PICARRO

A0601 Zero Reference Module (ZRM) User Manual

Picarro Inc.
3105 Patrick Henry Drive
Santa Clara, CA 95054, USA
Phone: +1 408 962 3944 • Fax +1 408 962 3200
www.picarro.com

Document Number 40-0102 Revision A

Picarro 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.

DISCLAIMER AND RESERVATION OF RIGHTS

Picarro has prepared this manual solely for the information and use by its customers as a guide for the selection, installation, operation, and maintenance of the products described.

EXCEPT AS PROVIDED IN THE TERMS AND CONDITIONS OF SALE FOR PICARRO PRODUCTS, PICARRO ASSUMES NO LIABILITY WHATSOEVER, AND PICARRO DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY, RELATING TO SALE OR USE OF PICARRO PRODUCTS, INCLUDING LIABILITY OR WARRANTIES RELATING TO MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Picarro reserves the right to change or update the contents of this manual and the specifications of its products at any time, without notice. Picarro has endeavored to include information that is current and accurate as of the date of the publication or revision of this document, but Picarro does not guarantee that this document is error free or that it is accurate with regard to any particular specification.

Picarro expressly reserves all intellectual property rights, including all intellectual property rights relating to any product described in this manual. This document does not grant any license, express or implied, by estoppel or otherwise, to any intellectual property rights of Picarro or any third party.

PATENTS

The products described in this manual are subject to Picarro patents and patents pending. Information about Picarro patents applicable to these products is available at www.picarro.com/company/patents.

TRADEMARKS

Picarro and the Picarro logo are trademarks of Picarro, Inc.
Airgas® is a trademark of Airgas, Inc.
AirVision™ is a trademark of Agilaire LLC.
Briskheat® is a trademark of Briskheat Corporation.
Envidas is a trademark of Envitech Ltd.
Grainger® is a trademark of W.W. Grainger, Inc.
Linux® is a trademark of Linus Torvalds
Snoop® is a registered trademark of Swagelok Company.
Swagelok® is a trademark of Swagelok Company.
Teflon™ is a trademark of the Chemours Company

Contact Information

General Technical Support:

Email: support@picarro.com

Phone: +1 408 962 3991

European Technical Support:

Email: support@picarro.com

Phone: +31 858 881 650

Order Support:

Email: orders@picarro.com

Phone: +1 408 962 3990, select option 3

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 Intended Use

The Picarro Zero Reference Module (ZRM) is an optional peripheral for the Picarro PI2920 Ambient Ethylene Oxide (EtO) analyzer. It has been designed to further improve the long-term stability of the PI2920, 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 PI2920. 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 PI2920, and PI2910 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 which, when pulled, provides access to the service area. 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.

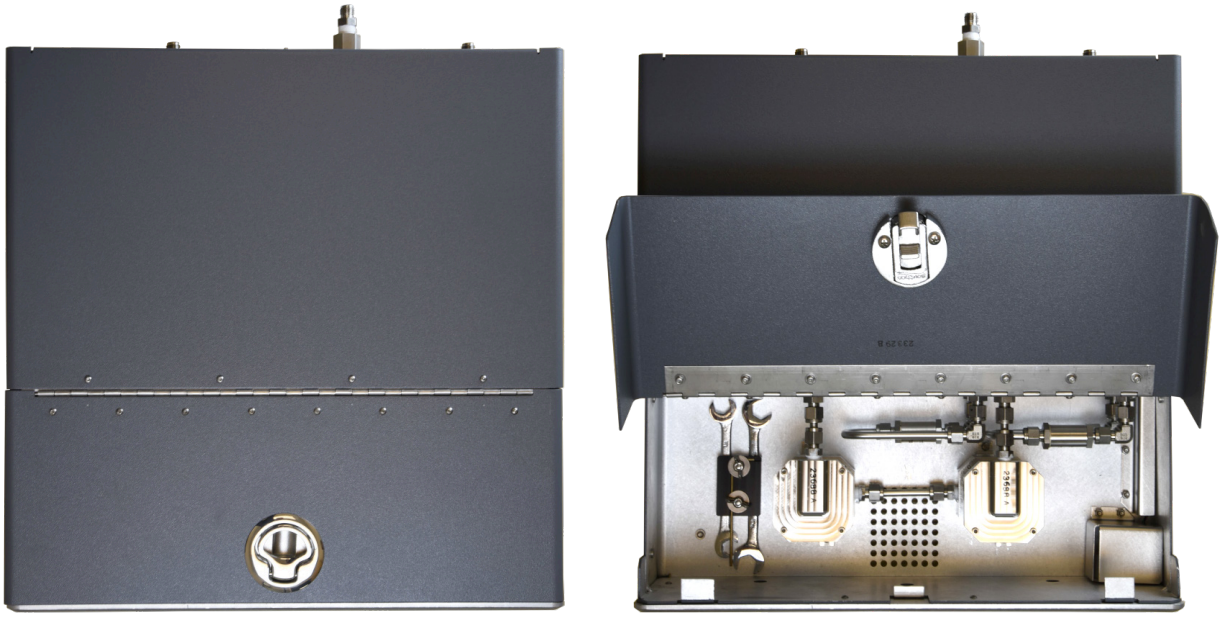
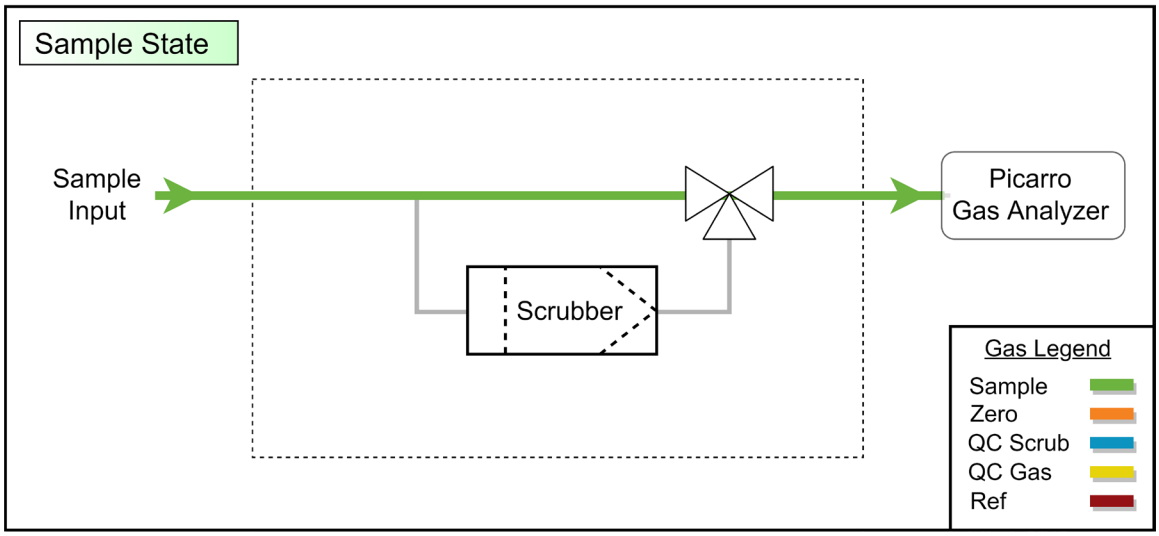


Figure 3: ZRM Top Panel with Service Access

1.3 Theory of Operation

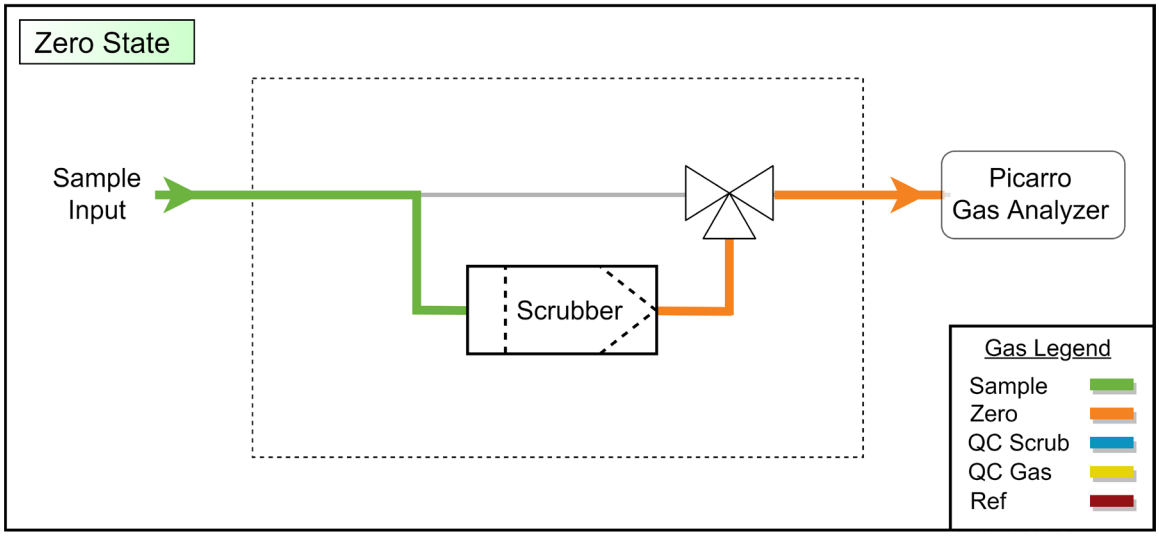
The Zeroing Correction

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 (ConcZERO) are then used as a baseline for subsequent Sample State measurements (ConcSAMP) yielding a corrected concentration (ConcCORR) via the following equation:

ConcCORR = ConcSAMP – ConcZERO

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.

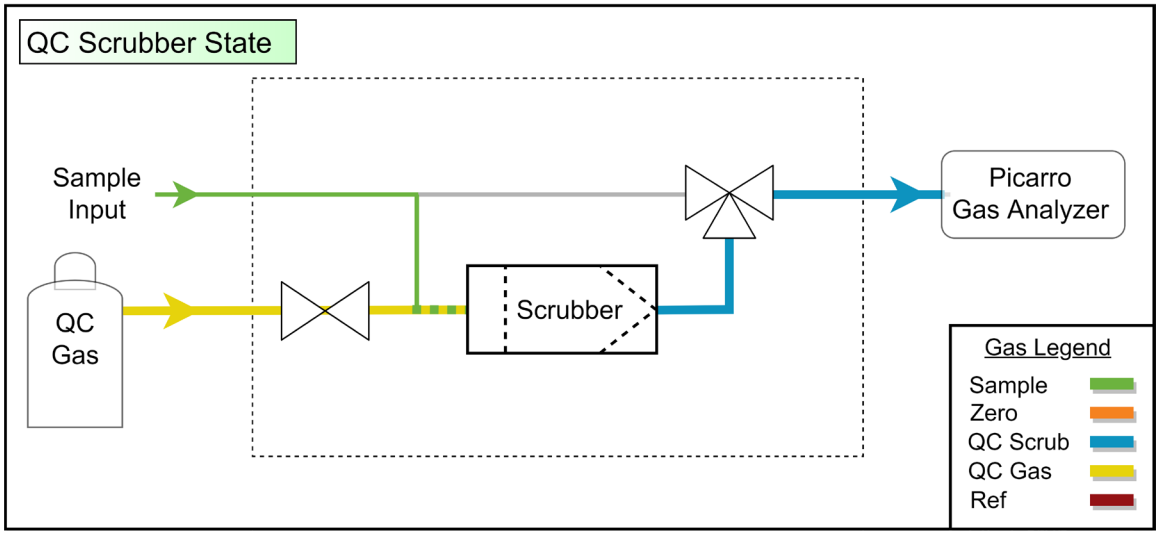


Figure 6: QC Scrubber State

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.

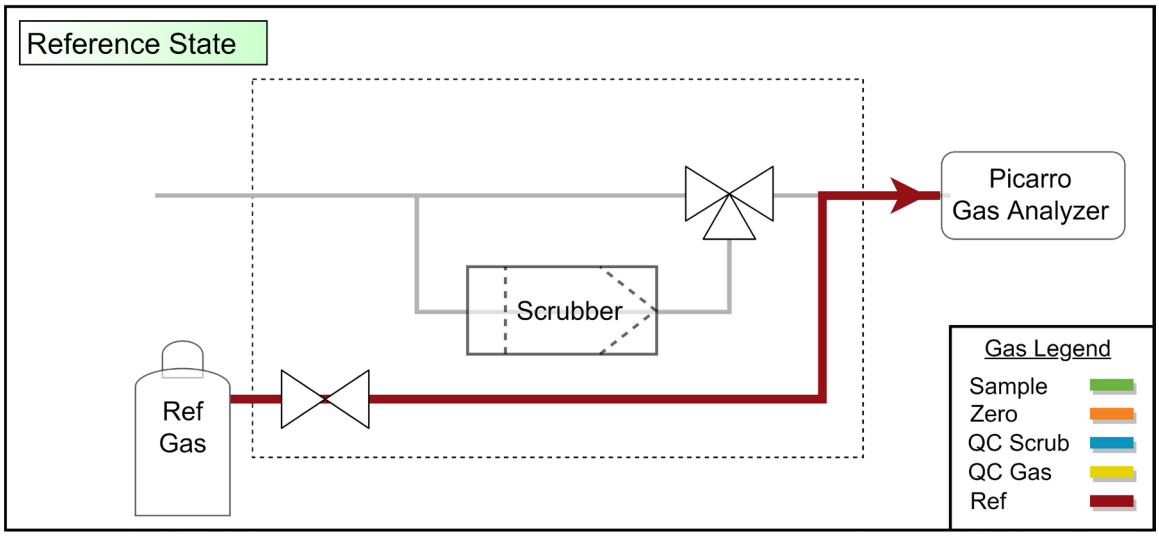


Figure 7: Reference State

1.4 ZRM Specifications

Table 1: Specifications

Parameter	Specification
Analyzer Compatibility	Picarro PI2920 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) Reference Gas (optional)
Operating System Requirements	Linux Ubuntu 20 running on Picarro PI2920 analyzer
Liquid Ingress Protection	None

1.5 Acronyms

This manual includes various acronyms.

Table 2: Acronyms, Formulas, Units, and Symbols

Acronym	Definition
” (as in 1/4”)	Length in Inches
’ (as in 10’)	Length in Feet
°C	Degrees Celsius
%	Percentage
cm	Centimeters
CH4	Methane
CO2	Carbon Dioxide
COM	Communication Port
CRDS	Cavity Ring-Down Spectroscopy
CSV	Comma Separated Values
DAS	Data Acquisition System (the Analyzer)
EtO	Ethylene Oxide (C2H4O)
GUI	Graphical User Interface
H2O	Water
Hz	Hertz
kg	Kilograms
kPa	Kilopascal; unit of pressure; 1 kPa = 0.145 PSI

Acronym	Definition
lbs	Pounds
Max	Maximum
min	Minimum
mm	Millimeters
OD	Outside Diameter
PAIAC	Phosphoric Acid Impregnated Activated Charcoal
PN	Part Number
ppb	Parts Per Billion
ppm	Parts Per Million
ppt	Parts Per Trillion
PSI (psi)	Pounds per Square Inch
PSIG	Pounds per Square Gauge
RS232	Recommended Standard 232 (serial communication protocol)
sec	Seconds
SS	Stainless Steel (i.e., tubing)
Torr	Torricelli (unit of pressure equal to 1/760 atmosphere)
USB	Universal Serial Bus
VAC	Volts AC power
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.

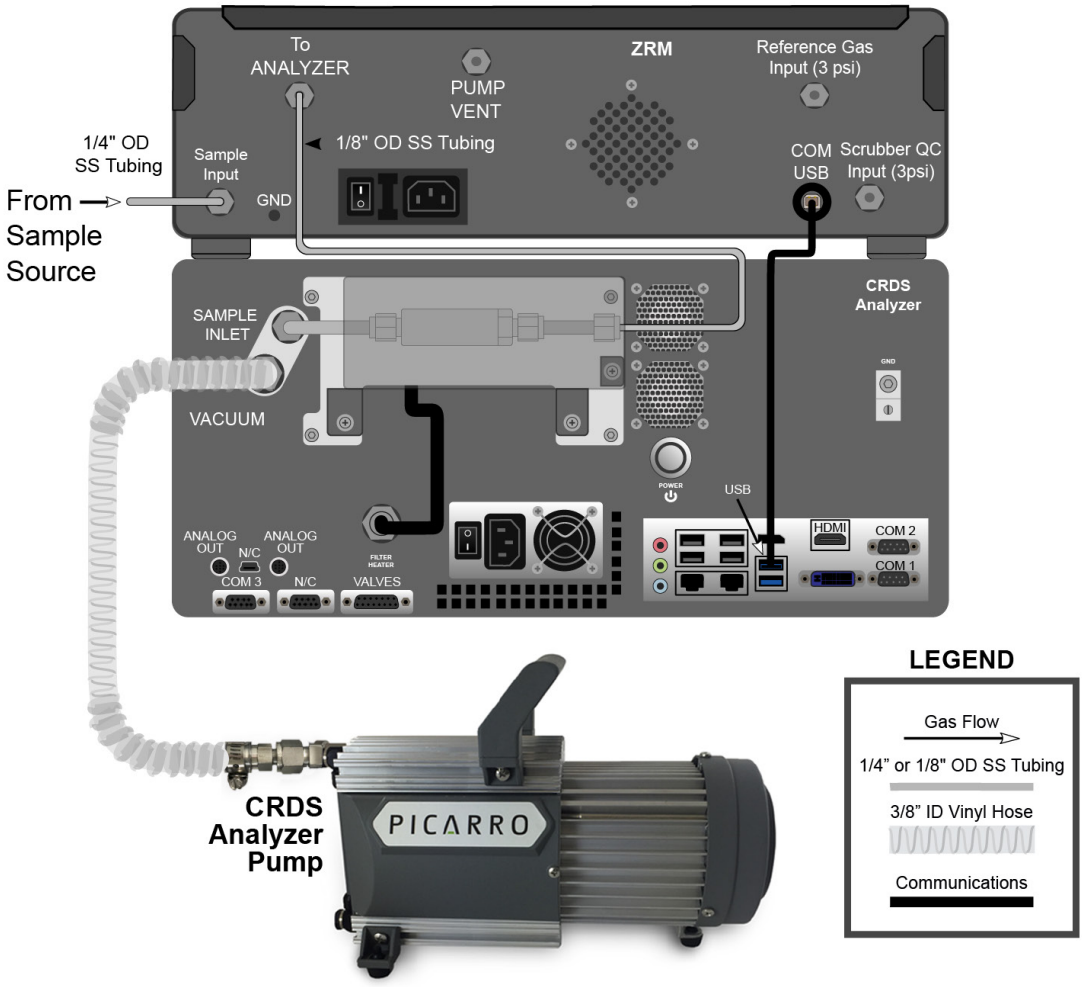


Figure 8: ZRM Connections – Quick Start

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.
5. Run the included software installation program.
6. Open the ZRM interface from the Picarro Launch Pad, Home menu. Note you must be logged in to access the ZRM button.
7. Once connected, the LED on the ZRM front panel turns 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

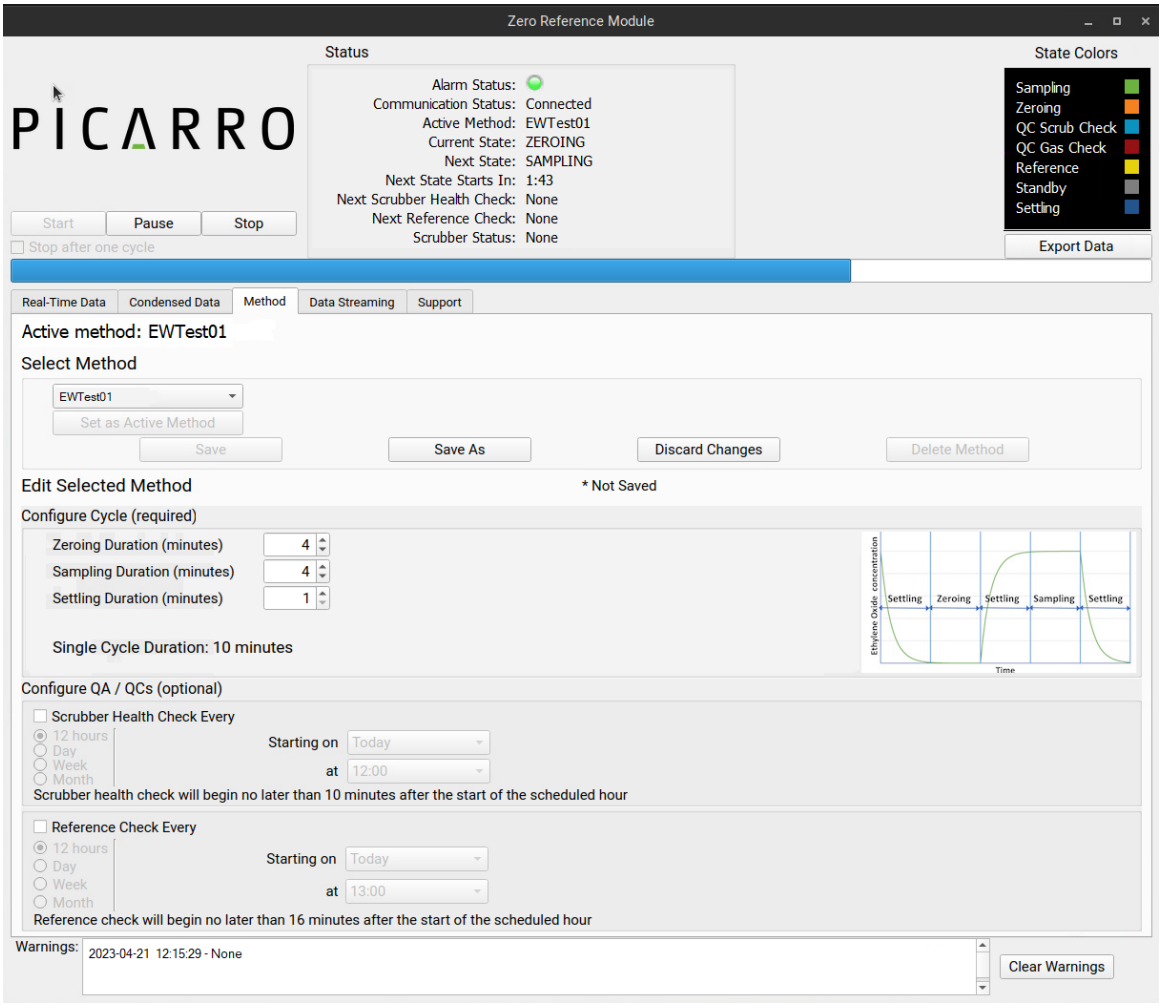


Figure 9: Operational Method Setup and Run

1. Launch the **ZRM** application from the **Picarro Launch Pad.**
2. Click the **Method** tab (Figure 9 above).
3. The default configuration cycle time durations for Zeroing, Sampling and Settling are recommended but can be adjusted if required.
4. De-select the **Scrubber Health Check Every** box.
5. De-select the **Reference Check Every** box.
6. Click the **Save As** button at the bottom. You will be prompted to name and save the new method.
7. Click the **Set as Active Method** button at the top of the window.
8. 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.

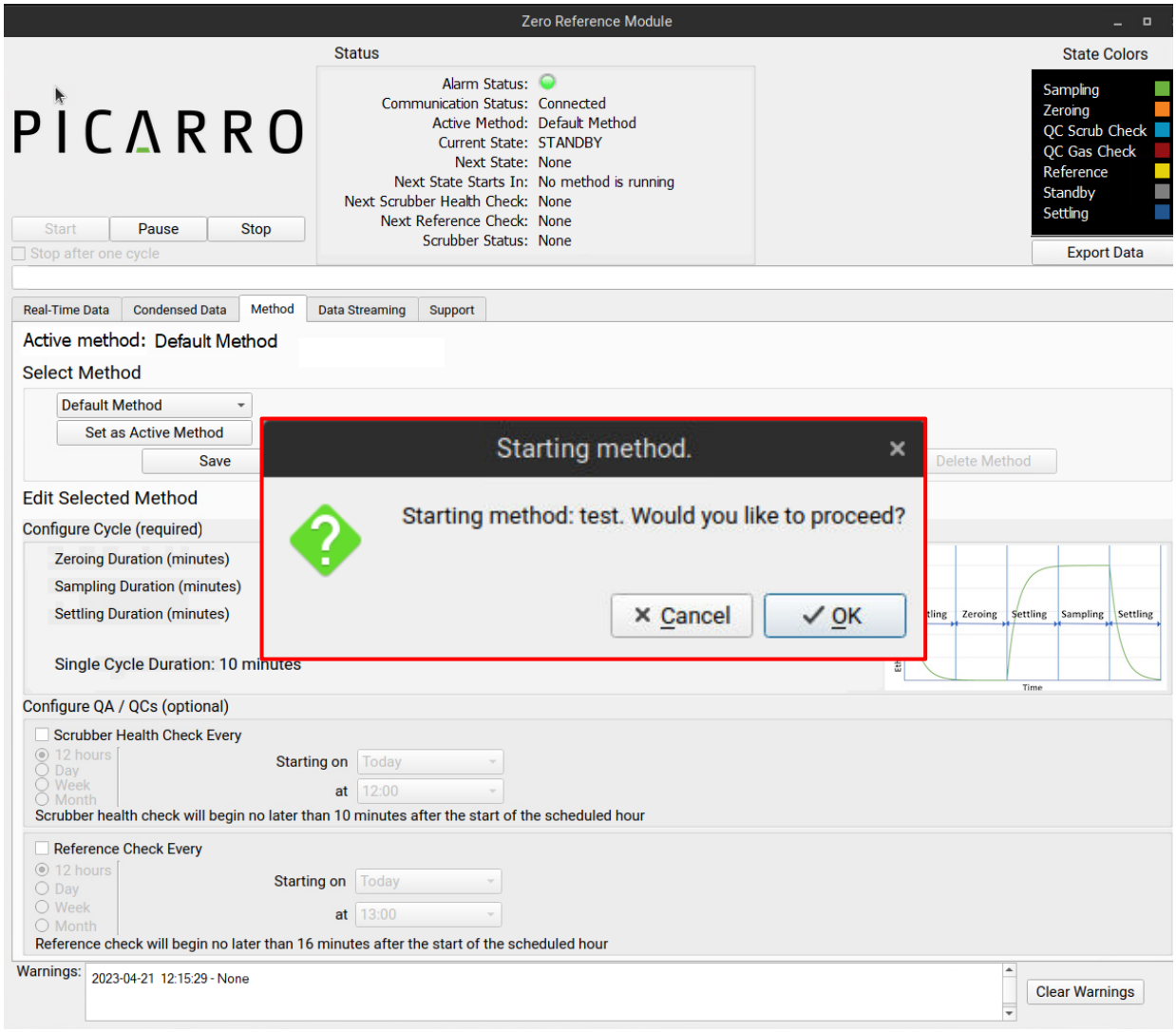


Figure 10: Method Start Confirmation Screen

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.

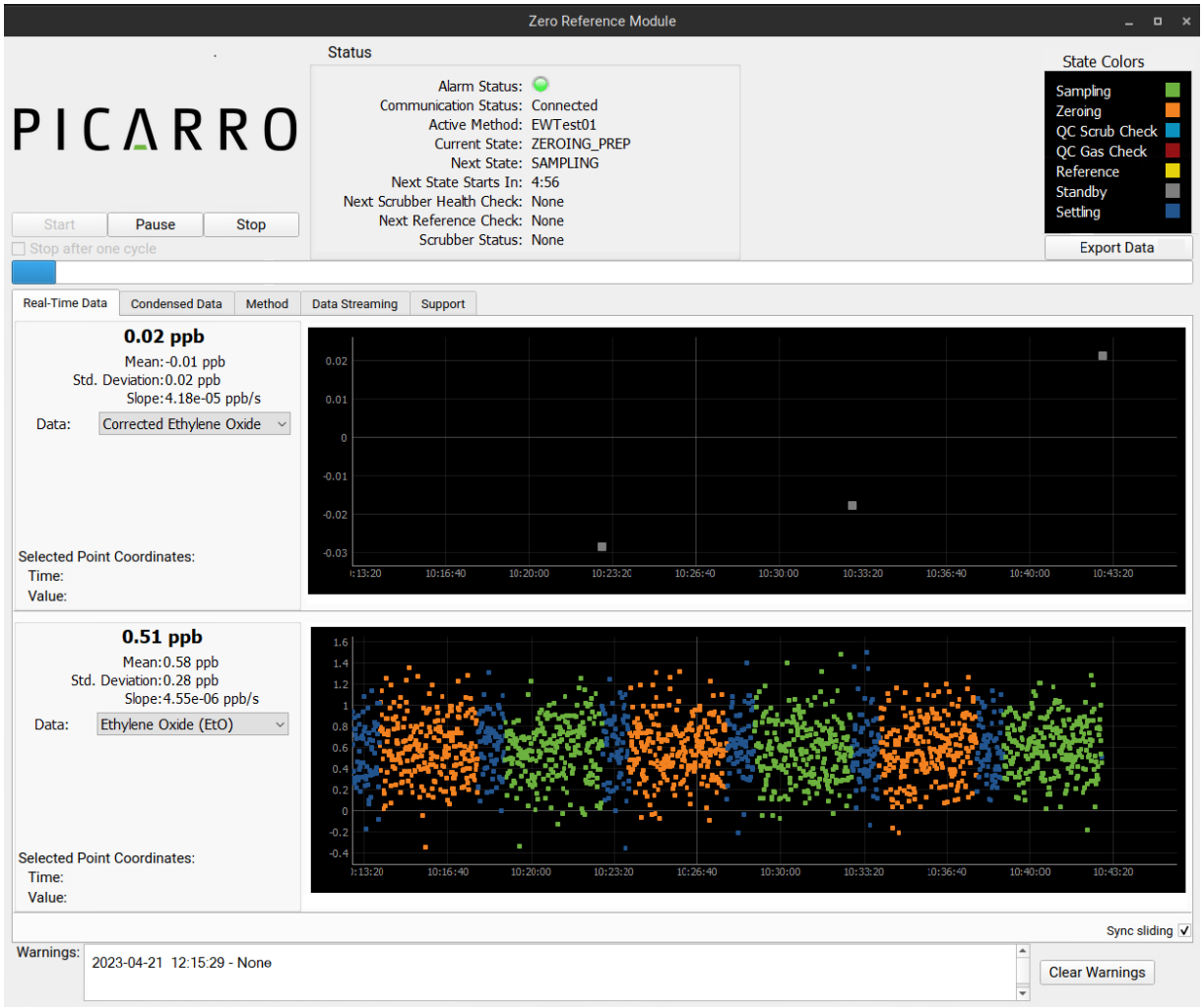


Figure 11: ZRM User Interface While Method is Running

2.5 ZRM Shutdown Procedure

CAUTION

The following procedures are for shutting down the ZRM when the Scrubber QC and Reference options are not 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.

1. In the ZRM software, click the Stop button at the top of the screen
2. From the Picarro Launch Pad select Home, ZRM, Shutdown ZRM.
3. If necessary, use the procedure in section 6.4 to ensure all gas lines including gas regulators are purged.
4. Close the ZRM Software Interface.
5. 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 3: 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, see APPENDIX B –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 E –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 4: 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 PI2920 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 PI2920 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.

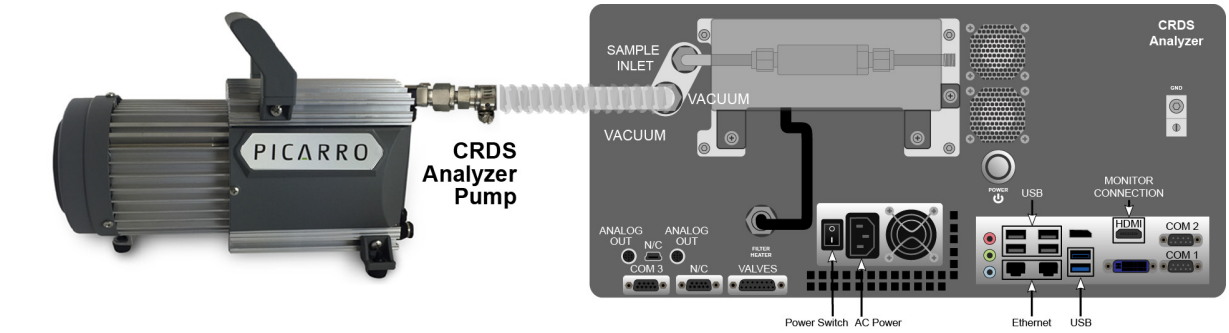


Figure 12: Basic Carbon Analyzer Setup

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.

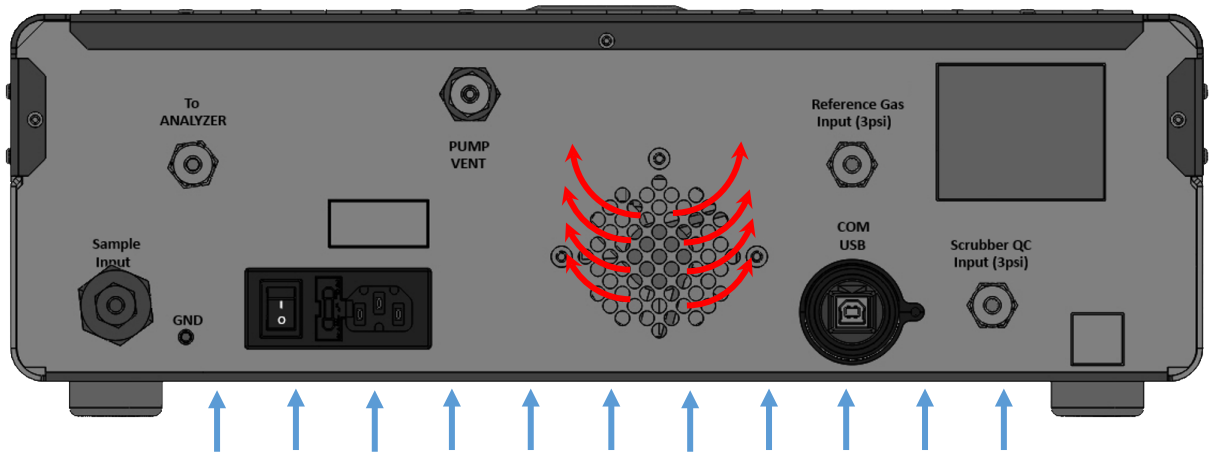


Figure 13: ZRM Cooling

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.

CAUTION

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

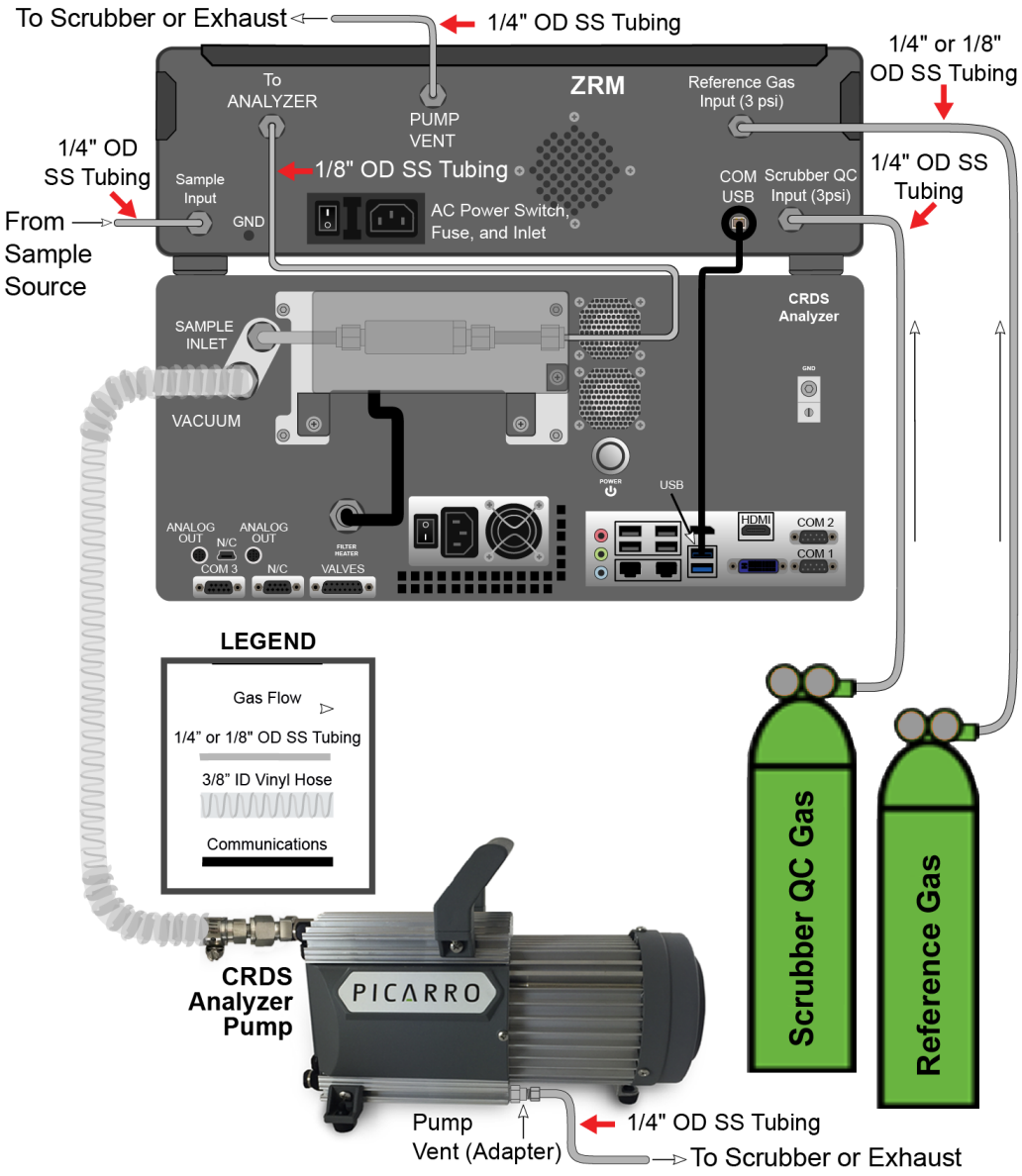


Figure 14: ZRM to Analyzer Connections

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 PI2920 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 C –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. 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, Software Startup via Picarro Launch Pad
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.

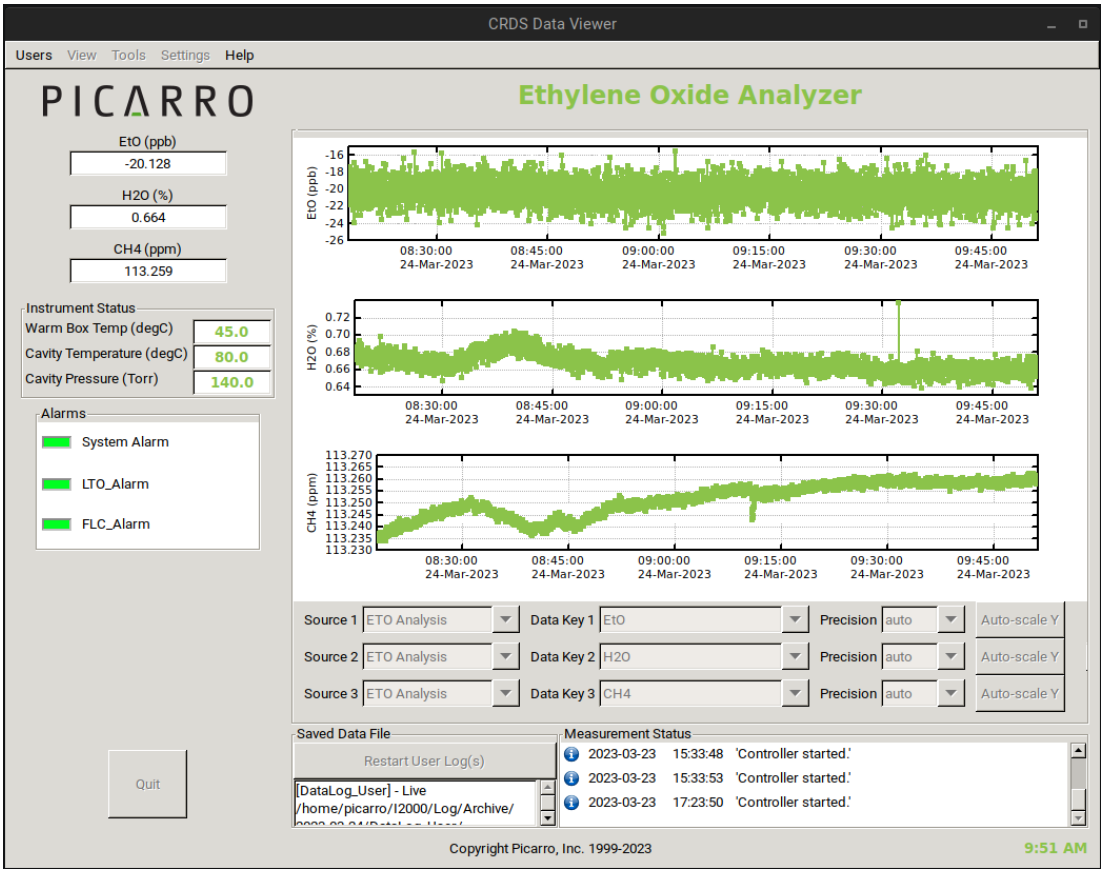
1. In the ZRM software, click the **Stop** button at the top of the screen
2. Click the **Support** tab
3. If necessary, use the following procedure to ensure all gas lines including gas regulators are purged.
4. Perform a Gas Tank Purge procedure:
    a. Close the valve on the top of the Reference Gas 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. From the **Picarro Launch Pad** select **Home**, **ZRM**, and **Shutdown ZRM**.
7. Turn off the ZRM power switch.

7. Software Startup, Overview, and Configuration

If the ZRM was purchased with a PI2920 analyzer, the ZRM software comes pre-installed on the analyzer and is accessible via the Picarro Launch Pad.

7.1 CRDS Data Viewer (Host Software)

The CRDS Data Viewer (sometimes referred to as the GUI) starts up automatically after 30 seconds when powering on the analyzer and logging into the computer. The host software interface is shown in Figure 16. While the analyzer warms up, this program displays relevant information about the warm-up sequence. This information includes hotbox temperature and cavity pressure.



The Picarro host software, showing 1.75 hours of uncorrected EtO data, alongside H2O, and CH4 data.

Figure 16: CRDS Data Viewer

Once the analyzer is warmed up, the host software begins to display measurement values. Different variables can be plotted on the graph by selecting them from the Data Key dropdown lists at the center of the window.

The CRDS Data Viewer software is a valuable tool for assessing basic analyzer operation and for troubleshooting the analyzer. For more information about the CRDS Data Viewer operation, see the PI2920 manual (PN 40-0101).

7.2 ZRM Software Startup via Picarro Launch Pad

The ZRM software interface is a separate program started from the Picarro Launch Pad, Home menu. When logged in the ZRM button is accessible and when selected provides the following actions as shown (Figure 17).

Figure 17: Picarro Launch Pad/ZRM Actions

Select Start ZRM to launch the software interface. Two things occur: the ZRM software interface (Figure 18) boots up in several seconds, and a background service of the ZRM software launches.

A few seconds after booting, the ZRM software automatically starts searching for the ZRM hardware and attempts to establish connection. As it is searching, the Alarm Status indicator light in the Status box at the top of the user interface blinks green. Once a connection is successfully established, the indicator light turns solid green to indicate the peripheral is ready for use.

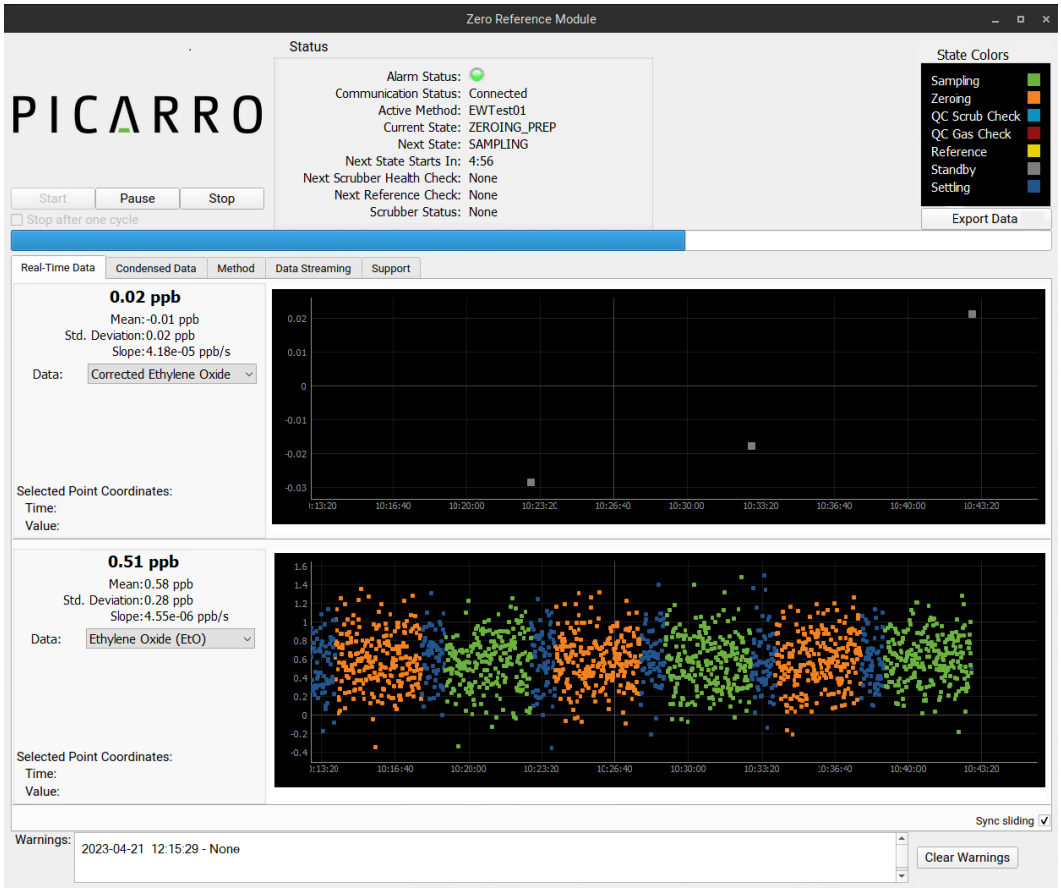


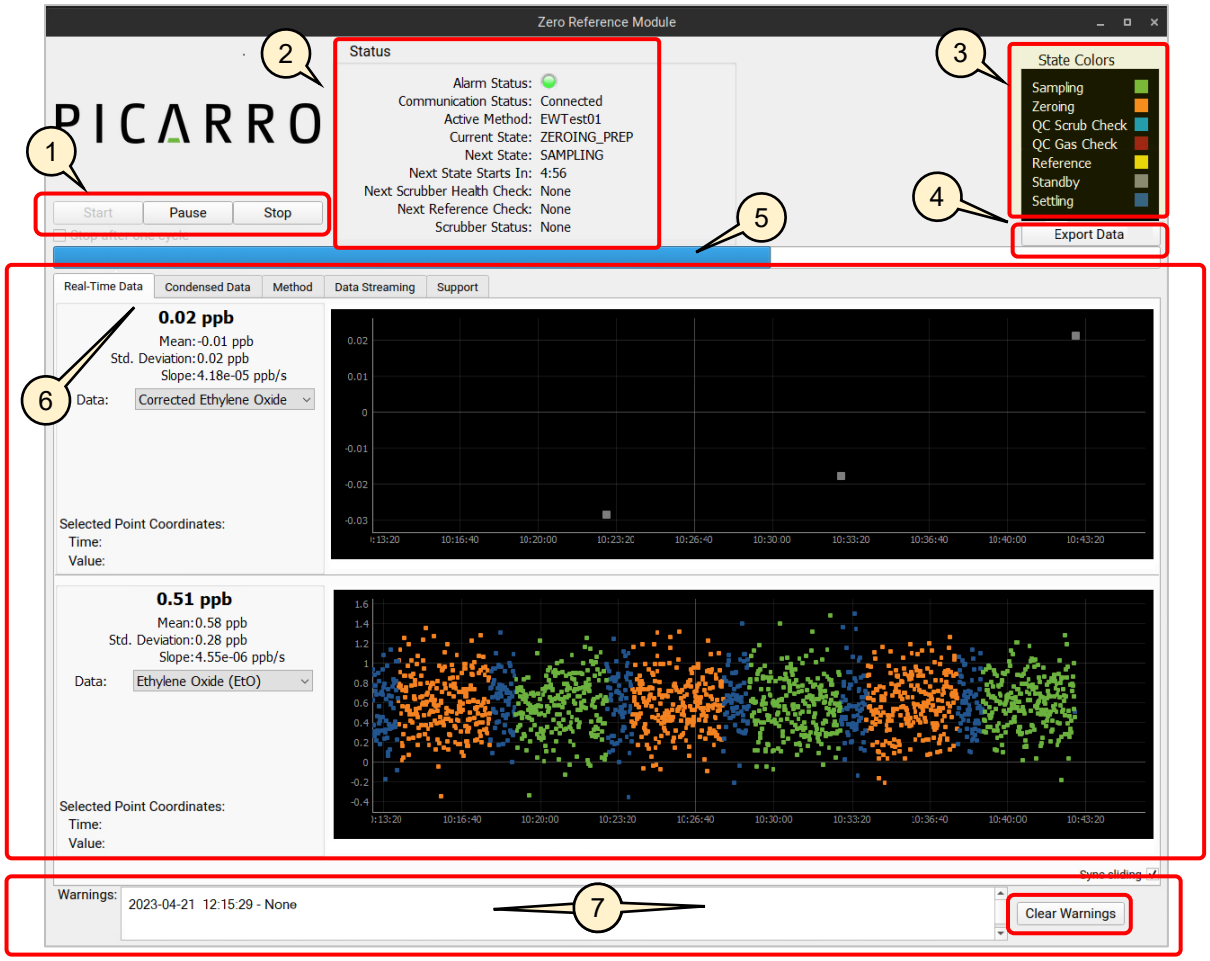
Figure 18: ZRM Software Interface

REMINDER

If, for any reason, the operating system restarts the analyzer for updates or the analyzer power is cycled by an outage, the ZRM software will not automatically restart. The user must restart the software and any running method from the Picarro Launch Pad.

7.3 ZRM Software Interface Overview

The Main Window (Figure 19) 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 19: 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 5.
- 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 B.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 B.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 B.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, 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 B.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 20 will appear.

- Analytical Data
- Analytical Data (Condensed)
- Sensor Data
- System Log Data

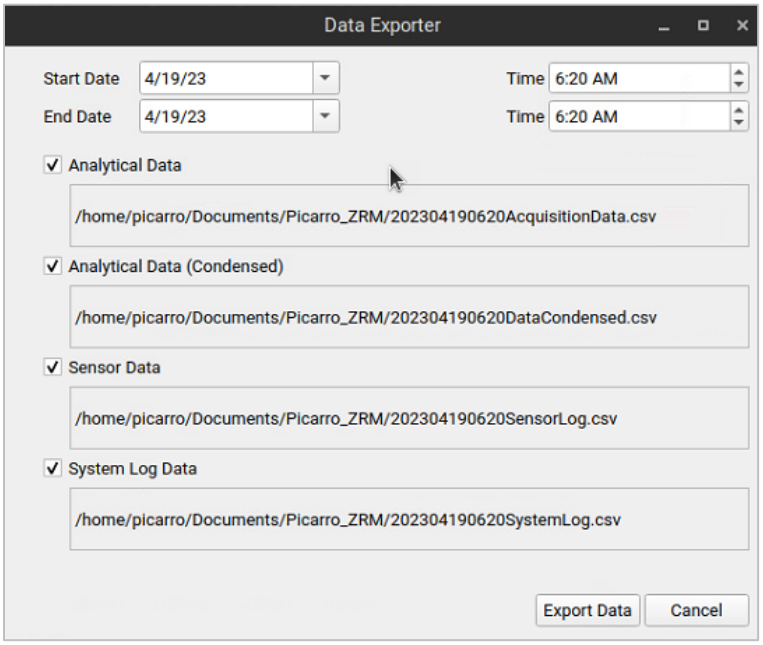


Figure 20: Data Exporter Dialog

Choose the start date/time and end date/time that is desired. Choose the desired export file type. The target file name and location are displayed in the text box below each file type.

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 displays. For more information about the contents of the four exported file formats, see APPENDIX A –Data Flow and Output.

NOTE

Use the Copy Files utility from the Picarro Launch Pad Tools menu to access the exported files and copy the data to an external device.

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 B.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 21) 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.

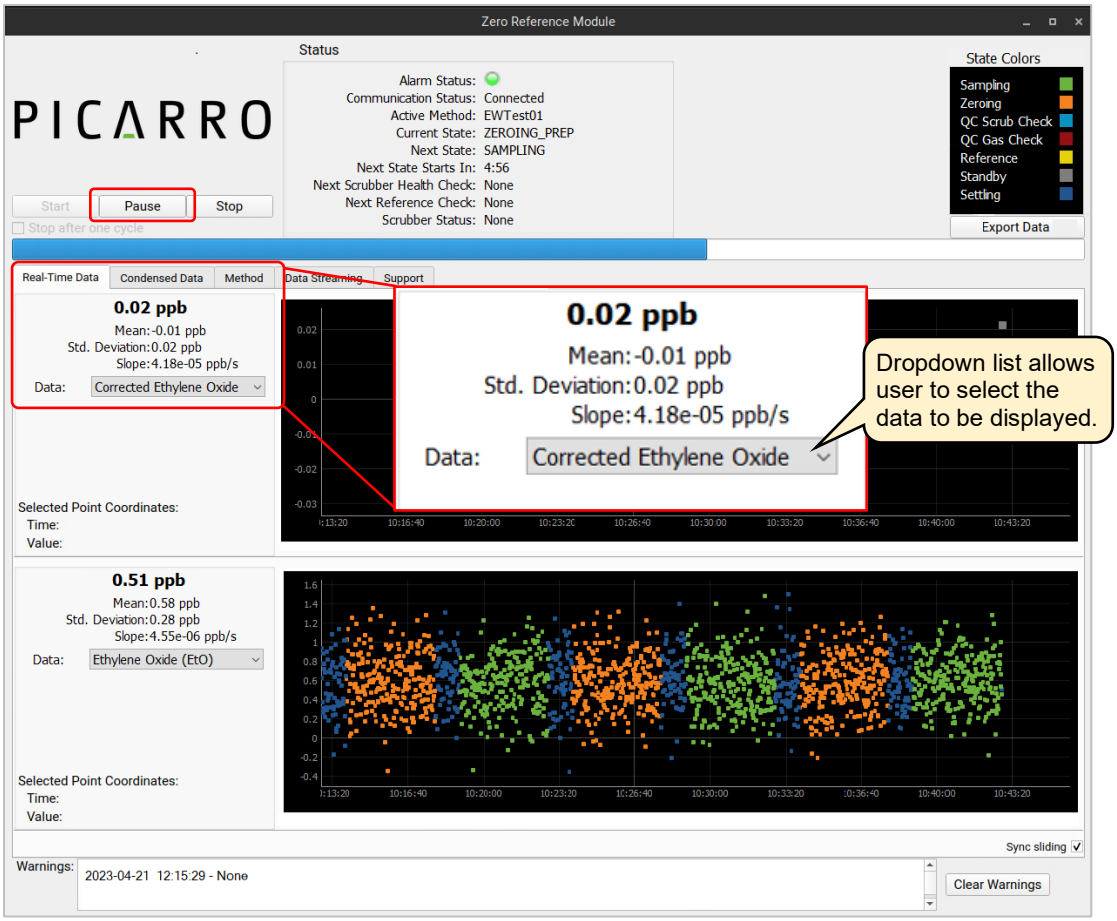


Figure 21: Real-Time Data Tab

7.5 Condensed Data Tab

The Condensed Data tab (Figure 22) 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.

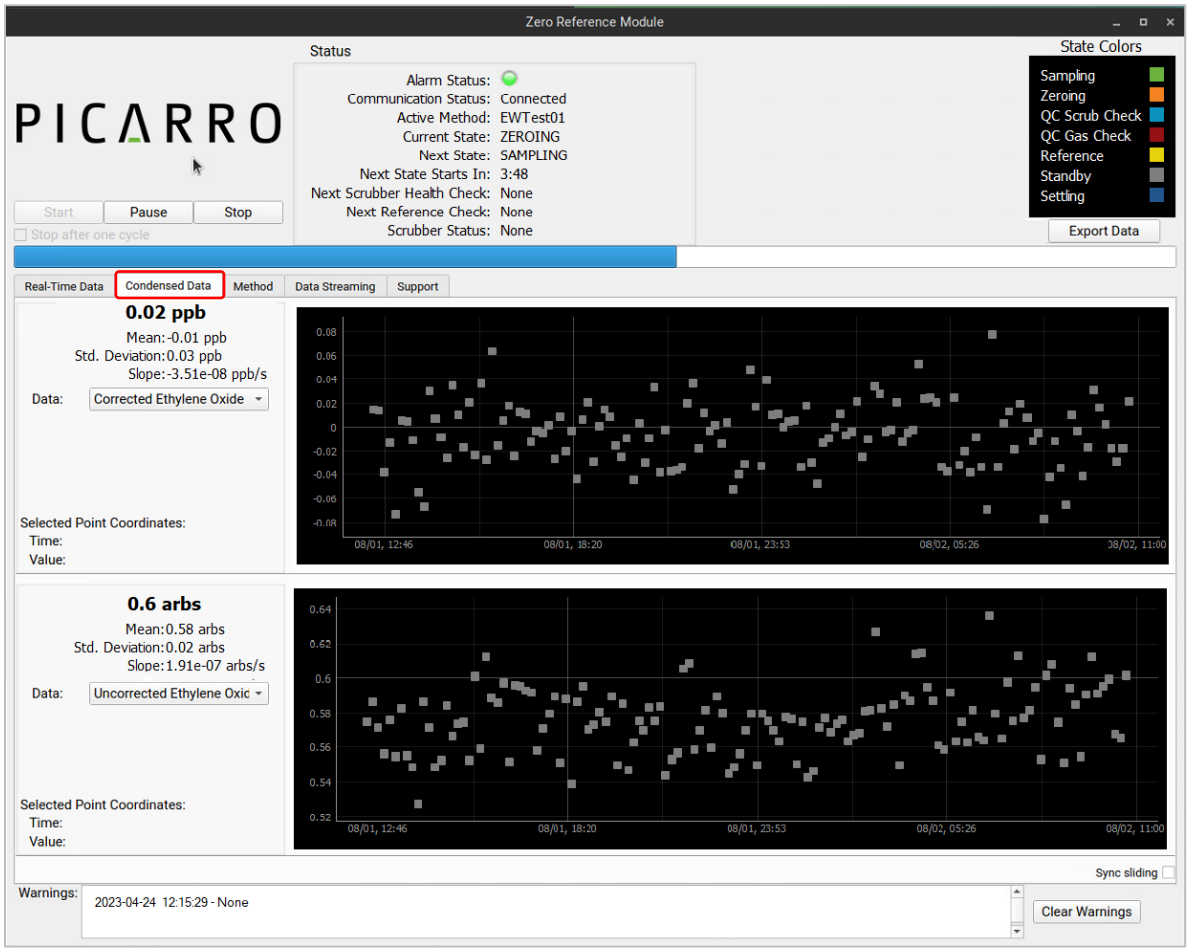


Figure 22: Condensed Data Tab

7.6 Method Tab

The Method tab (Figure 23) 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.

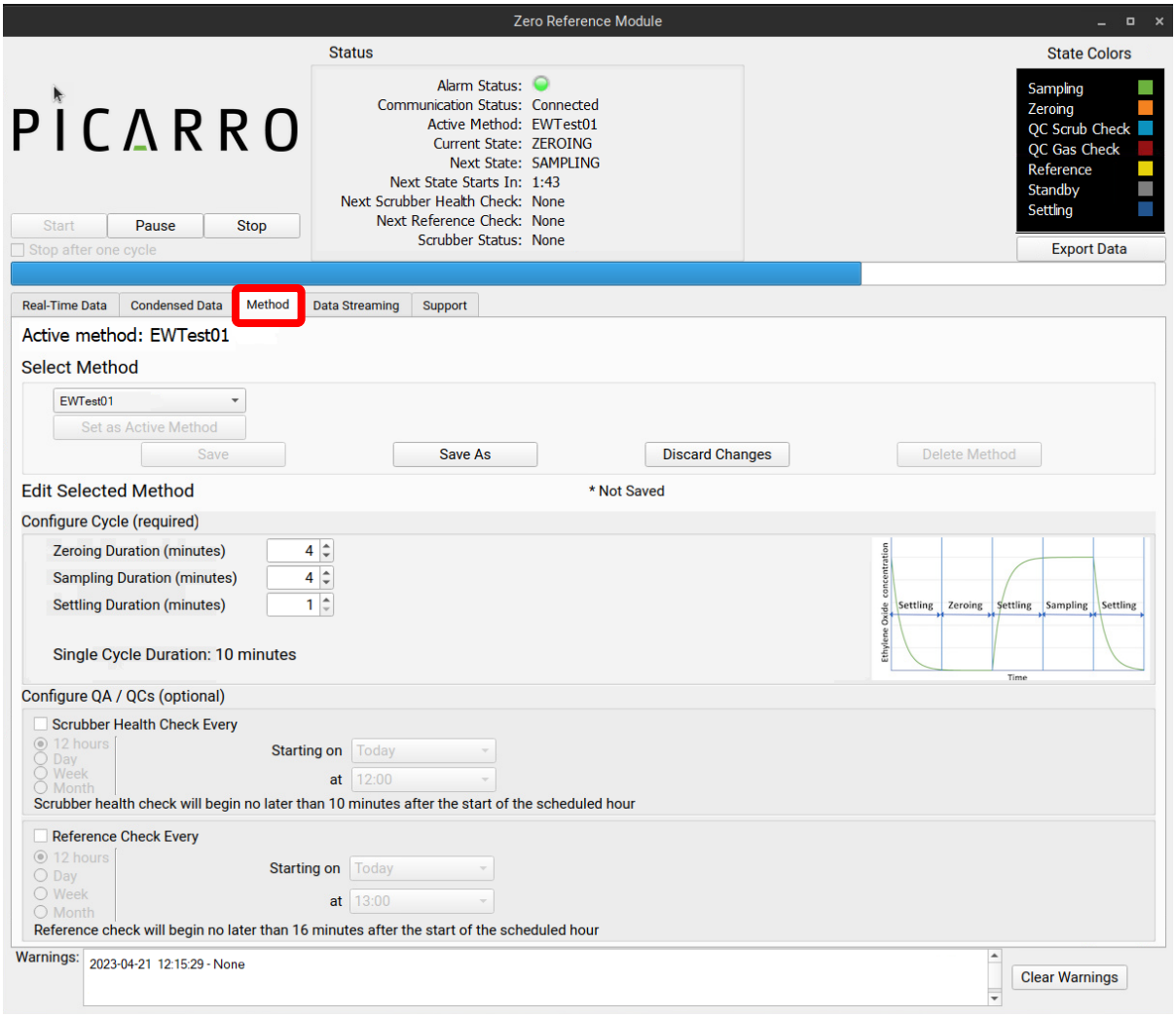


Figure 23: Method Tab Controls

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 24 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.

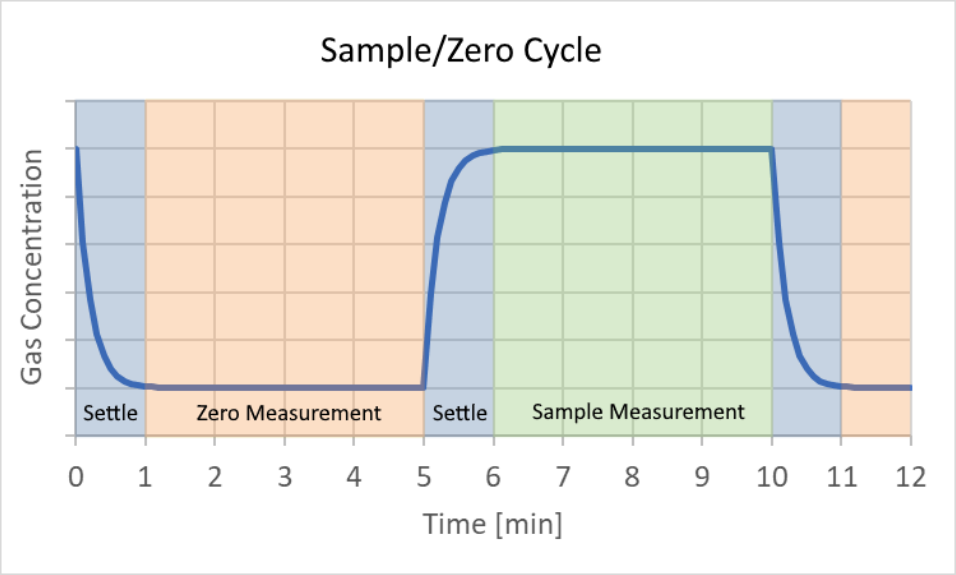


Figure 24: Zeroing, Settling, and Sampling Measurement Durations

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 25). 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.

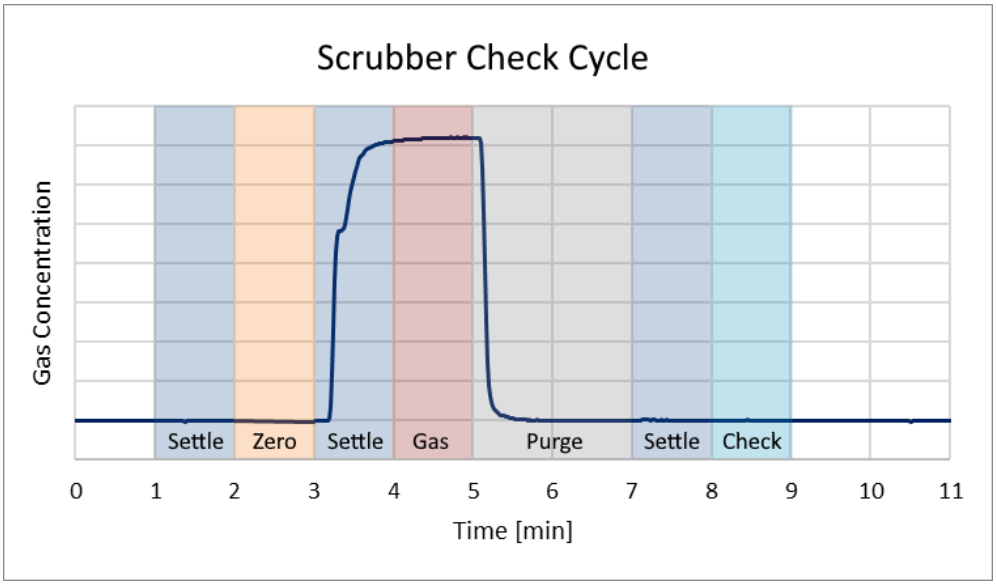


Figure 25: Scrubber Check Cycle

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.

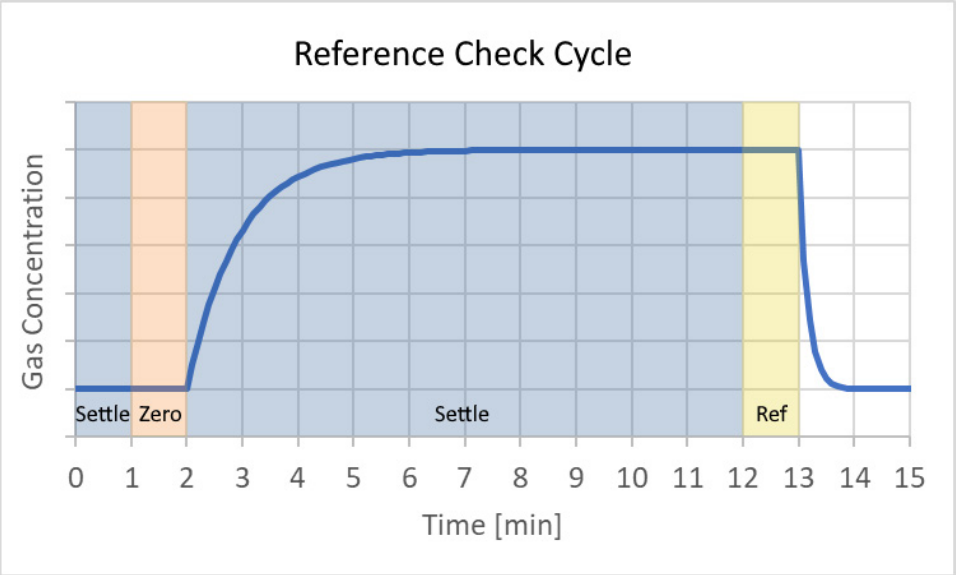


Figure 26: Reference Check Cycle

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.

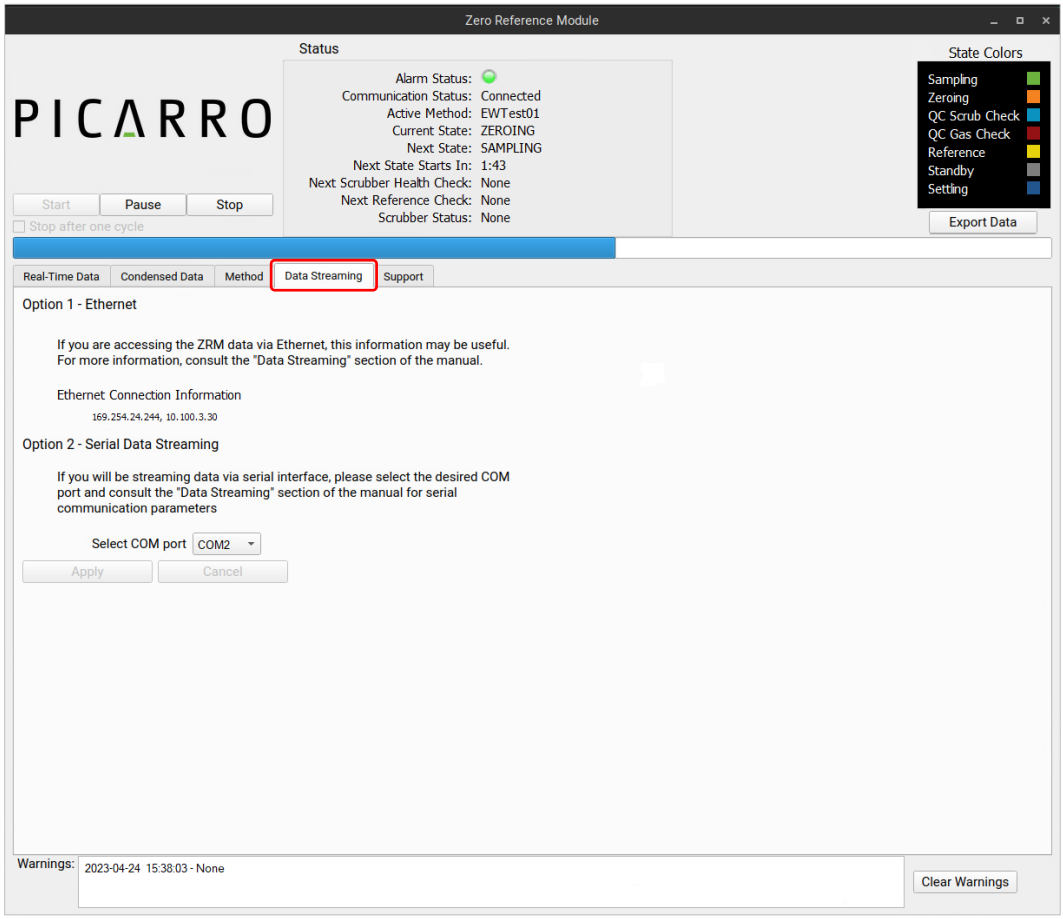


Figure 27: Data Streaming Tab

7.8 Support Tab

The Support tab (Figure 28) 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 29) 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 not 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 28: Support Tab

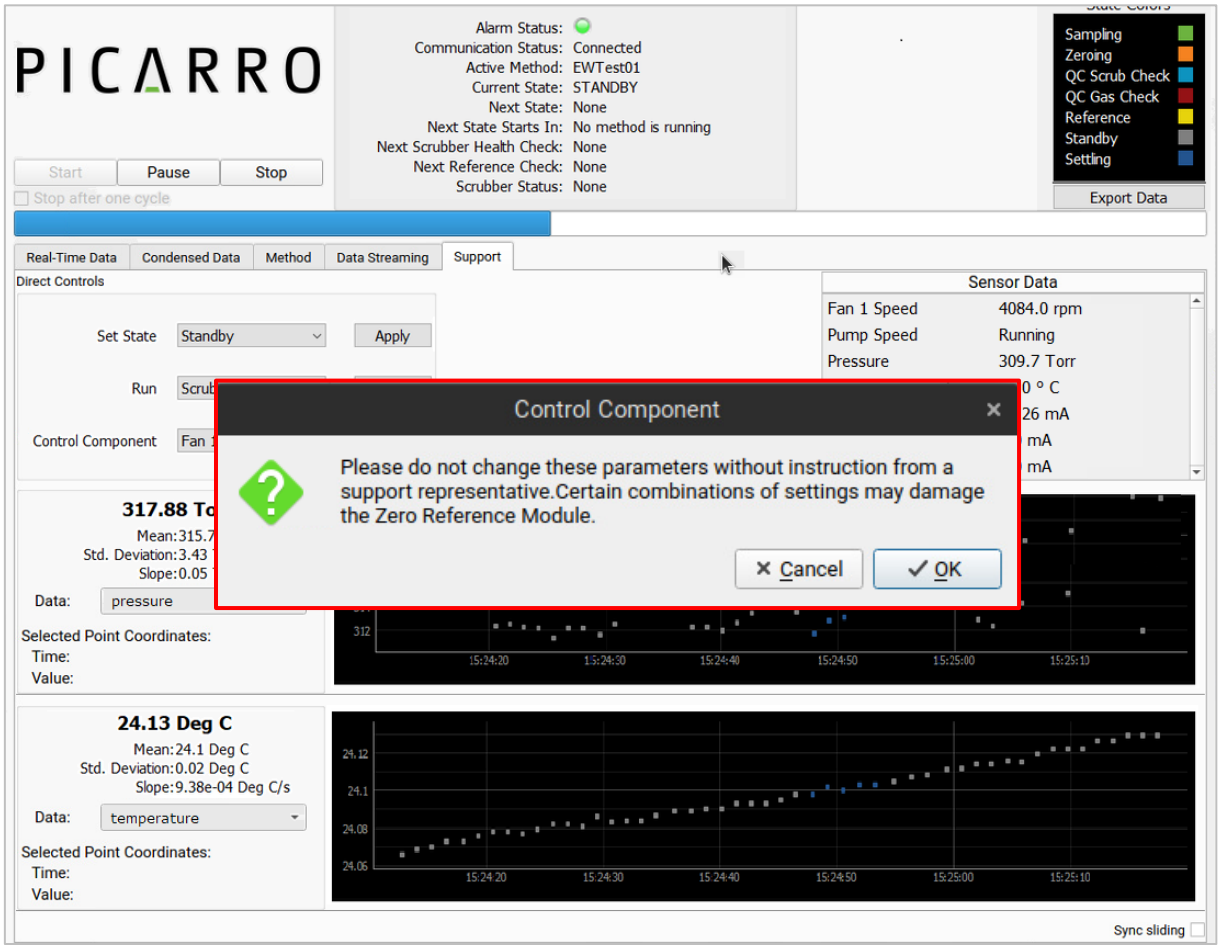


Figure 29: Support Tab State Change Warning

8. Operation

Once the ZRM has been connected to a PI2920 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 30).

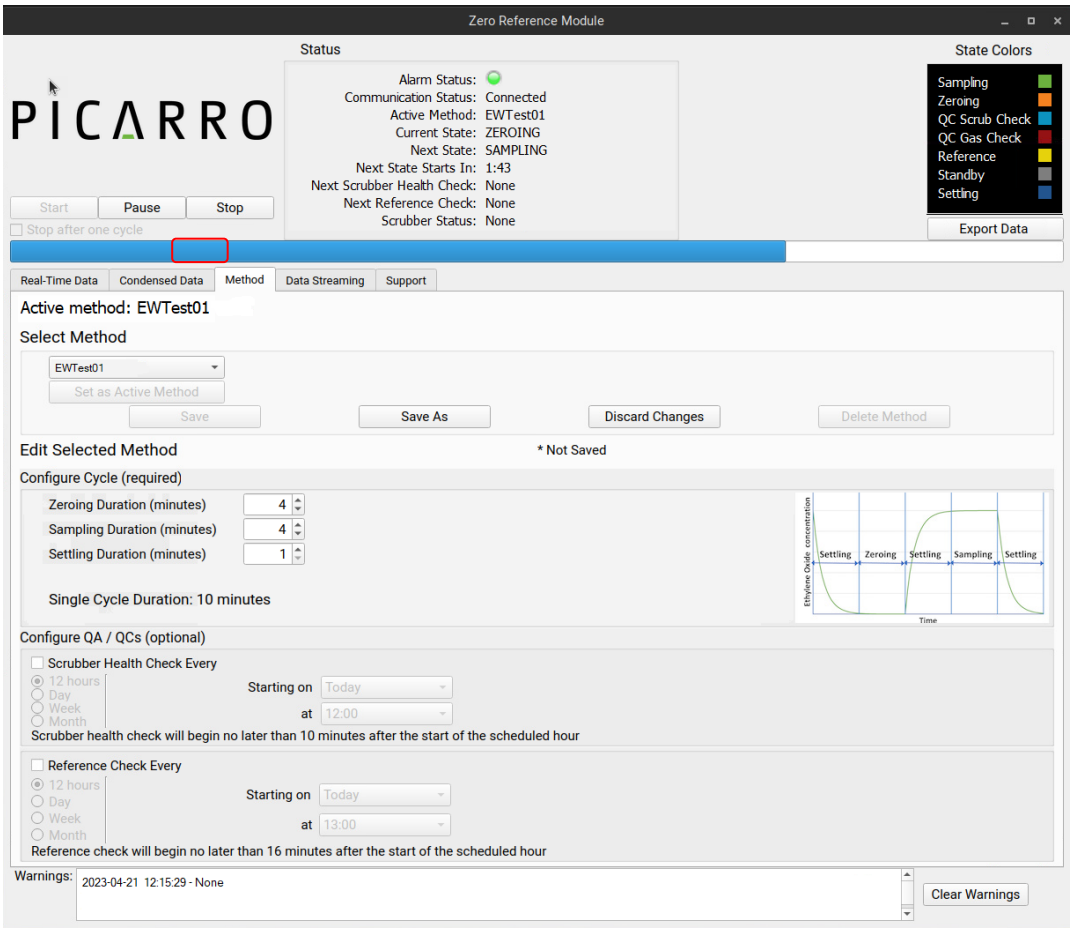


Figure 30: Operational Method Setup and Run

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 31.

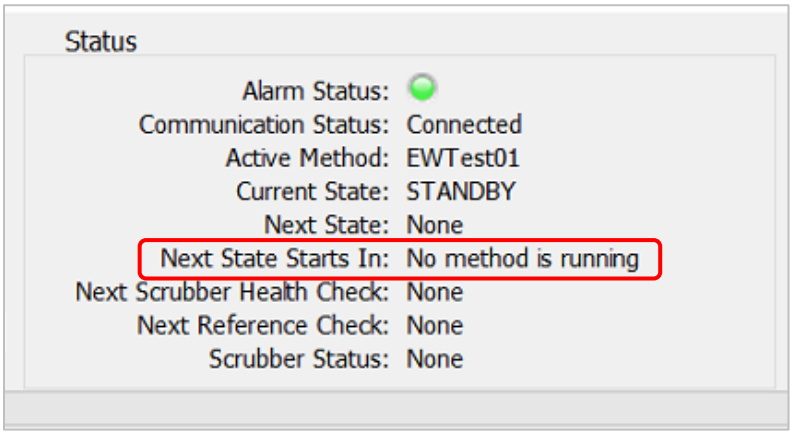


Figure 31: Status with No Method Running

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 32. The Measurement Progress Bar will begin to fill and the Next State Starts In timer will begin counting down until the following state begins.

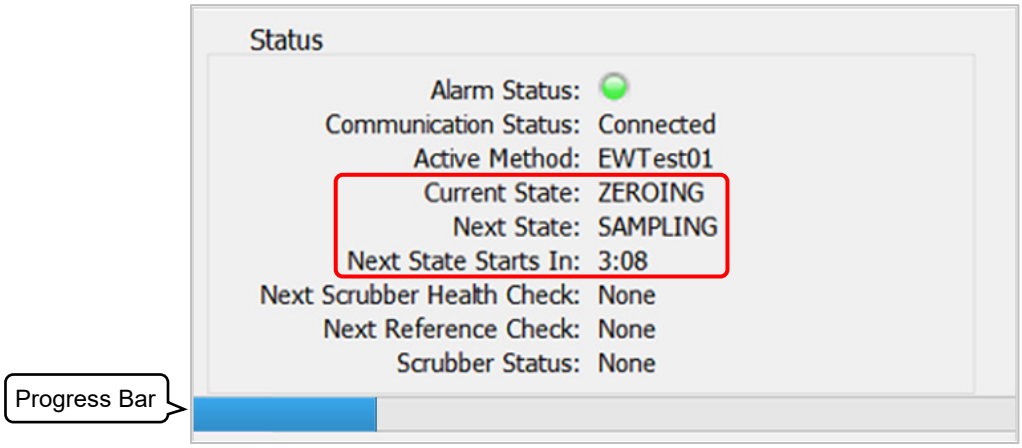


Figure 32: Status Box with System Running Active Method

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 33). 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 33 shows an example of how the Real Time Data tab will look after a few cycles.

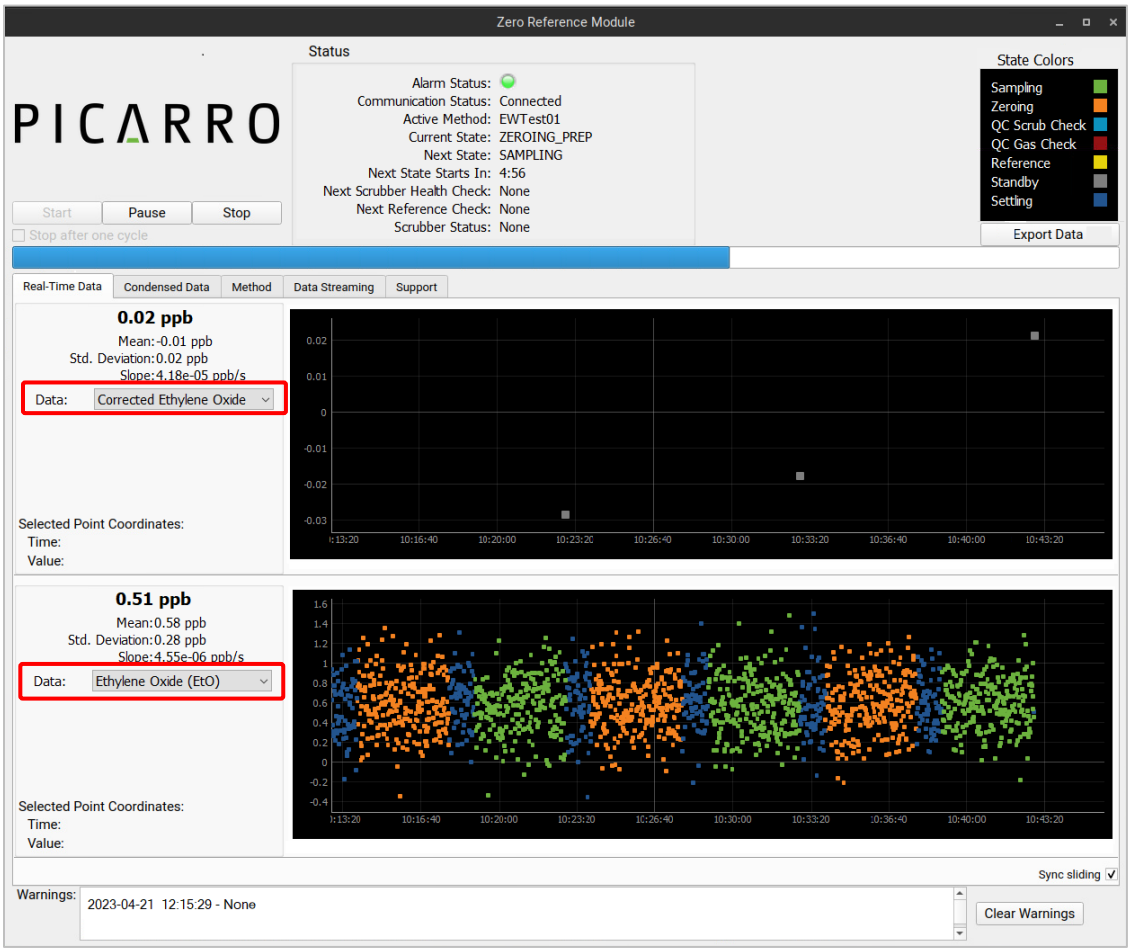


Figure 33: Real Time Data Tab Selected, Showing Corrected EtO

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 34 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.

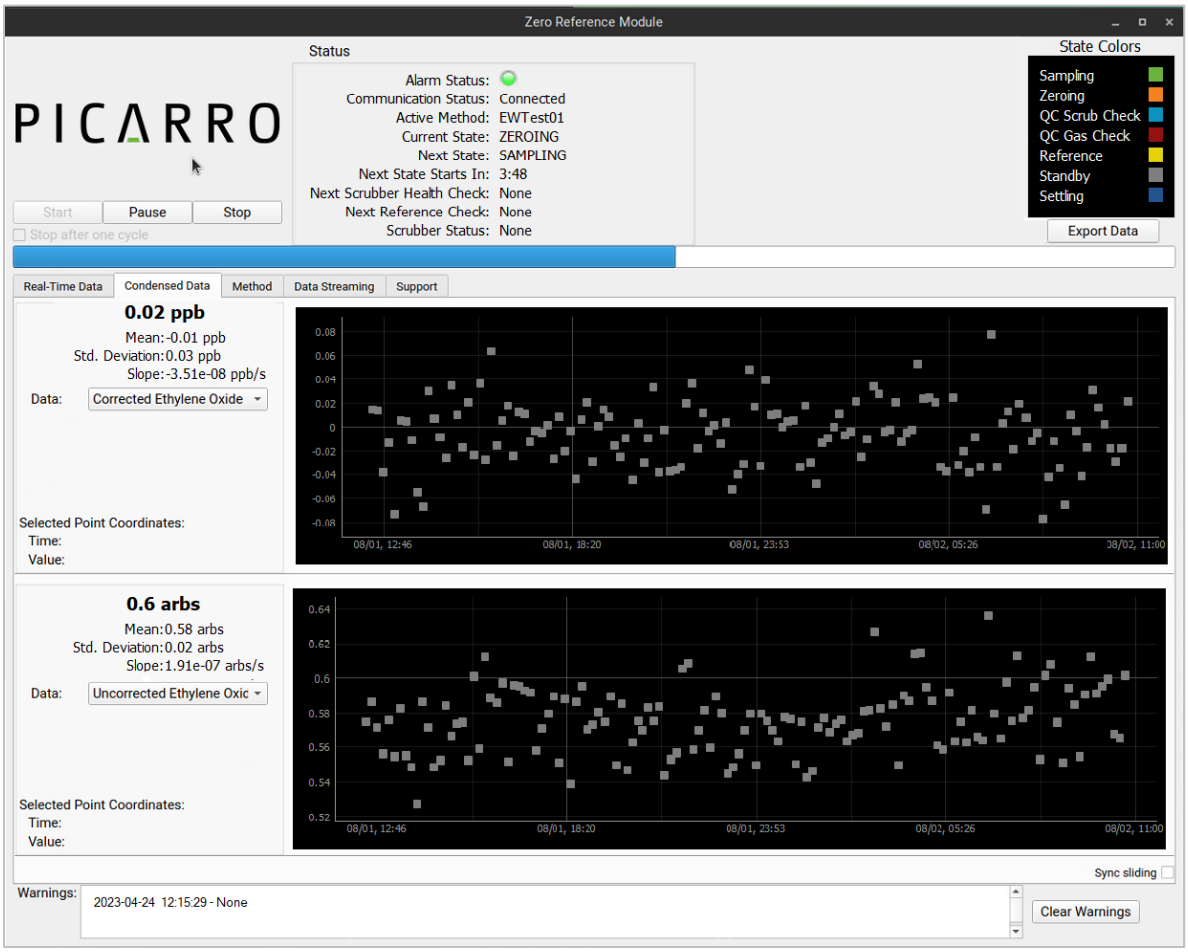


Figure 34: Condensed Data Tab Showing 24 Hours of Data

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 35).

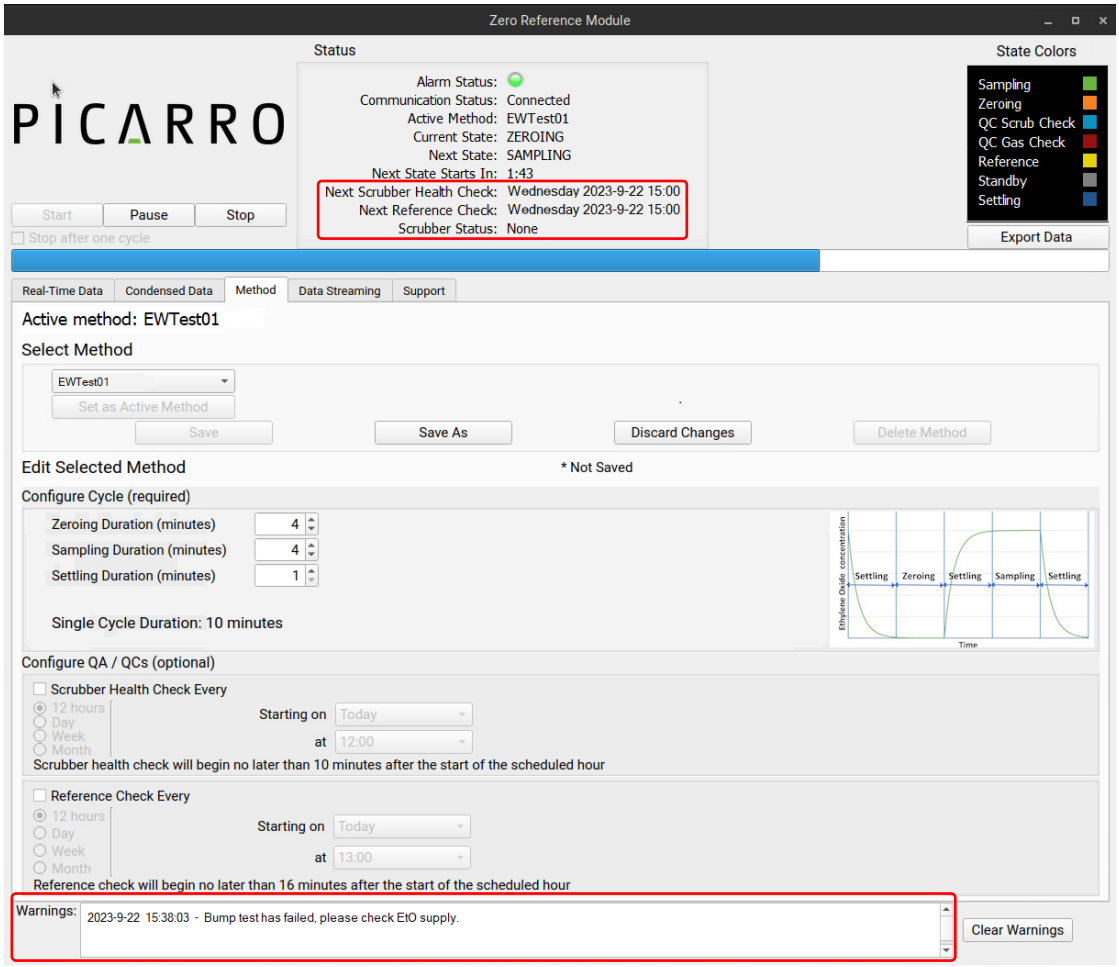


Figure 35: Scrubber Health Check Results

- 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 B.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 5: 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 B –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 36 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.

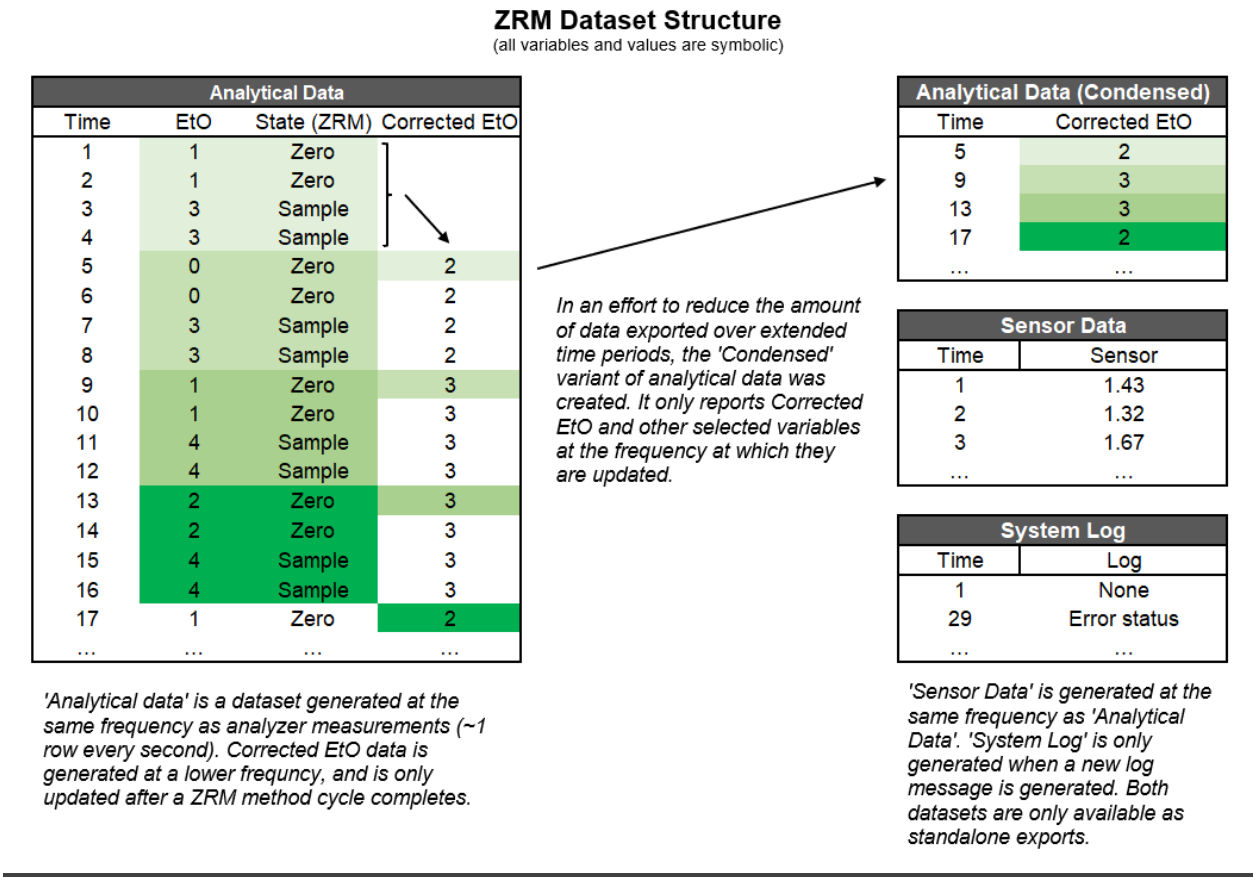


Figure 36: Output Data Format Schematic

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 7 in APPENDIX A –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 7 in APPENDIX A –Data Flow and Output.

Sensor Data includes data from individual ZRM components. For more information about these variables, see Table 8 in APPENDIX A –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 9 in APPENDIX A –Data Flow and Output. For a list of warnings and errors, see Appendix B.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 37 shows a typical sampling shelter setup.

Figure 38 shows a diagram of shelter ZRM/Analyzer elements and connections.

Figure 37: (L) Sampling Shelter (M) Inlet with Inverted Funnel (R) Bulkhead Passthrough

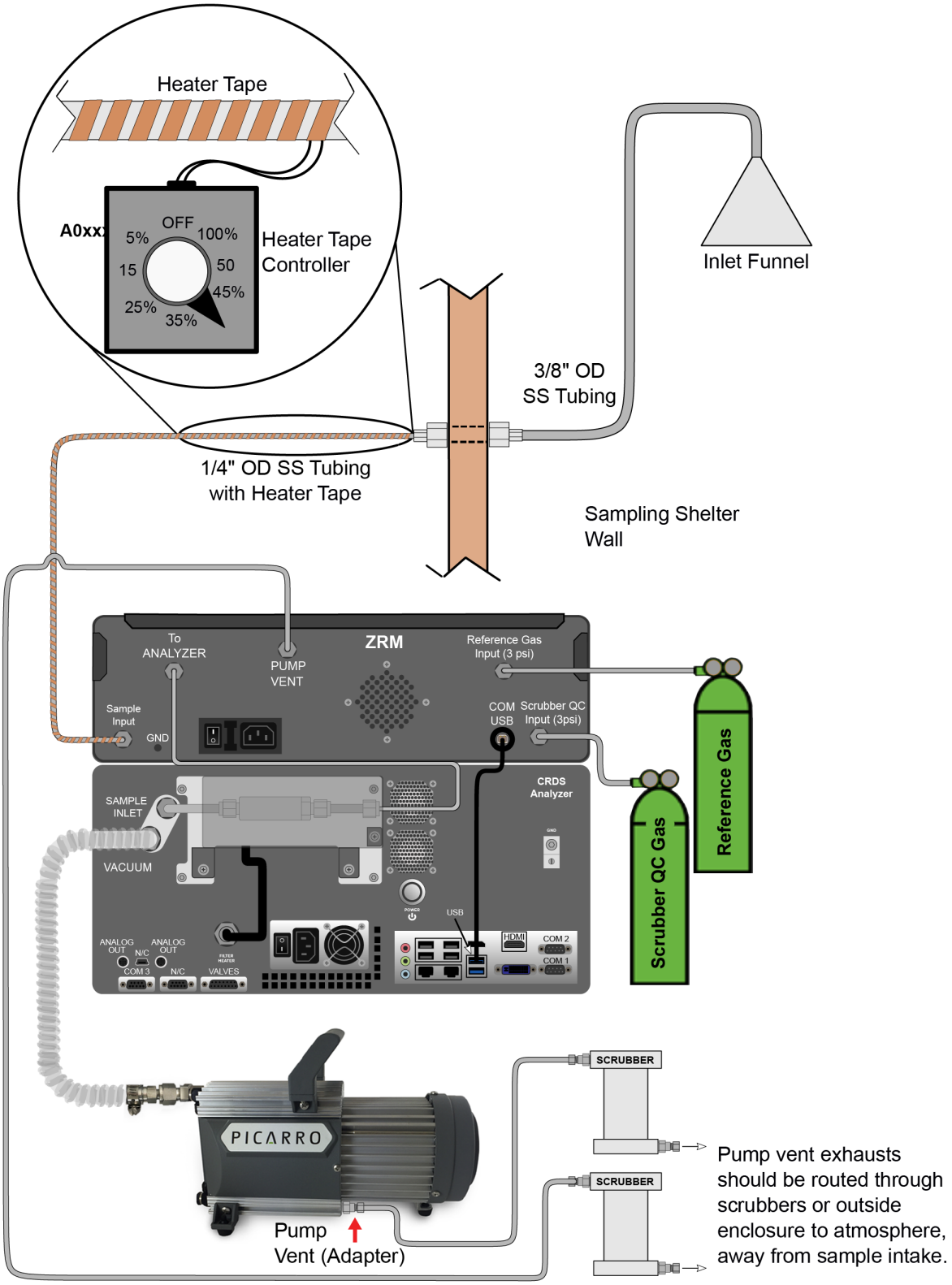


Figure 38: Station Integration Elements

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 37 (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 38) to above the outside dew point. Follow the guidance we provide in APPENDIX D –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 C –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 format is available for serial streaming and REST API access. For an ordered list of variables in the Analytical Data format, see Table 7 in APPENDIX A –Data Flow and Output.

The Analytical Data format includes measurement data from all species measured by the PI2920 and several variables useful for troubleshooting. A commonly useful subset of variables and a further reduced list are shown below in Table 6. The variable, ZRM_Status is especially valuable as it enables the monitoring of system operation (see section 8.3).

Table 6: 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 39). 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.

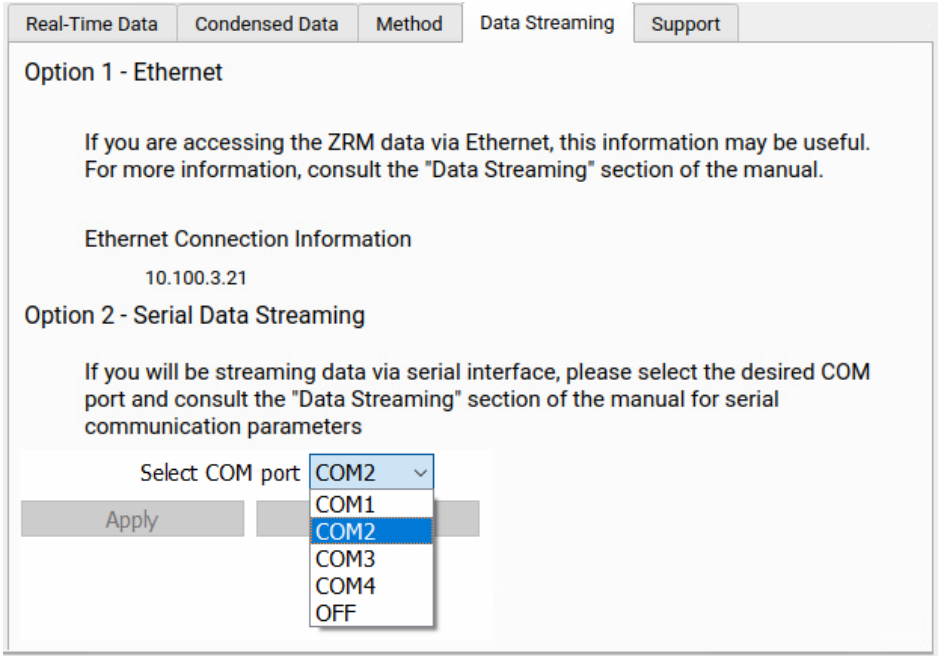


Figure 39: Data Streaming Tab in ZRM User Interface

NOTE

RS-232 cables should be limited to roughly 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 7.

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 40.

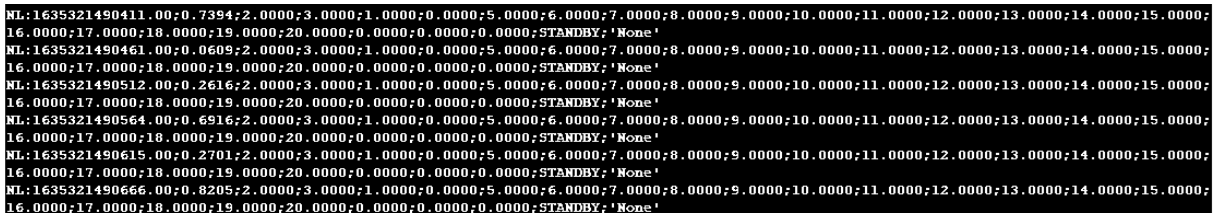


Figure 40: Terminal Session showing streamed ZRM data

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 of data formatted as a 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 40 above).

An example of the csv format used for the REST API is shown in Figure 41.

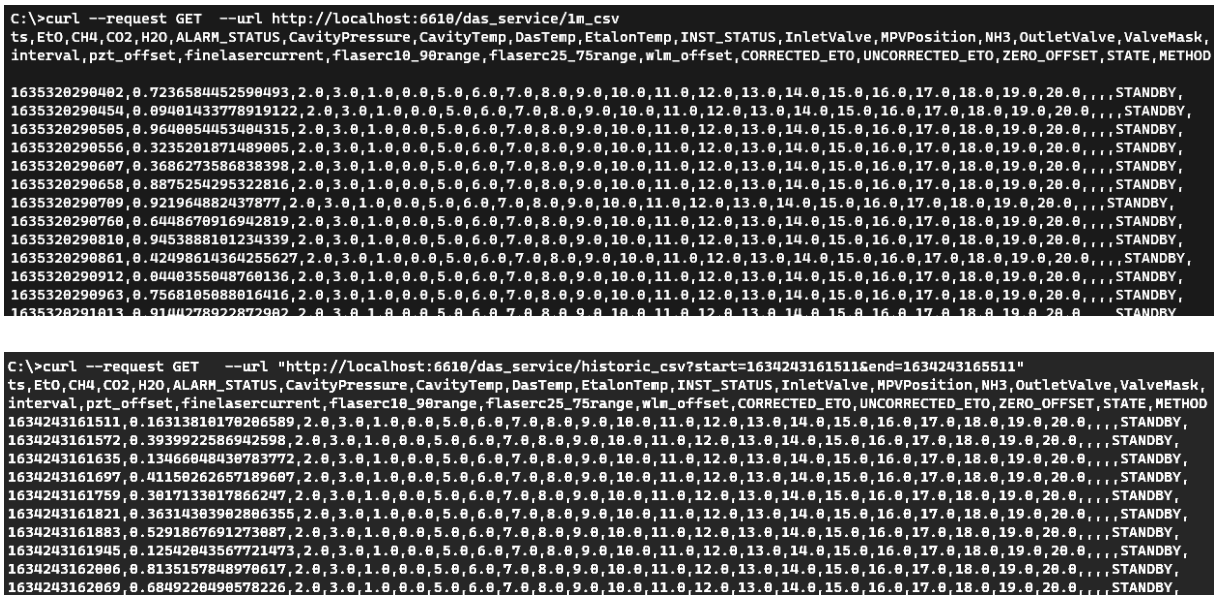
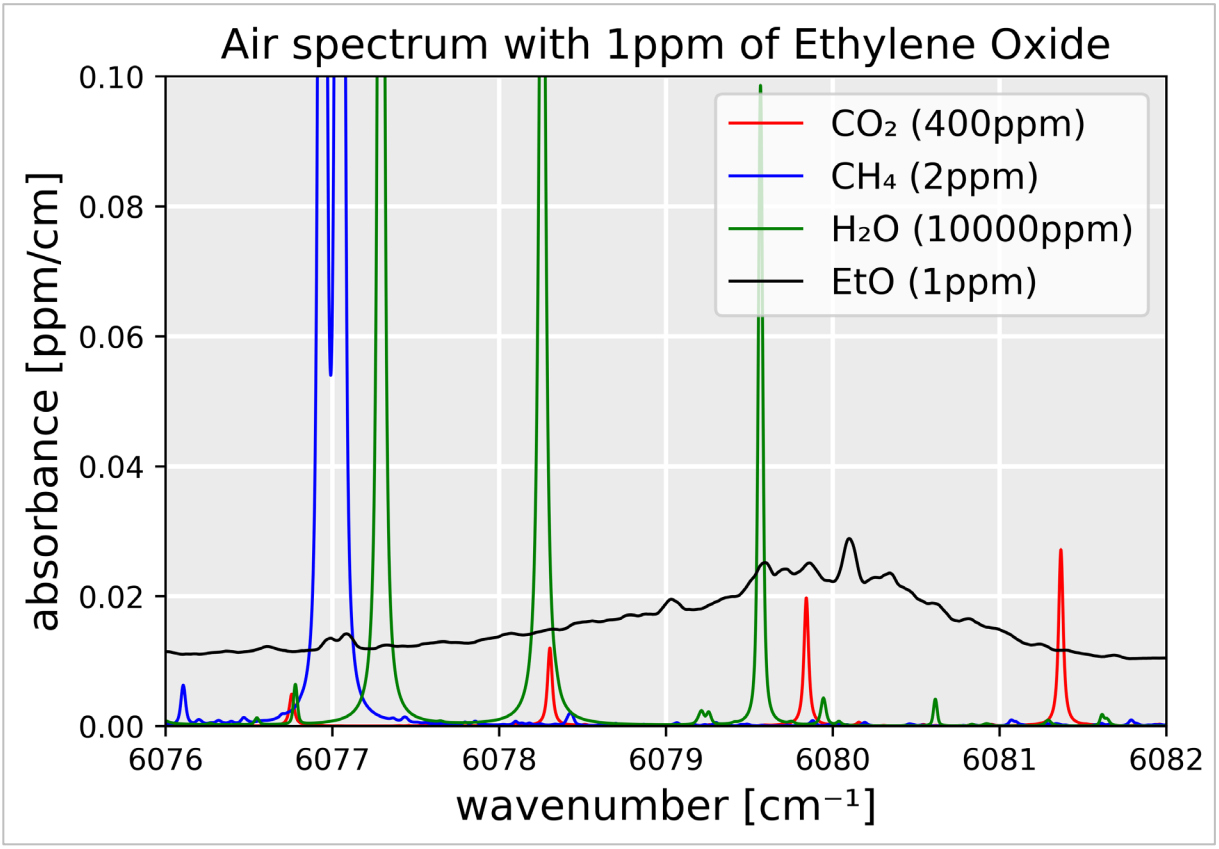


Figure 41: Terminal Sessions with ZRM REST API, Showing Results of Both Query Types

10. Calibration and Gas Standards

10.1 Spectroscopy

Ethylene Oxide is measured in the near infrared region of the spectrum. Figure 42 shows the spectral region that the instrument uses to quantify EtO, H2O, CO2, and CH4. 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, H2O, CO2, and CH4 are reported by the instrument on the user interfaces and the data logs.



EtO spectral region, showing major features for CO2, CH4, and H2O.

Figure 42: 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 PI2920 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 Airgas (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 E –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 B –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, 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 PI2920 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's 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.

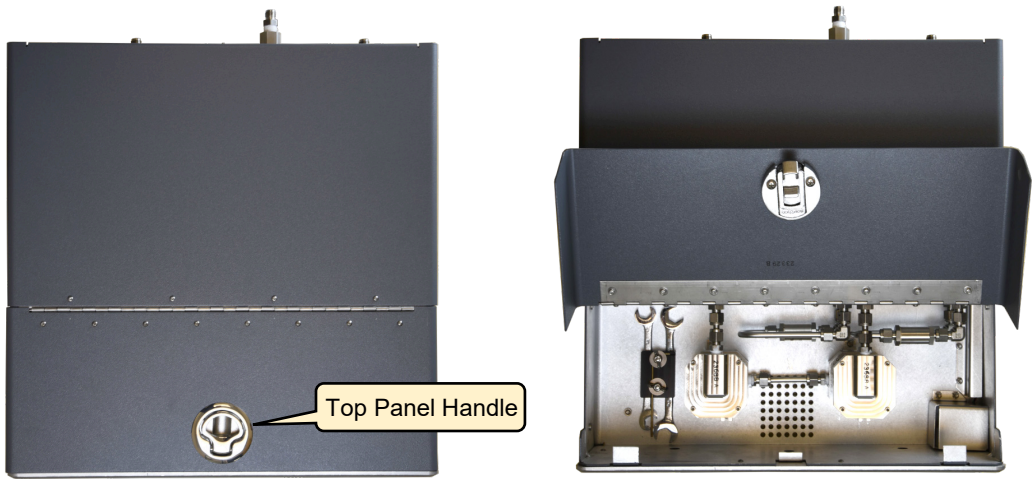


Figure 43: Accessing Scrubber/Filter/Tools Area

2. Using the available 2.5 mm hex wrench, loosen the inner base screw of the scrubber housing but do not remove (Figure 44).

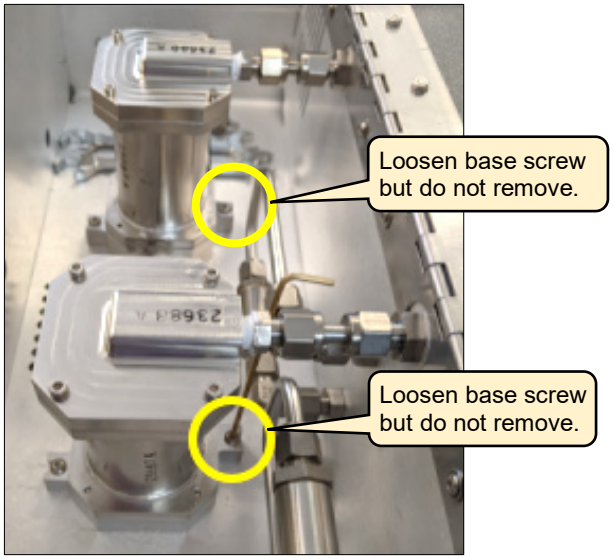


Figure 44: Loosening Scrubber Housing Inner Base Screw

3. Remove the outer base screw of the scrubber housing (Figure 45).

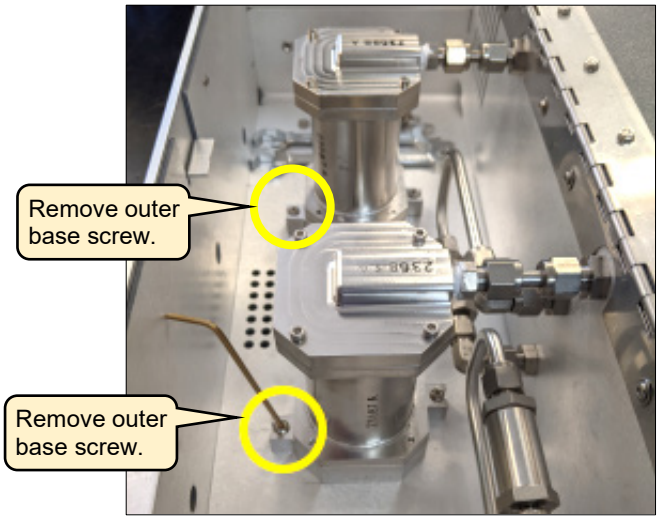


Figure 45: Removing Scrubber Housing Outer Base Screw

4. Unscrew the indicated Swagelok connections (Figure 46) 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.)

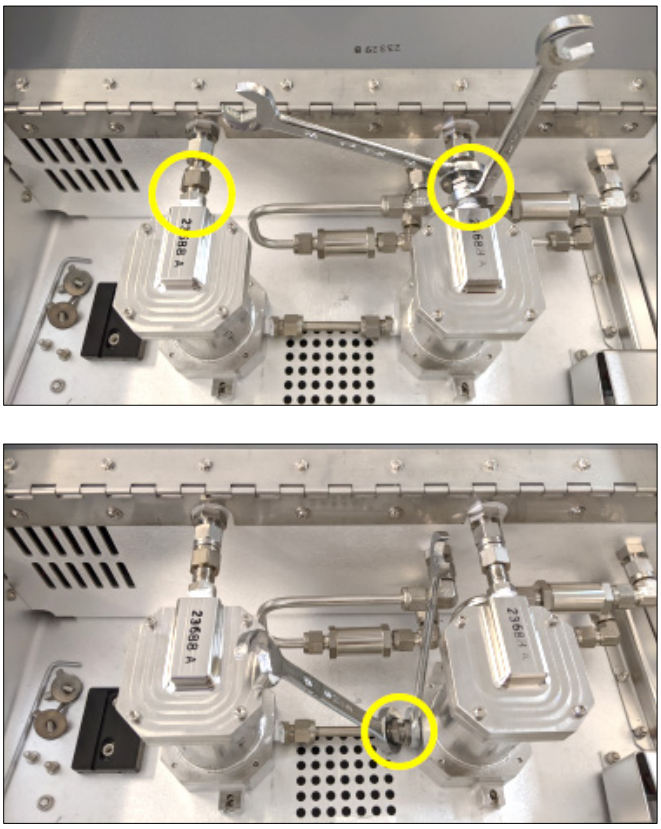


Figure 46: Disconnecting Scrubber Swagelok Fittings

5. Slide the scrubber housing towards the front module.

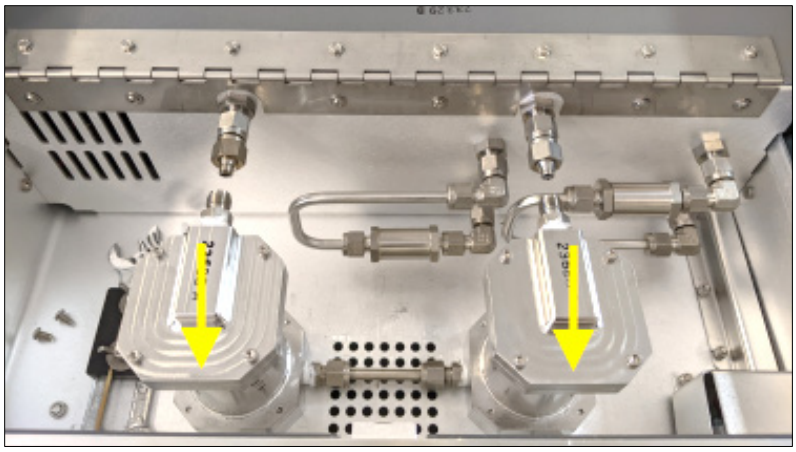


Figure 47: Scrubber Pair Removal

6. Remove the scrubbers.
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.

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

Figure 48: Removing Scrubber Top Cover Screws

2. Carefully remove the top cover. Remove both o-rings (Figure 49).

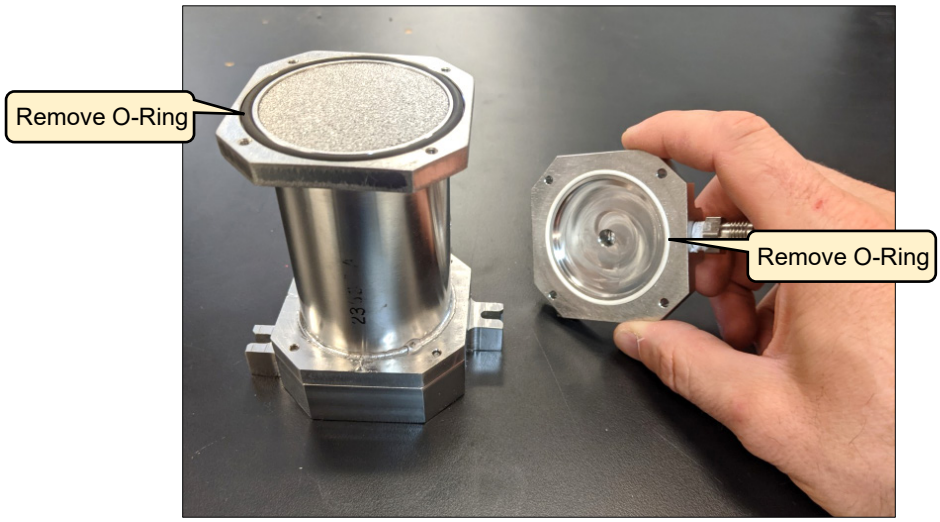


Figure 49: Removing Top Cover and O-rings

3. 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.

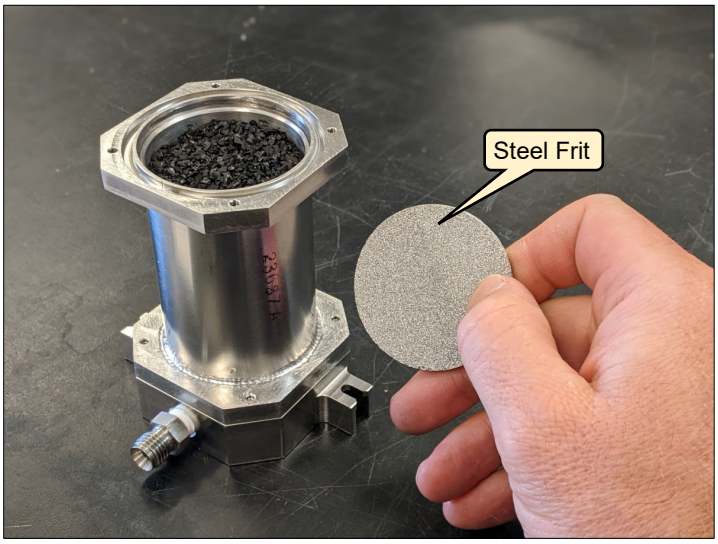


Figure 50: Removing Steel Frit

4. Remove the used scrubbing media and dispose of according to safety guidelines. See APPENDIX E –PAIAC Chemical and Disposal Information for the particular media used for your analyzer and the recommended disposal information.
5. Remove the four screws from the bottom cover as shown (Figure 51).

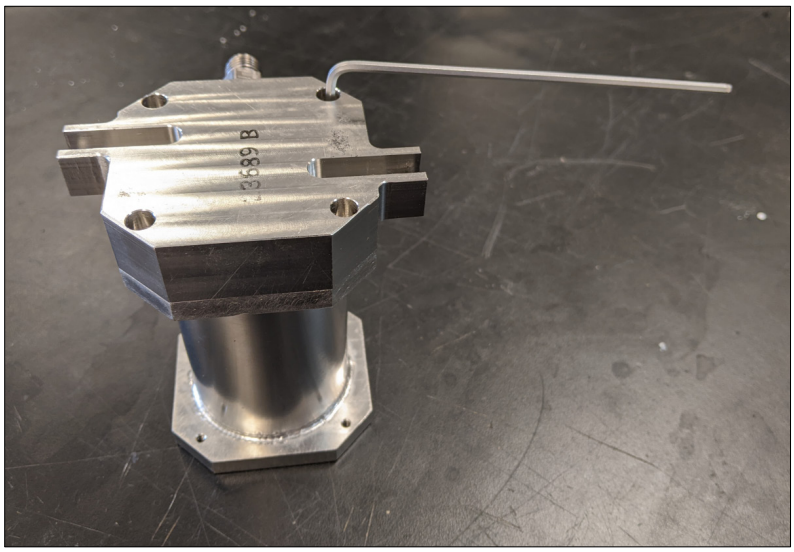


Figure 51: Scrubber Bottom Cover Screw Removal

6. Remove the bottom cover and remove the two O-rings shown (Figure 52).

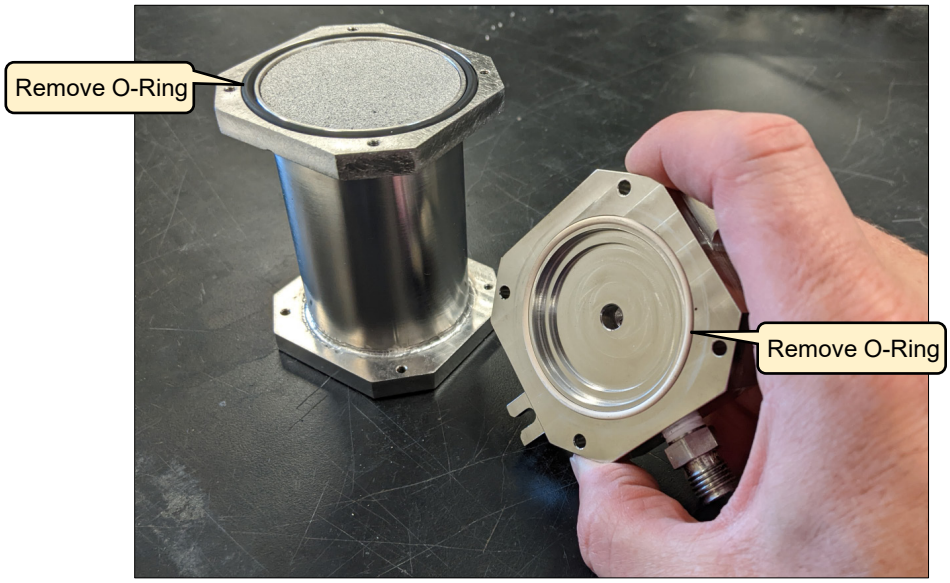


Figure 52: Bottom Cover and O-ring Removal

7. Remove the steel frit as shown in Figure 53 below.

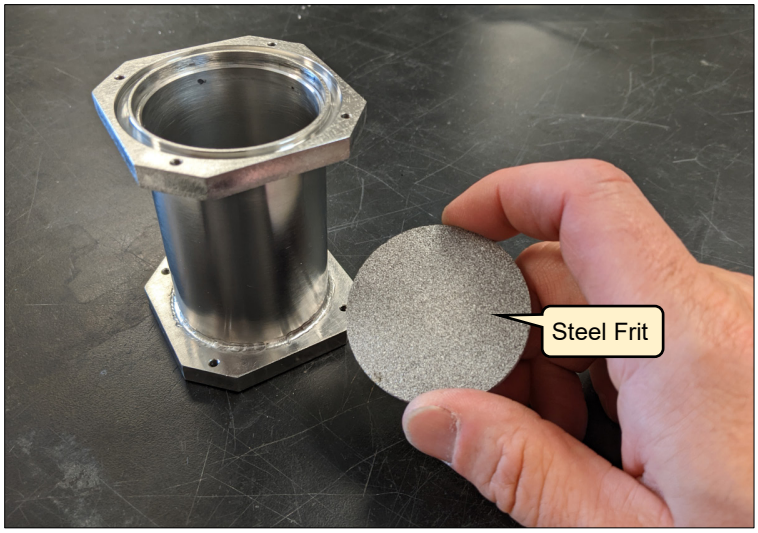


Figure 53: Bottom Frit Removal

8. 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.
9. 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 54).

Figure 54: Replacement of Scrubbing Media

10. 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.
11. Retighten the four screws. The top cover should be flush to the canister housing when the screws are fully tightened.

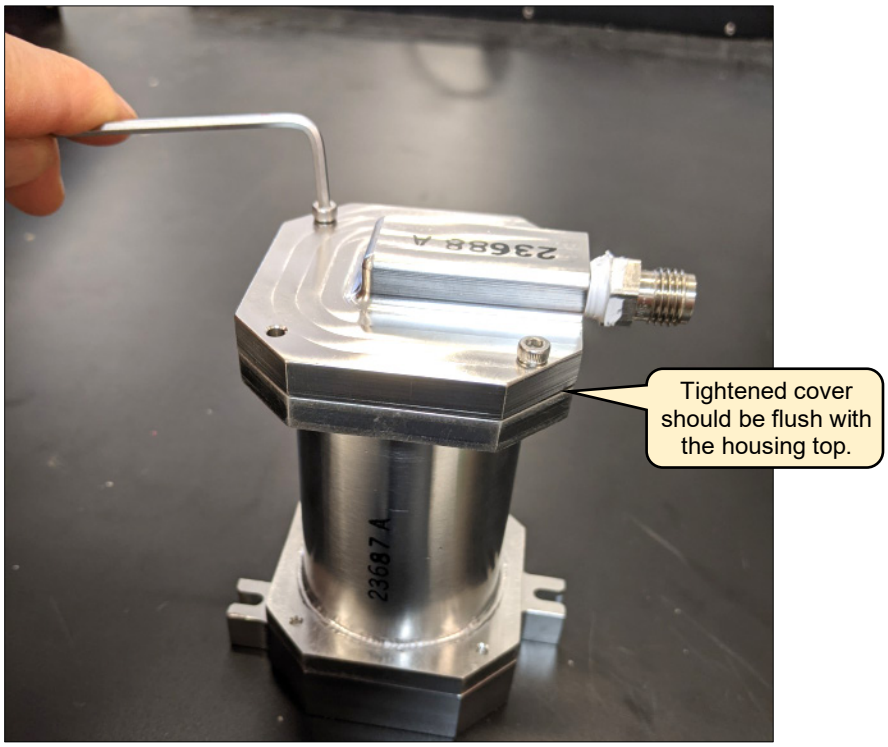


Figure 55: Installing Scrubber Cover Screws

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.

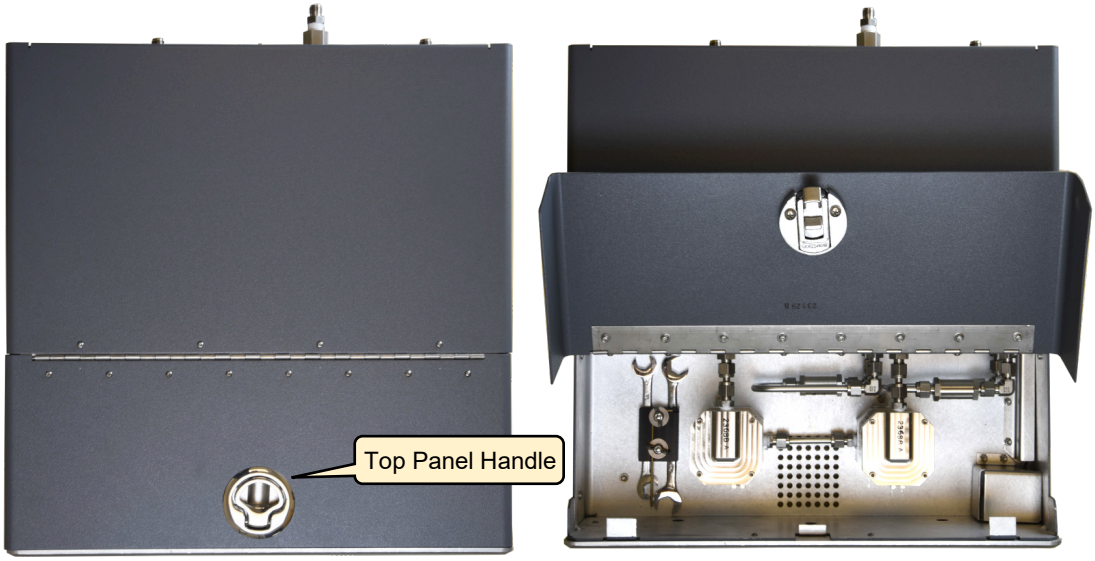


Figure 56: Servicing Area Open

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

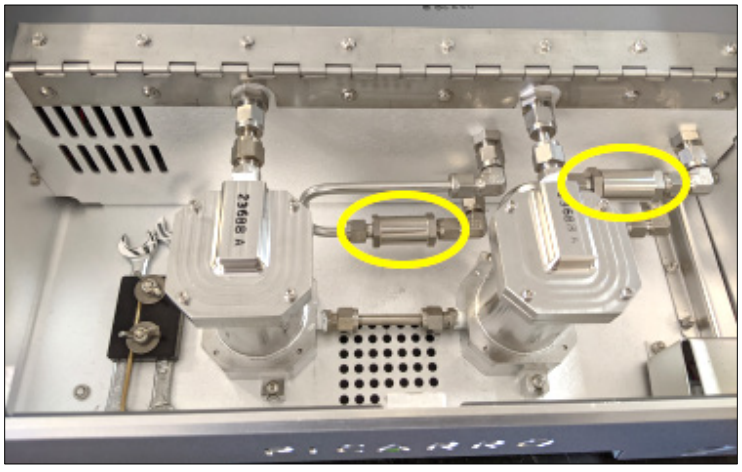


Figure 57: Note Filter Locations Before Removal

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.)

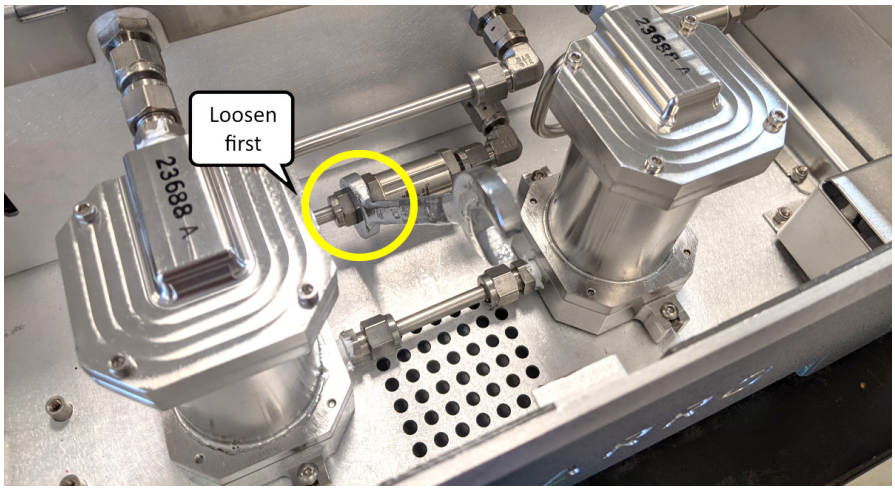


Figure 58: Loosening Filter Swagelok Connections

4. Disconnect the two Swagelok connections shown in Figure 59 and remove the filter along with the formed tubing (Figure 60).

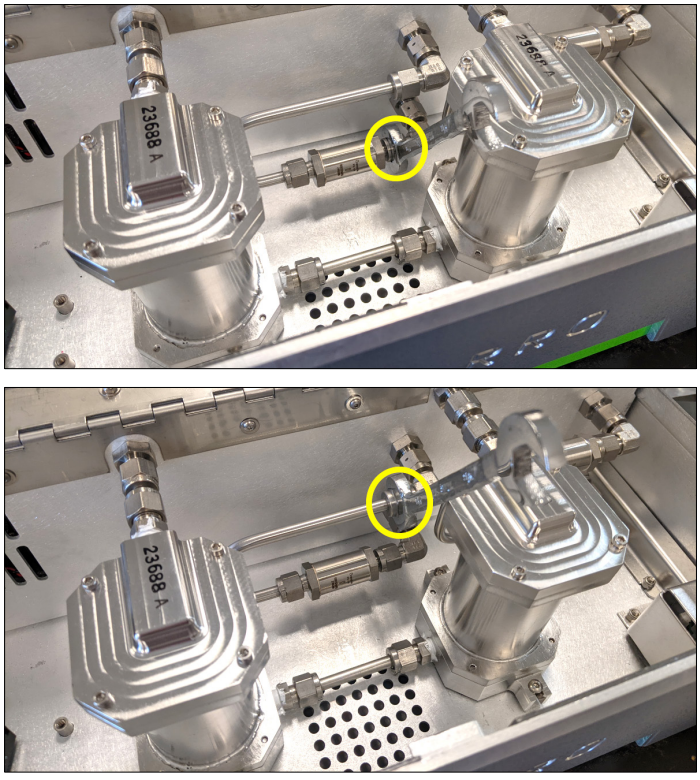


Figure 59: Disconnecting Filter with Attached Formed Tubing

5. Remove the old filter from the formed tubing.

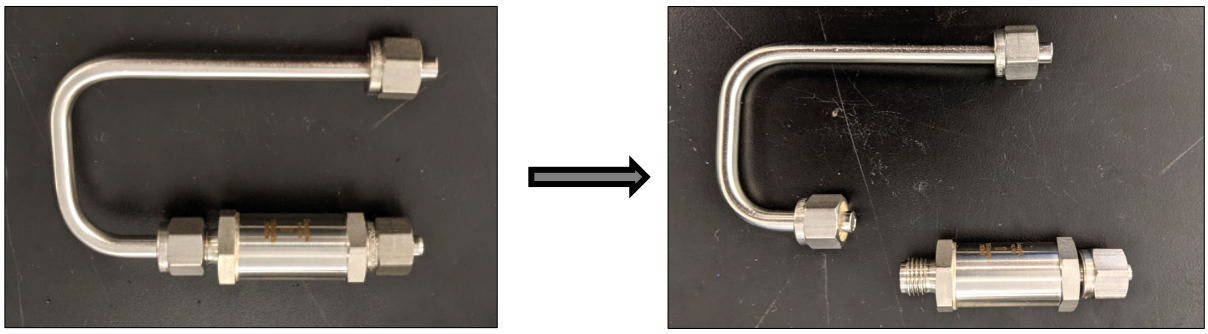


Figure 60: Disconnect Formed Tubing from Filter

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 59. (Recommended Swagelok tightening is 1/4 turn past finger tightened.)
8. Tighten the final Swagelok fitting shown in Figure 61 below.

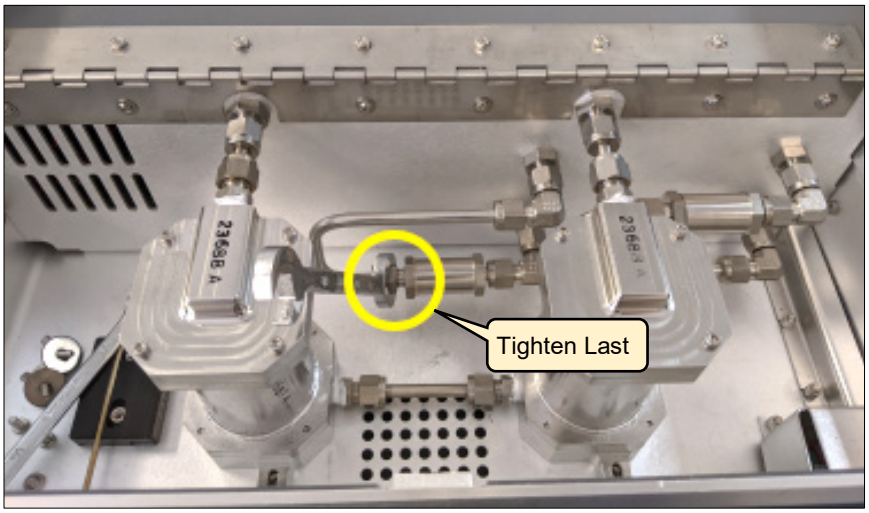


Figure 61: Tightening the Filter Final Fitting

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 62.
3. Connect the PUMP VENT Port to the To ANALYZER port with the tube.

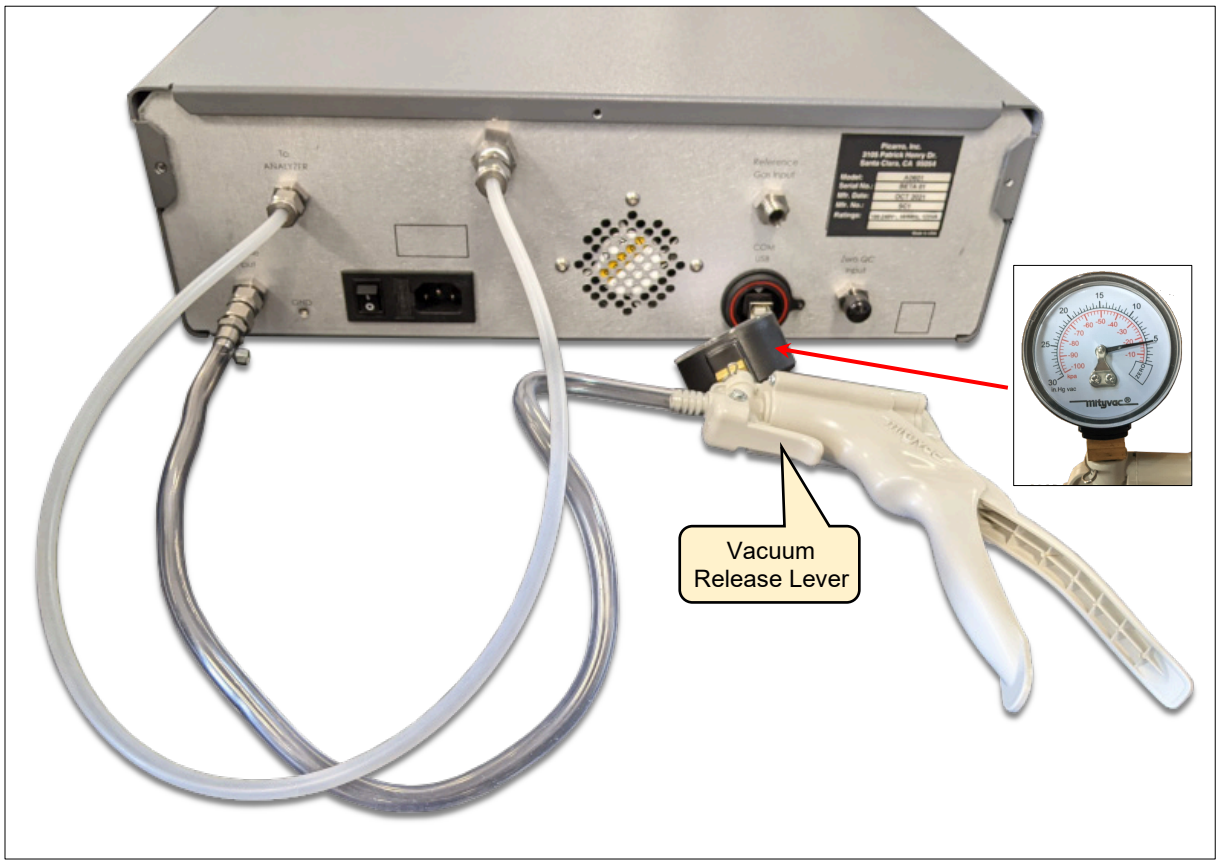


Figure 62: Post-service Leak Check Setup

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 63.
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.

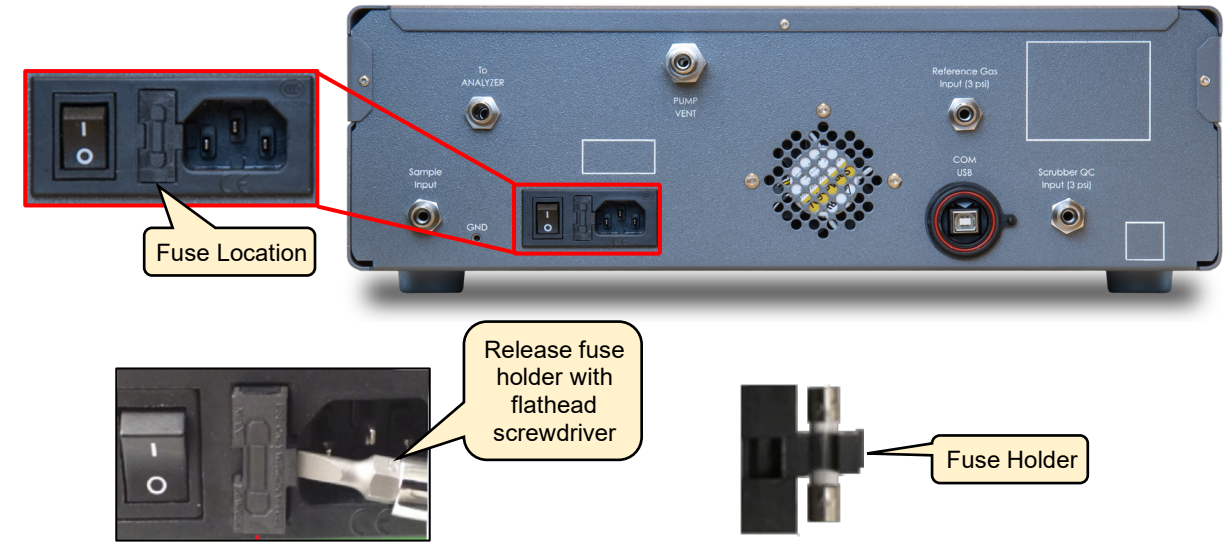


Figure 63: ZRM Fuse Replacement

APPENDIX A – Data Flow and Output

A.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.

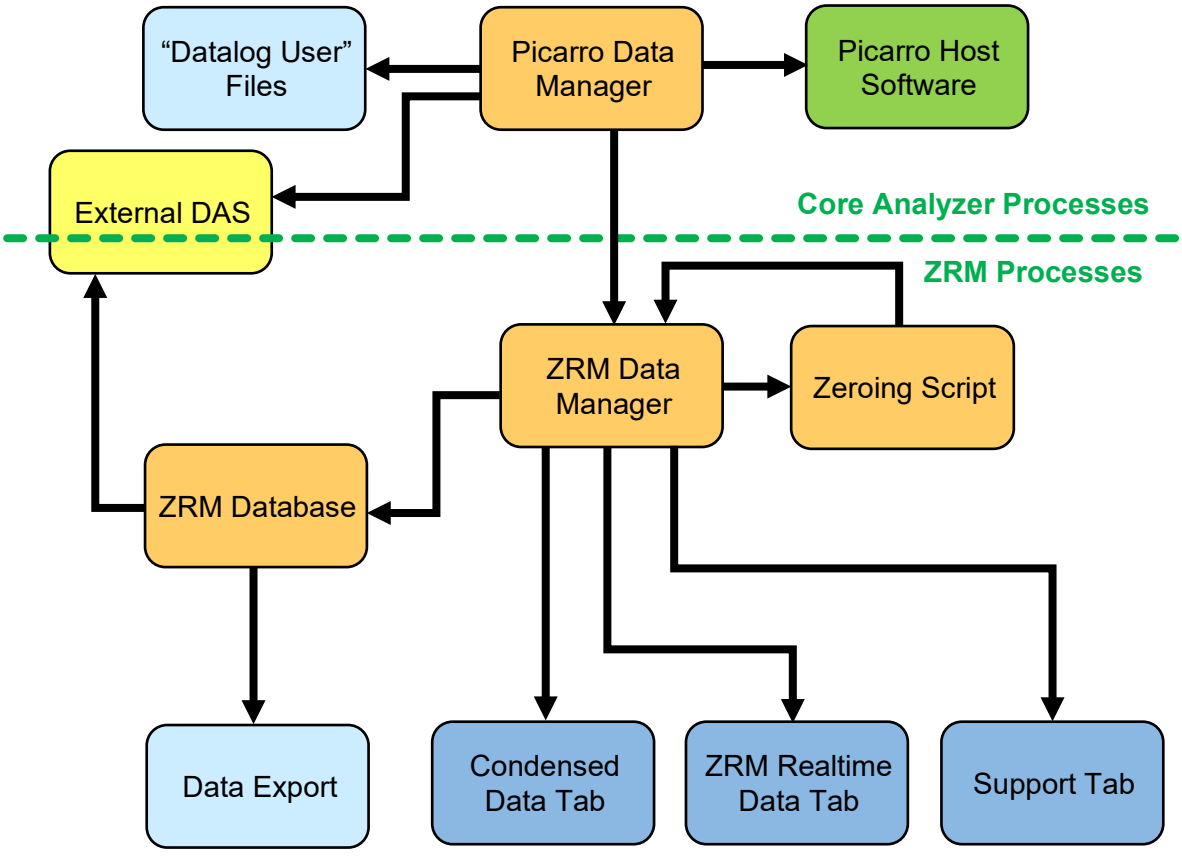


Figure 64: Data Flow Diagram

Raw CRDS data is collected by the Data Manager program. This program sends the raw data to the CRDS Data Viewer 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.

A.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 7: 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 PI2920, 140 for PI2910	x	
CavityTemp	(C), temperature of the measurement cavity, 80C when operational	x	
DasTemp	(C), temperature of the instrument computer board, should be <70°C	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 8: 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

Variable	Description
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 9: 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 9) of Level 40.

APPENDIX B – Errors and Troubleshooting

B.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.

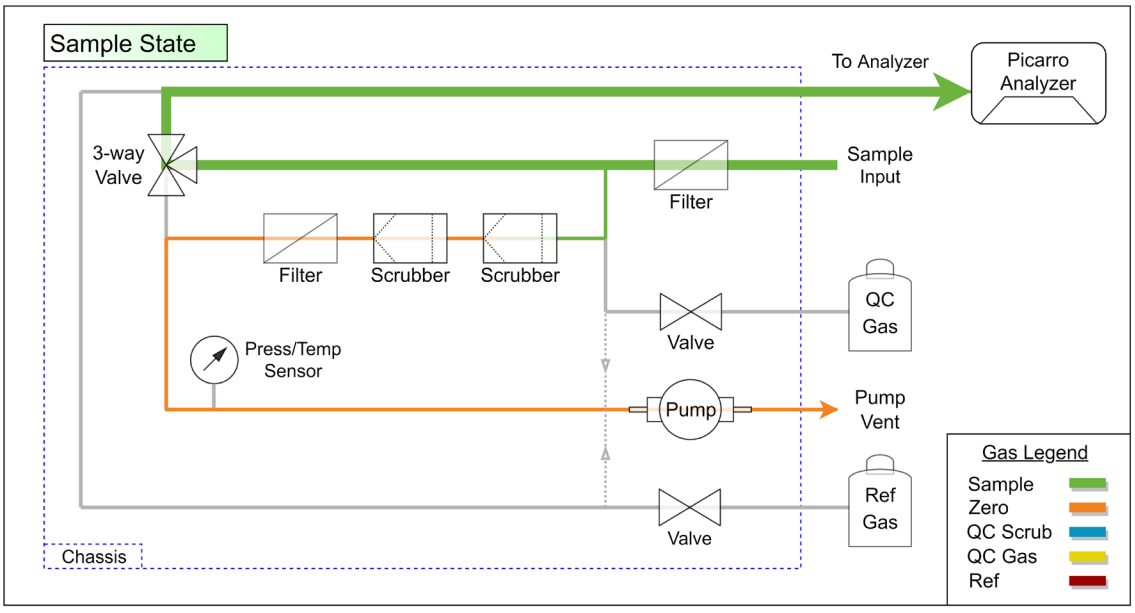


Figure 65: Sample State

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.

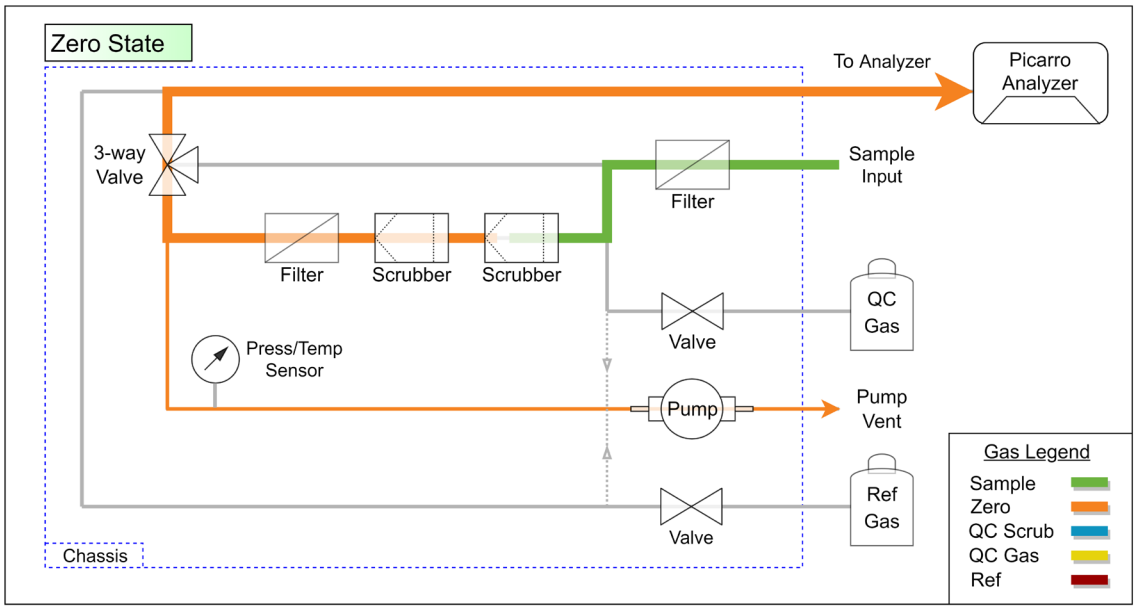


Figure 66: Zero State

Gas concentration measurements taken during the Zero State (ConcZERO) are then used as a baseline for subsequent Sample State measurements (ConcSAMP) yielding a corrected concentration (ConcCORR) via the following equation:

ConcCORR = ConcSAMP – ConcZERO

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.

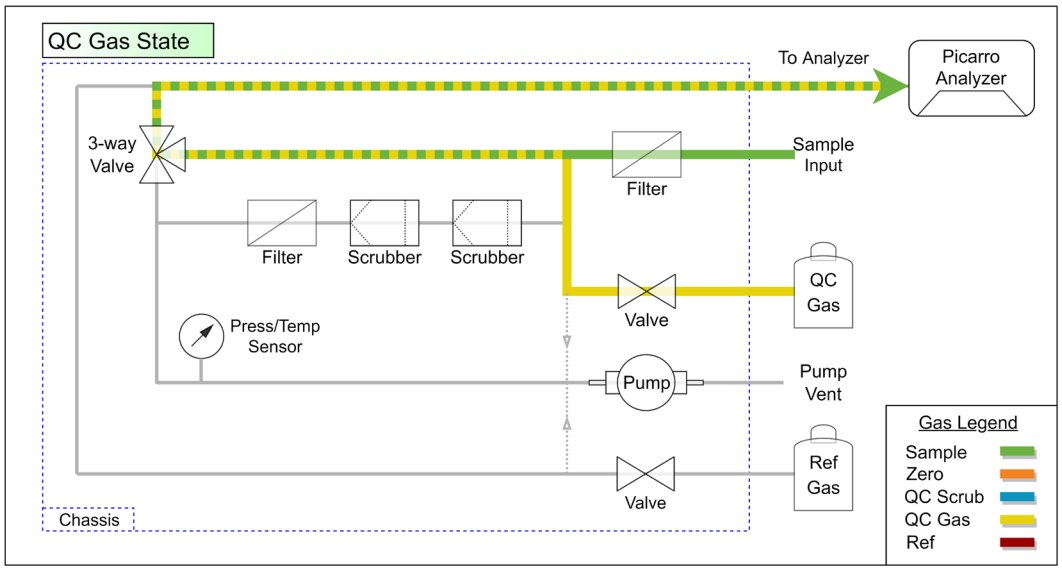


Figure 67: QC Gas State

In order to evaluate the efficiency of the internal scrubber, initial measurements of the average Zero State concentration, ConcZERO, and standard deviation, StdZERO, 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, ConcSCRUB, 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:

| ConcSCRUB - ConcZERO| < 4 X StdZERO

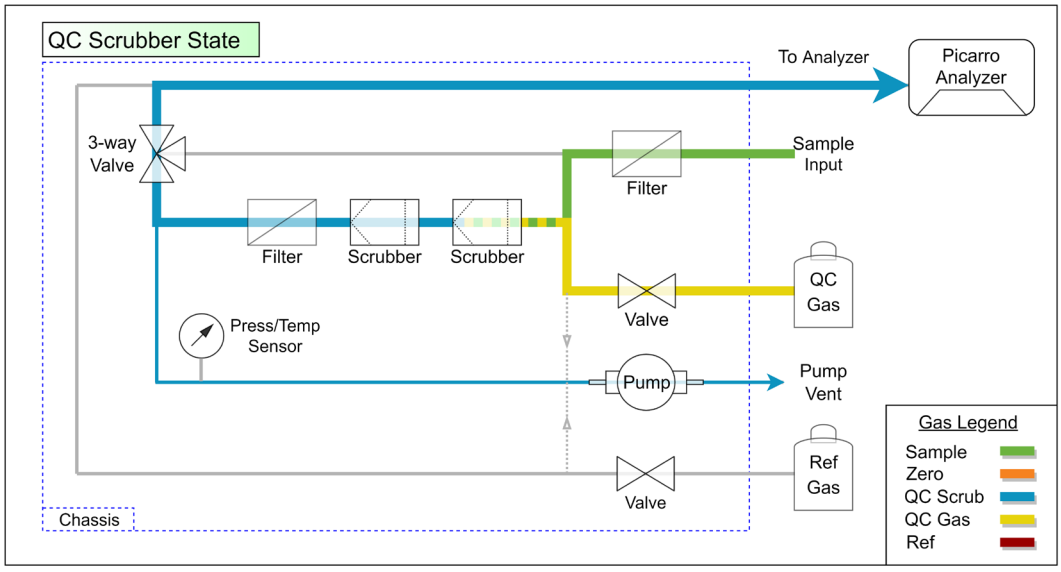


Figure 68: QC Scrubber State

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.

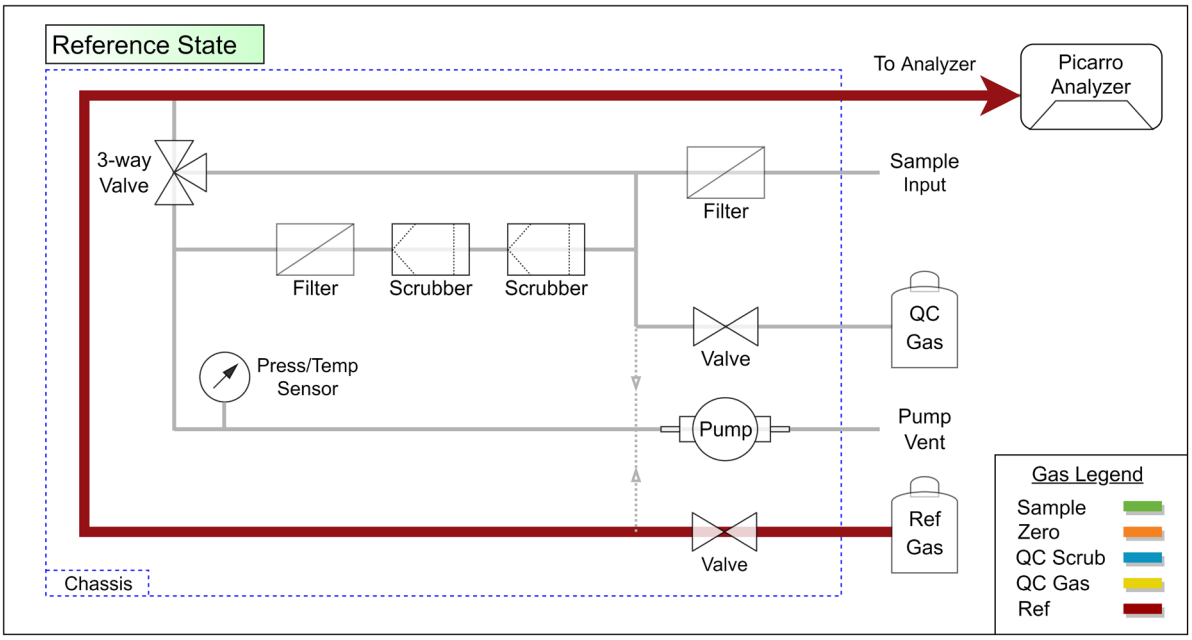


Figure 69: Reference State

B.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.

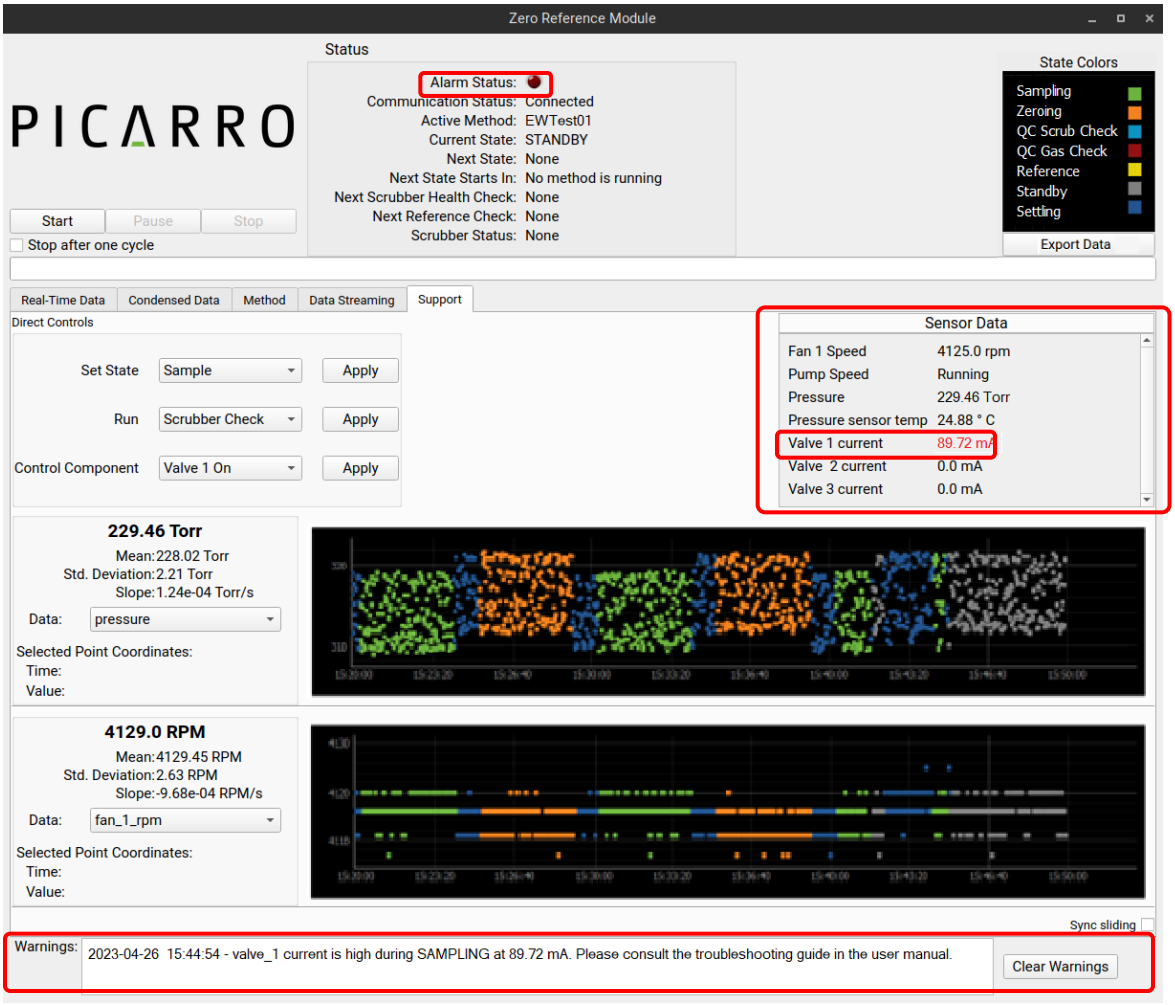


Figure 70: Example Alarm Indications on the ZRM User Interface

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.

B.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:
  - Disconnect the sample line from the “Sample Inlet”.
  - Determine if pressure recovers to an acceptable range.
- External particle filter may be blocked:
  - Disconnect external filter from the “Sample Inlet”.
  - Determine if pressure recovers to an acceptable range.
  - Replace filter if necessary.
- Internal particle filter may be blocked:
  - Replace internal particle filter #1. See section 12.3 for guidance.
  - Determine if pressure recovers to an acceptable range.
  - Replace internal particle filter #2. See section 12.3 for guidance.
  - Determine if pressure recovers to an acceptable range.

B.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:
  - Remove the vent line from ‘PUMP VENT’ port on the back of the ZRM.
  - Determine if pressure recovers to an acceptable range.
- Possible pump issue:
  - If high pressure error coincides with a Pump RPM Error, go to ‘Pump RPM’ troubleshooting section.
- Possible leak:
  - Power down the ZRM and leak check the system. See the Leak check procedure in section 11.5.

B.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.

B.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:
  - 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.

B.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 circuit board.
  - Check that the fan is free from debris that could slow or stop rotation. Clean if necessary.
  - 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:
  - 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.)
  - If fan is plugged into the correct receptacle and still generates RPM errors, replace the fan.

B.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.

B.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.

B.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.

B.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, contact Picarro Technical Support. See section B.14 for Firmware errors associated with communication errors.

B.12 Software System Error

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

- Close the ZRM software window.
- If the ZRM software will not close, shutdown the ZRM from the Picarro Launch Pad by selecting Home, ZRM, and Shutdown ZRM.

- To restart, launch the ZRM software from the Picarro Launch Pad by selecting Home, ZRM, and Start ZRM.

  Verify if any ZRM methods are running. If not, restart the method. If the problem persists, contact Picarro service support.

B.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.

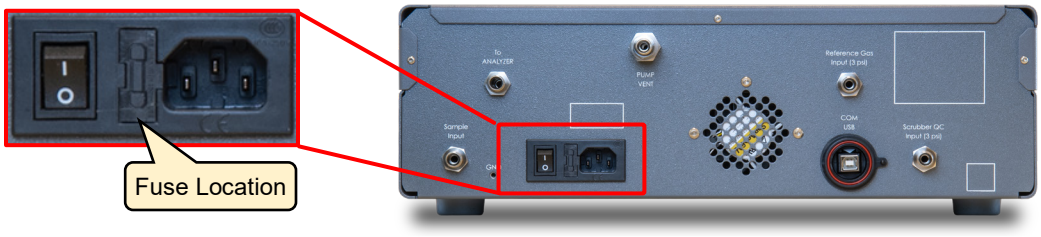


Figure 71: ZRM Fuse Location

B.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 C – 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 PI2910/PI2920 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.

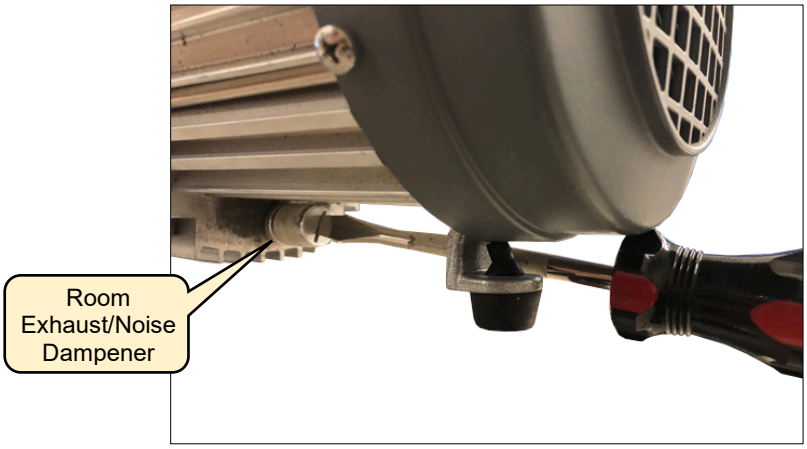


Figure 72: Pump Exhaust/Noise Dampener Removal

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).

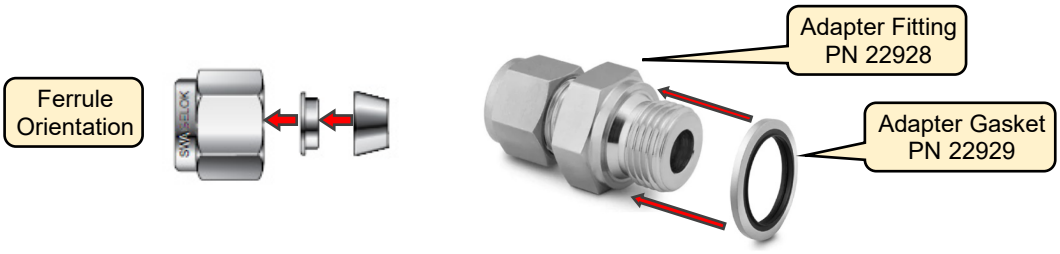


Figure 73: Adapter Assembly

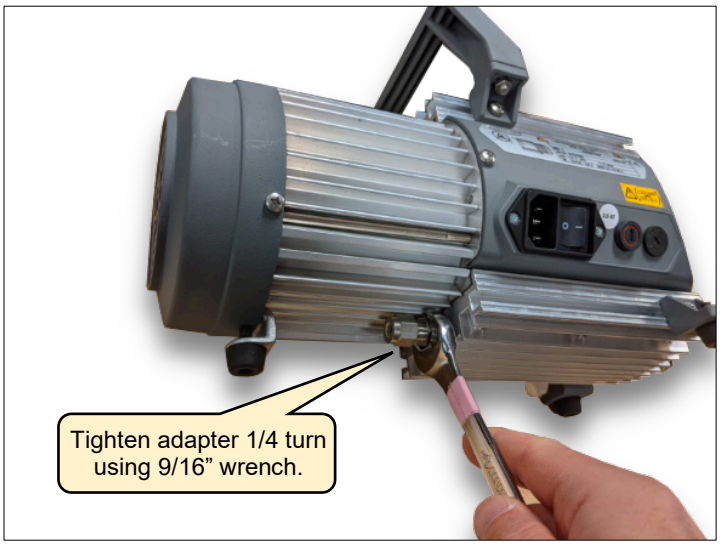


Figure 74: Exhaust Adapter Fitting Installation

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 D – 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.

D.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 38 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 E – PAIAC Chemical and Disposal Information

E.1 Handling PAIAC

Be sure to handle 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 E.3 , SDS Chemical Information for complete hazard information and safe handling details.

E.2 PAIAC Disposal

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

E.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. Use with adequate exhaust ventilation to draw dust away from workers' breathing zones. Keep away from ignition sources. Use in well ventilated areas. Protect containers from physical damage. Avoid prolonged contact with eyes and skin. Prevent or minimize exposures to dusts by using appropriate personal protection equipment Avoid Wash exposed skin areas thoroughly with soap and water after handling.
Storage:	Dry airtight storage recommended. Store in cool, dry, ventilated area and in closed containers. Maintain good housekeeping. Store away from strong oxidizers such as ozone, liquid oxygen, chlorine, permanganate, etc. 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 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 PEL**	**ACGIH 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. 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^{O} C
Auto Ignition Temperature:	> 220^{O} 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

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

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

Air	ICAO / IATA	Proper Shipping Description:	Steam Activated Carbon, Non-Regulated OR Carbon, Activated, Non-Regulated
		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 (40CFR122.21 and 40CFR122.42):	Activated carbon does not contain any substances regulated as pollutants.
Clean Air Act (CAA, Section112, 40CFR82):	Activated carbon does not contain any components listed as 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 (40CFR355):	This product is not listed as an extremely hazardous substance.
SECTION 313- List of Toxic Chemicals:	This product is not listed.

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 found on the following regulatory lists:	US EPA High Production Volume Program Chemical List 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

SECTION XVI

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 F – Swagelok Instructions

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

Installation
Straight Fittings
Elbows and Tees
Adapters
Parts
Accessories

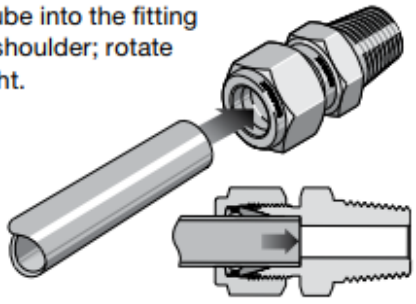
Swagelok Tube Fittings

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.

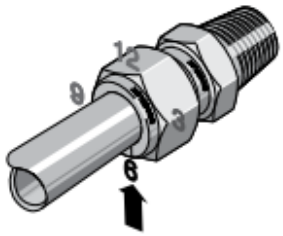
For 5/8, 3/4, 7/8 and 1 in.; 16, 18, 20, 22 and 25 mm tube fittings, in all materials except for aluminum and brass, it is a best practice to preswage the ferrules onto the tube adapter using a Swagelok multihead hydraulic swaging unit (MHSU) to lower installation time and increase ease of installation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

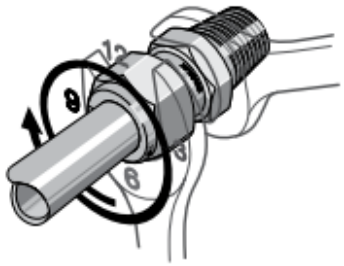


High-pressure applications and high safety-factor systems: *Further tighten the nut until the tube will not turn by hand or move axially in the fitting.*

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.