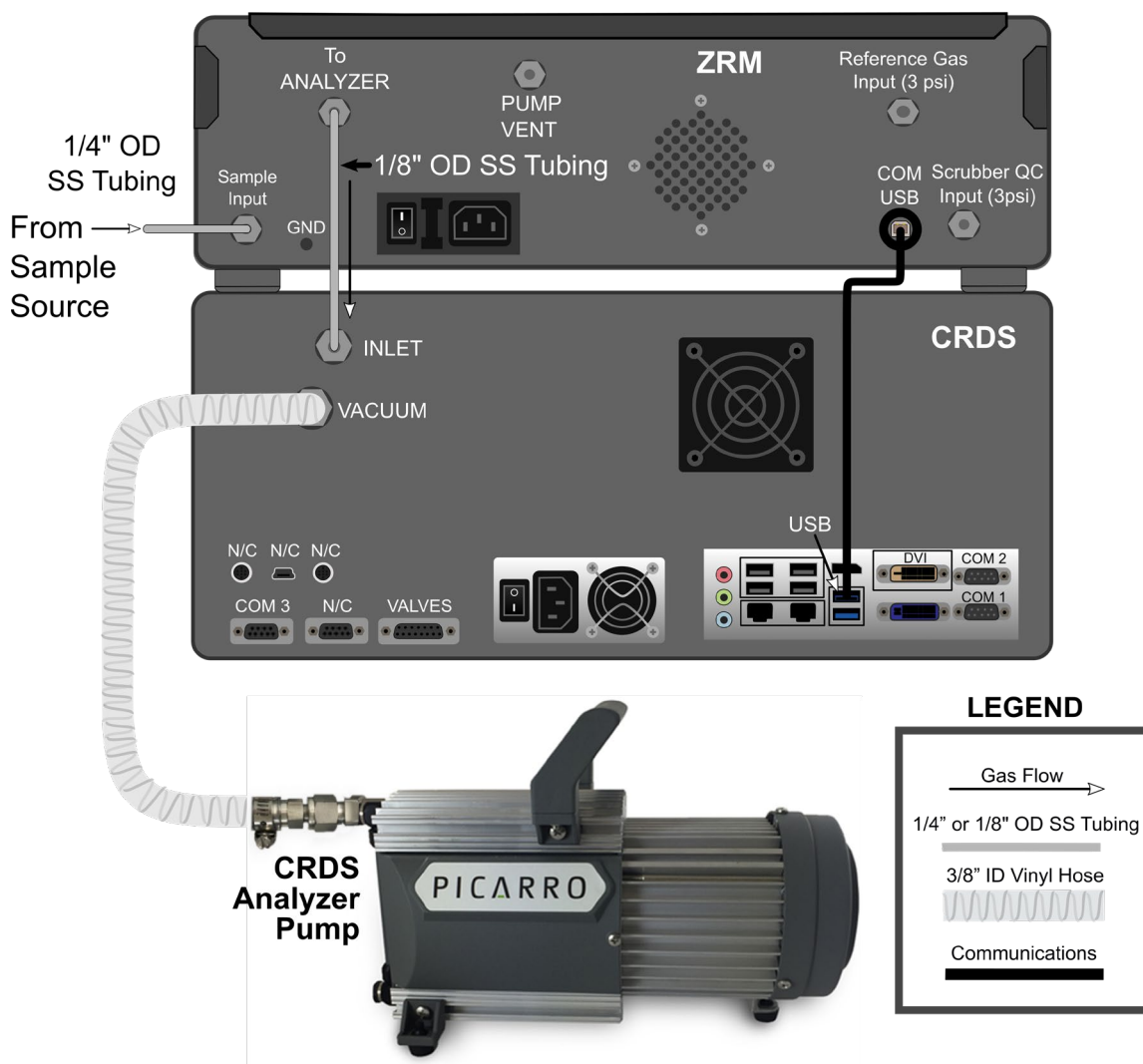


*Figure 8: ZRM Connections – Quick Start*

**Referring to Figure 8 above:**

1. Connect the USB cable from the ZRM to any USB port on the Analyzer.

2. Remove the port caps on the **Sample Input** and the **PUMP VENT** gas ports.

3. Connect the power cable to the ZRM.

4. Turn on the power switch on the rear of the ZRM. The LED on the front panel should flash green. You may hear the internal pump power on.

**NOTE**

**Steps 5 and 6 below are not relevant if you have purchased a ZRM and analyzer together. In this case the analyzer should come with software already installed.**

**If you purchased the ZRM separately and already own an analyzer, Steps 5 and 6 should be performed.** *APPENDIX A –Software Installation – ZRM Standalone Purchase* **provides installation details.**

5. Insert the USB drive included in the installation kit into any USB port on your Picarro Analyzer.

6. Run the included software installation program.

7. Open the ZRM interface by double-clicking on the **Zero Reference Module** icon on the analyzer desktop.

8. Once connected, the LED on the ZRM front panel should turn solid green.

## 2.2    Gas Line Connections

1. All gas connections on the ZRM are 1/4" Swagelok fittings and accept 1/4" tubing (or 1/8" OD tubing with the appropriate Swagelok adapter). Fittings can be tightened with a 9/16" wrench which is included inside the ZRM and can be accessed by opening the service cover. Initially hand tighten the connector onto the port, and then tighten the connector an additional 1/4 turn using a 9/16" wrench. Use this tightening procedure for all following Swagelok connections.

2. Connect your sample line to the ZRM port labeled **Sample Input**.

**NOTE**

**Before making the connection in the next step, the analyzer should be fully powered on and in standby mode.**

3. There is a 1/8" gas line in the installation kit. Connect this gas line from the ZRM port labeled **To ANALYZER** to the Picarro Gas Analyzer port labeled **INLET**.

## 2.3    Set Up the Operational Method and Run
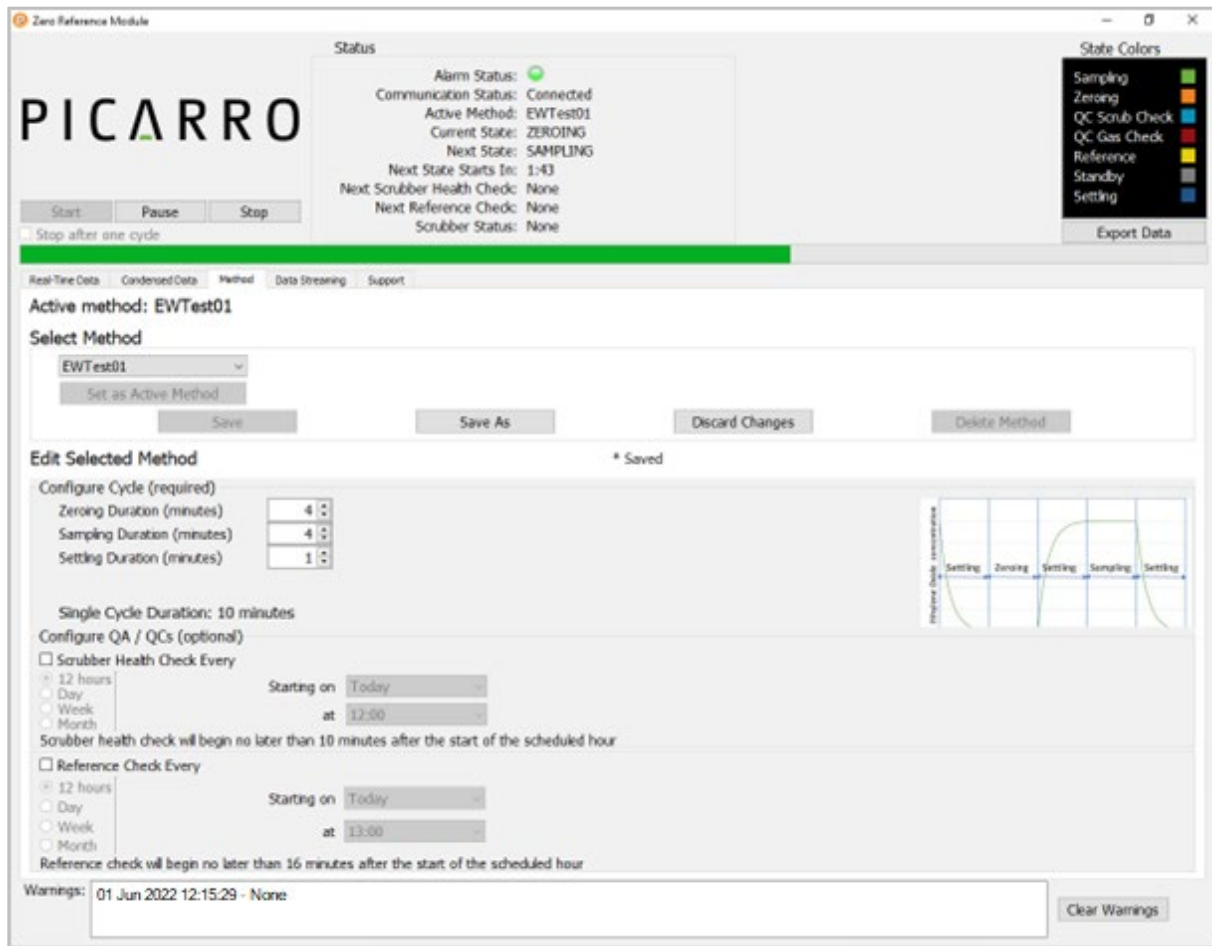


*Figure 9: Operational Method Setup and Run*

1. Click the **Method** tab (Figure 9 above).

2. The default configuration cycle  time durations for Zeroing, Sampling and Settling are recommended but can be adjusted if required.

3. De-select the **Scrubber Health Check** box.

4. De-select the **Reference Check** box.

5. Click the **Save As** button at the bottom of the window. You will be prompted to name and save the new method.

6. Click the **Set as Active Method** button at the top of the window.

7. Click the **Start** button at top of screen.

   A confirmation screen (Figure 10) will pop up stating the method name that is starting and asks if you would like to proceed.
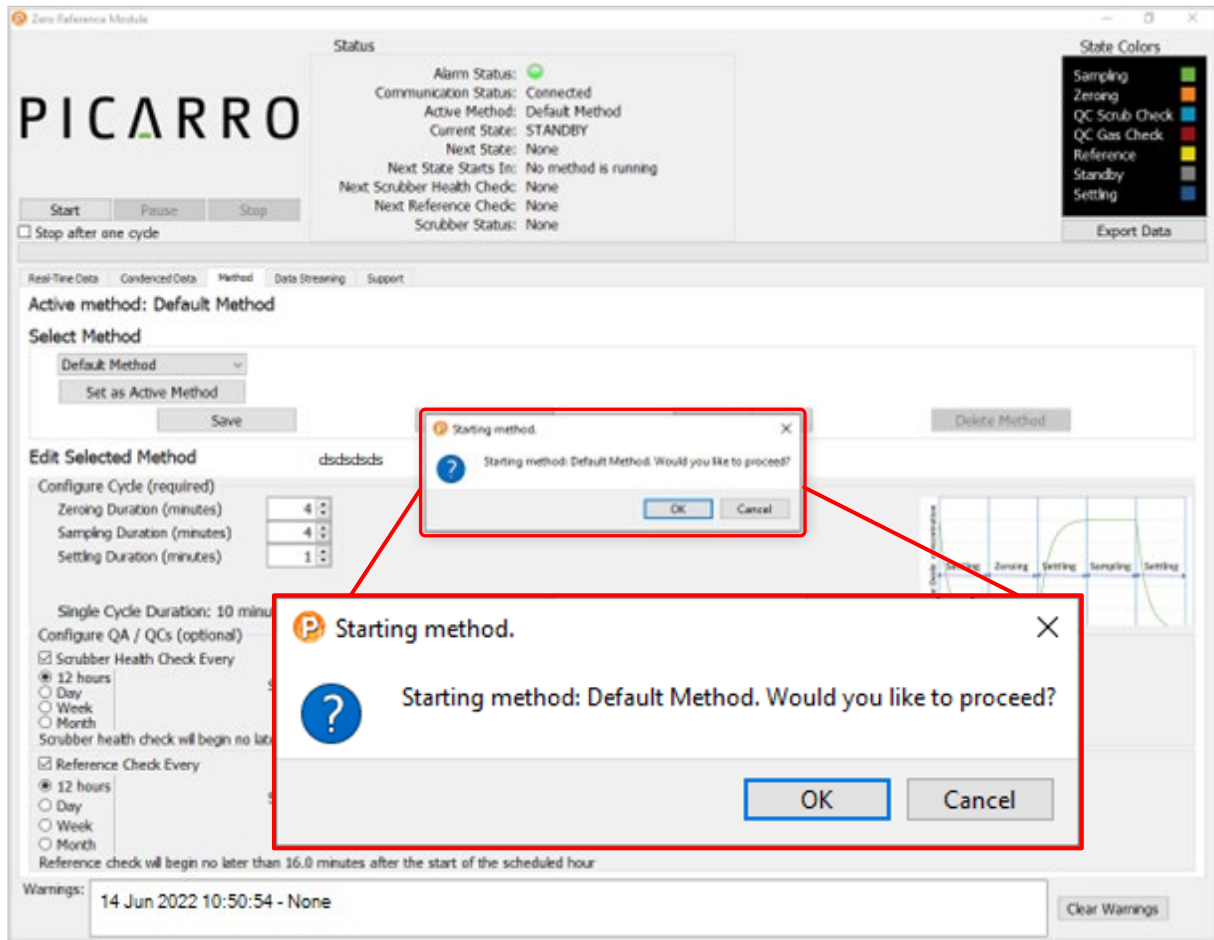
*Figure 10: Method Start Confirmation Screen*

## 2.4    ZRM Software During Operation

Figure 11 Illustrates the ZRM software user interface while a method is running. The **Real-Time Data** tab is active.



*Figure 11: ZRM User Interface While Method is Running*

## 2.5    ZRM Shutdown Procedure

**CAUTION**

**These directions are for shutting down the ZRM when the Scrubber QC and Reference options are <u>not</u> in use. See section *6.4 ZRM Shutdown* for detailed shutdown instructions when the Scrubber QC and Reference options are in use.**

**NOTE**

**Do not shut down the analyzer until after the ZRM has been shut down according to the steps below.**

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1. In the ZRM software, click the **Stop** button at the top of the screen

2. If necessary, use the procedure in section *6.4* to ensure all gas lines including gas regulators are purged.

3. Close the ZRM Software Interface.

4. Turn off the ZRM power switch.

# 3. Safety

## 3.1 Warning Symbols

The following icons are used throughout this manual to emphasize important information in the text. These icons indicate dangers to either the operator or to the analyzer and peripherals, and other important information.

*Table 2: Warning/Information Icons*

| | |
|---|---|
| ⚠️ | Consult the user manual for important information (When you see this symbol placed at hazard points on equipment, consult the user manual). |
| NOTE | **NOTE** is important information that you should be aware of before proceeding. |
| ⚠️ CAUTION | **CAUTION** alerts you of a potential danger to equipment or to the user. |
| ⚠️ WARNING | **WARNING** indicates an imminent danger to the user. |
| 💡 REMINDER | **REMINDER** is a helpful hint to procedures listed in the text. |

## 3.2 General Safety

### CE Certification

This Picarro product complies with European standards and the instrument is affixed with a CE label. This CE label is located on the back panel of the instrument.

**WARNING** — **Using the ZRM in a manner not specified by Picarro may result in damage to the unit and render it unsafe to operate.**

**WARNING** — **The ZRM is for indoor use only and has an ingress protection rating of IPx-0. It is NOT protected against exposure to water including dripping, spraying, splashing or immersion.**

**WARNING** — **Do not operate in an explosive atmosphere! Do not operate in the presence of flammable gases or fumes.**

**CAUTION** — **The ZRM contains two user serviceable components, the PAIAC scrubber cartridge and two particulate filters, described in section *11, Hardware Maintenance and Service*. Before attempting any additional service, please see APPENDIX C –Errors and Troubleshooting and then contact Picarro Support for advice.**

**WARNING** — **The inlet gas connector on the back panel of the Analyzer, and its immediate vicinity, runs hot during operation of the analyzer. Take care when connecting gas lines or working at the rear of the instrument to wear protective gloves or avoid contact with these surfaces.**

**WARNING** — **If the primary gas is toxic or otherwise hazardous, care should be taken to scrub or vent any reference gas, scrubber QC gas, or sample gases.**

**WARNING** — **PAIAC scrubber material contains phosphoric acid and may contain scrubbed hazardous gases. Handle and dispose of according to hazardous waste guidelines in *APPENDIX F –PAIAC Chemical and Disposal Information*.**

# 4. Unpacking

## 4.1 Inspect the Shipping Box

Picarro products are inspected and tested before leaving the factory. The shipping box provides proven safety from most dropping, crushing or spiking events.

If the equipment arrives damaged, photograph the damage, and contact Picarro (email pictures if possible) for consultation on the best course of action.

**NOTE**    **Save the original shipping materials for re-use when storing or shipping the unit.**

## 4.2 Unpack Box

Unpack the shipping box. It contains the following:

*Table 3: Box Contents: ZRM and Components*

| Item (Qty) | Description |
| --- | --- |
| ZRM (1) | Zero Reference Module |
| USB Drive (1) | USB, 2 GB: Contains ZRM software, ZRM release notes, and ZRM user manual (this manual) |
| Swagelok Nut (6) | For 1/8" Swagelok, 316 SS |
| Swagelok Ferrule (6) | 1 Front and 1 Back Ferrule for 1/8" Swagelok |
| AC Power Cable (1) | A power cable with connectors appropriate to your country is provided. |
| USB Cable (1) | A-B connectors 6' long (For communication between the ZRM and Analyzer) |
| Tubing/Fittings (1) | Kit for ZRM |
| Leak Test Kit | After servicing the scrubbing media or particle filters inside the ZRM and before reconnecting to the analyzer, a leak check is conducted using this kit to ensure all fittings within the ZRM have been seated and sealed correctly. See section *11.5* for leak testing procedure. |

# 5. ZRM Pre-Installation Requirements

The Zero Reference Module (ZRM) is intended to be used as an accessory to the Picarro 2920 Ambient Ethylene Oxide (EtO) Analyzer, it cannot function as a stand-alone device. The following pre-installation requirements are divided into two segments: requirements, and optional aspects a user may wish to prepare prior to installation. Many of the required connectors and fittings to install and operate the ZRM are included in the shipping box.

## 5.1 Required Setup

### Analyzer

A G2920 EtO analyzer is required to run the ZRM software and control the ZRM hardware. The basic gas analyzer setup (CRDS Analyzer and External Vacuum Pump as shown in Figure 12) should be completed. Setup information can be found in the CRDS analyzer User Manual.
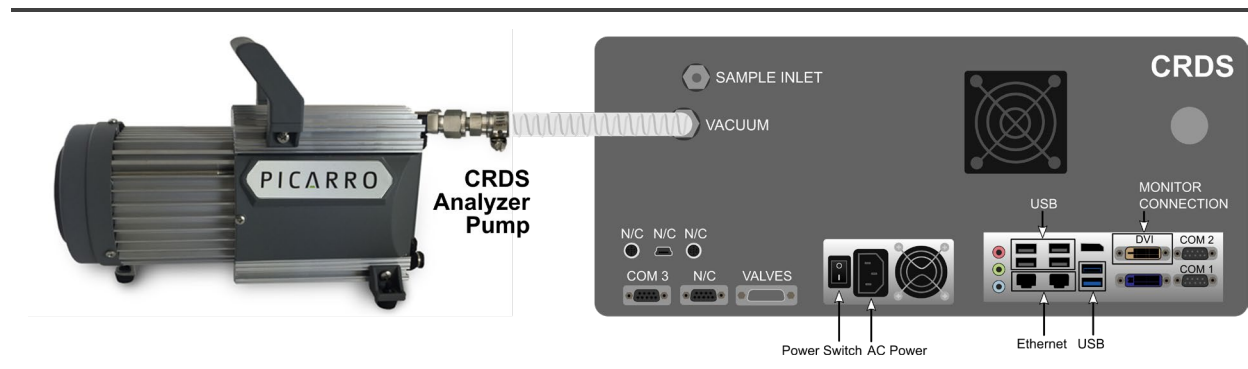


*Figure 12: Basic Carbon Analyzer Setup*

### Instrument Placement and Dimensions

The ZRM is 17 x 5-3/4 x 17 in. (43.2 x 14.6 x 43.2 cm) in dimension and weighs 25.7 lbs. (11.7 kg). It has rubber feet on its base. It can be placed directly on top of a Picarro Analyzer. It can also be placed into a standard 19" rack with a support platform.

### Electrical Connections

The ZRM requires 120-240 VAC 50/60Hz, 100VA. A standard power cable is included with the ZRM. A case ground terminal (labeled **GND**) is available to ground the chassis to desired ground point.

### Cooling

A cooling fan exhausts through the grating on the back panel. The cooling exhaust requires 2" of open space behind the back panel. Cooling air is pulled into

the unit from the base. The ZRM must be placed on a smooth flat surface to allow appropriate air flow.
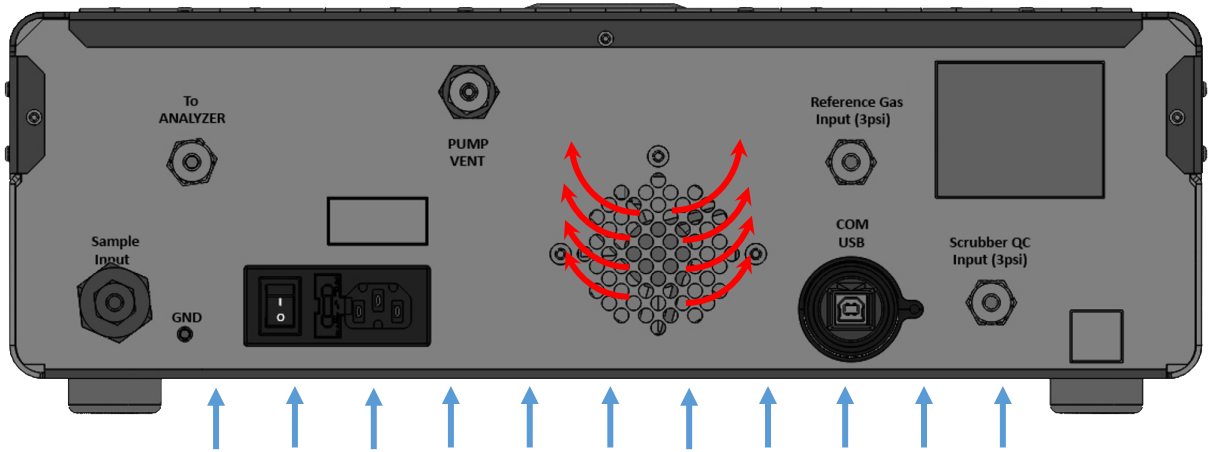


*Figure 13: ZRM Cooling*

| ⚠️ CAUTION | **It is imperative that the ZRM, analyzer and other peripherals have adequate ventilation and/or cooling to maintain the ambient temperature below 35 °C when operating.** Failure to provide adequate airflow, especially clearance at the front and rear panels, to ensure proper airflow and/or cooling to the equipment will result in overheating of the analyzer causing a shutdown and potential damage. There should be 2" (5 cm) of clearance in the front and back of the equipment. |

| Thermal Specifications | Min | Max | Description |
|---|---|---|---|
| Ambient Operating Temperature | 10 °C | 35 °C | Worst-case environmental limits (unless otherwise specified) |

## 5.2    Optional Setup

The ZRM has been designed with features that enable it to easily integrate into a variety of monitoring infrastructures. Chapters 6, 9 and 10 further explore how to take advantage of these features and easily integrate the ZRM. These chapters cover items such as: **gas sample input**, **ZRM pump venting**, **analyzer pump venting**, **setup and configuration of reference and QC gas cylinders.**

# 6. Hardware Setup and Configuration

Follow the steps described in this section to make the proper gas and electrical connections.

## 6.1 Setup Safety

| | |
|---|---|
| **WARNING** | **When using compressed gases, follow all appropriate safety conventions, including use of eye protection, physical restraint of cylinders, etc.** |

| | |
|---|---|
| **CAUTION** | **When the ZRM and the analyzer are being integrated to an external system, the safety of that system is the responsibility of the assembler of that system.** |

| | |
|---|---|
| **NOTE** | **It is imperative that all gas connections be free of leaks to achieve proper measurement of a sample and ensure performance of the system. For more details on ensuring leak-free connections, see section *11.5, ZRM Leak Test*. All gas connections should be made with stainless steel tubing and Swagelok connectors.** |

| | |
|---|---|
| **WARNING** | **The inlet gas connector on the back panel of the Analyzer, and its immediate vicinity, runs hot during operation of the analyzer. Take care when connecting gas lines or working at the rear of the instrument to wear protective gloves or avoid contact with these surfaces.** |

## 6.2 ZRM Startup and Setup
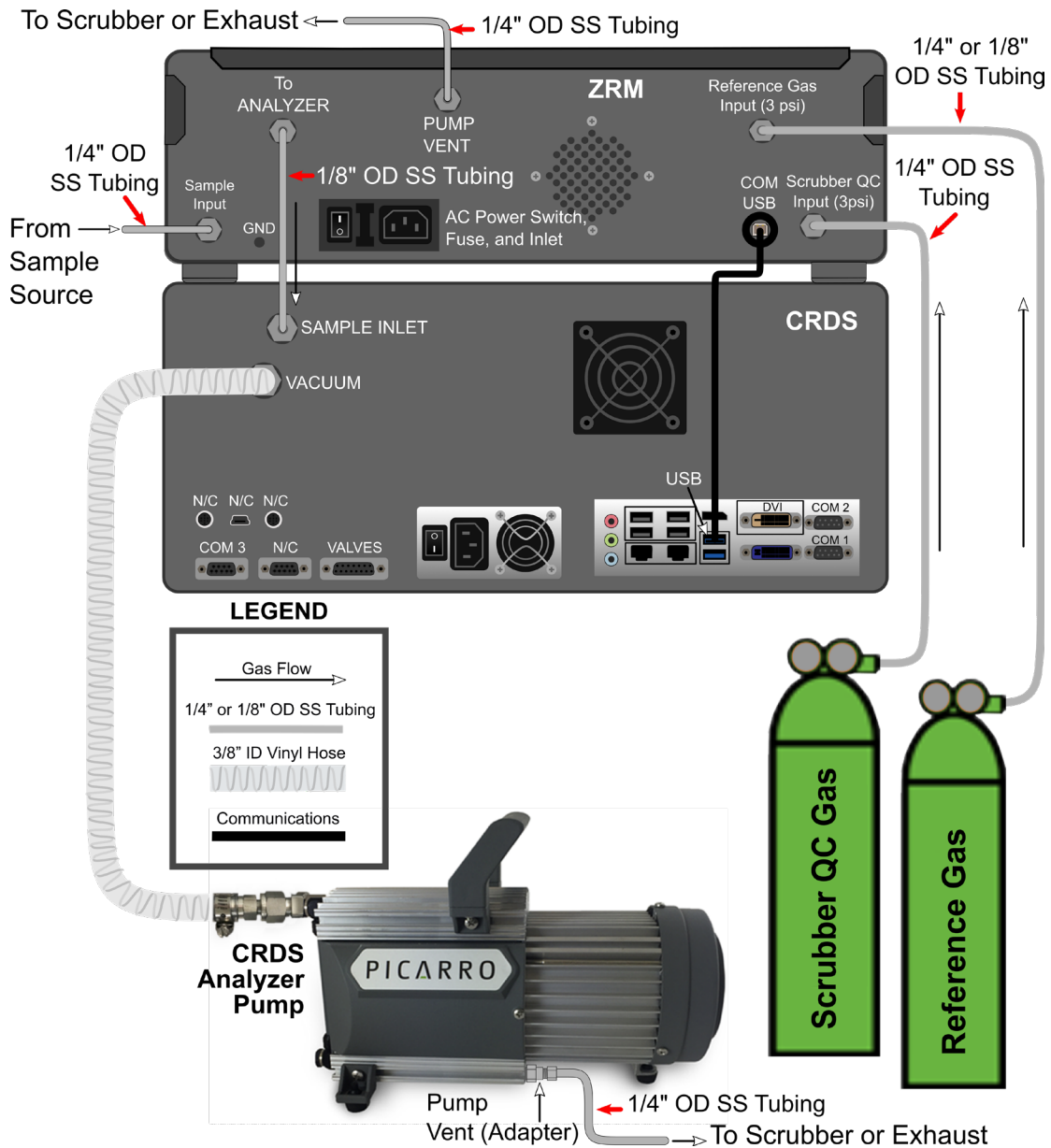


*Figure 14: ZRM to Analyzer Connections*

1. Before starting, make sure all the **ZRM Pre-Installation** Requirements have been met.

2. Place the ZRM on top of the Analyzer

3. Remove all rubber gas port caps.

4. Plug in the power cable and power-on the ZRM using the power switch on the back panel. When powered on the ZRM will enter a standby state. The internal pump will be running while in this state.

**NOTE**

**To ensure the best precision measurements, the G2920 analyzer should be allowed to run for at least 2 hrs prior to making the final gas connection from the ZRM to the analyzer (the analyzer must be stabilized). There should be no gas connection between the ZRM and analyzer as the analyzer is starting up.**

**NOTE**

**All gas connection ports on the ZRM accept 1/4" Swagelok female connectors. When connecting gas lines to the ports, initially finger tighten the Swagelok fittings and then tighten the fittings another 1/4 turn using the provided 9/16" wrench.**

5. Follow Figure 14 while making the following connections.

    a. Make the USB cable connection between the ZRM **COM USB** port and the analyzer USB port.

    b. Connect the ZRM **To Analyzer** port to the analyzer **INLET** port. A 1/8" OD stainless steel tube connection line is included in the ZRM kit to connect the ZRM to the Picarro Analyzer.

    c. Connect the tubing from the sample source to the ZRM Sample inlet. An optional external in-line 15-micron pore filter is included with the ZRM. This filter can be installed between the ZRM and your sample line for dusty environments. If operating in a particularly dusty enviroment a larger primary dust filter may be required.

    d. The Picarro Gas Analyzer pump exhaust must lead to a safe exhaust scrubber or vent location. There is a pump outlet fitting in the Picarro Gas Analyzer installation kit which will allow the connection of a 1/4" OD exhaust line to the analyzer pump. Perform the steps in *APPENDIX D –Analyzer Pump Exhaust Setup*.

    e. Connect your exhaust line to the ZRM port labeled **PUMP VENT**. *The ZRM exhaust line should lead to a safe exhaust scrubber or vented location.* See section *9.4, Exhaust Line Routing* located in the **Station Integration** section for a more complete discussion of exhausting standard gas safely.

    f. If using the Scrubber Health Check option, connect the Scrubber QC Gas tank to the ZRM port labeled **Scrubber QC Input** port and set pressure at the regulator to 3 psi.

    g. If using the **Reference Check** option connect the Reference Gas tank to the "Reference Gas Input" port and set pressure at the regulator to 3psi

6. Once all hardware connections have been made, the ZRM software can be started up. Please refer to section *7, Software Startup, Overview, and* Configuration  in the manual.

## 6.3    Prepare QC and Reference Gas Lines (if in use)

To reduce dead-volume effects in the regulators, tubing and ZRM, all gas pathways should be purged prior to use in an automated ZRM method.

1.  Before beginning make sure the ZRM vent line and the Picarro Analyzer pump exhaust are both plumbed to safe ventilation locations.

2.  Ensure the analyzer is powered on and in the Standby State. If necessary stop any methods that are running. The system will default to Standby when stopped.

3.  Open the ZRM software on the Analyzer (see section **7.2, Starting Up the ZRM Software)**.

4.  Click the **Support** tab (Figure 15).

5.  In the **Control Component** dropdown list, select **Valve 3 On** and then click the **Apply** Button.
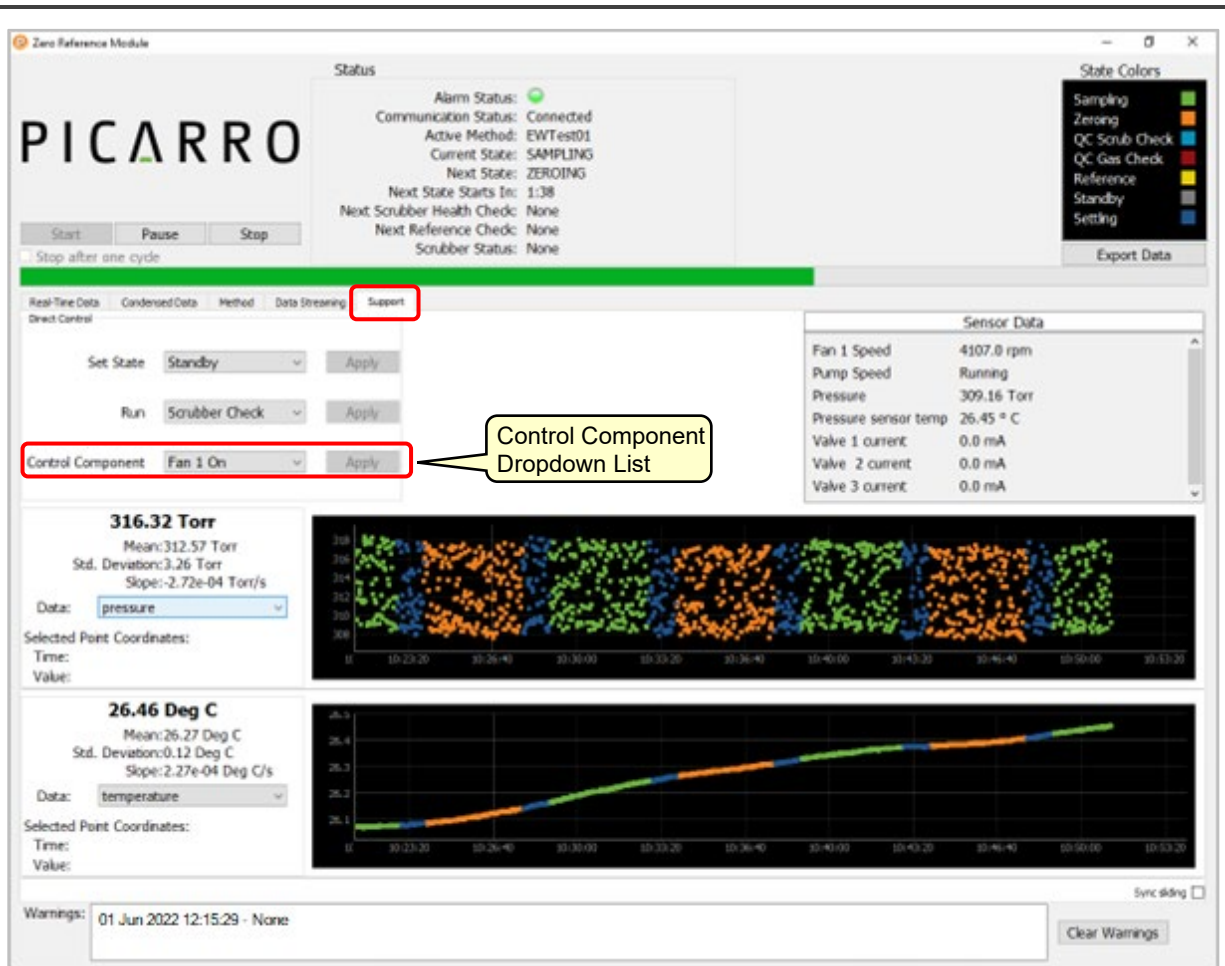


*Figure 15: ZRM Software User Interface – Support Tab Selected*

6. The unit will flow reference gas. Allow 3 minutes for the lines to purge. While flowing gas, verify that the pressure being supplied from the tank regulator is 3 psi.

7. In the **Control Component** dropdown list, select **Valve 3 Off** and then click the **Apply** button

8. Repeat this procedure for the **QC Gas Line** by selecting **Valve 2** and clicking the **Apply** button.

9. When complete, wait 3 mins for the ZRM lines to purge before starting any measurement cycle.

## 6.4 ZRM Shutdown

**NOTE**

**Do not shut down the analyzer until after the ZRM has been shut down according to the steps below.**

1. In the ZRM software, click the **Stop** button at the top of the screen

2. Click the **Support** tab

3. If necessary, use the following procedure to ensure all gas lines including gas regulators are purged.

4. Perform a Gas Tank Purge procedure:

   a. Close the valve on the top of the Reference Gas tank.

   b. In the Control Component dropdown list, select **Valve 3 On**, then click the **Apply** button.

   c. Wait for the Reference tank regulator pressure to dissipate.

   d. Close the valve on the top of the Reference Gas tank.

   e. In the **Control Component** dropdown list, select **Valve 3 Off**, then click the **Apply** Button

   f. Repeat these steps for the Scrubber QC Tank by selecting **Valve 2**.

   g. When above steps are complete wait 3 mins for the ZRM system to purge.

5. Close the ZRM Software Interface.

6. Turn off the ZRM power switch.

# 7. Software Startup, Overview, and Configuration

If the ZRM was purchased with a G2920 analyzer, the ZRM software comes pre-installed on the analyzer. If the ZRM was purchased separately follow instructions in **_APPENDIX A – Software Installation – ZRM Standalone Purchase_** for a step-by-step guide on the ZRM software installation.

## 7.1 The Picarro Host Software

The Picarro host software (sometimes referred to as the GUI or green data viewer) starts up automatically when you power on the analyzer and log into the computer. The host software interface is shown in Figure 16. While the analyzer is warming up, this program will display relevant information about the warm-up sequence. This information includes hotbox temperature and cavity pressure.
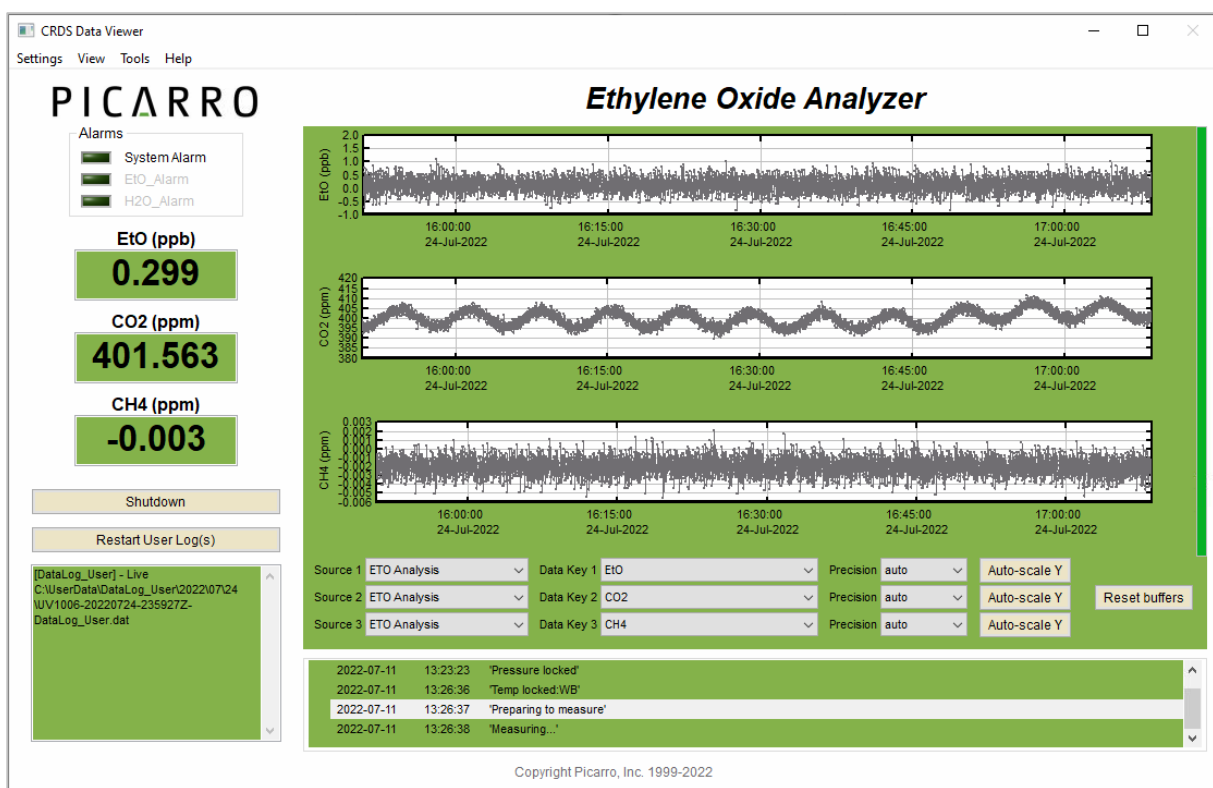


The Picarro host software, showing 1.5 hours of uncorrected EtO data, alongside $CO_2$, and $CH_4$ data.

**_Figure 16: Picarro Host Software_**

Once the analyzer is warmed up, the host software will begin displaying measurement values. You can plot different variables on the graph by selecting them from the Data Key dropdown lists at the center of the window.

The Picarro host software is a valuable tool for assessing basic analyzer operation and for troubleshooting the analyzer. For more information about operating the host software, see the G2920 manual (PN 40-0076).

## 7.2    Starting Up the ZRM Software
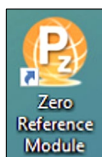
The ZRM Software Interface is a separate program started by the user from the analyzer desktop using the **Zero Reference Module** icon. (Do not delete the icon from the desktop.) After double-clicking on the icon two things will occur: (1) the ZRM Software Interface (Figure 17) will boot up in a couple of seconds and (2) a background service of the ZRM software will be launched. This service is accessible from the Windows System Tray at the bottom right of the Windows Task Bar.



*Figure 17: ZRM Software Interface*

A few seconds after booting up, the ZRM software will automatically start searching for the ZRM hardware, attempting to establish connection. As it is searching, the Alarm Status indicator light in the Status box at the top of the user

interface will blink green. Once a connection has successfully been established, the indicator light will turn solid green to indicate the peripheral is ready for use.

**REMINDER**

**If for any reason the Windows operating system restarts the analyzer for updates, or the analyzer power is cycled by an outage, the ZRM software will not automatically restart. The software must be restarted by the user from the desktop and any method that was running must be restarted.**

## 7.3 ZRM Software Interface Overview

The Main Window (Figure 18) includes the following components: Start/Stop/Pause buttons, Status window, State Colors legend, Export button, Measure Progress Bar, Warnings window and Clear Warnings button. The Main Window also contains five tabs dedicated to different user tasks.
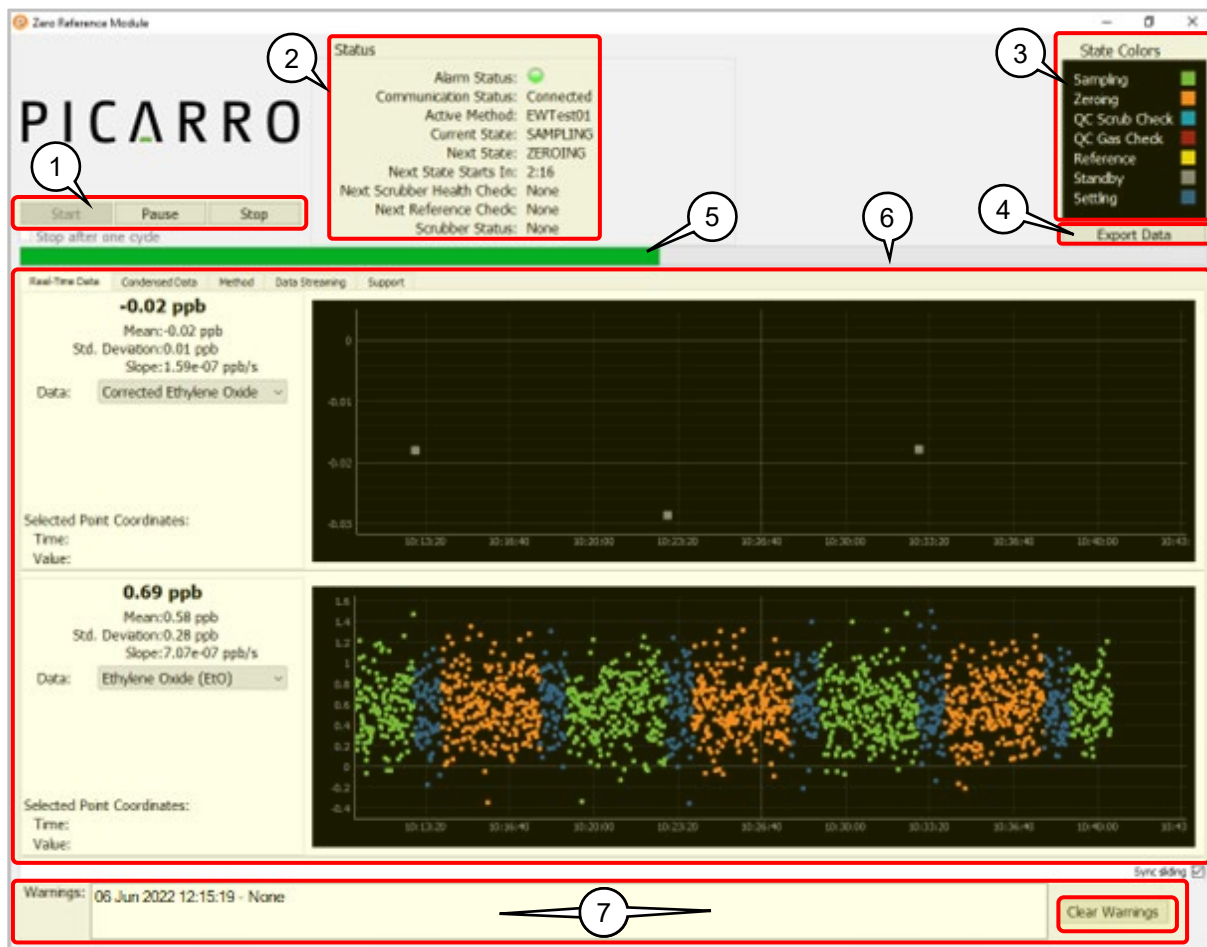


1. **Start/Stop/Pause Buttons**: Starts, stops, and pauses the Active Method.
2. **Status Window**: Displays status information about ZRM hardware and software operation.
3. **State Colors Legend**: Defines each measurement state color.
4. **Export Data Button**: Exports data to a CSV file.

5. **Measurement Progress Bar**: Displays the progress of the current measurement state.

6. **Tabbed Interface**: Displays tabs corresponding to specific workflows.

7. **Warnings Window and Clear Warnings Button**: Displays warning messages and allows user to clear warnings.

*Figure 18: ZRM Main Window*

## Start/Pause/Stop Buttons

Start, stop, or pause the active method using the Start/Pause/Stop buttons. If there is no active method selected, go to the Method tab, select a method, and set it as the active method.

## Status Window

View the Status Window to learn information about the current status of the ZRM hardware and data acquisition. The following information is provided in the Status Window.

- Alarm State: Shows high-level information about whether the ZRM peripheral is operating correctly. For more information about the different possible Alarm States, see section *8.3* and Table 4.

- Communication Status: Shows the status of communication between the ZRM software and the ZRM peripheral unit. For more information about the different possible communications states, see section *8.3*.

- Active Method: Shows the current active method. If no active method is selected, the text "None" will appear. For more information about choosing an active method, see section *7.6*.

- Current State: Shows the current ZRM operational state. If no method is running, the text "None" will appear. For more information about operational states, see section *C.1 , Operational States*.

- Next State: Shows the next operational state that will run after the current operational state has completed. If no method is running, the text "None" will appear. For more information about operational states, see section *C.1 , Operational States*.

- Next State Starts In: Shows the remaining duration of the current state. If no method is running, the text "None" will appear. For more information about operational states, see section *C.1 , Operational States*.

- Next Scrubber Health Check: Shows the date and time when the next Scrubber Health Check will occur. If Scrubber Health Checks have not been scheduled, the text "None" will appear. For more information about scheduling a scrubber health check, see *Configuring the Scrubber Health Check Cycle* in section *7.6*.

- Next Reference Check: Shows the date and time when the next reference check will occur. If Reference Checks have not been scheduled, the text "None" will appear. For more information about scheduling a reference check, see **Configuring the Reference Check Cycle** in section **7.6**.

- Scrubber Status: Shows the result of the most recent Scrubber Health Check. The possible outcomes are "Pass", "Fail", or "Incomplete" For more information on the meaning of these results, please see section **8.2**, **Utilizing QA/QC Features**. If no health check has been performed on the instrument, the text "None" will be displayed.

| | |
|---|---|
| **NOTE** | **When the ZRM software is establishing an initial connection with the ZRM peripheral, all status values besides the Alarm State will show the text "Initializing."** |

## State Colors Legend

Refer to the Status Colors Legend to learn the meaning of the different colored data points plotted in the graphs in the Real-Time Data tab and the Support tab. Data points for the condensed data variables (Corrected EtO, Uncorrected EtO and Zero Offset) are not color-coded. For more information about operational states, see section **C.1 , Operational States**.

## Export Data Button

Click the **Export Data** button in the upper right corner of the window to export any of the following data files. The Data Exporter Dialog shown in Figure 19 will appear.

- Analytical Data

- Analytical Data (Condensed)

- Sensor Data

- System Log Data
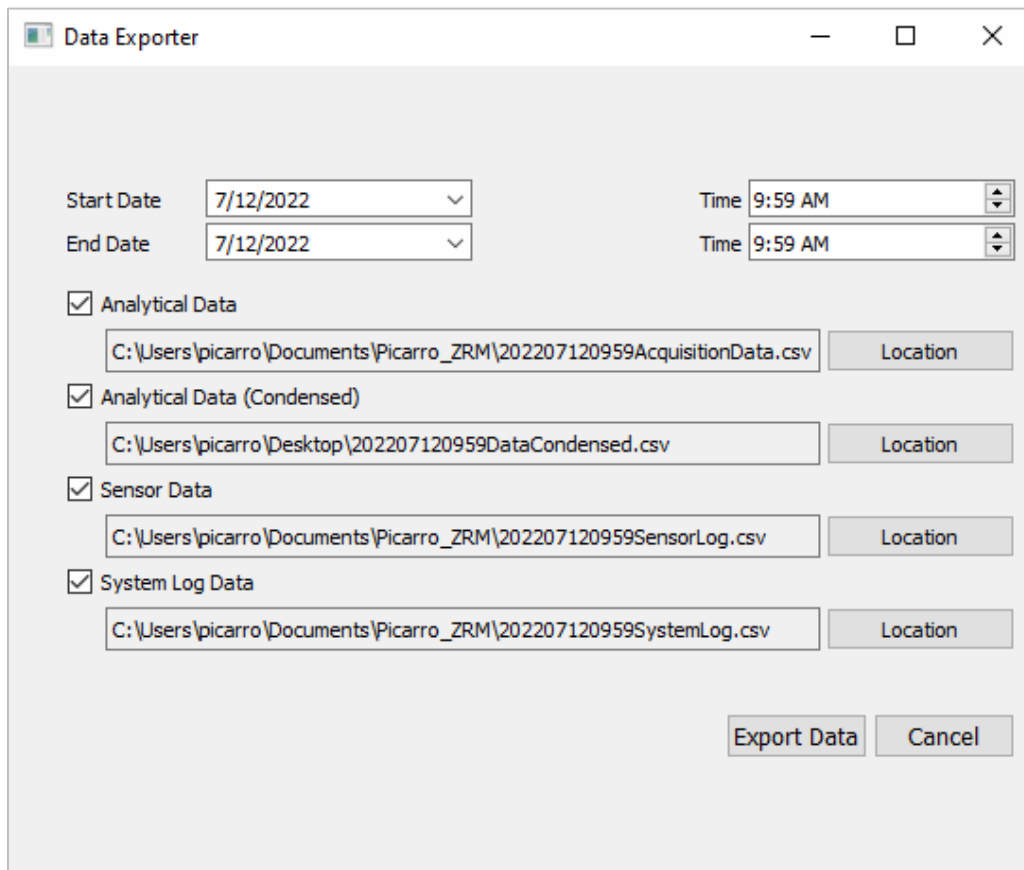
*Figure 19: Data Exporter Dialog*

Choose the start date/time and end date/time that is desired. Choose the desired export file type. The target file name and location will be displayed in the text box below each file type. Click the **Location** button to the right of the text box to change the target file name and storage locations. This will open file explorer dialog for location selection.

Click the **Export Data** button on the dialog window to export the selected files. Files are exported in csv format. When the export operation is completed, a confirmation popup dialog will appear. For more information about the contents of the four exported file formats, see *APPENDIX B –Data Flow and Output*.

## Measurement Progress Bar

View the Measurement Progress Bar to see a visual representation of the proportion of time completed for the current state. For more information about operational states, see section *C.1 , Operational States*.

## Tabbed Interface

The tabbed Interface has the following pages:

- Real-Time Data tab

- Condensed Data tab

- Method tab

- Data Streaming tab

- Support tab

For more information about individual tabs, see sections *7.4* through *7.8*.

## Warnings Pane and Clear Warnings Button

View the Warnings Pane to see ZRM warnings that have occurred since the last time the warnings have been cleared. You can clear the Warnings Pane by clicking the **Clear Warnings** button to the right. Warnings are stored regardless of whether the Warnings Pane has been cleared. To see previous warnings, export the "System Log Data" using the "Export Data" button in the upper right of the ZRM Software Interface window. For more information about exporting data, see the section **Export Data Button** above. For more information about warnings and their meanings,

## 7.4    Real-Time Data Tab

The **Real-Time Data** tab (Figure 20) displays real-time data from the analyzer, including corrected concentration data. Up to 35 minutes of continuous data can be displayed at one time.

There are two graphs shown on the Real-Time Data tab. To zoom in on a graph, click and drag your cursor to draw box. The graph will be adjusted to zoom in on the area inside the box. To zoom back out, click the box at the lower left corner of the graph. To select a data point, click on that data point. To deselect a data point, click on the data point again.

The dropdown list to the left of the graphs can be used to select the data to be displayed. In the table to the left of each graph, real-time measurement data is displayed, including the mean and slope of the currently displayed time range in the graph. If a data point is selected, the coordinates of that point will be displayed in the table at left.

*Figure 20: Real-Time Data Tab*

## 7.5   Condensed Data Tab

The **Condensed Data** tab (Figure 21) displays real-time data from the analyzer, including corrected concentration data. Only Corrected Ethylene Oxide, Uncorrected Ethylene Oxide and Zero Offset results can be displayed in the Condensed Data tab. Up to one week of data can be displayed at a time.

This tab is similar in function to the Real-Time Data tab (see previous section). As in the Real-Time Data tab, there are two graphs shown on the Real-Time Data tab. To zoom in on a graph, click and drag your cursor to draw box. To zoom back out, click the box at the lower left corner of the graph. The graph will be adjusted to zoom in on the area inside the box. To select a data point, click on that data point. To deselect a data point, click on the data point again.

The dropdown list to the left of the graphs can be used to select the data to be displayed. In the table to the left of each graph, real-time measurement data is displayed, including the mean and slope of the currently displayed time range in

the graph. If a data point is selected, the coordinates of that point will be displayed in the table at left. Click on the selected data point to de-select it.
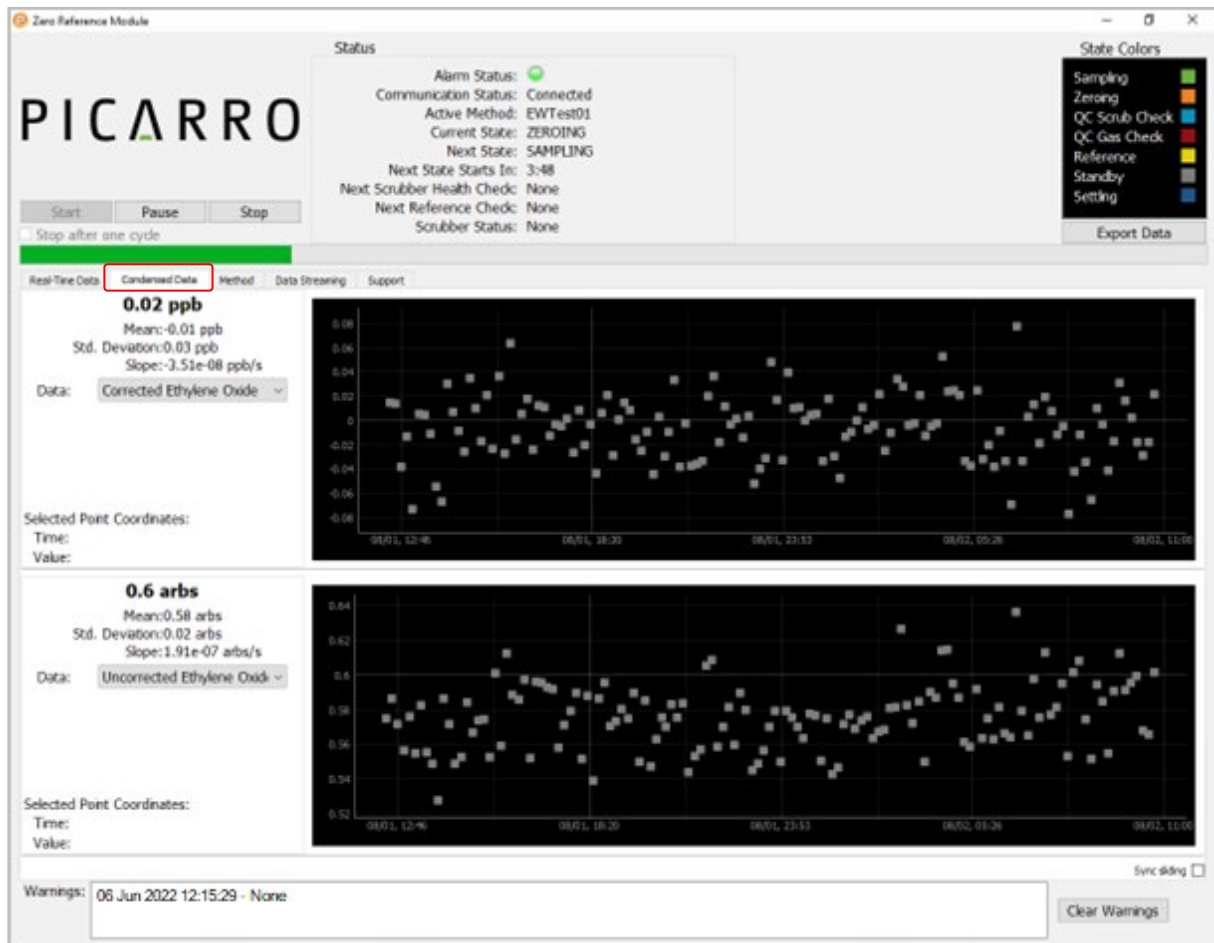


*Figure 21: Condensed Data Tab*

## 7.6 Method Tab

The **Method** tab (Figure 22) allows the user to configure the timing of the zeroing routine, the scrubber health check schedule, and the reference check schedule. The ZRM software includes a default method with Picarro-recommended settings.
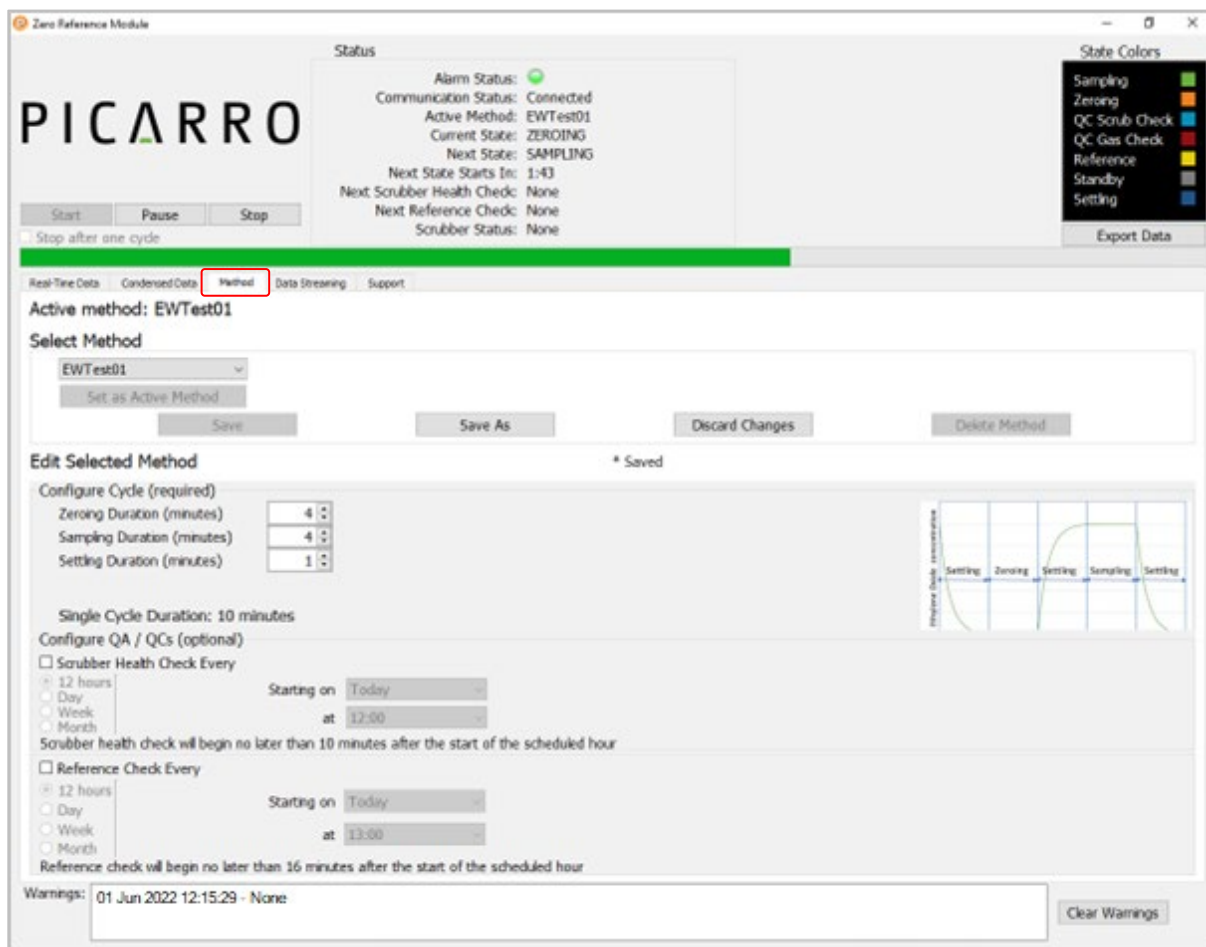
*Figure 22: Method Tab Controls*

## Creating a New Method

To create a new method, select an existing method from the **Select Method** dropdown list as a starting point and click the **Save As** button to launch a dialog that prompts you to name the method. The instructions below provide details about editing a method. Click the **Discard Changes** button to restore the displayed parameters to those in the saved method. When editing is complete, click the **Save** button to save the method.

## Running a New Method

*A method must be saved before it can be run.* To run a new method, first click the **Stop** button at the top of the screen to stop any method that is currently running. Choose the desired method from the **Select Method** dropdown list and click the **Set as Active Method** button. Then click the **Start** button to run the selected method.

## Editing an Existing Method

To edit an existing method, select the method from the **Select Method** dropdown list. A method may not be edited while it is being run. To edit an active method, first click the **Stop** button at the top of the screen to stop the method. Then edit the method as desired and save it. Restart the method by clicking on the **Start** button at the top of the screen.

Click the **Delete Method** button to delete the selected method.

## Configuring the ZRM Cycle

The duration of the zeroing, sampling, and settling time of a method can be configured. See Figure 23 for illustration. The settling time is the amount of time the system is allowed to come to equilibrium between states before measurements are made. The zeroing duration and sampling duration are the amount of time data is collected for each state. The minimum allowed time for each setting is one minute. The maximum allowed time for each setting is 60 minutes. Any changes made can be discarded by clicking the **Discard Changes** button at the bottom of the screen. Also, methods can be deleted by clicking the **Delete Method** button.
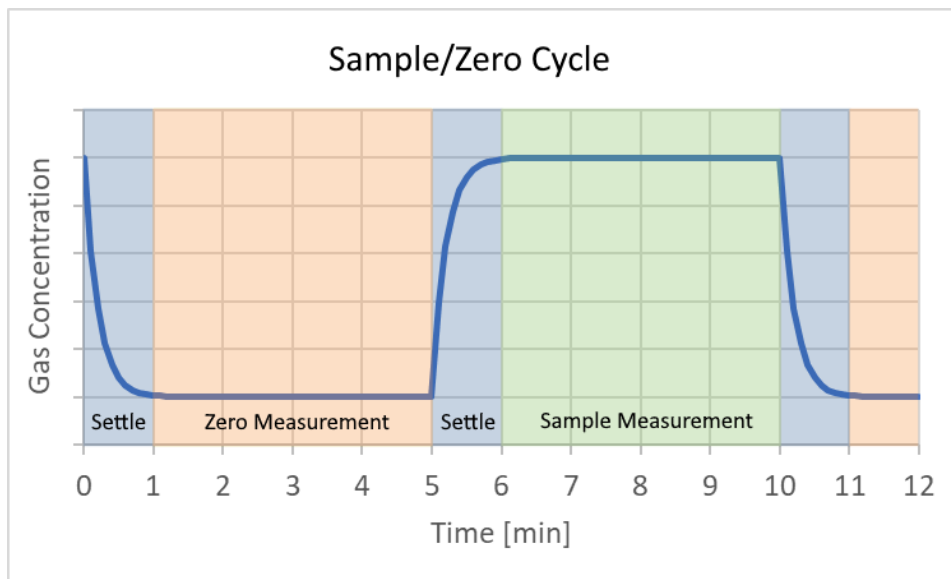


*Figure 23: Zeroing, Settling, and Sampling Measurement Durations*

## Configuring the Scrubber Health Check Cycle

The start time and the frequency of QA/QC scrubber health check can be scheduled. The actual start time of the measurement cycle is adjusted to occur after the completion of any currently running zero/sample cycle (Figure 24). The scrubber check cycle consists of an initial zero measurement, verification of the presence of QC gas, and measurement of the output from the QC gas challenged scrubber. Each measurement step has an initial settling time. There are also

purge steps to ensure any remnants of the challenge gas verification are removed from the system.
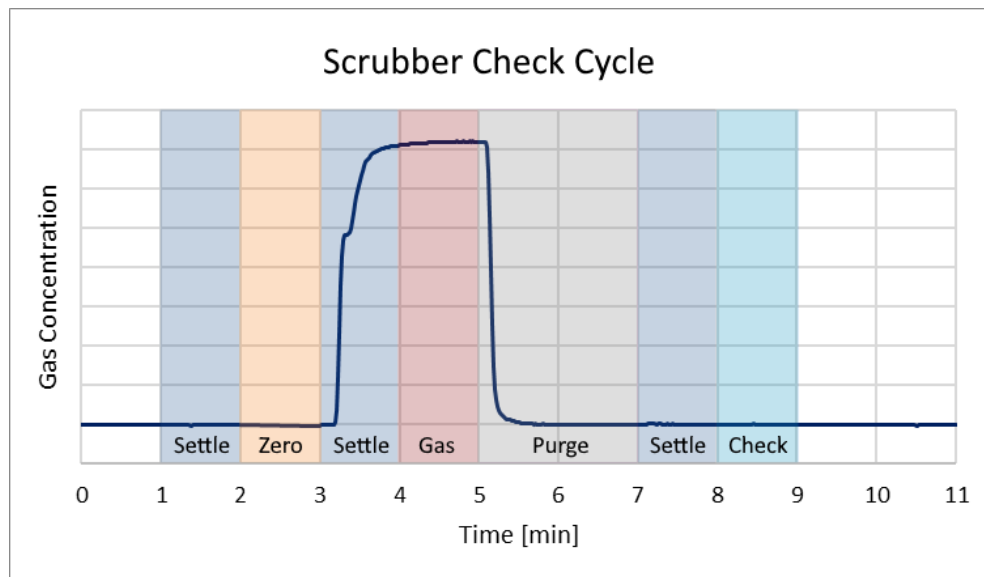


*Figure 24: Scrubber Check Cycle*

## Configuring the Reference Check Cycle

The start time and the frequency of QA/QC reference check can be scheduled. The actual start time of the measurement cycle is adjusted to occur after the completion of any currently running zero/sample cycle or scrubber health check cycle. The reference check cycle consists of an initial zero measurement and a reference gas measurement. Each measurement step has an initial settling time. The reference step is given a long settling time to ensure a stable measurement condition for increased accuracy.
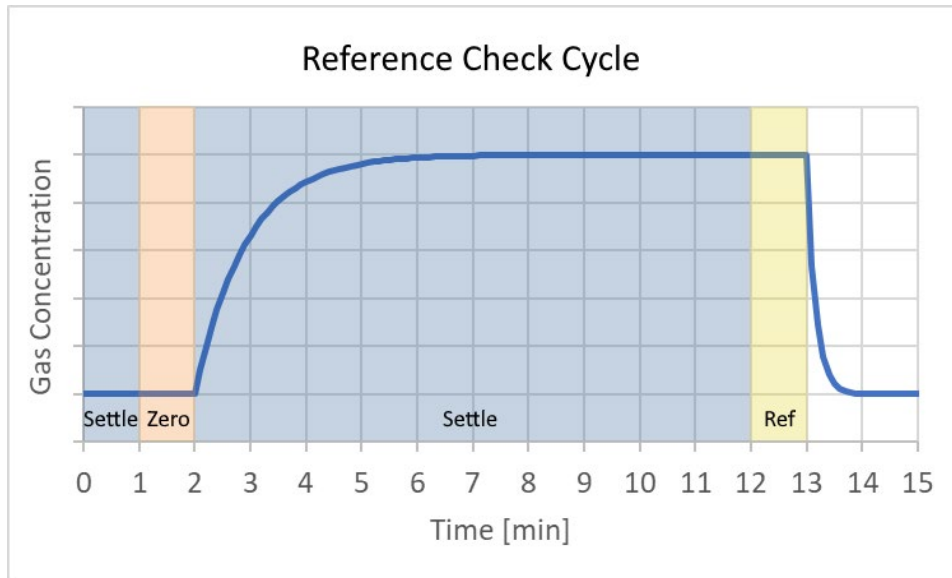
*Figure 25: Reference Check Cycle*

## 7.7    Data Streaming Tab

The **Data Streaming** tab can be used to assist in configuring automatic data transfer from the ZRM to another computer.

To use a REST API to retrieve data from the ZRM system, the available IP addresses are provided under Option 1. For details about the REST API, see section *9.5, Data Streaming – DAS Integration*.

To stream data via a serial interface, you can select the desired serial port from the dropdown list under Option 2. Serial ports that are in use by other processes will not be available. After you select the desired COM port, click the **Apply** button to save your choice.
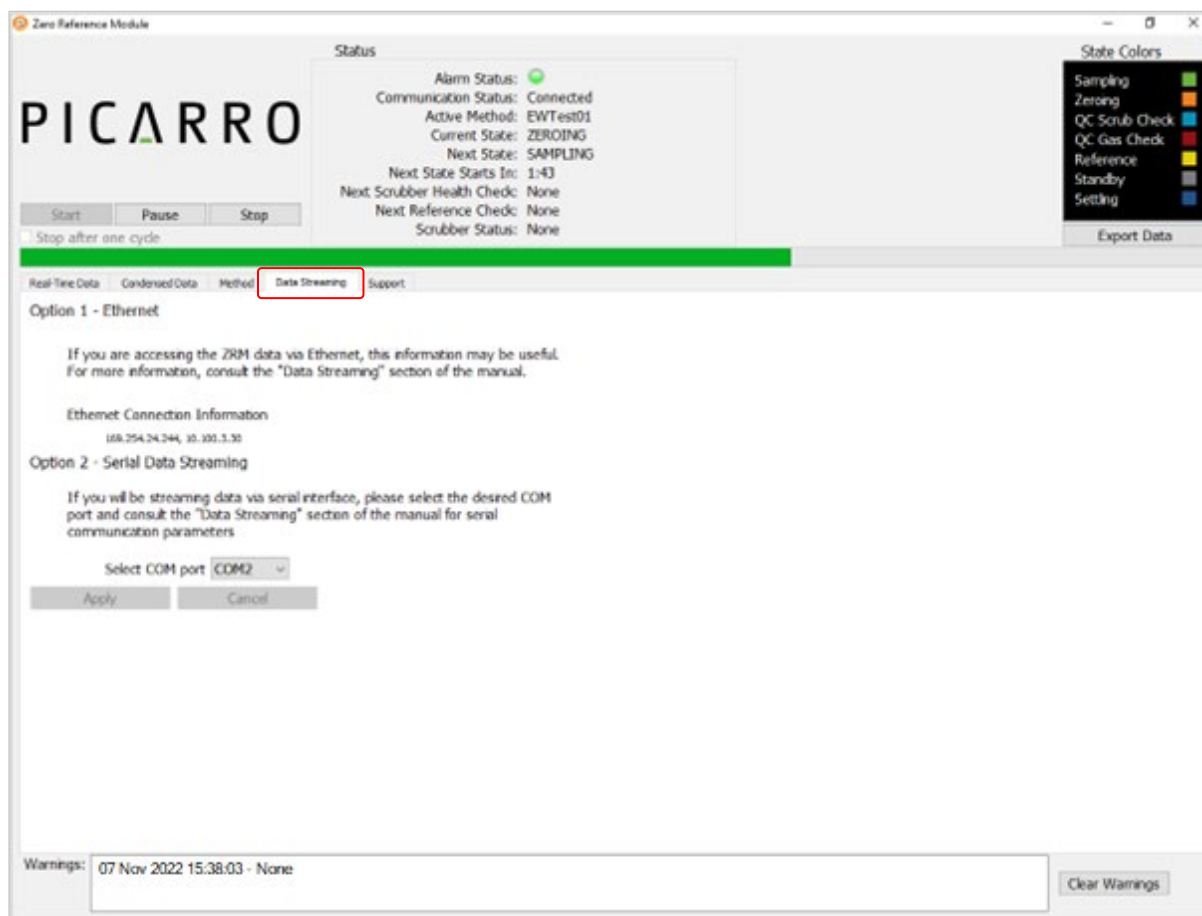
*Figure 26: Data Streaming Tab*

## 7.8 Support Tab

The **Support** tab (Figure 27) provides tools for system setup and troubleshooting. From this tab, you may run ad hoc scrub and reference checks, view sensor data, and control individual hardware components of the ZRM system. Use these controls as directed by this manual or by a Picarro service technician.

### Direct Control

Under **Direct Control**, hardware states and components can be controlled. Before using direct control, you must stop any method that is currently running using the "Stop" button at the top of the ZRM window. Use these controls only as directed by this manual or by a Picarro service technician.

Individual operational states list such as the sample state or zero state can be selected in the **Set State** dropdown. Select the desired state and then click **Apply**.

To run an ad hoc Scrubber Health Check or Reference Check, select an option from the **Run** dropdown list and click the **Apply** button to the right. The system will perform an entire Check cycle and then return to the standby state.

To control individual components to be controlled, select the desired action from the **Control Component** dropdown list and click **Apply**. A confirmation pop-up window (Figure 28) will appear warning users not to make changes without Picarro guidance.

## Sensor Data

The Sensor Data table at right displays the instantaneous readback value for each sensor. If the sensor value is outside of the acceptable operating range, the value will appear red. If the value remains outside of acceptable limits for an extended period, a message will be written to the system log. If the software is not communicating with the ZRM device, the most recent reading will be shown.

## Graphs

There are two graphs shown on the Support tab. To zoom in on a graph, click and drag your cursor to draw box. The graph will be adjusted to zoom in on the area inside the box. To zoom back out, click the box at the lower left corner of the graph. To select a data point, click on that data point. To deselect a data point, click on the data point again.

The dropdown list to the left of the graphs can be used to select the data to be displayed. In the table to the left of each graph, real-time measurement data is displayed, including the mean and slope of the currently displayed time range in the graph. If a data point is selected, the coordinates of that point will be displayed in the table at left.

**WARNING**

**Picarro recommends <u>not</u> attempting to control individual components without the guidance of a Picarro technician. Certain hardware states could damage equipment or create unsafe gas flows from Scrubber QC or Reference Check gas bottles.**

*Figure 27: Support Tab*
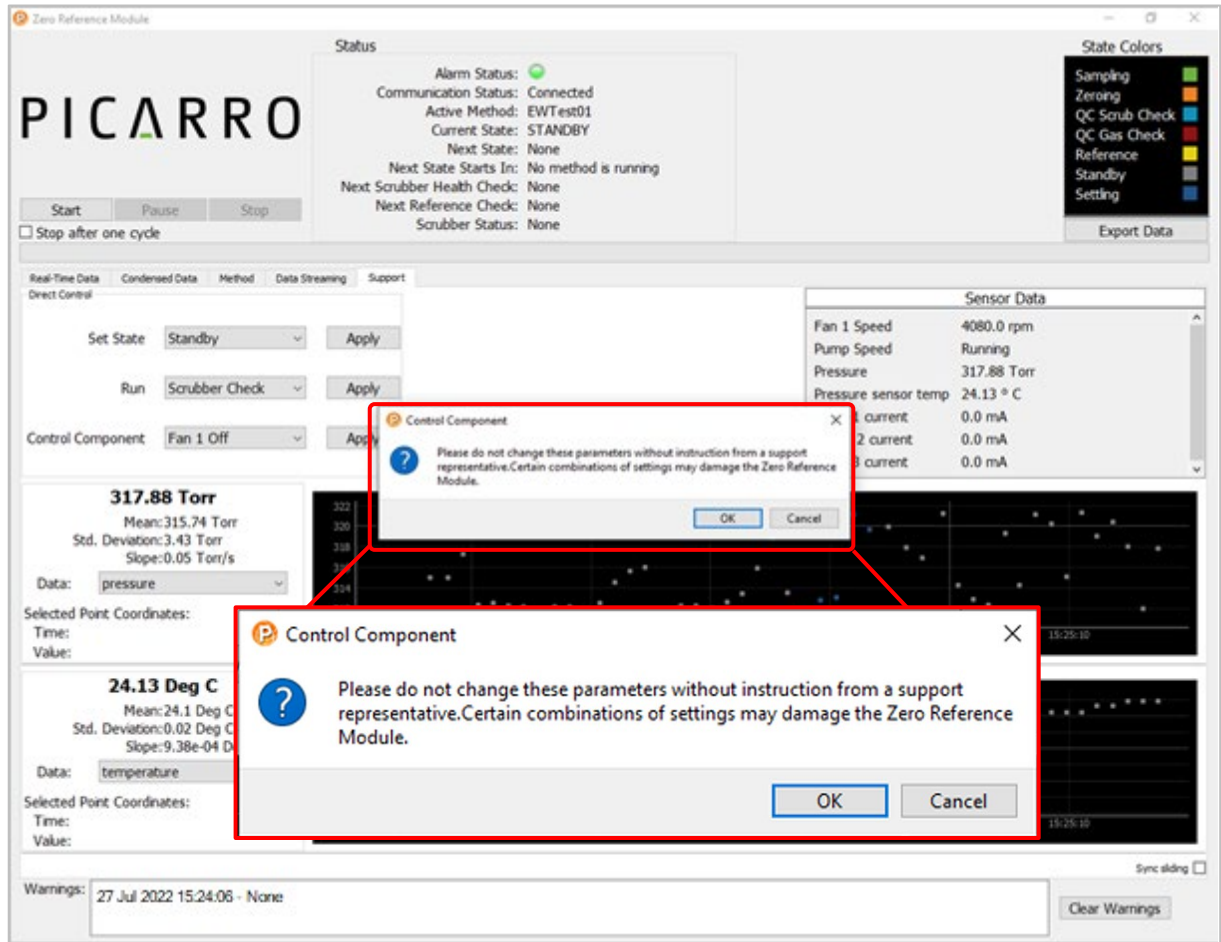
*Figure 28: Support Tab State Change Warning*

# 8. Operation

Once the ZRM has been connected to a G2920 analyzer and the software fully configured, the system is ready to begin making measurements. The following chapter is written around four operational principles that define a typical user experience:

1. Performing a Measurement

2. Utilizing QA/QC Features

3. Monitoring System Operation

## 8.1 Performing a Measurement

Once properly set up and configured, performing a measurement with the ZRM is simple. Under normal operation, the ZRM will perform two types of measurements: a Sample and a Zero. As such, the key to performing a measurement is configuring these variables and starting a method. All of this can be accomplished from the **Method** tab of the ZRM Software Interface (Figure 29).
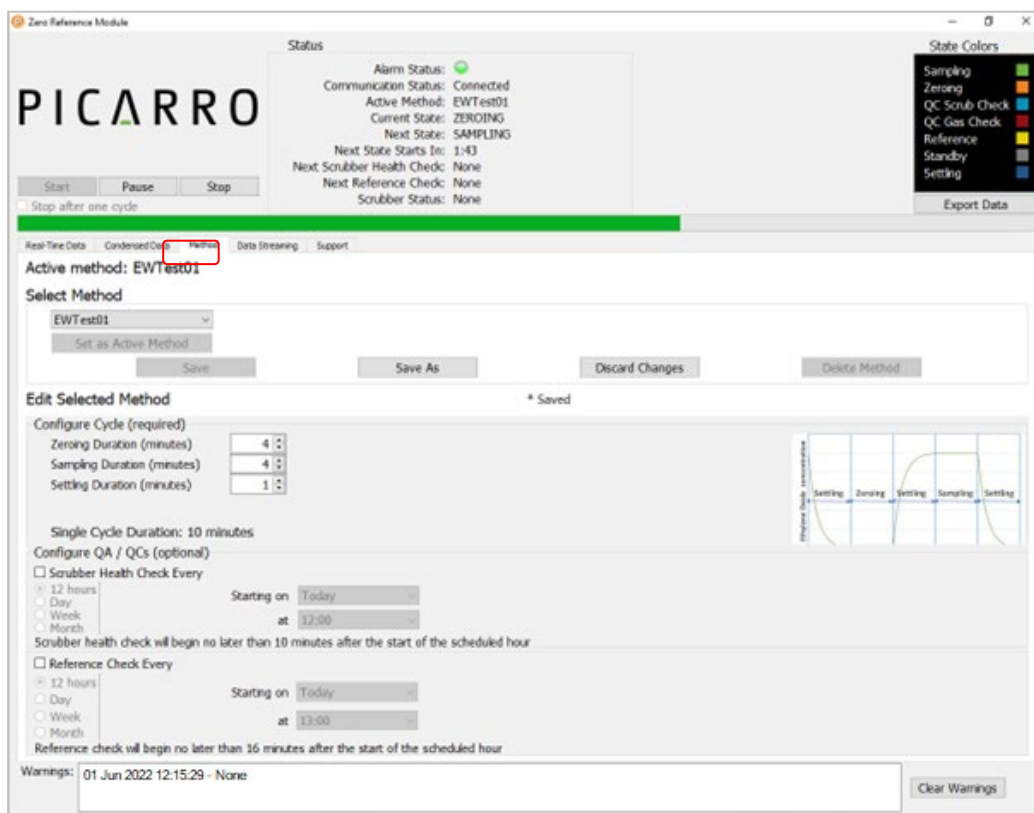


*Figure 29: Operational Method Setup and Run*

A typical measurement workflow would be as follows:

1. Select the appropriate **Zeroing Duration**. The maximum duration time for any step is 60 minutes and the minimum time is 1 minute.

2. Select the appropriate **Sampling Duration**. Note that the Zeroing and Sampling durations do not need to be the same. If they are different, be aware of the error in subtracting two different time averages.

3. **Settling Duration** is set at 1 minute by default and it should be suitable for most ambient measurement conditions.

4. Configuring QA/QC steps is an optional part of the method, therefore these options can be selected or deselected.

5. The start day can be configured up to 1 week in advance. The start time can be set to the beginning of any hour during the day and is shown in military time.

6. The actual check will start at the next natural break in the Sample/Zero cycle. For default Sample/Zero/Settling settings (4 min/ 4min/1 min) the Scrubber Health Check and Reference check will begin no later than 4 minutes and 10 minutes after the start of the scheduled hour respectively. The interval of the checks can be configured to 12 hours, 1 Day, 1 week, or 1 month only.

7. When a method has been fully edited and customized, it needs to be saved.

8. *The method that is shown at the top as the Active Method is the method which will be used in operation. To use the method you have created, set the method as active. Saving a method does not automatically set it as active.*

9. Click the **Start** button at top of screen. A confirmation screen (Figure 10) will pop up stating the method name that is starting and asks if you would like to proceed.

When no method is running, the Status box will appear as shown in Figure 30.
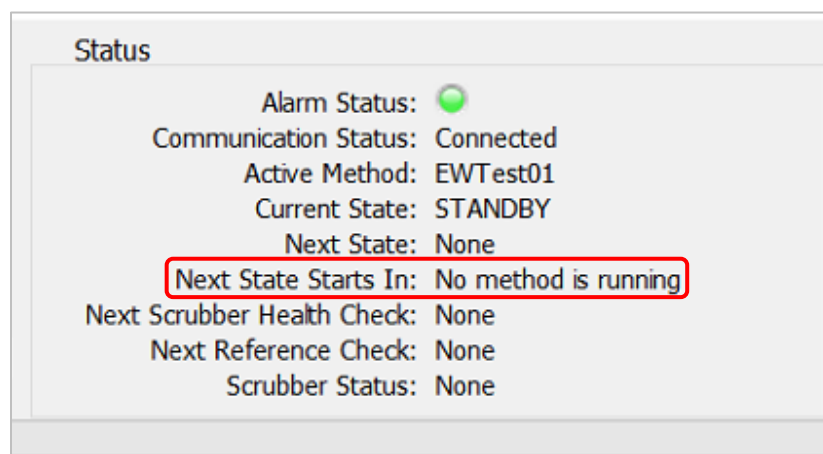


*Figure 30: Status with No Method Running*

After you click **Start**, the system will begin running the active method. The Status box will now display new information for Current State, Next State and Next State Starts In, as seen in Figure 31. The Measurement Progress Bar will begin to fill and the Next State Starts In timer will begin counting down until the following state begins.
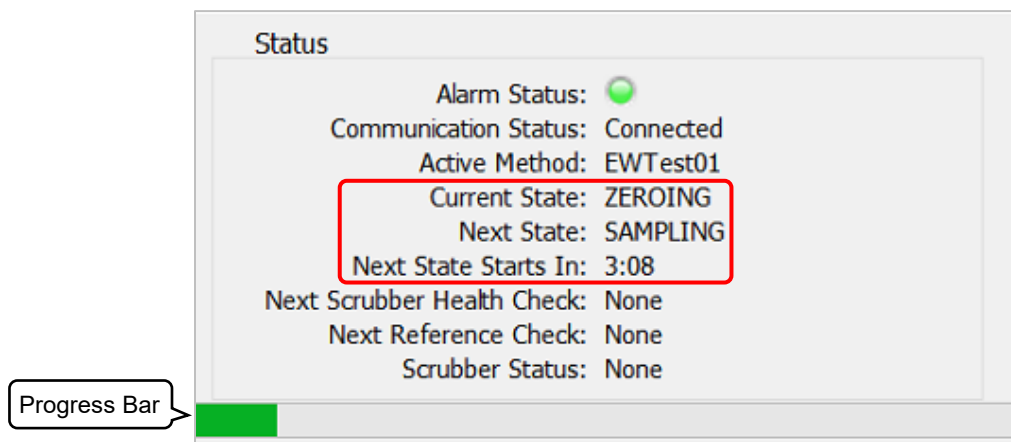


*Figure 31: Status Box with System Running Active Method*

To verify that the ZRM system is working correctly, observe the **Real-Time Data** tab. Ensure that "Corrected Ethylene Oxide" is displayed in the upper graph and "Ethylene Oxide (EtO) is displayed in the lower graph (Figure 32). As the method progresses, color-coded data points appear in the lower graph, corresponding to the current ZRM State. For more information about ZRM states, see section *1.3, Theory of Operation.*

The first step in the method is Zeroing. For the settling period of the Zero state, the Current State in the Status box will show ZEROING_PREP and the data points will be dark blue. Once the settling period is complete, the Current State will show ZEROING and the data points will be orange. The system will then progress through SAMPLING_PREP (dark blue) and SAMPLING (green). The duration that each color of points appears will correspond to the duration of that state stored in the Active Method.

Once the system has progressed through all four of the normal cycle states, the software will calculate the Uncorrected Ethylene Oxide, Zero Offset and Corrected Ethylene Oxide for that cycle. A corresponding data point (gray) will appear in the upper graph. Figure 32 shows an example of how the Real Time Data tab will look after a few cycles.

*Figure 32: Real Time Data Tab Selected, Showing Corrected EtO*

Once you are satisfied the ZRM is collecting data as expected, you can switch to the **Condensed Data** tab. From this tab you can view up to a week's worth of data. Figure 33 shows the Condensed Data tab with 24 hours of data displayed.

Once a method has been started and the system is taking measurements, it can remain operational for months.
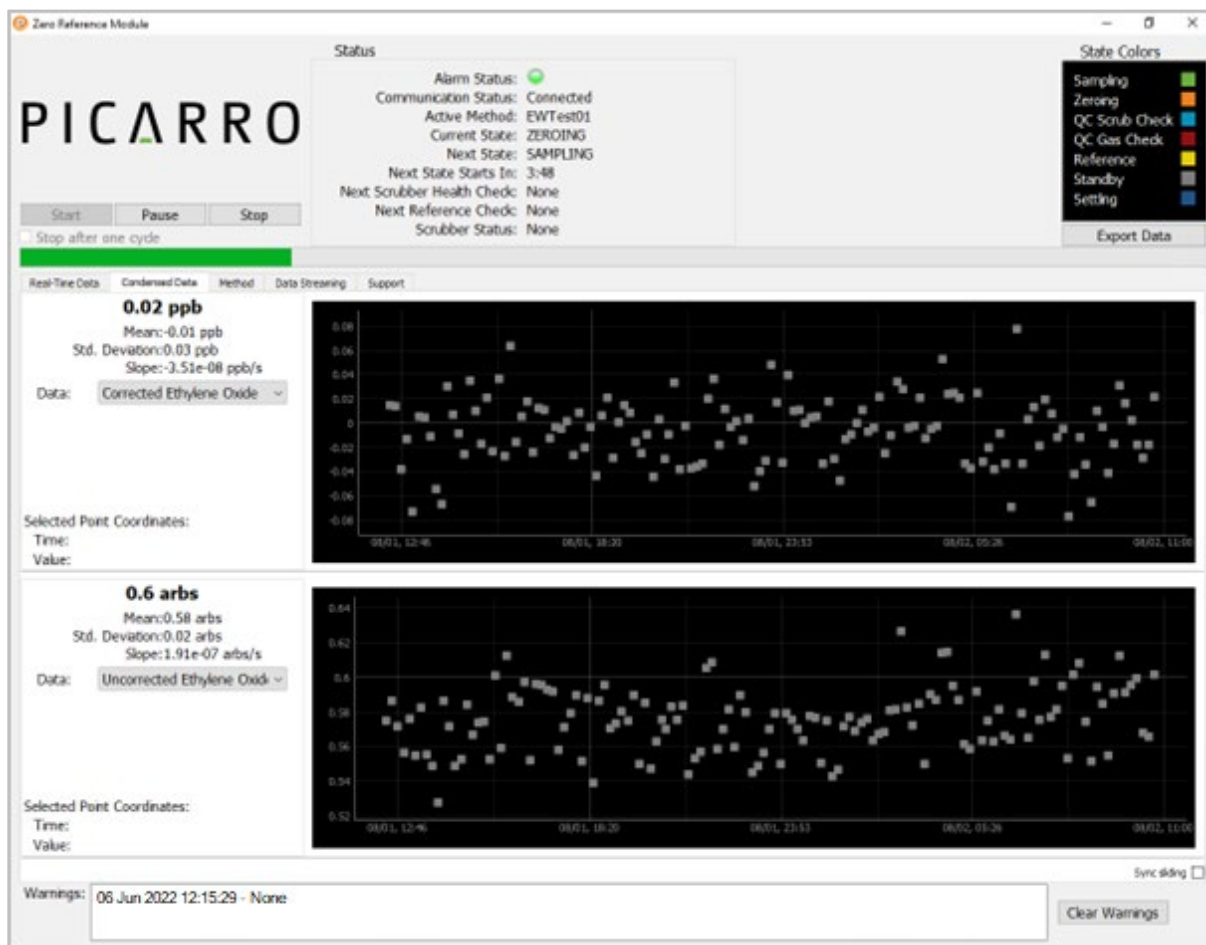
*Figure 33: Condensed Data Tab Showing 24 Hours of Data*

## 8.2 Utilizing QA/QC Features

### Performing a Scrubber Health Check

The zero referencing, and in turn the ZRM, is only effective if the PAIAC scrubbers are effective at removing EtO during the zero state. The 'Scrubber Health Check' is there to validate their effectiveness as often as is required. While the scrubbers have been designed to last at least 3 months under typical ambient conditions, we encourage users to utilize health checks and configure their frequency to suit the measurement objectives and requirements.

Once the health check has been set up (section *6.3*), configured (section *7.6*) and completed, it will yield a pass or one of two different fail conditions. The results will be visible in two components of the software interface (Figure 34).
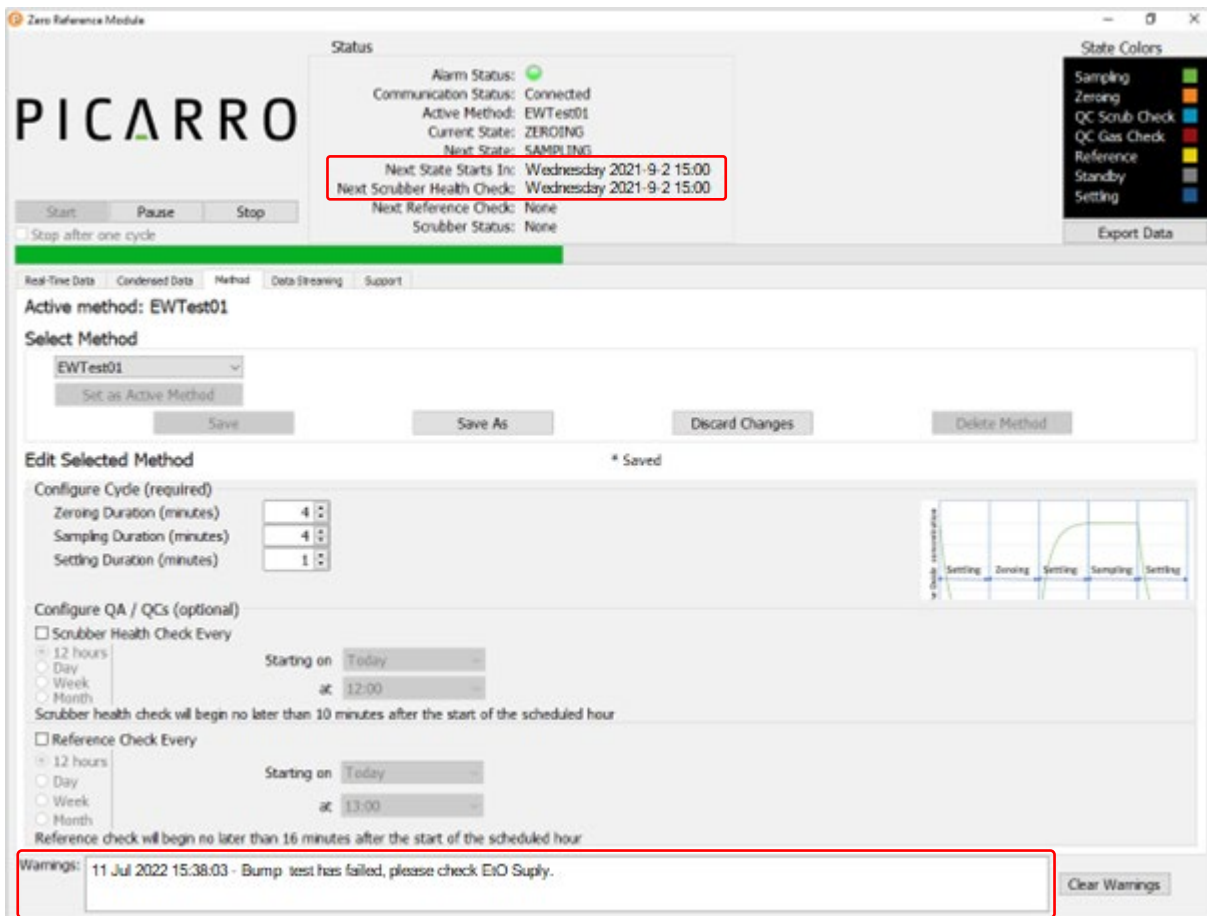
*Figure 34: Scrubber Health Check Results*

- If the check passes, the status indicator in the software user interface will display "Pass" and the ZRM will revert to its previous state of operation. If a method was running, that method would resume. If a stand-alone health check was started from the Support tab, the ZRM will revert to its standby state.

- The 'Bump test' failure condition will occur if no challenge (or bump) gas was detected during the first stage of the health check. In this case, a notification will appear in the Warnings box and the status indicator in the software user interface will display "Incomplete." Follow instructions in section *C.10* to evaluate any cylinder or gas supply issues to the Scrubber QC port.

- The 'Scrubber Health Check' failure condition will occur if the scrubbers were not able to remove EtO from the challenge gas and breakthrough has occurred. If this happens, the status indicator in the software user interface will display "Fail". Follow instructions in section *11.3* to replace the PAIAC material in the scrubber cartridges.

## Performing a Reference Check

The 'Reference Check' feature of the ZRM enables the automatic measurement of a reference tank. This measurement is tagged and recorded in the data files of the ZRM, available for future processing and analysis. The ZRM software does not have a pass or fail criteria associated with the Reference Check. It should be noted that EtO is a suitable reference gas, but any reference gas can be used as long as it meets measurement objectives and requirements.

Once a method has been started and the system is taking measurements it can remain operational for months. Should an error occur, the ZRM software interface will notify the user or any change. The next section describes how to monitor the system operation over its operational period.

# 8.3    Monitoring System Operation

The ZRM and Picarro analyzer log many variables associated with individual sensors, spectral parameters, and other operational outputs. To simplify and streamline the user experience, many of these have been factored into a single indication of system operation – **ZRM Status / Alarm**. ZRM Status is expressed in three different ways, to accommodate the different ways a user may interact with the system:

1.   It is expressed as a colored status light on the front panel of the ZRM. A technician or operator can know the operational state of the ZRM simply by looking at it.

2.   It is expressed as a colored indicator on the ZRM Software Interface. A technician or operator accessing the software directly or via remote access can know the operational state of the ZRM.

3.   It is expressed as a data key in the database and data stream. A technician or operator reviewing past datasets can compare anomalous data with the system operation. If the system is streaming its data keys to an external Data Acquisition System (DAS), a technician or operator can configure an alarm based on this indicator/data variable.

## Status Indications

**NOTE**

**In the table below, Status Color refers to both the color of the front panel LED on the ZRM device and the color of the Alarm Status indicator in the ZRM software.**

*Table 4: ZRM Status Indications*

| Status Color | Data Key | Flashing or Solid | Communication Status | Hardware Status | Data Quality |
|---|---|---|---|---|---|
| **Green** | Operational | Solid | ZRM hardware communicating with software on analyzer. | Hardware has no errors. | No impact |
| **Green** | N/A | Flashing | ZRM hardware not communicating with software on analyzer. | Hardware has no errors. | No data being logged |
| **Red** | service_error | Solid | N/A | Non-critical Hardware Error. Check the 'Warnings' window in the control software. | No impact |
| **Red** | critical_error | Flashing | N/A | Critical Hardware Error. Check the 'Warnings' window in the control software. | Data review required |

If the ZRM is working and there are no errors, the color on both the instrument front panel and the software status indicator will match. When the software and the ZRM are not communicating, it is possible that the front panel LED and the Alarm Status indicator will not show the same status. Once communication is re-established, this situation will resolve and both indicators will again display the same status.

When hardware errors are detected, the Alarm State light will continuously indicate there is an issue until the **Clear Warnings** button in the software user interface is clicked. Non-critical errors indicate the unit may require service or maintenance but will continue to function as required and generate good data.

Critical errors indicate the unit is no longer functioning correctly and may be generating incorrect data. See ***APPENDIX C –Errors and Troubleshooting*** for more information about errors and their possible causes. If the cause of the error persists, the warning light may re-illuminate in its error state. For example, this is the case if the most recent Scrubber Health Check has failed or was incomplete.

## 8.4    Accessing Data

### Data Output Options

You can retrieve data from the ZRM instrument in several ways. Figure 35 shows a high-level diagram of the different formats that are available.

Data can be accessed in four formats: Analytical Data, Analytical Data (Condensed), Sensor Data and System Log Data.

**ZRM Dataset Structure**
(all variables and values are symbolic)

| Analytical Data | | | |
|---|---|---|---|
| Time | EtO | State (ZRM) | Corrected EtO |
| 1 | 1 | Zero | |
| 2 | 1 | Zero | |
| 3 | 3 | Sample | |
| 4 | 3 | Sample | |
| 5 | 0 | Zero | 2 |
| 6 | 0 | Zero | 2 |
| 7 | 3 | Sample | 2 |
| 8 | 3 | Sample | 2 |
| 9 | 1 | Zero | 3 |
| 10 | 1 | Zero | 3 |
| 11 | 4 | Sample | 3 |
| 12 | 4 | Sample | 3 |
| 13 | 2 | Zero | 3 |
| 14 | 2 | Zero | 3 |
| 15 | 4 | Sample | 3 |
| 16 | 4 | Sample | 3 |
| 17 | 1 | Zero | 2 |
| … | … | … | … |

| Analytical Data (Condensed) | |
|---|---|
| Time | Corrected EtO |
| 5 | 2 |
| 9 | 3 |
| 13 | 3 |
| 17 | 2 |
| … | … |

*In an effort to reduce the amount of data exported over extended time periods, the 'Condensed' variant of analytical data was created. It only reports Corrected EtO and other selected variables at the frequency at which they are updated.*

| Sensor Data | |
|---|---|
| Time | Sensor |
| 1 | 1.43 |
| 2 | 1.32 |
| 3 | 1.67 |
| … | … |

| System Log | |
|---|---|
| Time | Log |
| 1 | None |
| 29 | Error status |
| … | … |

*'Analytical data' is a dataset generated at the same frequency as analyzer measurements (~1 row every second). Corrected EtO data is generated at a lower frequncy, and is only updated after a ZRM method cycle completes.*

*'Sensor Data' is generated at the same frequency as 'Analytical Data'. 'System Log' is only generated when a new log message is generated. Both datasets are only available as standalone exports.*

*Figure 35: Output Data Format Schematic*

The Analytical Data format includes rows generated at the same frequency as analyzer measurements (~1 row per second). At each time point, updated measurement and status values are recorded. The ZRM state at the time of the measurement is also recorded for each row. At the end of one ZRM cycle (Settling, Zero, Settling, Sampling), values are calculated for Zero Offset, Uncorrected EtO and Corrected EtO. These values remain static until the end of the next ZRM cycle. The calculated values from the preceding ZRM cycle are recorded in each row until the calculations are updated at the end of the next cycle. Descriptions of these variables and their meanings can be found in Table 6 in ***APPENDIX B –Data Flow and Output***.

Analytical Data (Condensed) includes rows generated once per ZRM cycle. The result is that calculated values (Zero Offset, Uncorrected EtO and Corrected EtO) are not repeated. This data set also includes aggregated alarm status, instrument status and ZRM status reflecting any errors that may have occurred across the entire ZRM cycle. For more information about these variables, see Table 6 in *APPENDIX B –Data Flow and Output*.

Sensor Data includes data from individual ZRM components. For more information about these variables, see Table 7 in *APPENDIX B –Data Flow and Output*.

System Log Data includes a log of ZRM warnings, errors, and status events. For more information about this format, see Table 8 in *APPENDIX B –Data Flow and Output*. For a list of warnings and errors, see *Appendix C.2 , Diagnostic Warnings and Errors*.

The different formats above can be accessed by three methods: csv file export, serial streaming, and REST API.

## Data Access Methods

All four formats of data are available for csv file export: Analytical Data, Analytical Data (Condensed), Sensor Data and System Log data. Export data by clicking the **Export** button at the top right of the ZRM user interface and select the output file type. The output file will be stored to the selected location. For more details about the File Export function, see section *7.3*.

Several options are available for viewing the contents of a csv file, including text editors, spreadsheet programs and scientific data processing applications.

Serial streaming is available to access the ZRM Analytical Data. For more information about accessing the analytical data via serial streaming, see section *9.5*.

The ZRM Analytical Data can also be accessed via a REST API. For more information about accessing the analytical data via REST API, see section *9.5*.

# 9. Station Integration

## 9.1 General Setup at Station Site

A complete system for assimilation of a Picarro analyzer and Zero Reference Module for long-term monitoring should include the following elements:

1. A temperature-controlled sampling building or enclosure.

   See the Specifications Table in this and the analyzer manual for temperature requirements.

2. A power strip with at least 6 sockets.

3. An appropriately-chosen inlet (see section below).

4. Sampling lines using approved materials, with a minimum of 1/4" outer diameter, with 3/8" preferred.

5. A passthrough from outdoors to the measurement shelter.

6. (Strongly recommended) Line heaters for the portion of the sampling line that sits within the sampling shelter or enclosure.

7. (Strongly recommended) Vent lines for sample pump and ZRM exhaust lines if EtO is being used as a scrubber QC or reference gas.

Figure 36 shows a typical sampling shelter setup.

Figure 37 shows a diagram of shelter ZRM/Analyzer elements and connections.
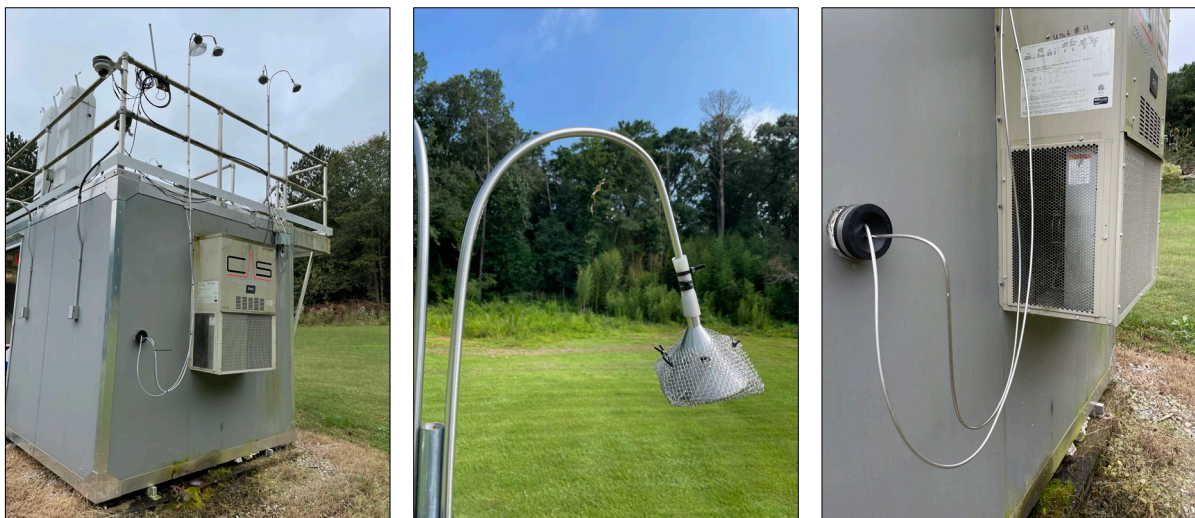


*Figure 36: (L) Sampling Shelter (M) Inlet with Inverted Funnel (R) Bulkhead Passthrough*
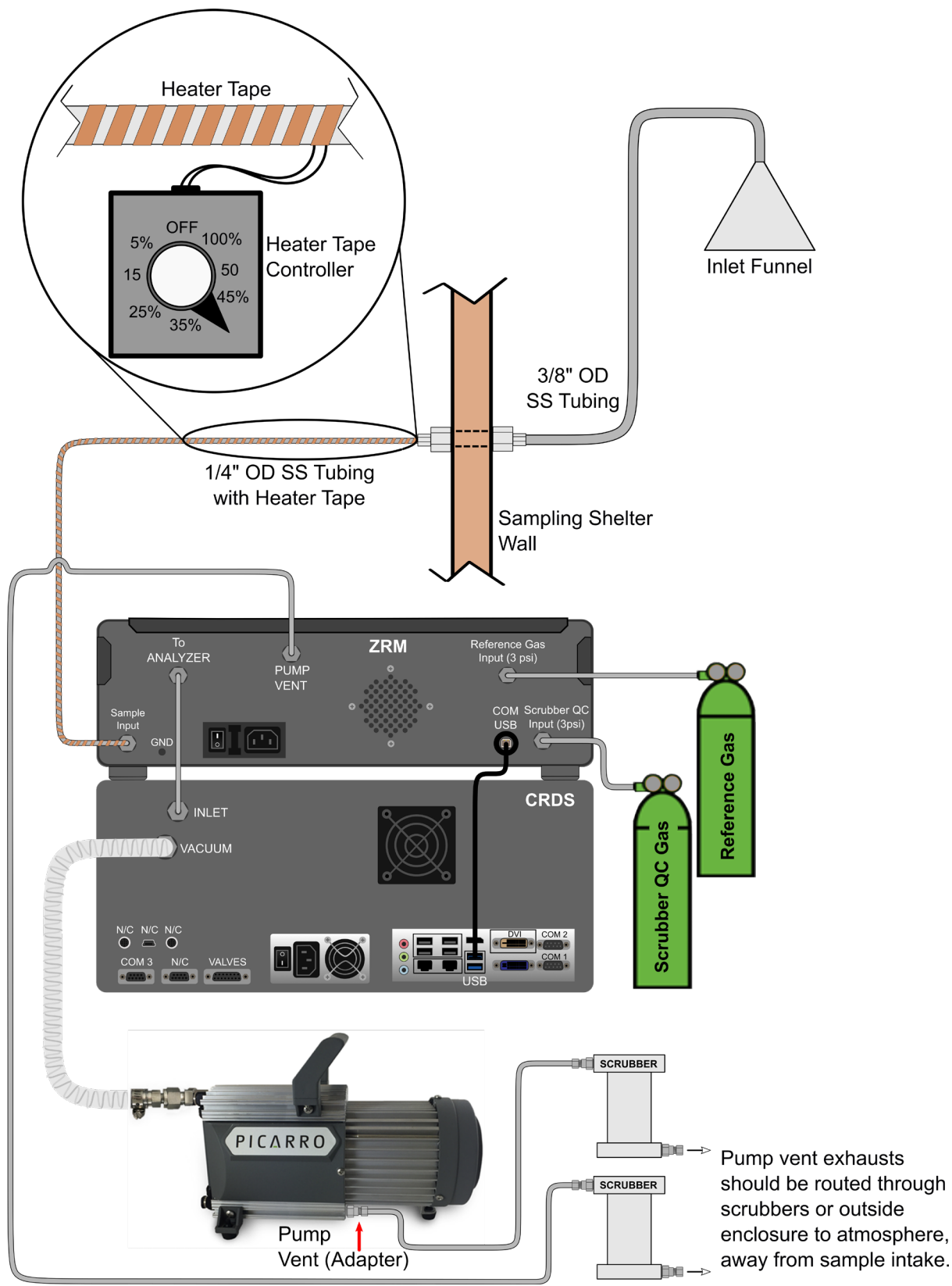
*Figure 37: Station Integration Elements*

## 9.2    Inlet Line Considerations

Inlet design should follow best practices for long-term monitoring sites, including:

1.  An inverted inlet line, typically 3/8", set away from any emissions sources, and far enough off the ground to avoid flooding, as shown in Figure 36 (middle image).

2.  An inverted funnel to prevent hydrometeors (rain, snow, sleet, hail) entering the line.

3.  Inlet mesh to keep out insects.

4.  Sample line material chosen per regulation or recommendation:

    For EtO, this is historically stainless-steel components (for PAMS sites), which will require a tubing bender. See section *9.3* below for guidelines on best bending and routing practices.

5.  Inlet should be as close as possible to the instrument to minimize sample and pressure loss along the lines.

6.  Sample lines inside an air-conditioned enclosure or shelter should be heated with heat tape (illustrated in Figure 37) to above the outside dew point. Follow the guidance we provide in *APPENDIX E –Heated Inlet Lines for Station Integration*. This is especially important in areas with high relative humidity, and during summer months.

## 9.3    Stainless Steel Bending and Routing

Stainless steel lines from 1/4" and above are challenging to bend by hand without appropriate tools. Picarro suggests the following approaches:

1.  1/4" and 3/8" tubing requiring bends with small bending radiuses (e.g. 6" or less) should be bent with a tubing bender, e.g. MS-HTB-4 1/4" or MS-HTB-6T 3/8" from Swagelok.

2.  Larger radius bends may be achieved by taking a straight piece of tubing and wrapping it around a circular object like a spool, pillar, or rigid water jug.

3.  Larger radius bends may be useful to reduce total line length (i.e. running lines along one rather than two sides of a triangle), while small bends tend to make for neater lines that can be tucked out of sight.

4.  As much as possible, line length should be minimized to reduce residence time, reduce pressure drop, and limit the distance that must be heated.

5.  Broadly, lines should proceed from a high point (sampling inlet funnel) to lowest (ZRM inlet) as much as possible, avoiding dips where water vapor can condense and eventually be aspirated into instrument filters.

## 9.4 Exhaust Line Routing

If the user intends to use EtO standards for scrubber check or span check gases, exhaust lines from Picarro pumps should be sent either to an activated charcoal scrubber vessel (Picarro PN: S3197) or vented to the atmosphere outside the shelter. ***APPENDIX D –Analyzer Pump Exhaust Setup*** provides a brief discussion of this consideration, and we expand on that discussion here.

1. Exhaust lines should be plumbed in such a way as to avoid backpressure. Venting to a small tee can create backpressure of one pump by another (e.g. the A2000 can backpressurize the ZRM pump), so Picarro recommends that each vent line be connected to its own scrubber. Descriptions and details for connecting to scrubbers can be found in section ***11.3, Servicing the ZRM Scrubber***.

2. When venting to a scrubber vessel, short lines between the pump exhaust and vessel will reduce backpressure and wear on the pumps. If long lines are required, the sample line should be stepped up in diameter to 3/8" or 1/2" OD.

---

⚠️ **CAUTION**

**Exhaust lines should never vent into the enclosure if EtO is being used as a reference or scrubber check gas.**

---

3. Exhaust lines plumbed to outside should terminate at least 20 feet away from the sample intake to avoid sample contamination, and ideally should be located downwind of the intake.

4. Avoid venting exhaust lines to areas where humans congregate.

## 9.5 Data Streaming – DAS Integration

### Overview

At a broad level, integration with external data acquisition systems (DAS) requires that the configuration of the DAS be compatible with the configuration of the output from the Picarro ZRM software. We encourage users to read this section for specific information about how ZRM data can be retrieved from the Picarro analyzer. For more complete discussions of how to set variables up correctly for particular DAS products, we recommend speaking directly with the vendor's software representative.

The following list provides some guiding principles for DAS integration.

1. The connection to the external DAS (e.g. Agilaire's ***AirVision***, or Envitech's ***Envidas Ultimate***) should be done through a null modem serial (RS232) "streaming" cable or by REST API.

2. Serial output via RS232 streams continuously, rather than requiring polling from the DAS.

3. The REST API (Representational State Transfer Application Programming Interface) communicates through an Ethernet interface, requiring polling by the DAS using the commands mentioned in the sections below.

## Data Format

The "Analytical Data" data format is available for serial streaming and REST API access. For an ordered list of variables in the Analytical Data format, see Table 6 in *APPENDIX B –Data Flow and Output*.

The Analytical Data format includes measurement data from all species measured by the G2920 and several variables useful for troubleshooting. A commonly useful subset of variables and a further reduced list are shown below in Table 5. The variable, 'ZRM_Status' is especially valuable as it enables the monitoring of system operation (see section *8.3*).

*Table 5: Commonly Used Variables for DAS Integration*

| Variable | Commonly Used | Reduced |
|---|---|---|
| ts | x | x |
| EtO | x | x |
| CH4 | x | |
| CO2 | x | |
| H2O | x | |
| ALARM_STATUS | x | x |
| INST_STATUS | x | x |
| Corrected_EtO | x | x |
| Uncorrected_EtO | x | x |
| Zero_Offset | x | x |
| State | x | x |
| Method | x | x |
| ZRM_Status | x | x |

Data type information for both the serial interface and the REST API is as follows.

- Numeric-type variables are output as **8-byte floats** in which the value corresponds to the units in the ZRM user interface (e.g., ppb digital units etc.).

- Timestamp is output as an **integer**

- State, Method, and ZRM Status variables are output as **strings**.

## Serial Streaming via RS-232

To access data through a serial connection, connect your serial line to a COM port on the Picarro analyzer. COM1-3 are accessible via the DB-9 9-pin serial ports on the back of the instrument. More COM ports can be made available by connecting a USB to Serial converter to one of the USB ports on the analyzer and configuring it according to manufacturer instructions

From the **Data Streaming** tab of the ZRM user interface, select an available COM port from the "Select COM port" dropdown list (Figure *38*). Once the port is selected, click **Apply.** The ZRM software will immediately start streaming data to that port and will resume streaming to that port if the software is restarted.
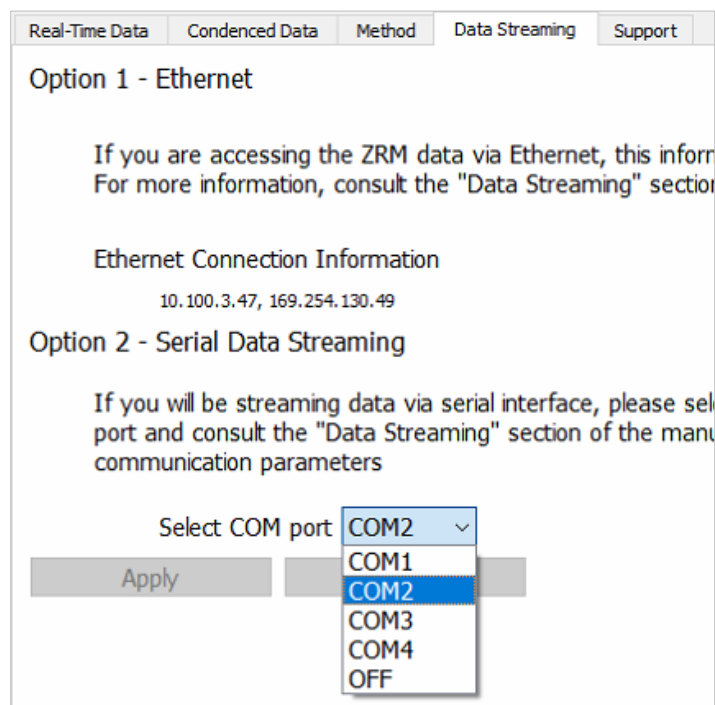


*Figure* 38*: Data Streaming Tab in ZRM User Interface*

**NOTE**

**RS-232 cables should be limited to 50' (~15m) length between the Picarro and DAS to avoid the cable providing too much capacitance.**

The parameters for the RS-232 streaming in the DAS should be matched to the parameters used by the Picarro. These are:

- **Baudrate**: 115200

- **Bytesize**: 8

- **Parity**: N

- **Stopbits**: 1

To interpret the serial stream, use the following information.

- The serial stream does not contain variable labels.

- Each new line starts with "NL:".

- All values are separated by a semicolon, ";".

- The list of streamed variables is given in Table 6.

The appearance of the stream, as seen in a correctly set up terminal on the DAS computer should be similar to the image in Figure 39.



*Figure 39: Terminal Session showing streamed ZRM data*

## REST API

The following two commands may be sent by the DAS to query the data from the Picarro ZRM.

- /das_service/1m_csv

  - Returns a payload containing the last 60 seconds worth of data formatted as CSV file. Request requires no payload.

- /das_service/historic_csv

  - Returns a payload containing all the data within a requested time period, formatted as CSV file. The request requires keys `start` and `end`, expressed in epoch time (in milliseconds, not seconds).

Existing endpoints are available for making GET requests to port 6610. The endpoints are continuously available, with no need for configuration. The IP addresses of the Instrument are displayed at the Data Streaming tab in the user interface (see Figure *38* above).

An example of the csv format used for the REST API is shown in Figure 40.

```
C:\>curl --request GET  --url http://localhost:6610/das_service/1m_csv
ts,EtO,CH4,CO2,H2O,ALARM_STATUS,CavityPressure,CavityTemp,DasTemp,EtalonTemp,INST_STATUS,InletValve,MPVPosition,NH3,OutletValve,ValveMask,
interval,pzt_offset,finelasercurrent,flaserc10_90range,flaserc25_75range,wlm_offset,CORRECTED_ETO,UNCORRECTED_ETO,ZERO_OFFSET,STATE,METHOD

1635320290402,0.7236584452590493,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290454,0.09401433778919122,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290505,0.96400544534404315,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290556,0.3235201871489005,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290607,0.36862735586838398,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290658,0.8875254295322816,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290709,0.921964882437877,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290760,0.64486709169428419,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290810,0.9453888101234339,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290861,0.42498614364255627,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290912,0.0440355048760136,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320290963,0.7568105088016416,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1635320291013,0.9144278922872902,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
```

```
C:\>curl --request GET  --url "http://localhost:6610/das_service/historic_csv?start=1634243161511&end=1634243165511"
ts,EtO,CH4,CO2,H2O,ALARM_STATUS,CavityPressure,CavityTemp,DasTemp,EtalonTemp,INST_STATUS,InletValve,MPVPosition,NH3,OutletValve,ValveMask,
interval,pzt_offset,finelasercurrent,flaserc10_90range,flaserc25_75range,wlm_offset,CORRECTED_ETO,UNCORRECTED_ETO,ZERO_OFFSET,STATE,METHOD
1634243161511,0.16313810170206589,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243161572,0.39399225869425998,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243161635,0.13466048430783772,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243161697,0.41150262657189607,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243161759,0.3017133017866247,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243161821,0.36314303902806355,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243161883,0.5291867691273087,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243161945,0.12542043567721473,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243162006,0.8135157848970617,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
1634243162069,0.6849220490578226,2.0,3.0,1.0,0.0,5.0,6.0,7.0,8.0,9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,,,,STANDBY,
```

*Figure 40: Terminal Sessions with ZRM REST API, Showing Results of Both Query Types*

# 10. Calibration and Gas Standards

## 10.1  Spectroscopy

Ethylene Oxide is measured in the near infrared region of the spectrum. Figure 41 shows the spectral region that the instrument uses to quantify EtO, $H_2O$, $CO_2$, and $CH_4$. The CRDS instrument rapidly (in about 2-5 seconds) scans this spectral region. The resulting spectrograms are analyzed using a non-linear least squares optimization algorithm, using pre-calculated model functions for each of the spectral features in this region. The concentrations of EtO, $H_2O$, $CO_2$, and $CH_4$ are reported by the instrument on the user interfaces and the data logs.
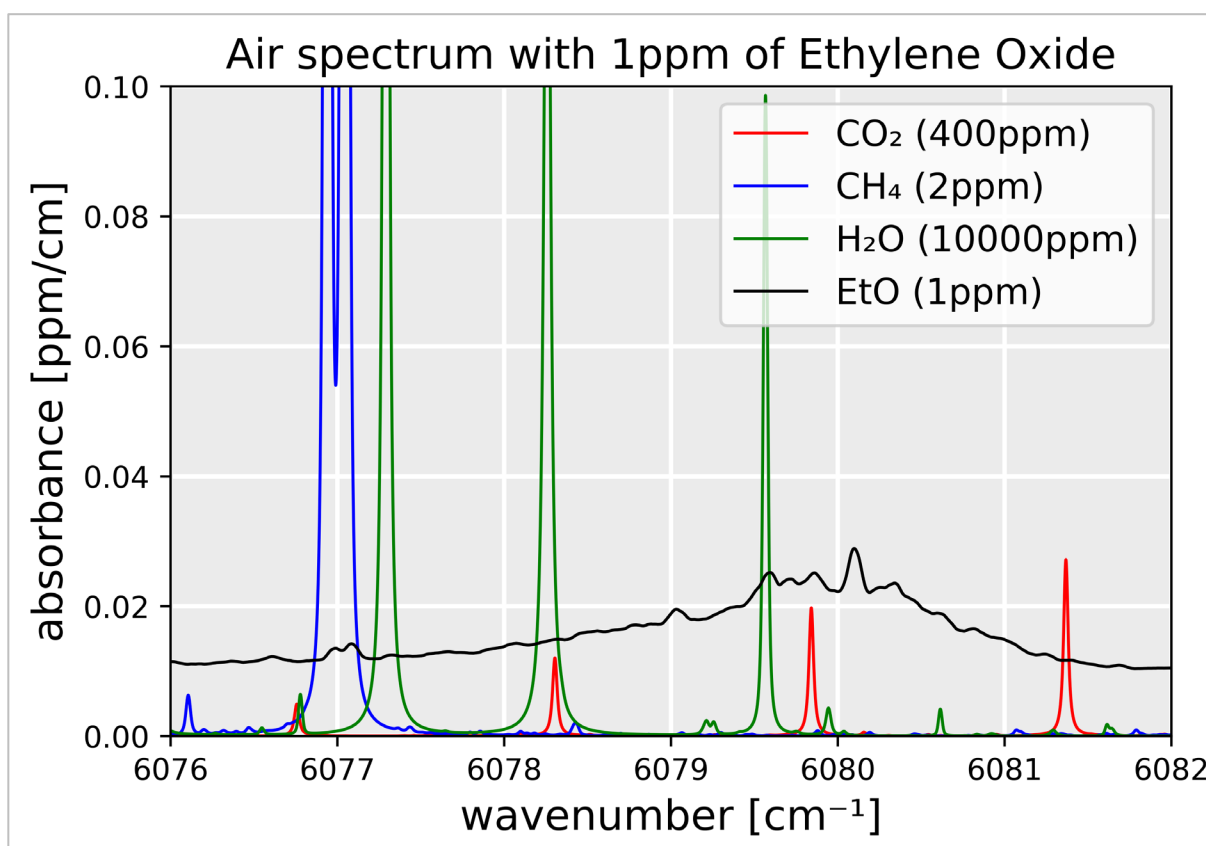


EtO spectral region, showing major features for $CO_2$, $CH_4$, and $H_2O$.

*Figure 41: EtO Spectral Region Used as "Proxy" Calibration Check*

## 10.2  Original Calibration

In 2019, Picarro measured the calibration factor of an early EtO instrument, using a gravimetrically prepared 1 ppm EtO gas bottle. A peak loss factor of 36.43 ppb EtO per ppb/cm was determined at that time. However, this peak loss is always

measured relative to a baseline loss value. The resulting difference is calibrated according to the concentration value of the gas bottle. For additional details about the factory calibration of Picarro analyzers, refer to the *Traceable Calibration of Ethylene Oxide* document (support@picarro.com).

## 10.3 Measurement of Air versus Nitrogen Background

Picarro has found there to be a 0.43% relative increase for EtO values measured in an air background versus a nitrogen background. This is due to differences in spectroscopic broadening caused by these two backgrounds.

## 10.4 Reference and QC Gas Connections

The ZRM has a **Reference Gas Input** port and a **Scrubber QC Input** port on the rear panel. Both require any attached gases to be regulated to 3 psig of pressure. Once tanks are open and lines are pressurized it is recommended to check all connections for leaks with a liquid leak detector (For example, Snoop made by Swagelok). Picarro recommends using 1/8" Stainless Steel tubing (with appropriate reducers) to connect the **Scrubber QC Gas** tank and the **Reference Gas** tank to the ZRM. Tubing length should be kept below 10' in length to allow adequate purging. Always ensure proper venting of all standards, even at low ppb concentrations.

### EtO Gas Kit (A0956)

There are several ports on the ZRM that can be connected to a compressed gas cylinder. The above-mentioned kit, composed of stainless-steel components, can be purchased from Picarro (Part Number: A0956). It includes a single regulator, a flip valve, fittings, reducers and 1/8" stainless steel tubing. Multiple kits can be purchased.

## 10.5 Gas Standard Selection

The ZRM software does not have the ability to fully calibrate the analyzer. For a complete guide on how to calibrate a Picarro G2920 analyzer, refer to the *Calibration Guide for Picarro Analyzers* document. The ZRM can utilize a single gas standard of EtO and deliver it to the analyzer for an offline correction.

For a reference gas cylinder, we recommend a concentration of EtO in the ppb range, preferably as close to the measured concentrations. Low concentration standards in nitrogen (<= 100 ppb), with good stability are now available from Air Gas (www.airgas.com). A similar tank can also be used to QA/QC the operation of the scrubber.

# 11. Hardware Maintenance and Service

This section covers replacement of the ZRM scrubber cartridges and particle filters. It also includes instructions for scrubber media replacement and after-service leak testing.

## 11.1 Service Recommendations

### Scrubber Material

The scrubber material used in the ZRM for the Ethylene Oxide Analyzer application is Phosphoric Acid Impregnated Activated Charcoal (PAIAC). Picarro suggests replacing the PAIAC in both canisters every 3 months. See *APPENDIX F –PAIAC Chemical and Disposal Information* for handling and disposal guidelines.

### External and Internal Particle Filters

The lifetime for the particle filter is dependent on the environment of the application. If the system is registering low pressure errors, it may be necessary to replace filters. See APPENDIX C –Errors and Troubleshooting for guidance on troubleshooting low pressure errors. To replace the filters, see section *11.4, Servicing the ZRM Particle Filter*.

### Additional Service

Troubleshooting the ZRM may reveal that additional components may require service. Many of the components may be replaced by the user with the help and guidance of Picarro support. For additional guidance on how to service the ZRM pump, pressure sensor, ZRM fan, valves, and associated boards, please contact Picarro support at support@picarro.com.

## 11.2 Spare Parts

### Scrubber Cartridge and PAIAC Replacement Kits

- S3193 – ZRM PAIAC Replacement, Single-use kit

- S3196 – ZRM PAIAC Replacement, Multi-use kit (annual)

- S3197 – ZRM Scrubber Assembly (PAIAC Included)

The recommended PAIAC replacement interval is once every three months under typical ambient conditions. The replacement interval can be longer or shorter depending on where the ZRM is being deployed and under what ambient conditions. A high-water vapor (relative humidity) or high volatile organic compound (VOC) load in ambient air may shorten the replacement interval.

Ultimately, the ZRM's QA/QC features can be used to evaluate the health of the scrubber to determine if a replacement is needed. S3193 has enough PAIAC material to refill both scrubber cartridges and replace key components that may require cleaning (O-rings and steel frits), once. S3196 has enough material and parts for four (4) replacements. Picarro recommends an annual cleaning and inspection of the scrubber cartridge. If a new cartridge is required, S3197 can be purchased. S3197 is a complete ZRM scrubber cartridge assembly with pre-filled PAIAC, for use as a single replacement.



**WARNING**

**NOTICE: Freshly procured PAIAC directly from a supplier can off-gas certain compounds that interfere with the spectroscopy of the G2920 analyzer. All PAIAC provided by Picarro has been aerated and primed with a VOC-free atmospheric mixture. Once removed from its packaging, it will be ready for operation with minimal to no downtime. If PAIAC is procured from a supplier, several hours of aeration and priming may be required before it is ready for use with the ZRM.**

## Particle Filter Parts

- S3155 – ZRM Particulate Filter (internal) (Qty 2)

- S3156 – ZRM Particulate Filter (external)

The ZRM particulate filters should be replaced once per year, under typical ambient conditions. Under a higher particulate load, replacement may be more frequent. The built-in health tracking of the ZRM monitors the operational pressure. If any issues with pressure are reported, a particulate filter replacement may be required. External filter replacement should occur first. If the problem persists, or if no external filters were used, then internal filter replacement should occur.

## EtO Gas Kit

- A0956 – EtO Gas Kit

There are several ports on the ZRM that can be connected to a compressed gas cylinder. The above-mentioned kit, composed of stainless-steel components, can be purchased from Picarro. It includes a regulator, a flip valve, fittings, reducers and 1/8" stainless steel tubing.

## 11.3   Servicing the ZRM Scrubber

### Removing the Scrubber

1.   Lift the top panel handle to access the service area. The area includes the scrubbing housing, particle filters and tools for service.



Top Panel Handle
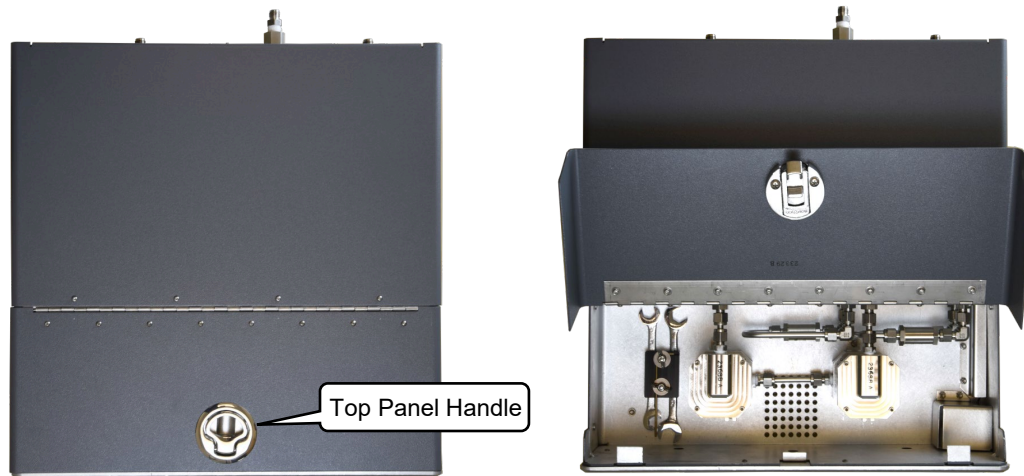
*Figure 42: Accessing Scrubber/Filter/Tools Area*

2.   Using the available 2.5 mm hex wrench, loosen the inner base screw of the scrubber housing but do not remove (Figure 43).



Loosen base screw but do not remove.

Loosen base screw but do not remove.
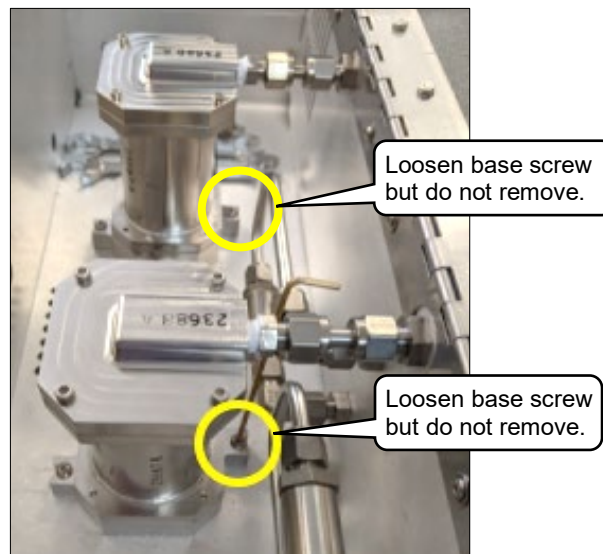
*Figure 43: Loosening Scrubber Housing Inner Base Screw*

3.   Remove the outer base screw of the scrubber housing (Figure 44).
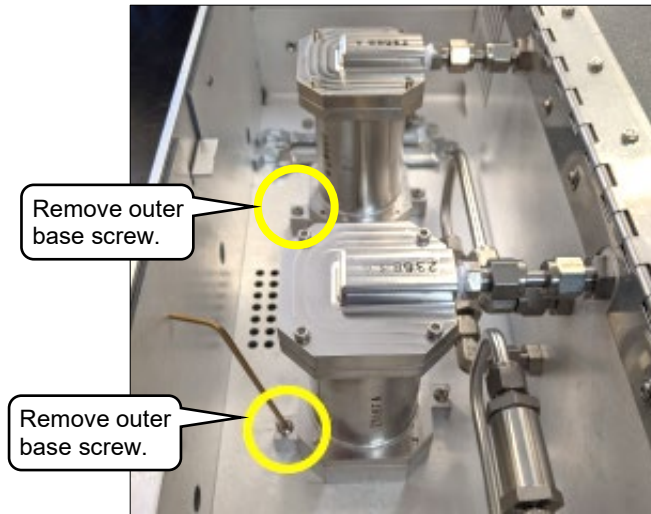
Figure 44: Removing Scrubber Housing Outer Base Screw

4. Unscrew the indicated Swagelok connections (Figure 45) with the available 1/2" and 9/16" wrenches. (Be sure to use both available wrenches and hold the connection attached to the scrubber housing in place when loosening the Swagelok connection.)
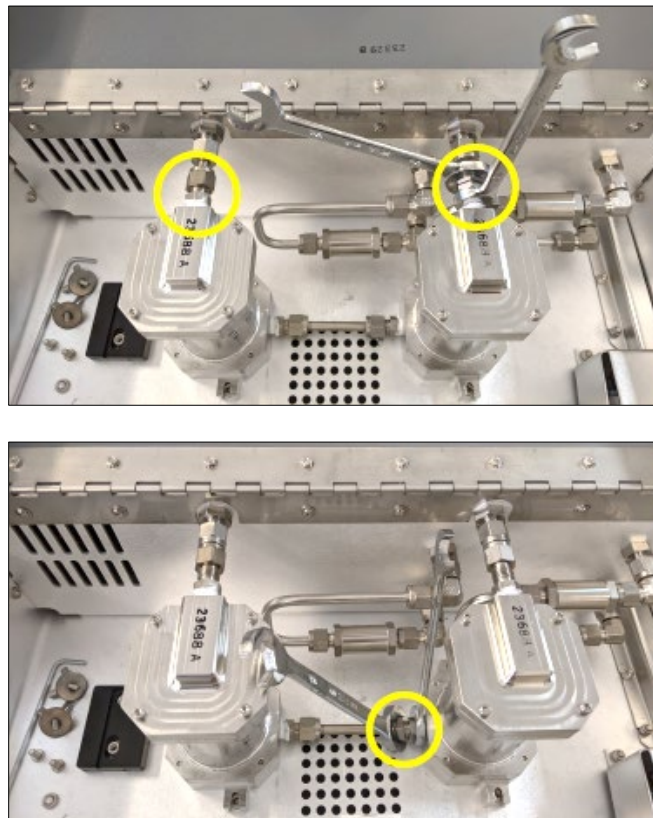


Figure 45: Disconnecting Scrubber Swagelok Fittings

5.  Slide the scrubber housing towards the front module.
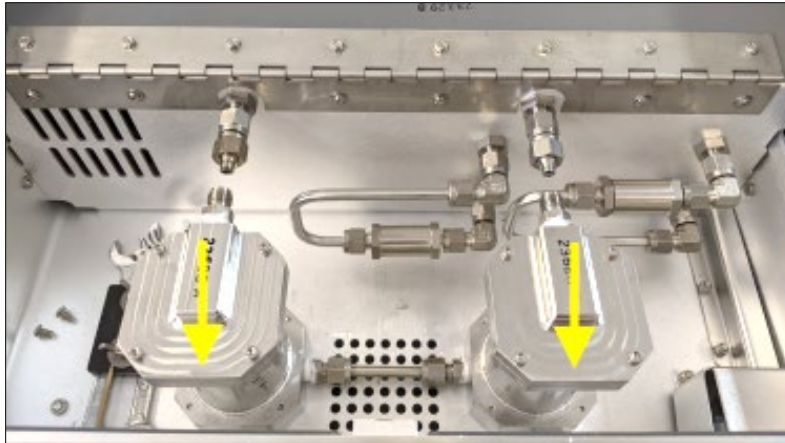


*Figure 46: Scrubber Pair Removal*

6.  Remove the scrubber(s).

7.  If installing new scrubbers, remove the stainless-steel tube section connected between the two scrubber housings. If refilling the unit with new media, the tubing section may remain in place.

## Reinstalling the Scrubber

1.  Reattach the gas fitting tube between the two scrubbing scrubber housings but leave it slightly loose.

2.  Follow the above removal directions in reverse order.

3.  Once installed, be sure to finish by tightening all fittings.

4.  After the scrubber has been reinstalled, perform the ***ZRM Leak Test*** procedure found in section ***11.5*** to assure the ZRM unit is free of gas leaks.

## Refilling the Scrubber with New Media

The scrubber refill kit includes 2 stainless steel frits, 4 O-rings and 1 packet of PAIAC scrubbing media. The following instructions demonstrate how to disassemble the scrubbing canister and replace the frits, O-rings, and media.

5.  Remove the four screws from the top cover with the available 2.5 mm hex wrench.

*Figure 47: Removing Scrubber Top Cover Screws*

> **6.** Carefully  remove the top cover. Remove both o-rings (Figure 48).



Remove O-Ring
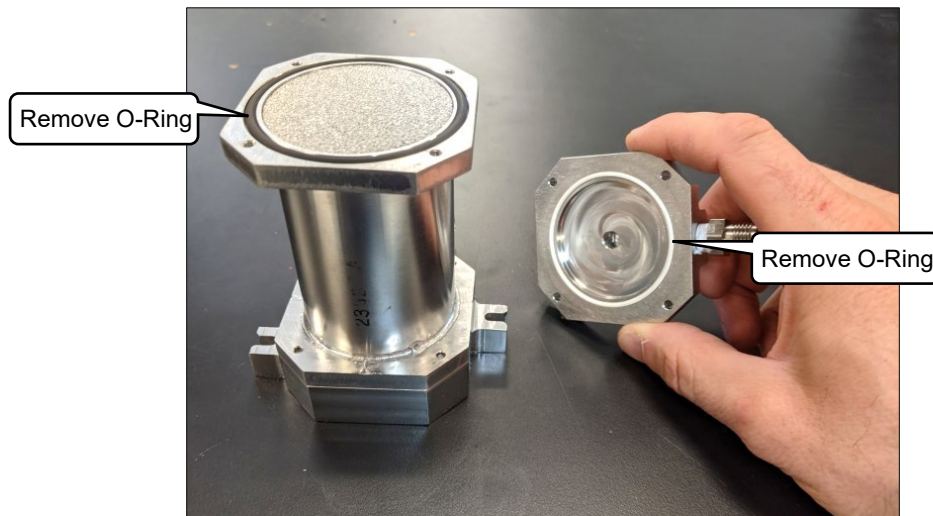
Remove O-Ring

*Figure 48: Removing Top Cover and O-rings*

> **7.** Remove the steel frit. If the frit is difficult to lift out from the top, it should easily fall out when pouring out the used media.
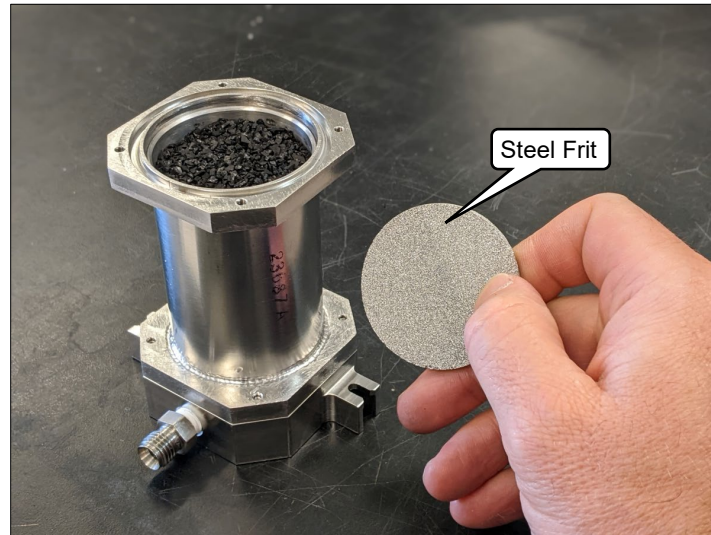
*Figure 49: Removing Steel Frit*

8. Remove the used scrubbing media and dispose of according to safety guidelines. See ***APPENDIX F –PAIAC Chemical and Disposal Information*** for the particular media used for your analyzer and the recommended disposal information.

9. Remove the four screws from the bottom cover as shown (Figure 50).
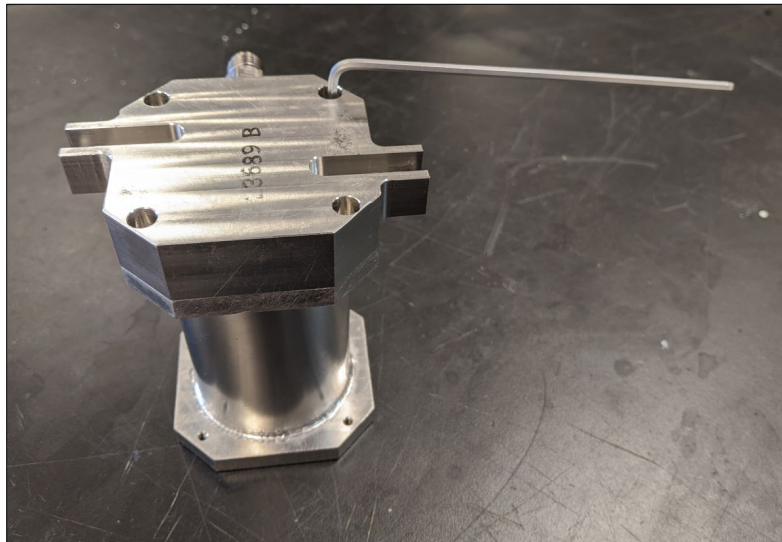


*Figure 50: Scrubber Bottom Cover Screw Removal*

10. Remove the bottom cover and remove the two O-rings shown (Figure 51).

Remove O-Ring
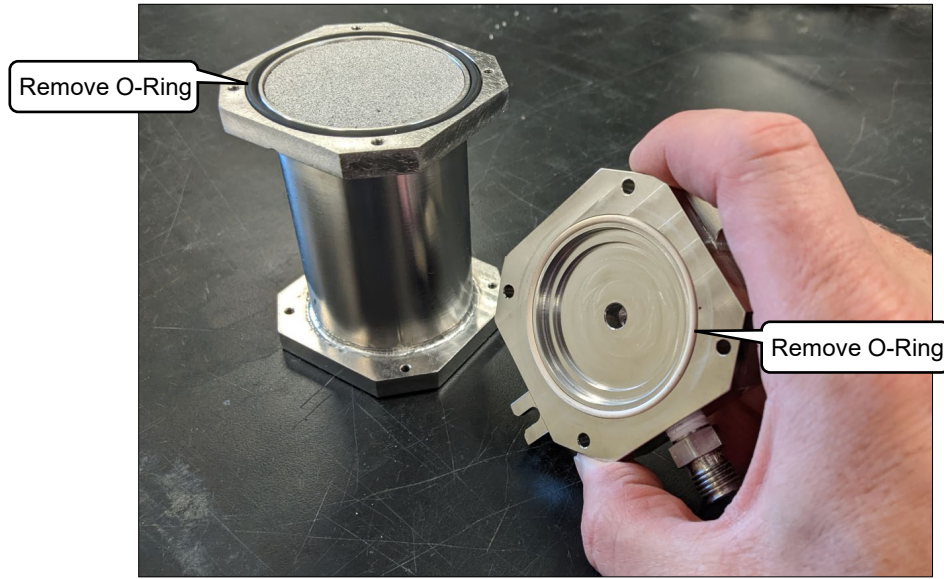
Remove O-Ring

*Figure 51: Bottom Cover and O-ring Removal*

**11.** Remove the steel frit as shown in Figure 52 below.
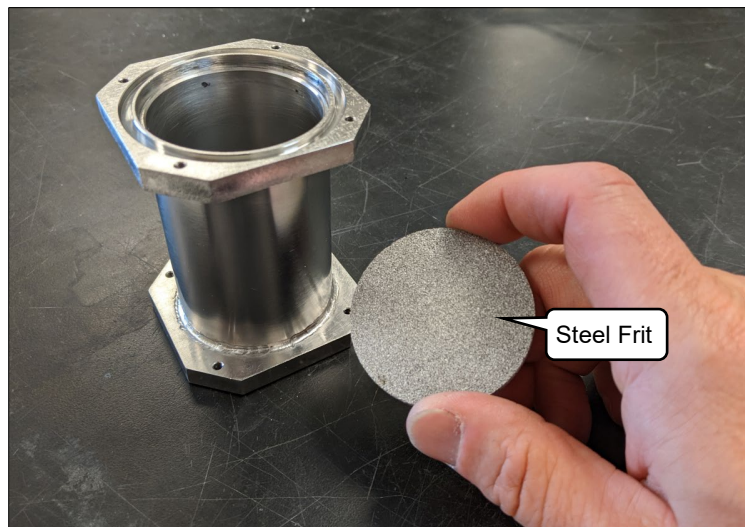


Steel Frit

*Figure 52: Bottom Frit Removal*

**12.** Replace the two O-rings and the steel frit with new items from the kit. The orings should seat easily into the machined grooves. Re-install the bottom cover. Take care when closing the bottom cover that the O-rings do not fall out of place. Retighten the four screws. The bottom cover should be flush to the canister housing when the screws are fully tightened.

**13.** Turn the unit over. Using the provided packet of PAIAC scrubbing media refill the unit to just below the seat for the steel frit as shown (Figure 53).

*Figure 53: Replacement of Scrubbing Media*

**14.** Replace the top steel frit and both o-rings similarly to the bottom cover. Re-install the top cover. Note the orientation of the top cover port relative to the bottom cover port. For proper orientation, see images in the section: **Removing the Scrubber** in section **12.3**. Take care when closing the top cover that the O-rings do not fall out of place.

**15.** Retighten the four screws. The top cover should be flush to the canister housing when the screws are fully tightened.
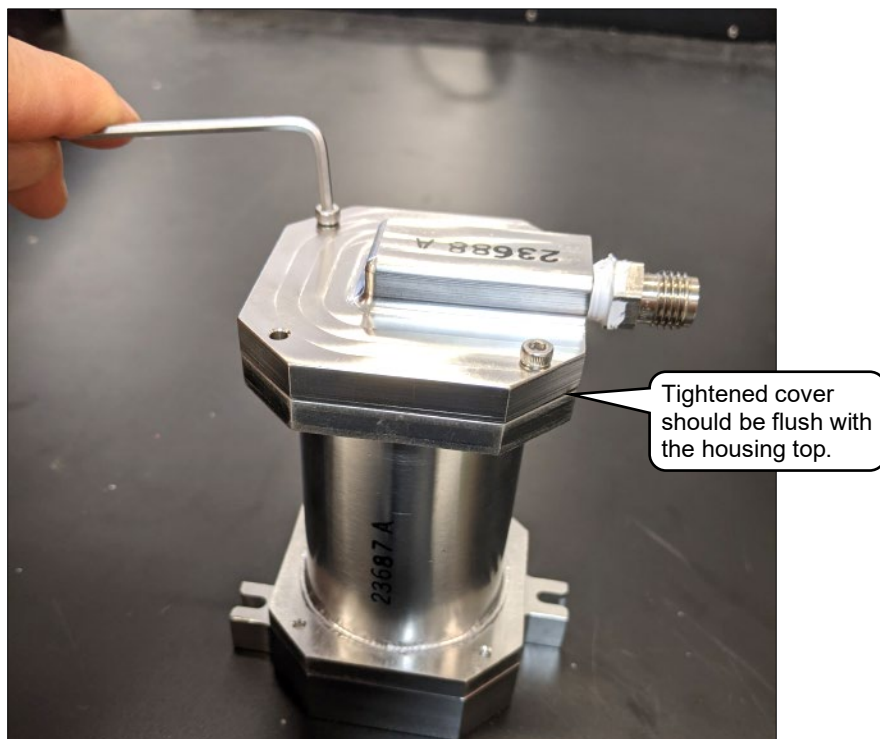


*Figure 54: Installing Scrubber Cover Screws*

## 11.4  Servicing the ZRM Particle Filter

**NOTE**

**An adjustable wrench may be necessary to firmly hold the filters during removal and installation.**

1.  Lift the top panel handle to access the service area. The area includes the scrubbing unit, particle filters and tools for service.



Top Panel Handle
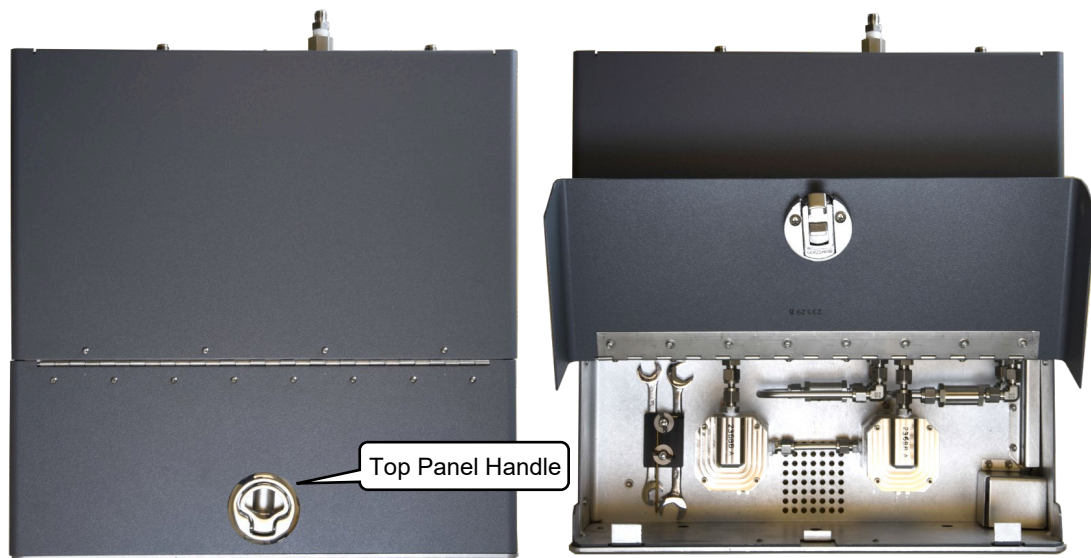
*Figure 55: Servicing Area Open*

2.  Make note of the location of the particle filters. Be sure new filters are replaced in their correct positions and flow orientation.
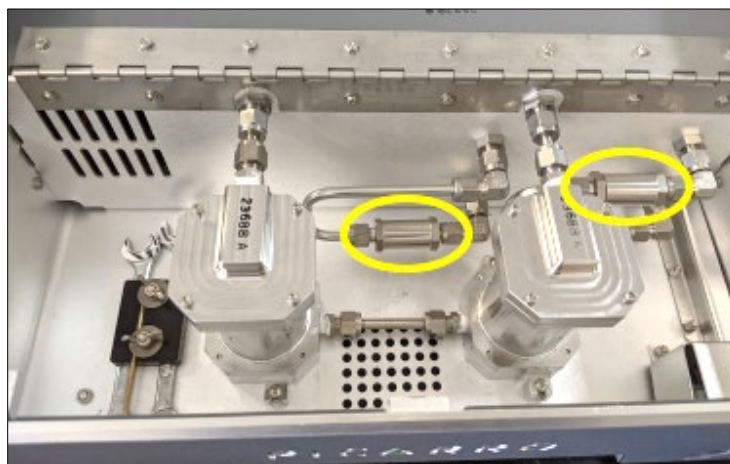


*Figure 56: Note Filter Locations Before Removal*

**3.** Loosen the Swagelok connection indicated in the figure below using the available 9/16" wrench. (The images in this procedure show the removal and replacement of one of the particle filters. The same steps can be applied to the other filter.)
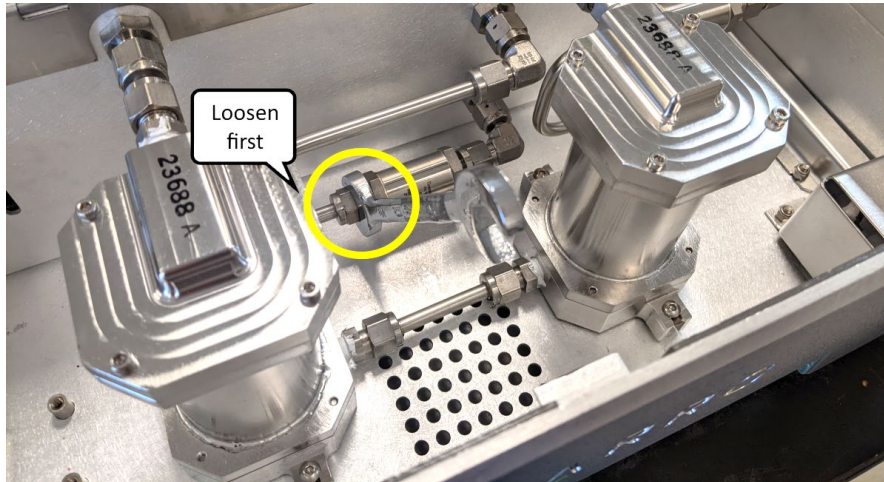


*Figure 57: Loosening Filter Swagelok Connections*

**4.** Disconnect the two Swagelok connections shown in Figure 58 and remove the filter along with the formed tubing (Figure 59).
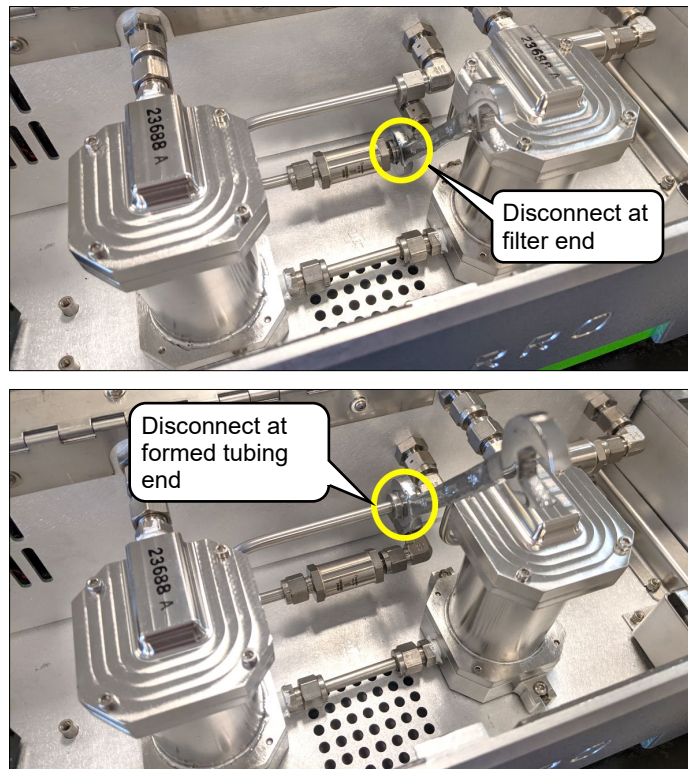


*Figure 58: Disconnecting Filter with Attached Formed Tubing*

**5.** Remove the old filter from the formed tubing.
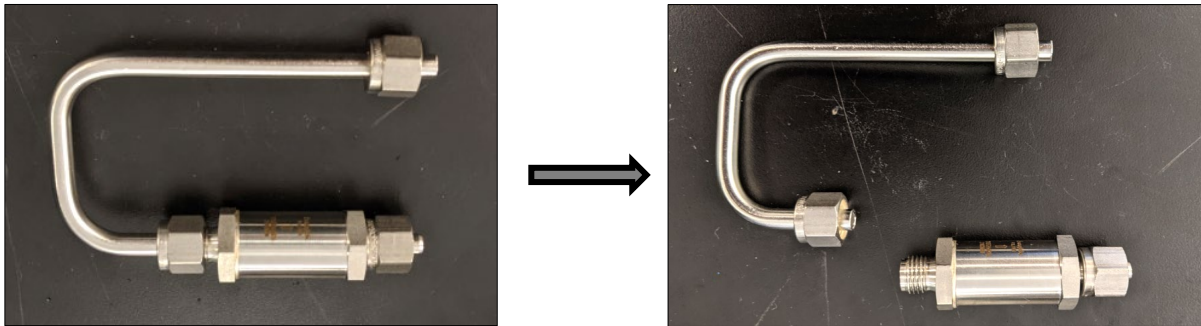


*Figure 59: Disconnect Formed Tubing from Filter*

**6.** Loosely attach the new filter onto the formed tubing and re-insert it back into the ZRM.

**7.** Tighten the two Swagelok connections shown in Figure 58. (Recommended Swagelok tightening is 1/4 turn past finger tightened.)

**8.** Tighten the final Swagelok fitting shown in Figure 60 below.



Tighten Last
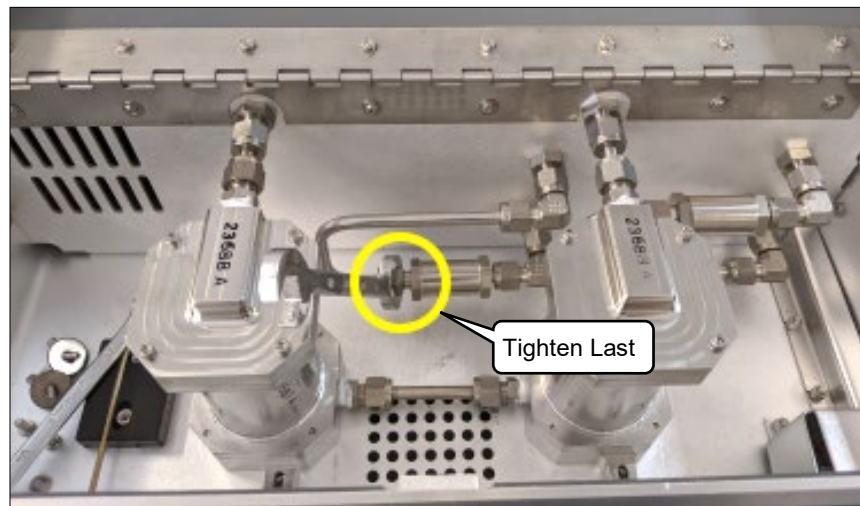
*Figure 60: Tightening the Filter Final Fitting*

**9.** Perform the *ZRM Leak Test* procedure in section *11.5* to assure the unit is free of gas leaks.

**10.** Reinstall the service tools in the tool caddy (ensure the wing nuts are tight) and close the chassis cover.

## 11.5 ZRM Leak Test

After servicing the scrubbing media or particle filters inside the ZRM, a leak check should be conducted to ensure all fittings within the ZRM have been seated and sealed correctly.

### Required Materials

- Leak Test Kit (included with the ZRM)

    - Hand Vacuum Pump with tubing and 1/4" Swagelok fitting

    - 1 x Tube with 1/4" Swagelok connections on both ends

- 9/16" and 1/2" Wrench (located in the filter/scrubber area inside ZRM)

### Procedure

1.  Make sure the unit is powered off.

2.  Connect the hand pump to the ZRM **Sample Input** port a shown in Figure 61.

3.  Connect the **PUMP VENT** Port to the **To ANALYZER** port with the tube.



Vacuum Release Lever
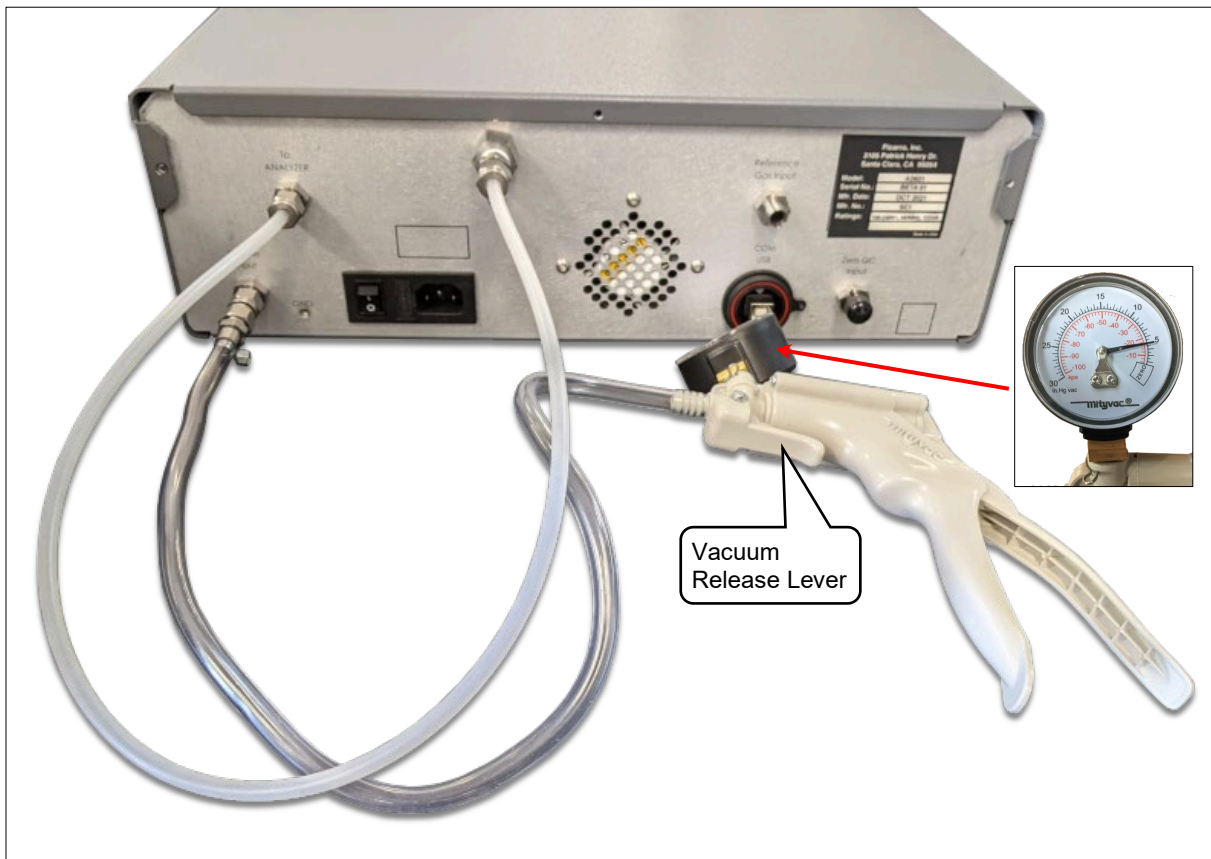
*Figure 61: Post-service Leak Check Setup*

4. Squeeze the handle on the hand pump to lower the pressure. If necessary, pressing the small lever just below gauge will purge the vacuum.

5. Hand pump the unit down to about 5 in. Hg of vacuum.

   If you encounter a gross leak, halt the procedure, and check all Swagelok connections in the ZRM that were disconnected during service.

6. Wait 1 minute.

   This wait time is to allow outgassing of the scrubber to settle. You may notice some initial pressure change due to this outgassing.

7. Record the pressure change for 1 minute.

8. The pressure change should be < 1 in. Hg vac.

   If the pressure change is too large, check all the scrubber Swagelok connections and seals, and repeat the test.

9. When leak test is successfully completed, remove the Hand Pump and tube.

10. Reconnect the ZRM to the system.

## 11.6　Fuse Replacement

If the ZRM will not power up, a blown fuse may be the cause. To check and replace the replace the fuse. The ZRM uses a 2.0A / 250 VAC, 5mm x 20mm, slow blow fuse. Follow this procedure to replace the fuse.

1. Ensure the ZRM switch is in the off position.

2. Remove the power cord from the back panel.

3. Insert a flathead screw driver under the tab on the fuse holder as shown in Figure 62.

4. Carefully push the screw driver handle away from you to leverage the fuse holder out of the back panel.

5. Remove the fuse from the fuse holder and insert a new one of the same rating.

6. Push the fuse holder into the back panel. You will hear a click when it is fully inserted.
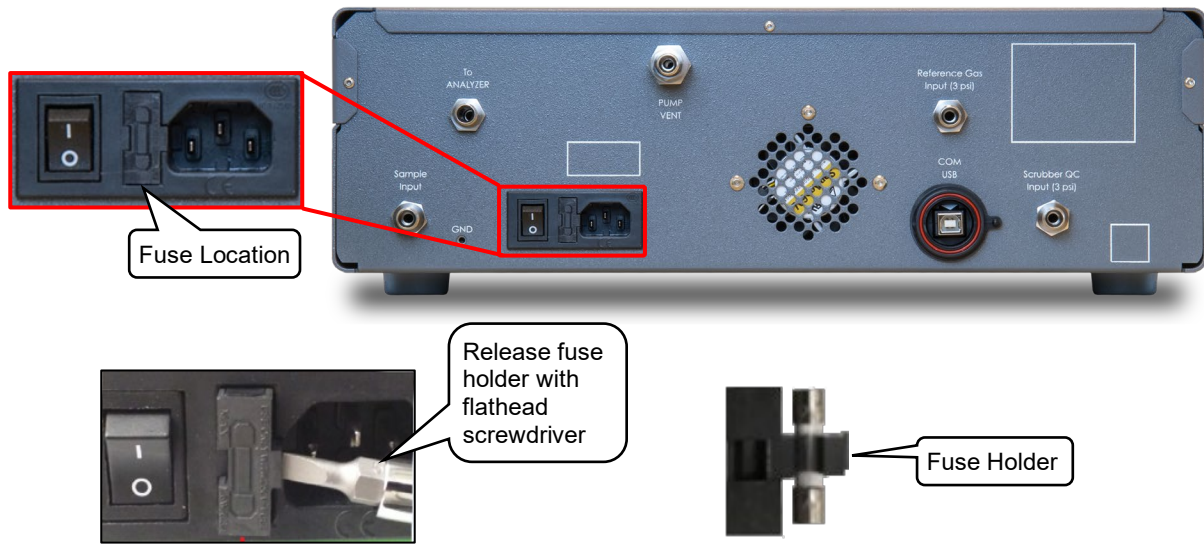
**Figure 62: ZRM Fuse Replacement**

# APPENDIX A – Software Installation – ZRM Standalone Purchase

## A.1 Installation

1. Insert the USB drive included in the installation kit into any USB port on your Picarro Analyzer.

2. Navigate to and double-click the file named **Picarro-ZRM–#.#.#.msi** to begin installation. The following **Zero Reference Module Setup** windows (Figure 63) open which will require user interaction as installation progresses:

   a. Select a destination directory: Default directory is:

      C:\Picarro\Zero Reference Module\

   b. Click **Next**: An Installation status progress bar appears and remains until installation is finished.

   c. During this time, some Windows Defender Firewall warnings may appear. Click **Allow Access** to each one to continue installation.

   d. Click **Finish** to exit the installer. The ZRM app icon appears on the analyzer desktop.
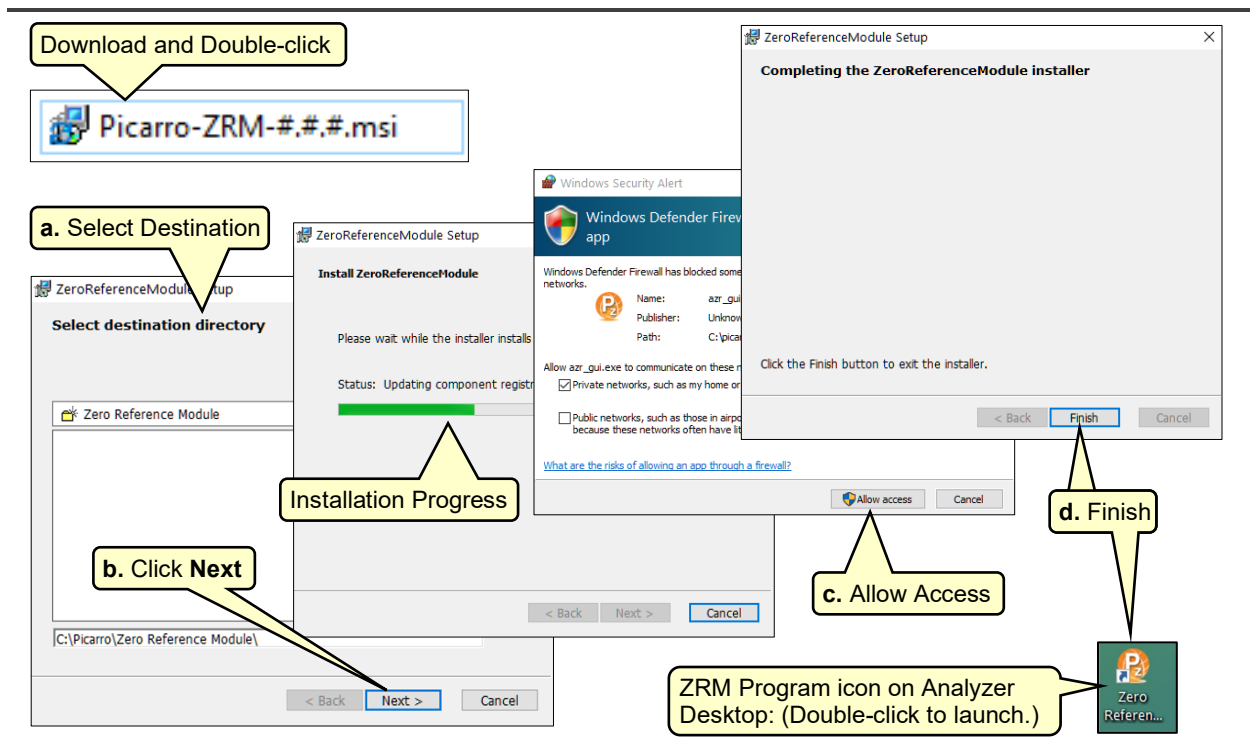
*Figure 63: ZRM Software Installation Process*

# APPENDIX B – Data Flow and Output

## B.1  Data Flow

The ZRM and the Picarro analyzer run two related but separate programs to acquire, process and display data to the Picarro user. The following section describes how these two programs work together to generate ZRM data.

In a conventional Picarro instrument with no peripherals, the flow of data is as shown above the green dashed line in Figure 64. With the ZRM in place, the flow of data follows the full diagram.
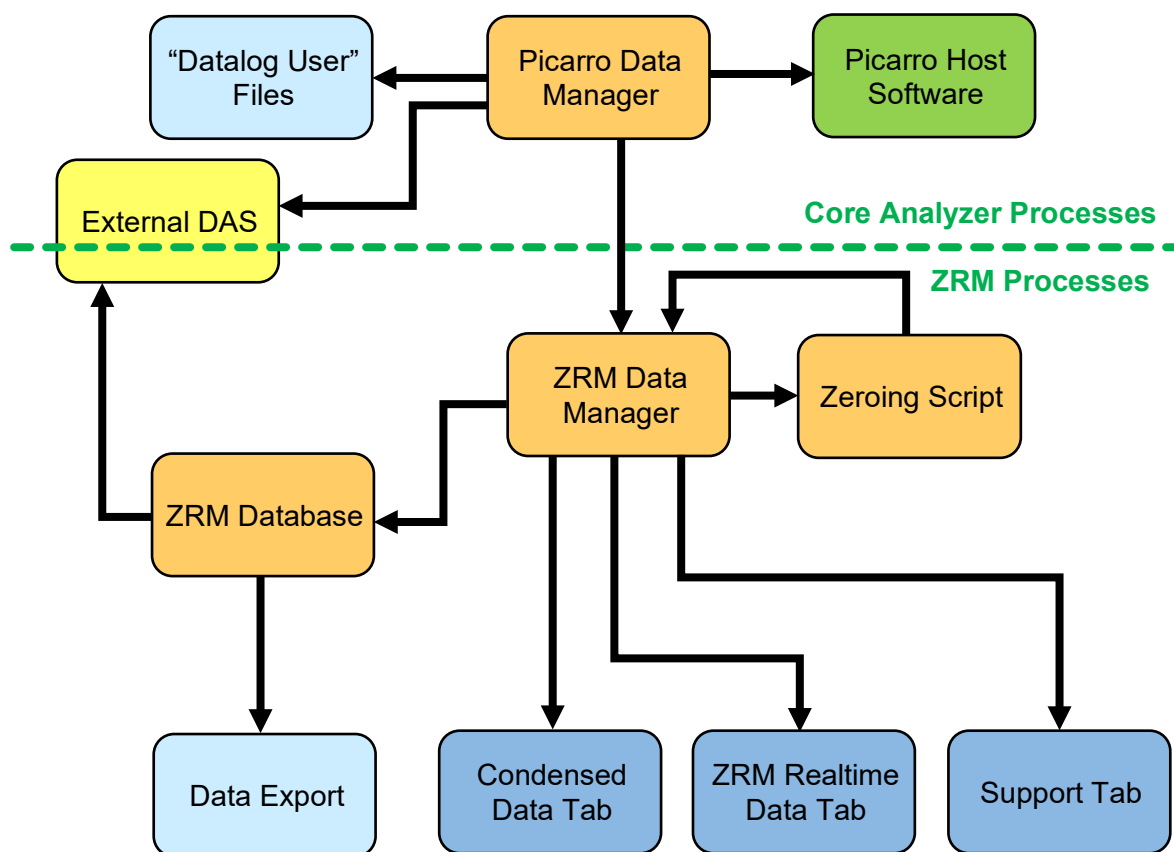


*Figure 64: Data Flow Diagram*

Raw CRDS data is collected by the Data Manager program. This program sends the raw data to the Picarro host software (see section *7.1*) and writes it to data files. The Data Manager also makes the data available to be sent directly to external devices or programs such as a DAS (data acquisition system).

The ZRM Data Manager receives data from the Data Manager program. The ZRM software coordinates the states of the ZRM hardware and labels the raw data according to the ZRM states. The software then processes the data as described in section *1.3*. The ZRM Data Manager stores the ZRM data to the ZRM Database and makes it available for serial streaming and for display in the Realtime Data, Condensed Data, and Support Tabs.

Once the ZRM data is stored in the ZRM Database, it is available for export and sharing with external programs via a REST API. For more information about accessing data via serial streaming or REST API, see section *9.5*.

## B.2  Data Output Formats

The tables below describe the variables included in each ZRM data output format. X's indicate which variables are included in each format.

*Table 6: Analytical Data and Analytical Data (Condensed) Output Formats*

| Variable | Description | Analytical Data | Analytical Data (Condensed) |
|---|---|---|---|
| ts | Epoch time (seconds since Jan 1, 1970) | x | |
| EtO | (ppb) ethylene Oxide, real time value | x | |
| CH4 | (ppm) methane, real time value | x | |
| CO2 | (ppm) carbon dioxide, real time value | x | |
| H2O | (%) water, real time value | x | |
| ALARM_STATUS | Status of 'System Alarm' on analyzer | x | |
| CavityPressure | (torr), 450 Torr for G2920, 140 for G2910 | x | |
| CavityTemp | (C), temperature of the measurement cavity, 80C when operational | x | |
| DasTemp | (C), temperature of the instrument computer board, should be <70C | x | |

| Variable | Description | Analytical Data | Analytical Data (Condensed) |
|---|---|---|---|
| EtalonTemp | (C), temperature of the instrument etalon, ~45 | x | |
| INST_STATUS | bitsum, 963 when fully functioning | x | |
| InletValve | (digU) openness of valve upstream of cavity, typ: 50,000 exactly during operation | x | |
| MPVPosition | (1-16) position of a multiposition valve if used | x | |
| NH3 | (ppb) concentration of ammonia, non-calibrated channel | x | |
| OutletValve | (digU) openness of valve downstream of cavity, typ: 20-50,000, a rough proxy for flow | x | |
| ValveMask | State of valves in the ZRM | x | |
| interval | (sec) interval between data points in units of seconds | x | |
| pzt_offset | cavity mirror offset | x | |
| finelasercurrent | current controlling laser tuning | x | |
| flaserc10_90range | Range in arbitrary units that the middle 80% of the fine laser current readings fall | x | |
| flaserc25_75range | Range in arbitrary units that the middle 50% of the fine laser current readings fall | x | |
| wlm_offset | peak adjustment factor of the wavelength monitor | x | |
| CORRECTED_ETO | (ppb) ethylene Oxide, difference between uncorrected EtO and zero offset for the most recent ZRM cycle | x | x |

| Variable | Description | Analytical Data | Analytical Data (Condensed) |
|---|---|---|---|
| UNCORRECTED_ETO | (ppb) ethylene Oxide, mean of the ethylene oxide value over the Sampling state of the most recent ZRM cycle | x | x |
| ZERO_OFFSET | (ppb) ethylene Oxide, mean of the ethylene oxide value over the Zeroing state of the most recent ZRM cycle | x | x |
| STATE | ZRM state: usually Zeroing_Prep, Zeroing, Sampling_Prep or Sampling | x | |
| METHOD | ZRM Method in use at the time of the data output | x | x |
| ZRM_Status | Status of the ZRM (see section **8.3**) | x | |
| ALARM_STATUS (aggregated) | Aggregated status of the "System Alarm" on the analyzer | | x |
| INST_STATUS (aggregated) | Aggregated Instrument Status over the most recent ZRM cycle | | x |
| ZRM_Status (aggregated) | Aggregated ZRM_Status over the most recent ZRM cycle | | x |

*Table 7: Sensor Data Output Format*

| Variable | Description |
|---|---|
| ts | Epoch time (seconds since Jan 1, 1970) |
| PRESSURE | (Torr) ZRM Pressure measured just before pump |
| TEMPERATURE | ('C) ZRM Temperature |
| FAN_1_RPM | (RPM) ZRM cooling fan rotations per minute |
| VALVE_1_CURRENT | (A) Valve 1 current |
| VALVE_1_VOLTAGE | (V) Valve 1 Voltage |
| VALVE_2_CURRENT | (A) Valve 2 current |
| VALVE_2_VOLTAGE | (V) Valve 2 Voltage |
| VALVE_3_CURRENT | (A) Valve 3 current |
| VALVE_3_VOLTAGE | (V) Valve 3 Voltage |
| VALVE_4_CURRENT | (A) Valve 4 current |
| VALVE_4_VOLTAGE | (V) Valve 4 Voltage |
| STATE | ZRM state: usually Zeroing_Prep, Zeroing, Sampling_Prep or Sampling |
| METHOD | ZRM Method in use at the time of the data output |
| ZRM_Status | Status of the ZRM (see section **8.3, Monitoring System Operation**) |

*Table 8: System Log Output Format*

| Variable | Description |
|---|---|
| ClientTimestamp | Local time |
| ClientName | Device type and communication port used |
| EpochTime | Seconds since Jan 1, 1970 |
| LogMessage | System log messages |
| Level | Type of message. 10 = debug, 20 = informational messages, 30 = errors, 40 = warnings |

**NOTE**

**Warnings that appear in the Warnings box at the bottom of the ZRM user interface also appear as System Log messages (LogMessage in Table 8) of Level 40.**

**NOTE**

**The ZRM software automatically detects changes to the database version. If the ZRM software is updated or the .db file is damaged, the software will automatically back up the current database. The previous version is saved with suffix _old. It is recommended to rename or relocate this file. Future changes will also overwrite the file with the suffix _old. The software will request confirmation before overwriting.**

# APPENDIX C – Errors and Troubleshooting

## C.1  Operational States

When the ZRM is set up and powered on, it will automatically enter its **Standby State**. It will remain in its Standby state until a method is started, or a manual state change is triggered. The Standby state of the ZRM is identical to the Sample State.

### The Sample/Zero Baseline Correction

The ZRM controls the flow of gas sampled from the gas inlet. In the **Sample State** (Figure 65), gas flows from the inlet and is sent directly to the analyzer via a 3-way valve. The Picarro analyzer has its own pump to pull sample gas in. A particle filter protects the ZRM from debris entering the gas path. Sample gas is also pulled through the ZRM scrubber via an internal pump. The scrubber can remove the gas of interest that is measured by the Picarro analyzer. Gas is continuously pulled through the scrubber in order to keep a refreshed scrubbed sample of gas ready to use for zeroing at any moment. Purge orifices allow a small amount of flow to keep all lines in the system free of any stagnant gas. The ZRM can be run in the sample state indefinitely for diagnostic or measurement purposes.
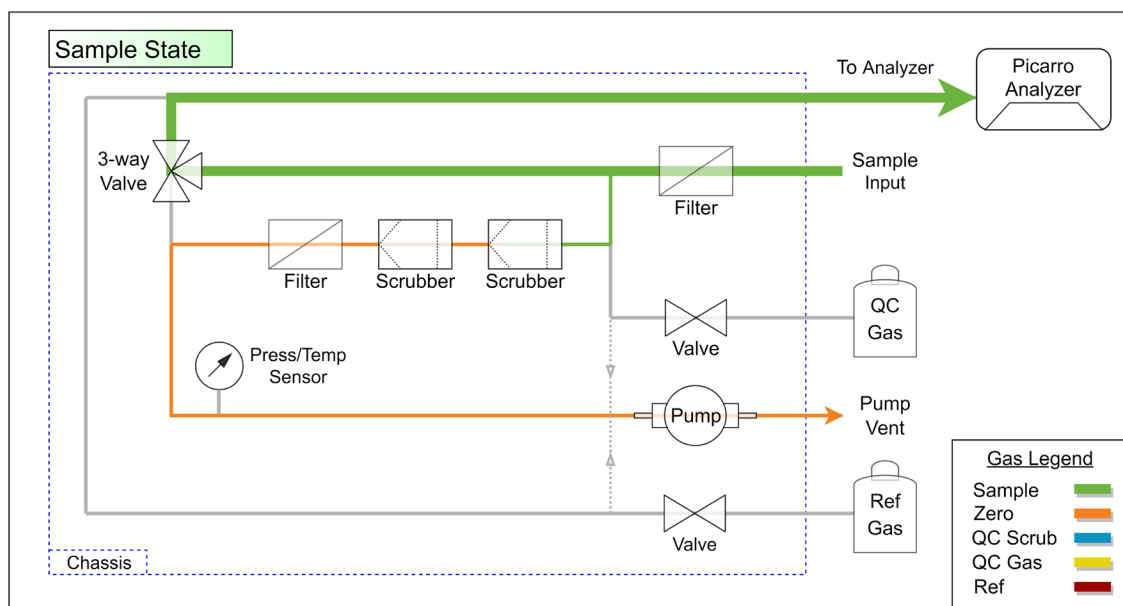


*Figure 65: Sample State*

In the **Zero State** (Figure 66), gas flow from the inlet is initially directed through the scrubber and then into the analyzer. A particle filter is located downstream of

the scrubber to prevent any loose material in the scrubber from entering the system. The scrubber removes the gas of interest measured by the analyzer.
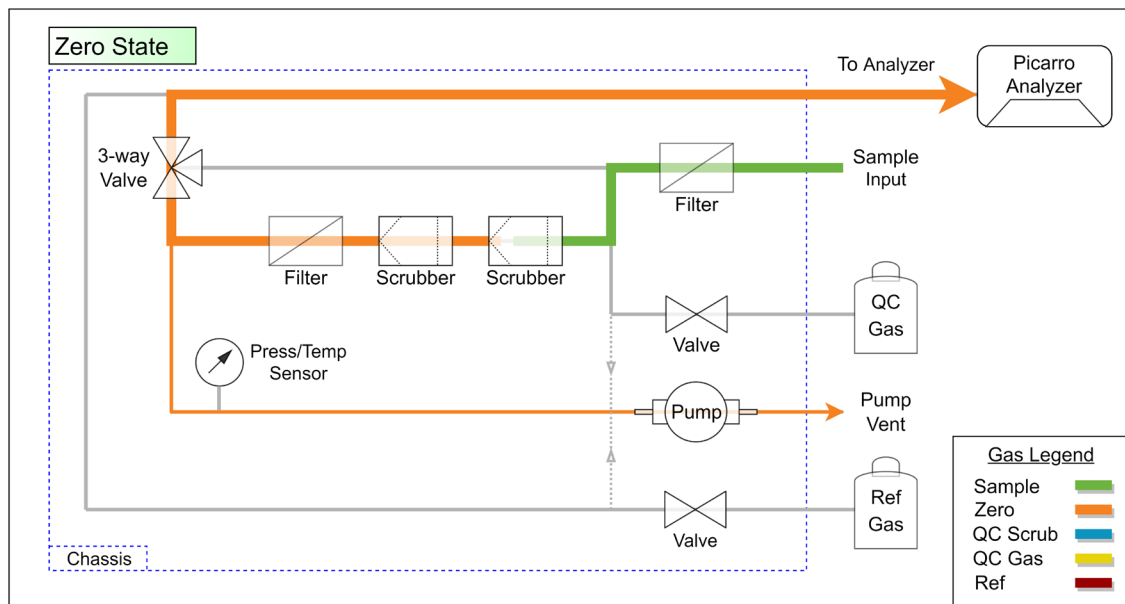


*Figure 66: Zero State*

Gas concentration measurements taken during the Zero State ($Conc_{ZERO}$) are then used as a baseline for subsequent Sample State measurements ($Conc_{SAMP}$) yielding a corrected concentration ($Conc_{CORR}$) via the following equation:

$$Conc_{CORR} = Conc_{SAMP} - Conc_{ZERO}$$

This correction eliminates concentration drift due to factors external to the measurement of the gas of interest such as aging and environmental changes.

## Scrubber Verification

An external tank of gas known as the Scrubber QC Gas Tank can be used to verify the efficiency of the scrubber to assure that it is zeroing the system correctly. Picarro recommends a tank consisting of between 1000 ppb and 100 ppb of Ethylene Oxide (EtO). Before testing the scrubber, the output of the QC tank is checked. In the **QC Gas State** (Figure 67), the ZRM flows gas from the QC tank to the Picarro Analyzer. The concentration measured during this step simply assures that the gas tank is present, contains sufficient gas concentration, and is flowing correctly. Some gas dilution occurs from gas pulled in through the inlet, however this flow configuration is maintained in order to assure that no gas from the QC tank can backflow through the inlet line.
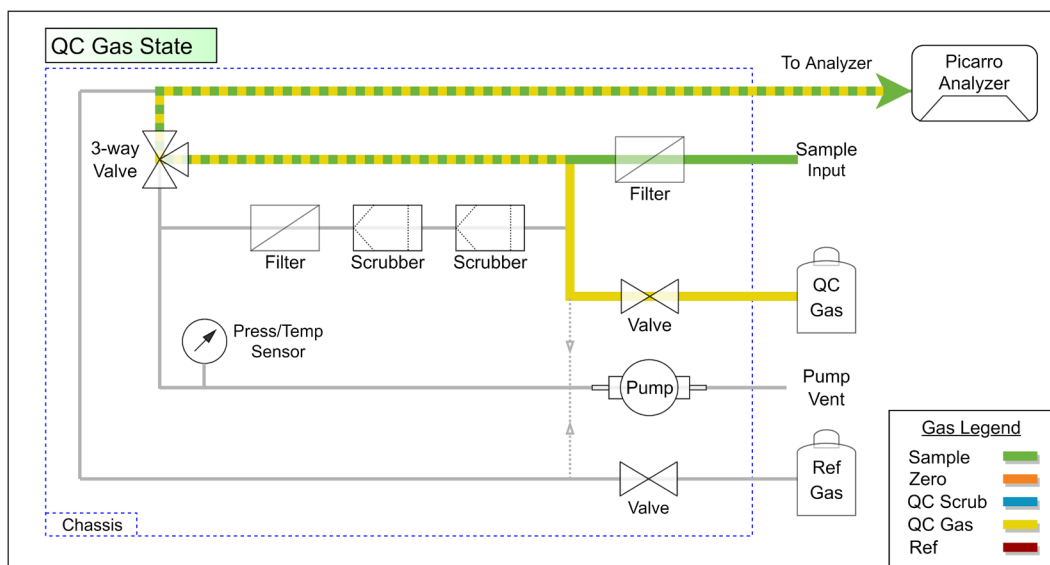
*Figure 67: QC Gas State*

In order to evaluate the efficiency of the internal scrubber, initial measurements of the average Zero State concentration, $Conc_{ZERO}$, and standard deviation, $Std_{ZERO}$, are made as baselines to compare against. The system then enters the **QC Scrubber State** (Figure 68). QC gas is then directed through the scrubber to the analyzer and the average concentration, $Conc_{SCRUB}$, is measured. The requirement for passing scrubber efficiency is that the scrubbed concentration lies within four deviations of the zero concentration and is given by the following equation:

$$| Conc_{SCRUB} - Conc_{ZERO}| < 4 \times Std_{ZERO}$$
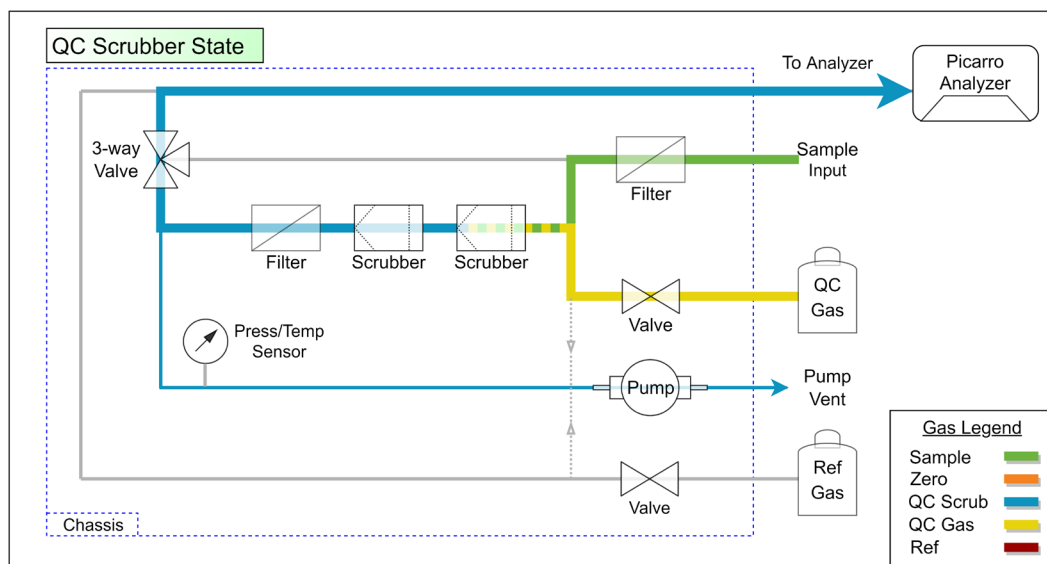


*Figure 68: QC Scrubber State*

## The Reference Measurement

A tank of reference gas can be connected to the ZRM. This gas can be used to verify the analyzer is reading concentration correctly or may be used for diagnostic purposes. During the **Reference State** (Figure 69), gas flows directly to the gas analyzer without dilution. The pump runs during this state to assure that no gas from the reference tank can backflow through the inlet line.
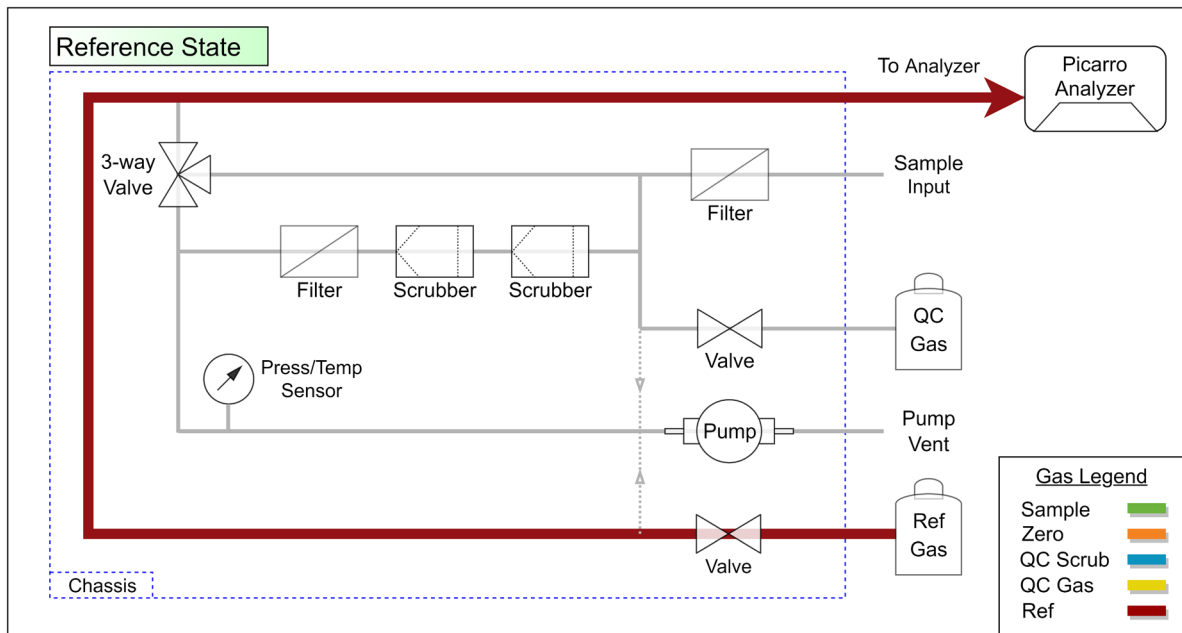


*Figure 69: Reference State*

## C.2  Diagnostic Warnings and Errors

The ZRM Software Interface has an **Alarm Status** indicator in the **Status** area at the top of the screen and a **Warnings** status window at the bottom of the screen (Figure 70). These two status indicators appear under *all* tabs on the software interface. However, clicking on the **Support** tab on the screen also shows the **Sensor Data** field which provides more specific information about the alarm. If a warning is issued, or a malfunction is suspected, use the following sections to aid in diagnosing and repairing the problem. The headings below correspond to error messages that appear in the System log data. You can export the System log in csv format by clicking the **Export** button at the upper right corner of the ZRM window below the color legend. For more information about exporting data, see section 7.3.
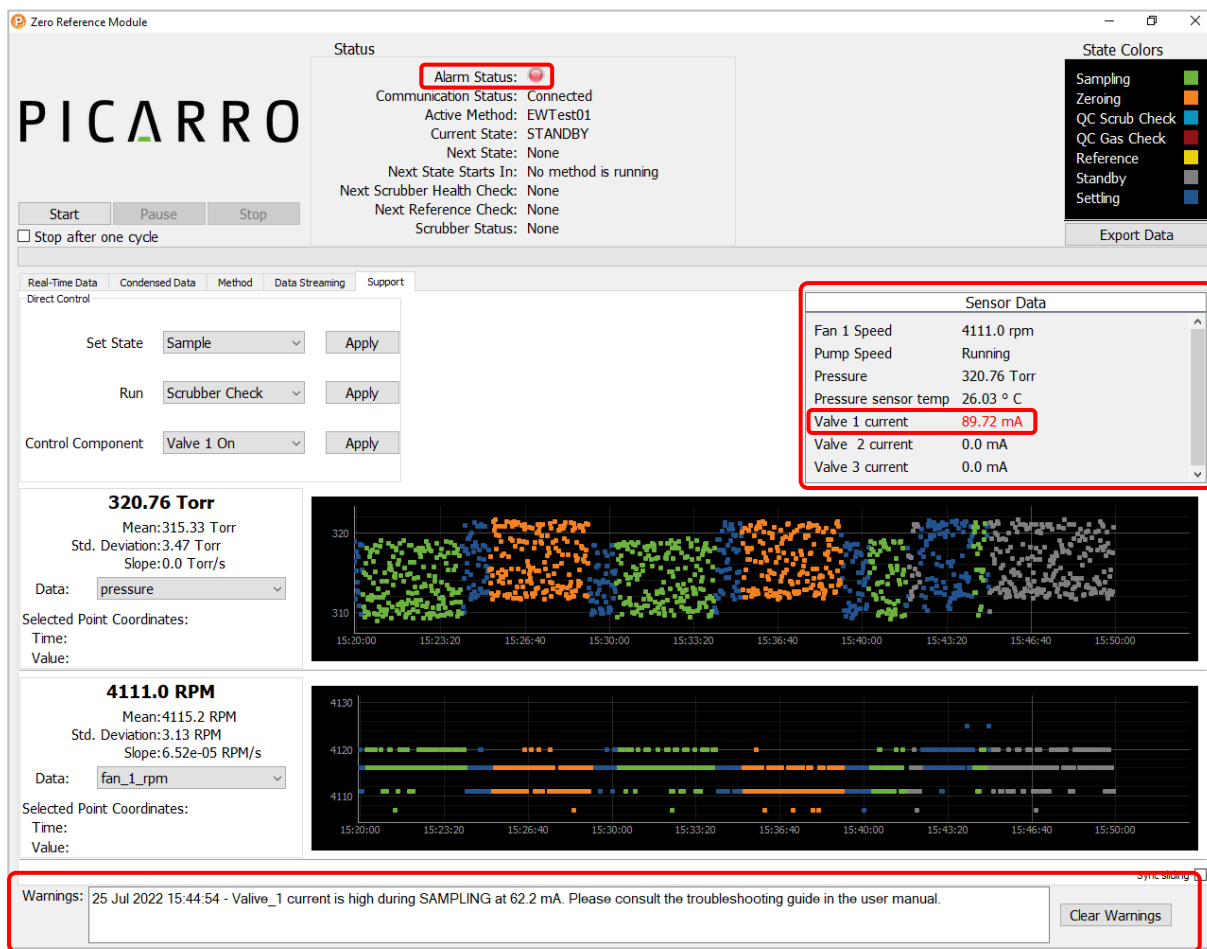
*Figure 70: Example Alarm Indications on the ZRM User Interface*

It is possible to monitor outputs from hardware components in the ZRM system. The **Support** tab provides graphs and data displays that are helpful for diagnosis. For example, by selecting "pressure" in the **Data** dropdown list next to either one of the graphs, the real time pressure of the system is displayed.

For all diagnostic purposes, stop any method that is running in the ZRM software by clicking the **STOP** button in the top left corner of the screen. The system will default to the standby state. Use this state for diagnosis unless directed otherwise.

## C.3  Pressure Error (Low)

The ZRM pressure in the standby state should be > 260Torr

Monitor the sample pressure in the ZRM software while conducting the following checks.

- **Sample Inlet line may be pinched or blocked:**
  - o Disconnect the sample line from the "Sample Inlet."
  - o Determine if pressure recovers to an acceptable range.

- **External particle filter may be blocked:**
  - o Disconnect external filter from the "Sample Inlet."
  - o Determine if pressure recovers to an acceptable range.
  - o Replace filter if necessary.

- **Internal particle filter may be blocked:**
  - o Replace internal particle filter #1. See section 12.3 for guidance.
  - o Determine if pressure recovers to an acceptable range.
  - o Replace internal particle filter #2. See section 12.3 for guidance.
  - o Determine if pressure recovers to an acceptable range.

## C.4  Pressure Error (High)

The ZRM pressure in the standby state should be < 360Torr

Monitor the sample pressure in the ZRM software while conducting the following checks.

- **Pump vent line may be pinched or blocked:**
  - o Remove the vent line from 'PUMP VENT' port on the back of the ZRM.
  - o Determine if pressure recovers to an acceptable range.

- **Possible pump issue:**
  - o If high pressure error coincides with a Pump RPM Error, go to 'Pump RPM' troubleshooting section.

- **Possible leak:**
  - o Power down the ZRM and leak check the system. See the Leak check procedure in section *11.5*.

## C.5  Pump Tach Error

In the standby state, the ZRM pump RPM should be between 2350 and 1300 RPM.

Monitor the pump RPM in the ZRM software while conducting the following checks.

- **Check if the pump is running:**

  - In standby mode the pump should be running. Remove the exhaust line from the 'pump vent' port and feel with your finger if gas is being exhausted. Also, the sound of the pump running should be clearly audible from the port.

- **If the pump is not running:**

  - Power down the ZRM, open the chassis and check the pump electrical connection to the main circuit board.

- **If pump will not run or continues to exhibit an RPM error while running:**

  - Replace the pump.

## C.6  High or Low Temperature Error

The internal ZRM temperature should be within 5°C to 45°C.

Monitor the sample pressure in the ZRM software while conducting the following checks:

- **Ambient Environment:**

  - Ensure ZRM is placed in an ambient area with a temperature of 10°C to 35°C

- **Fan Rear Vent Obstruction:**

  - Check to see if the rear vent fan is running and not obstructed. Air should flow from the inside of the ZRM out through the back panel. If the fan is not running refer to the Fan RPM Error section.

- **Bottom Vent Obstruction:**

  - Make sure vent holes on bottom of ZRM are not obstructed

- **Fan Electrical Connection:**

  - Power down the ZRM, open the chassis and check that the pressure sensor/thermistor assembly is electrically connected to the circuit board

- **Overheating Components:**

  o Immediately after powering down the ZRM, open the chassis and check the pump, valves, and power supply for overheating. Components may be warm to the touch but should not be hot. Replace overheating components if necessary.

## C.7 Fan Tach Error

The ZRM fan RPM should be between 5200 and 2700 RPM. The cooling fan should blow air continuously when the unit is powered on.

Monitor the fan RPM in the ZRM software while conducting the following checks.

- **The fan is not running:**

  - If the fan is not running, power down the ZRM, open the chassis and check if the fan is connected to the circuit board.

  o Check that the fan is free from debris that could slow or stop rotation. Clean if necessary.

  o If properly connected and the fan is free of debris, replace the fan.

- **The fan is running but software continues to generate an RPM error:**

  o Power down the ZRM, open the chassis and ensure that the fan is plugged into slot "Fan 0" on the main circuit board. ("Fan 1" is available and will power fan but does not allow RPM to be recorded.)

  o If fan is plugged into the correct receptacle and still generates RPM errors, replace the fan.

## C.8 Valve Current Error

⚠️
**CAUTION**
**The valves in the ZRM are activated according to the measurement state. Care should be taken when activating the valves for troubleshooting purposes. Activated valves could direct gas from attached tanks into the ZRM system. Prior to troubleshooting, disconnect or close any gas tanks connected to the system.**

When activated, the ZRM valve current for any valve should be between 130 mA and 70 mA. To check valve currents:

- Click the **Component Control** dropdown list on the ZRM software **Support** tab to open and close the valves. For example, select **Valve 1 On** from the list. A warning message will pop up warning you to be careful when changing parameters. Click **OK** in the upper right-hand corner.

- Under **Sensor Data** the valve current will be displayed.

- To turn the valve off, select **Valve 1 Off**. When the pop-up window shows, select **OK**.

- If the valve shows no current reading, power down the ZRM, open the ZRM chassis and verify that the valve is connected to the main circuit board correctly. Valve cables should be labeled (#0, #1, #2) and should connect to corresponding labeled board receptacles.

- If the connection is correct, and the valve does not activate, replace valve.

## C.9   Scrubber Health Check Failure

This error only arises if implementing the Scrubber QC Gas Check option. When challenged with gas the scrubber material in the ZRM has shown signs of breakthrough. Replace the scrubber material. See *Refilling the Scrubber with New Media* in section *11.3* for instructions.

## C.10     Bump Test Failure

This failure only arises if implementing the Scrubber QC Gas Check option. The verification of the presence of QC gas has failed.

- Make sure the QC gas tank is not empty.

- Check to see that the QC gas is connected to the correct port and the appropriate pressure is being supplied at the port.

## C.11     Firmware Error

The main circuit board in the ZRM has found an internal firmware error. Picarro recommends cycling power on the ZRM. If the problem persists, please contact Picarro Technical Support. See section *C.14* for Firmware errors associated with communication errors.

## C.12     Software System Error

The ZRM software has experienced an error. Picarro recommends restarting the ZRM software:

- Close the ZRM software main window.

- If the main software window will not close, right click the ZRM software icon in the toolbar at the bottom of the screen and select **Shut down ZRM** to close the background ZRM process. Note: Closing the background process will halt any active measurement methods.

> o  If the background process will not close, open the windows task manager.
>
>> ▪ If **Azr_gui.exe** is present in the process list, right click on it and select **End Task**.
>>
>> ▪ If **Azr_tray.exe** is present in the process list, right click on it and select **End Task**.

- Double click the ZRM software icon on the desktop to restart. Check that any desired ZRM method is running. If not, restart the method. If the problem persists, please contact Picarro service support.

## C.13     ZRM Does Not Turn On

If ZRM does not turn on, ensure the power outlet where the power cord is plugged in is functional and the power cord itself is plugged in all the way at the wall and the ZRM.

If there is still no power, check the fuse next to where the power cable plugs into the ZRM as shown below. See *11.6, Fuse Replacement* for instructions on removing and installing the fuse.

If fuse replacement does not solve the problem, contact Picarro Support.
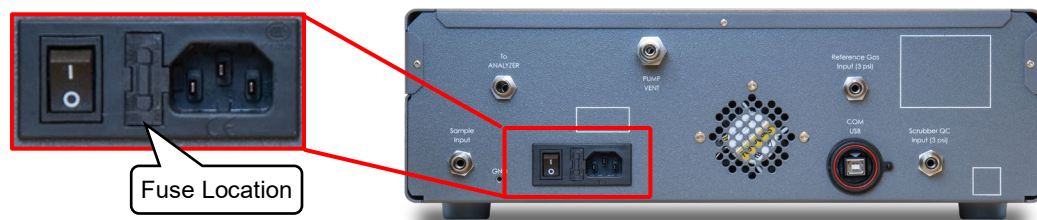


Fuse Location

*Figure 71: ZRM Fuse Location*

## C.14     Maintaining Communication

Communication is only established between the ZRM and the control software when the ZRM is powered on, connected via a USB cable to the Picarro Analyzer and the control software is open and running. If for any reason the USB cable is disconnected during communication, the cable can be re-connected, and communication should resume. After reconnecting the cable, you must re-start any method that had been running and clear any errors.

If the cable is disconnected two sets of errors can be reported by the ZRM: (1) 'ZRM device doesn't respond to ping' and (2) two types of firmware errors (FIRMWARE_RESPONSE_ERR; FIRMWARE_WRITE_ERR).

If a firmware error occurs, then the Alarm Status indicator in the software user interface will appear red and flash. To recover from this error, re-establish communication between the software and the ZRM. Then clear the errors using the "Clear Warnings" button at the lower left of the user interface.

# APPENDIX D – Analyzer Pump Exhaust Setup

1.  You will need a flat head screwdriver, a 9/16" wrench, and the pump exhaust fitting included in the ZRM kit.

2.  Power down your Picarro Analyzer by clicking the **Shutdown** button on the main screen. Picarro recommends following the Shutdown section located in the G2910/G2920 User Manual (PN 40-0072). Once powered down, turn off the analyzer pump using the switch on the side and unplug the power cable.

3.  Using a flat head screwdriver, remove the analyzer pump room exhaust/noise dampener from the bottom of the pump (Figure 72). Note that due to close the proximity of the pump foot, it may be difficult to remove the dampener using the screwdriver. As an alternative, use adjustable locking type pliers to remove the dampener.
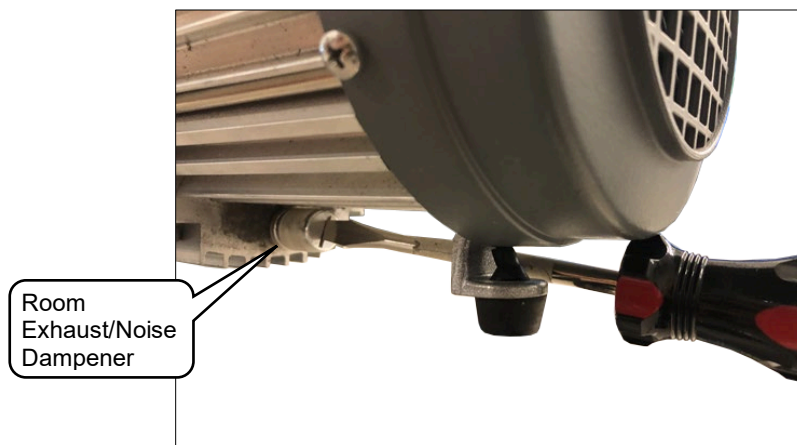


*Figure 72: Pump Exhaust/Noise Dampener Removal*

4.  Slide the adapter gasket PN 22929 onto the adapter fitting PN 22928 (Figure 73), screw it into the pump exhaust port, and then tighten it 1/4 turn using a 9/16" wrench Figure 74).
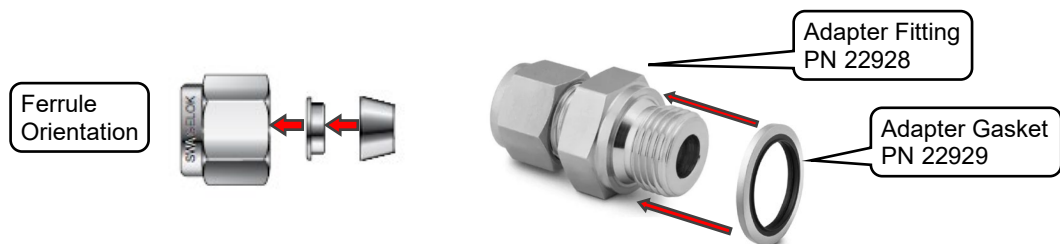


*Figure 73: Adapter Assembly*
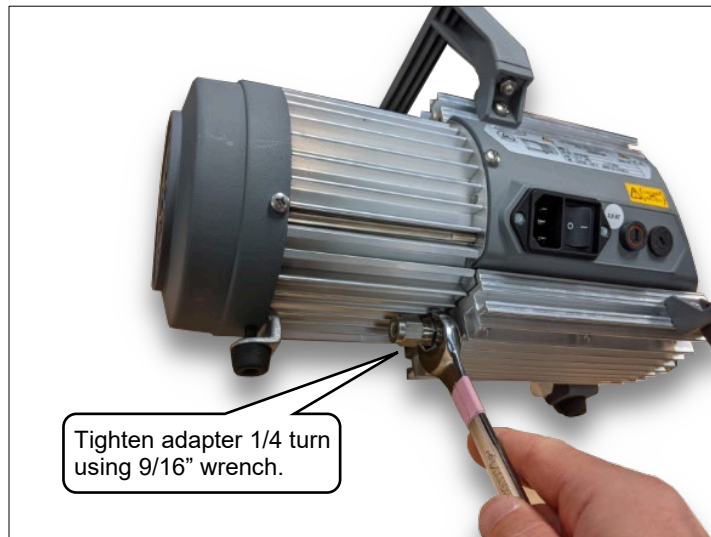
*Figure 74: Exhaust Adapter Fitting Installation*

5.  Remove the Swagelok nut and ferrules from the adapter fitting to ensure their orientation is as shown below, then loosely reattach to the adapter.

6.  Slide the 1/4" OD ventilation exhaust tubing into the Swagelok nut and ferrules until the tubing is fully seated, tighten the nut finger tight, then using a 9/16" wrench, tighten the nut approximately seven flats (420 degrees).

    A guide to this process can be found on the Picarro Video Gallery here: https://mktg.picarro.com/acton/media/39674/picarro-video-gallery

7.  With the pump running on room air, apply Snoop leak detection fluid to the installed exhaust components to confirm that the system is leak tight. Instructions for leak testing using Snoop can be found in this video:

    https://vimeo.com/375518688 (go to time 5:20 minutes in the video)

8.  Reconnect the pump power line, turn on the switch, and power on your analyzer.

**NOTE**

**Ventilation exhaust tubing should be 1/4" or larger to avoid back pressure build-up in the analyzer pump.**

# APPENDIX E – Heated Inlet Lines for Station Integration

Because stainless steel tubing conducts heat significantly better than polymer materials, SS tubing within sampling stations kept at room temperature poses a significant risk for condensation of sample air, which can lead to obstructed or reduced sample flow with time. Picarro recommends that all tubing between the walls of a sample shelter and the ZRM or Picarro instrument be heated to a temperature higher than the outside ambient dew point, typically 45°C. We give the following recommendations on best practice with heater tape.

## E.1  Best Practice for Heater Tape Installation

1.  While pre-wrapped Teflon tubing can be purchased in predefined lengths from certain companies, this is more challenging with stainless steel, which is challenging to bend to convenient lengths and shapes. Accordingly, Picarro recommends the use of heat tape, which can be wrapped around inlet tubing lines and equipped with a heater control module.

2.  Heater tape can be purchased from many online vendors, including Grainger.com under the category "Lab Heating Blankets, Tapes, and Cords". Heat tape should be chosen by the expected length and temperature range, with lower temperature ranges (e.g. 4-99°C) preferred over greater temperature ranges (e.g. 0-300°C). An inexpensive choice like the Briskheat BSAT101004 available at Grainger, PN 21EK12, or equivalent is a good choice.

3.  Heater tape is controlled via power not via a thermostatic set point, so best practice includes wrapping the line, placing a thermistor or other temperature sensing device on the tubing at a representative point, and adjusting the power setting until the line is at the target temperature, typically 45°C.

**CAUTION**

**Avoid wrapping tape over itself. This can lead to the insulation material burning, and the heater tape being destroyed. Tape should be coiled along the tubing as seen in the Figure 75 below, and in Figure 37 in section *9, Station Integration.***

4.  At 45°C, the inlet lines will be warm to the touch. Users may place foam or other insulation around the lines if desired. If using insulation, ensure that the power set point is chosen with the insulation in place to record a representative set temperature.

5.  Once the temperature is set, the heater should be quite consistent with time, but users may check this periodically to ensure temperature hasn't dropped as the heater coil ages.

*Figure 75: Heat Tape on Metal Line with Power Controller*

# APPENDIX F – PAIAC Chemical and Disposal Information

## F.1   Handling PAIAC

Be sure to manage PAIAC in an area with good ventilation. Use a NIOSH/MSHA approved respiratory protection mask to avoid dust exposure. Safety glasses or goggles with side shields are recommended. Avoid contact with the skin. Protective gloves are recommended. Wash skin thoroughly after handling. Wear appropriate dust resistant clothing. Read section *F.3 , SDS Chemical Information* for complete hazard information and safe handling details.

## F.2   PAIAC Disposal

In its original state, activated carbon is not a hazardous material or hazardous waste. Unused product may have a lot of pH. Do not release to a sewer or waterway. Used activated carbon may become classified as a hazardous waste depending upon the application. Hazard classification is determined by the adsorbate that the carbon has picked up. Please consider your use case and dispose in accordance with local, state, and federal regulations. Read section *F.3 , SDS Chemical Information* for complete hazard information and safe disposal details.

## F.3  SDS Chemical Information

## CARBON ACTIVATED CORP.
### Activated Carbon & Related Services

### Safety Data Sheet

| SECTION I |
|---|

DATE: **May 21st, 2021**

MANUFACTURER: Carbon Activated Corp,
2250, South Central Ave,
Compton CA 90220

EMERGENCIES: **(310) 885-4555**

PRODUCT IDENTIFICATION: **COC – L60**
(8X20)
CHEMICAL NAME: Activated Carbon
CHEMICAL FORMULA: C+ H3PO4
SYNONYMS: Phosphoric acid treated Coconut Base Granular
Activated Carbon

| SECTION II |
|---|

HAZARDS IDENTIFICATION

**GHS-US Classification**
Eye Irritation     2B H320
STOT               SE 3 H335

Hazards not otherwise classified: May form combustible dust concentrations in air. Given the necessary conditions of a strong ignition source, right concentrations of airborne carbon dust, adequate oxygen levels, and confinement, the potential for a deflagration event exists. A combustible dust hazard assessment and employee training should be carried out.

**Label Elements**

**Hazard Pictograms**

Signal word (GHS-US)             : Warning
Hazard Statements                : H320- Causes eye irritation
                                 : H335- May cause respiratory irritation
Precautionary statements (GHS-US): P261- Avoid breathing dust
                                 : P264- Wash thoroughly after handling
                                 : P271- Use in well-ventilated area
                                 : P280- Wear protective gloves/clothing/eye & face protect
                                 : P304&340: IF INHALED: Remove person to fresh air
                                 : P305&351&P338: If in eyes, Rinse cautiously with water for
                                 several minutes. Remove contact lenses if present and easy to do so.
                                 Continue rinsing.
                                 : P312- Call Poison Control Center/Doctor if you feel sick
                                 : P403& P233- Store in well-ventilated place. Keep container tightly closed

Other Hazards
No additional information available
Unknown acute toxicity (GHS-US) No data available

| SECTION III |
|:---:|

**INGREDIENTS:**

| Chemical Name (CAS#) | % | PEL(OSHA) | TLV(ACGIH) | Other |
|---|---|---|---|---|
| Carbon* (7440-44-0) | >70 | N/A | N/A | N/A |
| Phosphoric Acid (7664-38-2) | <30 | 1 mg/ m3 | 1 mg/m3 | -- |

*ACGIH (TWA) for reparable dust is 2.5 mg/m$^3$

There are no established PEL, TWA or TLV values for this material. Caution should be taken for respirable dust. The product has no known carcinogenic properties.

Non-Hazardous components are recorded at 3% or >; Acute hazards are recorded when present at 1% or >; Chronic hazards are recorded when present at 0.01% or >.

This is not intended to be a comprehensive compositional disclosure.

| SECTION IV |
|:---:|

**EMERGENCY FIRST AID MEASURES:**

In ease off ingestion do not induce vomiting. Dilute by giving water or milk.
Seek medical attention.

In case of inhalation remove to fresh air. Administer first aid as appropriate.
Seek medical attention.

In case of skin contact, wash thoroughly with soap and water.
If irritation persists seek medical attention.

In case of eye contact flush with lukewarm water for at least 15 minutes. Lift upper and lower eye lids occasionally.
Seek medical attention.

OTHER:

The effects of chronic and sub-chronic exposure have not been determined. Safe handling on a long-term basis should emphasize protection against respective or long-term exposure to carbon dust inhalation and avoidance of contact to any liquids that may leach off the impregnated carbon.

Affected individuals with pre-existing conditions pertaining to digestive, respiratory, skin or eye problems can be more susceptible to potential effects of carbon dust.

**HEALTH HAZARD DATA:**

Route (s) of Entry:

| | |
|---|---|
| Ingestion: | Carbon is non-toxic through ingestion Potassium Hydroxide is a corrosive irritant. |
| Inhalation: | The physical nature of carbon may irritate the respiratory system Potassium Hydroxide (if leached from carbon) can damage nasal a id respiratory passages. |
| Skin: | Carbon is non-toxic through skin absorption.Potassium Hydroxide is corrosive to skin and eyes. Permanent eye injury may result from continued contact. |
| Eye Irritation: | The physical nature of carbon may cause, eye irritation.Potassium Hydroxide can damage the eyes. |

| SECTION V |
|---|

**FIRE & EXPLOSION DATA:**

| | |
|---|---|
| Flash Point: | N/A |
| Extinguishing media: | Alcohol foam, $CO_2$, dry chemical, water. |
| Special Firefighting procedures: | Exercise caution when responding to any chemical fire. Respiratory protection is essential. |
| Decomposition Products: | CO may be formed in fire. |
| Thermal Decomposition: | Sulfur Oxides ($SO_x$) |

**FIRE FIGHTING MEASURES:**

| | |
|---|---|
| Flashpoint: | Not Applicable. |
| Non-flammable: | 16CFR1500.44. |
| Not Self Heating: | UN Manual of Tests and Criteria, Test N.3. |
| Flammability Limits in Air: | LFL and UFL Not Applicable. |

| | |
|---|---|
| GENERAL HAZARD: | Carbon Monoxide and Carbon Dioxide gas may be generated during combustion. Caution is advised. |
| | Contact of activated carbon with strong oxidizers such as ozone or liquid oxygen may cause rapid combustion. |
| | Fire is possible at elevated temperatures or by contact with an ignition with most types of organic solids. Activated carbon is difficult to ignite and when it does, it has a tendency to burn or smolder very slowly without any smoke or flame. |
| | Toxic gases will form upon combustion. |
| FIRE FIGHTING INSTRUCTIONS: | If possible to do safely, move smoldering activated carbon to a non-hazardous area, preferably out of doors. Extinguish fire using water fog, fine water spray, carbon dioxide or foam. Avoid stirring up dust clouds. |

FIREFIGHTING EQUIPMENT:      Firefighting personnel should wear full protective equipment, including self-contained breathing apparatus (SCBA) for all inside fires and large outdoor fires.

HAZARDOUS COMBUSTION PRODUCTS:      Combustion products may include smoke and oxides of carbon (for example, carbon monoxide). Materials allowed to smolder or long periods in enclosed spaces, may produce amounts of carbon monoxide which reach the lower explosive limit (carbon monoxide LEL = 12.5% in air). Under certain conditions, any airborne dust may be an explosion hazard. Used activated carbon may produce additional combustion products.

| SECTION VI |
|:---:|

**SPILL AND/OR ACCIDENTAL RELEASE HANDLING MEASURES:**

Reportable Quantities:      No EPA requirements.

Personal Precautions:      Wear protective equipment, keep unnecessary personnel away, and ventilate area of spill.

Environmental Precautions:      The carbon is not soluble in water; however, dust particles can cause a particulate emission if discharged to waterways.
Block all entrances to sewers and drains to avoid introducing the material into the waterways.

Steps To Be Taken For Containment & Clean-up:      Block all entrances to sewers and drains.
Vacuum, shovel or sweep up spilled material, neutralize and place in closed container for disposal.
**Do not release to sewer or waterway**
Remove product to appropriate storage area until it can be properly disposed of in accordance with local, state and federal regulations.
Avoid formation of dust.

Waste Disposal Method:      Unused product may have a lot pH.
Used product may contain hazardous chemicals or hazardous properties that may have to be examined to determine proper disposal method.
Dispose in accordance with local, state, and federal regulations.

Disposal Considerations:      Activated carbon, in its original state, is not a hazardous material or hazardous waste.
Follow applicable governmental regulations for waste disposal.
Used activated carbon may become classified as a hazardous waste depending upon the application.
Follow applicable regulations for disposal.
Recycling (reactivation) may be a viable alternative to disposal.
Contact Carbon Activated Corp. for information.

| SECTION VII |
|:---:|

**STORAGE AND HANDLING INFORMATION:**

Storage Temperature:      Ambient

Storage Pressure:      Atmospheric

| | |
|---|---|
| Handling: | Follow good handling and housekeeping practices to minimize spills, generation of airborne dusts, and accumulation of dusts on exposed surfaces.<br>Use with adequate exhaust ventilation to draw dust away from workers' breathing zones.<br>Keep away from ignition sources.<br>Use in well ventilated areas.<br>Protect containers from physical damage.<br>Avoid prolonged contact with eyes and skin.<br>Prevent or minimize exposures to dusts by using appropriate personal protection equipment<br>Avoid Wash exposed skin areas thoroughly with soap and water after handling. |
| Storage: | Dry airtight storage recommended.<br>Store in cool, dry, ventilated area and in closed containers.<br>Maintain good housekeeping.<br>Store away from strong oxidizers such as ozone, liquid oxygen, chlorine, permanganate, etc.<br>Keep away from heat or flames or ignition sources. |

---

**SECTION VIII**

---

**SPECIAL PROTECTION INFORMATION:**

| | |
|---|---|
| Respiratory Protection: | Use NIOSH/MSHA approved respiratory protection equipment appropriate to the material and/or its concentration where airborne exposure is likely. If exposures cannot be kept to a minimum with engineering controls, consult respirator manufacturer to determine appropriate type equipment for a given application. Observe respirator use limitations specified by NIOSH/MSHA or the manufacturer. |
| Ventilation/Local Exhaust: | Essential in confined areas |
| Eye Protection: | Safety glasses or goggles with side shields are recommended for any type of handling. Where eye contact or dusty conditions may be likely, dust tight goggles are recommended. Have eye flushing equipment available. |
| Skin Protection: | Avoid contact with the skin. Wear appropriate dust resistant clothing. Wash contaminated clothing and clean protective equipment before reuse. Wash skin thoroughly after handling. Protective gloves are recommended. |

| Airborne Exposure Guidelines: | Recommended Exposure Limits<br>8-hr TWA | Activated Carbon |
|---|---|---|
| | Total Dust | 10 mg/m3* |
| | Respirable Fraction | 3 mg/m3* |

**EXPOSURE CONTROL:**

| NOTE: | PEL, TLV and Toxicological data when available are provided for the pure component knowing that the carbon product contains a lesser percentage. | | |
|---|---|---|---|
| **Component** | **OSHA**<br>**PEL** | **ACGIH**<br>**TLV** | **Other Limits** |
| *Activated Carbon | Data not available | Data not available | |
| Exposure Guidelines | Wet activated carbon removes oxygen from air posing a hazard to workers in enclosed or confined space. Before entering such an area, sample the air within to assure sufficient oxygen supply. Use work procedures for low oxygen levels, observing all local, state and federal regulations. Comment: Remove from the area any worker who shows allergic reactions from exposure to sulfur. | | |
| Engineering Controls | Exhaust ventilation should be designed to prevent accumulation and recirculation in the workplace and safely remove carbon black from the air.<br>Note: Wet activated carbon removes oxygen from air causing a severe hazard to workers in enclosed or confined space. If risk of overexposure exists, wear an approved respirator. Provide adequate ventilation in warehouse or closed storage area. | | |
| Personal Protective Equipment | Use of NIOSH approved particulate filter is recommended if dust is generated in handling. The usual precautionary measures for handling chemicals should be followed, i.e. gloves, safety glasses w/side shields or goggles, long sleeve shirt or lab coat, dust respirator if dusty and/or other protective clothing/equipment as determined | | |

| | |
|---|---|
| | appropriate. |
| General Hygiene | The usual precautionary measures for handling chemicals should be followed: i.e. Keep away from food and beverage; remove contaminated clothing immediately; wash hands before breaks or eating; avoid contact with eyes and skin. |
| *OSHA and ACGIH have not established specific exposure limits for this material. The recommended exposure limits for these activated carbon products are based on the Threshold Limit Values adopted by ACGIH for Particulates (insoluble) Not Otherwise Classified. The OSHA PEL for Nuisance Dust is 15 mg/m$^3$ (5 mg/m$^3$ respirable fraction). | |

## SECTION IX

**PHYSICAL DATA:**

| | |
|---|---|
| Appearance: | Granular |
| Odor: | None |
| Color: | Black |
| pH Value: | 6-10 |
| Specific Gravity, (H2O = 1): | 3.5 |
| Solubility in water: | Insoluble |
| Vapor Pressure: | 0 |
| Vapor Density: | Solid |
| Relative Density: | 0.50 – 0.56 |
| Flammability: | > 220$^\circ$ C |
| Auto Ignition Temperature: | > 220$^\circ$ C |
| Melting Point: | N/A |
| Boiling Point: | N/A |
| Freezing Point: | N/A |
| Flash Point: | N/A |
| Evaporation: | N/A |
| Molecular Weight: | N/A |

## SECTION X

**STABILITY & REACTIVITY DATA:**

| | |
|---|---|
| Chemical Stability : | Stable ☑ Unstable ☐ |
| Conditions to Avoid : | None |
| Possibility of Hazardous Reaction : | Will Not Occur ☑ May Occur ☐ |
| Conditions to Avoid : | None |
| Incompatibility / Materials to Avoid : | Strong oxidizers such as oxygen, ozone, chlorine, permanganates, etc…alkali metals, liquid acids. |
| Hazardous Decomposition Products : | Carbon monoxide and carbon dioxide gas can be generated if combustion of this material takes place. Sulfur oxides emission is possible during combustion. |
| Caution: | High concentrations of organics in air will cause temperature rise due to heat of adsorption. At very high concentration levels this may result in a thermal excursion, referred to as a bed fire. High concentrations of Ketones and Aldehydes may cause a rise in bed temperature due to adsorption and oxidation. |

| SECTION XI |
|---|

**TOXICOLOGICAL INFORMATION:**

*NOTE: Toxicological data is provided for the pure component knowledge that the carbon product contains a lesser %*

**ACUTE EFFECTS**

| | | |
|---|---|---|
| Toxicity Studies | Oral LD50 | Not determined on the finished product. |
| | Dermal LD50 | Not determined on the finished product. |
| Inhalation | See section IV | - |
| Ingestion | See section IV | - |
| Eye Irritation | See section IV | - |
| Skin Irritation | See section IV | - |
| Target Organs or Systems | | Eyes, skin, and upper respiratory system |
| Signs and Symptoms of Exposure | See section III & IV | Irritation and redness of eyes, irritation of skin and respiratory system may result from exposure to carbon dust |

**CHRONIC EFFECTS**

| | |
|---|---|
| Carcinogenicity | Not determined on the finished product |
| Mutagenicity | Not determined on the finished product |
| Reproductive Effects | Not determined on the finished product |
| Developmental Factors | Not determined on the finished product |

| SECTION XII |
|---|

**ECOLOGICAL INFORMATION:**

*NOTE: Ecological data is provided for the pure component knowledge that the carbon product contains a lesser %.*

| | |
|---|---|
| Ecotoxicity | Not determined on the finished product. |
| Mobility in Environmental Media | Not determined on the finished product. |
| Bioaccumulation/Accumulation | Not determined on the finished product. |
| Persistence/Degradability | Not determined on the finished product. |
| Any Other Adverse Effects | Not determined on the finished product. |

| SECTION XIII |
|---|

**DISPOSAL CRITERIA:**

See Section VI.

Storage and disposal should be in accordance with applicable local, state and federal laws and regulations.

Activated Carbon is an adsorbent media; hazard classification is generally determined by the adsorbate that the carbon has picked up.

Consult with the US EPA Guidelines as per 40 CFR Part 261.3 for the classifications of hazardous waste before disposal.

| SECTION XIV |
|---|

**TRANSPORTATION INFORMATION:**

USDOT (United States Department of Transportation) Regulations
| | |
|---|---|
| Proper Shipping Name: | Steam Activated Carbon, Non-Regulated OR Carbon, Activated, Non-Regulated |
| Shipping Class: | Class 70 |
| Hazard Class: | Not Applicable See *Note Below |
| UN/NA Number: | Not Applicable |
| Packing Group: | Not Applicable |
| Freight Classification: | STCC Code - #2899643 / NMFC #40560 |
| DOT Marking: | Not Applicable |
| DOT Placard: | Not Applicable |
| Precautions To Be Taken In Transportation: | No specific precautions See Section |

EMERGENCY ACCIDENT PRECAUTIONS AND PROCEDURES:
Contact: Carbon Activated Corporation
Phone: 310 885 4555

| | Global Transport Regulations | Proper Shipping Description: | Steam Activated Carbon, Non-Regulated OR Carbon, Activated, Non-Regulated |
|---|---|---|---|
| Land | | Hazard Class: | Not Applicable See *Note Below |
| | | UN/NA Number: | Not Applicable |
| | | Packing Group: | Not Applicable |
| | | Marine Pollutant: | Not Applicable |

| | IMO / IMDG | Proper Shipping Description: | Steam Activated Carbon, Non-Regulated OR Carbon, Activated, Non-Regulated |
|---|---|---|---|
| Water | | Hazard Class: | Not Applicable See *Note Below |
| | | UN/NA Number: | Not Applicable |
| | | Packing Group: | Not Applicable |
| | | Marine Pollutant: | Not Applicable |

| | ICAO / IATA | Proper Shipping Description: | Steam Activated Carbon, Non-Regulated OR Carbon, Activated, Non-Regulated |
|---|---|---|---|
| Air | | Hazard Class: | Not Applicable See *Note Below |
| | | UN/NA Number: | Not Applicable |
| | | Packing Group: | Not Applicable |
| | | Marine Pollutant: | Not Applicable |
| | | + Information reported for product/size: 0.5 Kg | |

*Note: *Under the UN classification for activated carbon, all activated carbons have been identified as a class 4.2 product. However, This product has been tested according to the United Nations Transport of Dangerous Goods test protocol for a "self-heating substance" (United Nations Transportation of Dangerous Goods,*

*Manual of Tests and Criteria, Part III, Section 33.3.1.6 - Test N.4 - Test Method for Self Heating Substances) and it has been specifically determined that this product does not meet the definition of a self-heating substance (class 4.2) or any other hazard class, and therefore should not be listed as a hazardous material. This information is applicable only for the Activated Carbon Product identified in this document.*

| SECTION XV |
|---|

**FEDERAL REGULATIONS:**

**US FEDERAL REGULATIONS**

OSHA (29 CFR1910:1200):            Not Regulated
                                   See Table Z-1 of 29CFR1910.1000,
                                   Limits For Air Contaminates.

CERCLA/SUPERFUND (40CFR117, 302):  Contains no CERCLA hazardous substances.
                                   Notification of spills of this material is not required
                                   Specific reporting requirements at the local, regional, or state
                                   level pertaining to releases of this material may exist.

RCRA (40CFR261.33, 261.20-24):     This product, in its original state, does not meet the criteria of
                                   hazardous waste.

Toxic Substances Control Act (40CFR710):   Activated carbon does not contain any relevant components.

Clean Water Act                    Activated carbon does not contain any substances regulated as
(40CFR122.21 and 40CFR122.42):     pollutants.

Clean Air Act                      Activated carbon does not contain any components listed as
(CAA, Section112, 40CFR82):        Hazardous Air Pollutants, Flammable Substances, Toxic
                                   Substances, or Class 1 or 2 Ozone Depletors.

California Prop. 65                 Product and impregnate component are not listed.

Section 302 - Extremely Hazardous Substances   This product is not listed as an extremely hazardous substance.
(40CFR355):

SECTION 313-                       This product is not listed.
List of Toxic Chemicals:

Amendments and Reauthorization Act of 1986 (Title III), Sections 302, and 313

SARA 311/312 Hazard Categories
    Acute Health Hazard              NO
    Chronic Health Hazard            NO
    Fire hazard                      NO
    Sudden release of pressure hazard NO
    Reactive Hazard                  NO

Activated carbon, (CAS: 7440-44-0) is    US EPA High Production Volume Program Chemical List
found on the following regulatory lists:  US FDA CFSAN Color Additive Status List 4
                                   US FDA CFSAN Color Additive Status List 6
                                   US DOE Temporary Emergency Exposure Limits (TEELs)
                                   US - Hawaii Air Contaminant Limits
                                   US - Idaho - Toxic and Hazardous Substances - Mineral Dust
                                   US - Minnesota Hazardous Substance List
                                   US - Minnesota Permissible Exposure Limits (PELs)
                                   US - Rhode Island Hazardous Substance List
                                   US - Vermont Permissible Exposure Limits Table Z-1-A Final Rule Limits
                                   for Air Contaminants
                                   US - Washington Permissible exposure limits of air contaminants
                                   Canada - British Columbia Occupational Exposure Limits
                                   Canada - Yukon Permissible Concentrations for Airborne Contaminant
                                   Substances
                                   Canada Domestic Substances List (DSL)

International Air Transport Association (IATA) Dangerous Goods Regulations
OECD Representative List of High Production Volume (HPV) Chemicals

**CANADIAN CLASSIFICATION**

WHMIS (CPR, SOR/88-66):               Product and impregnate component are listed

DSL #.                                Product and impregnate component are listed

EEC Council Directives relating to the classification, packaging, and labeling of dangerous substances and preparations

Risk and Safety Phrases               R36: Irritating to the eyes
                                      R37: Irritating to the respiratory system
                                      R38: Irritating to the skin

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**SECTION XVI**

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**OTHER INFORMATION:**

The information contained herein is based on data considered to be accurate and applies to this specific material as supplied.

This SDS will not be valid for this material if it is used in combination with any other material/s.

It is the user's responsibility to determine the suitability and completeness of this information for their particular use and to ensure that its activities comply with federal, state, provincial and local laws.

Carbon Activated Corp. makes no warranty with respect to the information and recommendations provided and disclaim all liability for any reliance or usage. Furthermore, no warranty is expressed or implied regarding the accuracy of this data.
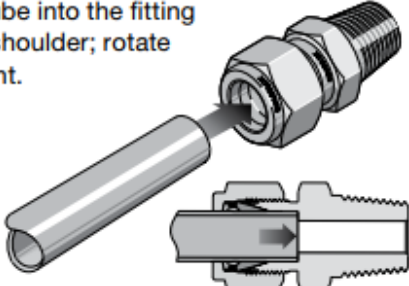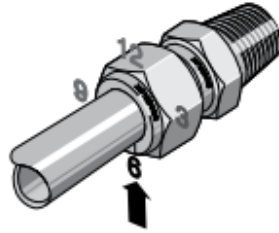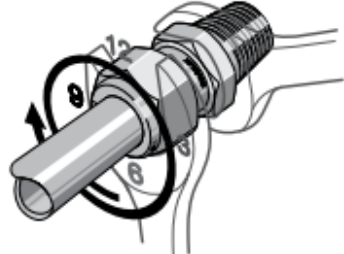
Prepared in accordance with the United States Hazard Communication
*Standard: 29 CFR 1910.1200 (March 26, 2012)*
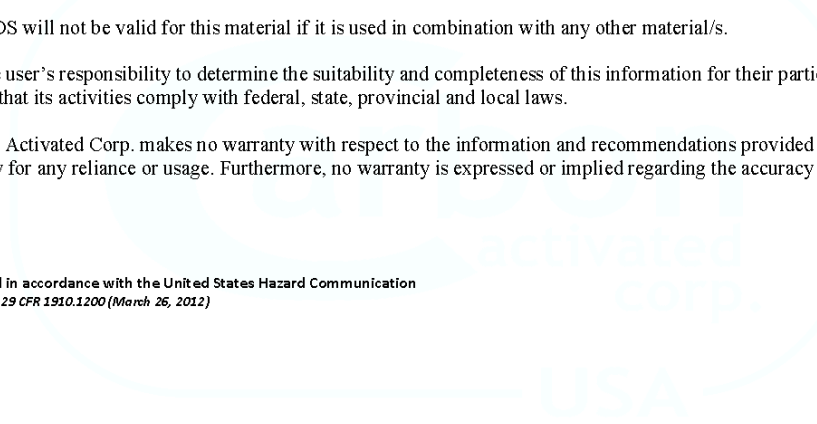
# APPENDIX G – Swagelok Instructions

Use the instructions below for making proper Swagelok fittings. Click the following link to view the entire Installer's Pocket Guide for Swagelok Tube Fittings:

https://www.swagelok.com/downloads/webcatalogs/en/ms-13-151.pdf

## Swagelok Tube Fittings

### Up to 1 in./25 mm

Safe practices and proper installation are imperative to the performance of the Swagelok tube fitting, especially in critical applications.

For 5/8, 3/4, 7/8 and 1 in.; 16, 18, 20, 22 and 25 mm tube fittings, in all materials except for aluminum and brass, it is a best practice to preswage the ferrules onto the tube adapter using a Swagelok multihead hydraulic swaging unit (MHSU) to lower installation time and increase ease of installation (see Multihead Hydraulic Swaging Unit (MHSU), Setup and Operating Instructions, MS-12-37).

Fully insert the tube into the fitting and against the shoulder; rotate the nut finger-tight.

*High-pressure applications and high safety-factor systems:* Further tighten the nut until the tube will not turn by hand or move axially in the fitting.

Mark the nut at the 6 o'clock position.

While holding the fitting body steady, tighten the nut one and one-quarter turns to the 9 o'clock position.

*For 1/16, 1/8, and 3/16 in.; 2, 3, and 4 mm tube fittings, tighten the nut three-quarters turn to the 3 o'clock position.*