PICARRO

G2910/G2920
Ethylene Oxide Concentration Analyzer
User Manual

Picarro G2910/G2920 User Manual

Thank you for purchasing a Picarro product. Your Picarro system is a quality product that has been designed and manufactured to provide reliable performance.

This User Manual (UM) is an important part of your purchase as it will help familiarize you with the system and explain the numerous features that have been designed into it. Please read this manual thoroughly before using your Picarro system.

Please contact Picarro or your authorized Picarro distributor should you have questions regarding specific applications or if you require additional information.

NOTICES

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.

Windows® is a trademark of Microsoft Corporation

Swagelok® is a trademark of Swagelok Company

FCC WARNING

This equipment has been tested and found to comply with the limits of a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

CE MARK WARNING

This is a Class A product. In a domestic environment, this product may cause radio interference, in which case the user may be required to take adequate measures.

CANADA ICES WARNING

This product complies with **CAN ICES-3 (A)/NMB-3(A)**

PICARRO

Contact Information

Please contact Picarro for questions regarding specific applications and additional information.

General Technical Support:

      Email: support@picarro.com

      Phone: + 1 408 962 3991

European Technical Support:

      Email: support@picarro.com

      Phone: +31 85 888 1650

Customer Service:

      Email: orders@picarro.com

      Phone: + 1 408 962 3992

Table of Contents

List of Figures

List of Tables

1. Introduction

The G2910 and G2920 analyzers are designed to measure concentrations of ethylene oxide (EtO) gas. The G2910 has been configured for measurements near the source of emission and can accommodate a broad measurement range of EtO in a complex air matrix. The G2920 has been configured for improved sensitivity and can accommodate measurements of EtO further away from the source of emission (e.g. at the fenceline). A such, the specifications for the G2910 and G2920 are different. However, the setup, method of use, and data logging are virtually identical.

This manual is written for operators, service technicians and maintenance technicians who install, operate, and maintain the G2910 or G2920 analyzer.

For calibration, repairs, or service other than user maintenance detailed in this manual, contact Picarro Service Engineering or your local Picarro-authorized and certified technicians.

NOTE

It is not possible to transition from a G2910 analyzer to a G2920, and vice versa. The final configuration is performed during production.

1.1 Intended Use

The G2910/G2920 Ethylene Oxide Analyzer measures concentrations of ethylene oxide (C_2H_4O) gas using Picarro's patented Cavity Ring-Down Spectroscopy (CRDS). Picarro's CRDS enables state of the art lower limits of detection, exceptionally low drift, all in an easy to use and deploy system. It is an ideal tool for background, near-source and source monitoring of EtO from a variety of emission sources.

Zero drift corrections using ultra-high purity gases or cartridges are not required to meet instrument specifications. Additionally, carbon dioxide (CO_2), methane (CH_4), and water vapor (H_2O) can be measured.

This analyzer can be deployed in a lab or in the field, allowing in-situ analysis for trace EtO or ambient EtO monitoring applications.

1.2   External Vacuum Pump

The external vacuum pump (Figure 1) is used to maintain cavity pressure inside the analyzer. The pump should be connected and running whenever the analyzer is in use.

Figure 1: Vacuum Pump – Side Views

1.3   Analyzer Specifications

Table 1: G2910/G2920 Operating Specifications

Parameter	Specification
Measurement Technique	Cavity Ring-Down Spectroscopy (CRDS)
Measurement Cell Temperature and Pressure Control	±0.005 °C (±.009 °F); ±0.0002 atm. (±0.0203 kPa)
G2910 Sample Temperature	−10 °C to 80 °C (14 °F to 176 °F)
G2920 Sample Temperature	−10 °C to 80 °C (14 °F to 113 °F)
G2910 Sample Flow Rate and Pressure	~ 200 sccm at 760 Torr (101.4 kPa), 300 to 1000 Torr (40 to 133 kPa)
G2920 Sample Flow Rate and Pressure	~ 200 sccm at 760 Torr (101.4 kPa), 600 to 1000 Torr (40 to 133 kPa)
Sample Humidity	< 99% RH non-condensing at 40 °C (104 °F), no drying required
Ambient Temperature Range	Operating: 10 °C to 35 °C (50 °F to 95 °F) Storage: −10 °C to 50 °C (14 °F to 122 °F)
Ambient Humidity	< 85% RH non-condensing

Parameter	Specification
Maximum Altitude (During operation)	3,048 m (10,000 ft.)
Clearance	Front: 15.3 cm (6"); Rear: 15.3 cm (6")
Primary Gas Measured	C_2H_4O Ethylene Oxide (EtO)
Other Gases Measured	CO_2, CH_4 and H_2O
Accessories	Included: Pump (external), keyboard, mouse Required: LCD monitor (Supplied by Customer) Optional: A0311 or A0311-S 16-port Distribution Manifold
Operating System and Data Outputs	Windows 10 RS–232, Ethernet, USB, Data Streaming; Optional Analog 0–10 VDC
Fittings	6.35 mm (¼") Swagelok SST fittings
Dimensions	Analyzer: 43.2 cm W x 17.9 H x 44.6 D (17" x 7" x 17.5") not including analyzer feet 12.7 mm height (0.5") External Pump: (19 x 10.2 x 28 cm) (7.5" x 4" x 11")
Installation	Benchtop or 48.3 cm (19") rack mount chassis
Weight	Analyzer: 21.3 kg (47.0 lbs) External Pump: 6.5 kg (14.3 lbs)
Power Requirements	100 – 240 VAC; 47 – 63 Hz (auto-sensing) < 375 W (at start-up – total) 120 W (steady-state operation: analyzer) 150 W (pump)
Liquid Ingress Protection	None

2. Conventions

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 other important information.

Table 2: Warning/Information Icons

Icon	Description
⚠	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.
WARNING	**LASER WARNING** alerts you of a laser danger.
CAUTION	**CAUTION** alerts user of a potential danger to equipment or to the user.
WARNING	**WARNING** indicates an imminent danger to the user.
WARNING	**HAZARDOUS VOLTAGE** alerts user to areas that may expose a user to electrical energy that is high enough to cause injury or death.
CAUTION	**HOT SURFACE** alerts user to potential injury from hot surfaces.
REMINDER	R**EMINDER** is a helpful hint for procedures listed in the text.

3. Safety

3.1 General Safety

The Picarro G2910/G2920 complies with the following safety standards:

- **CE:** IEC EN61010-1:2010 (safety) and EN61326-1:2013 (EMC) requirements for electrical equipment for measurement, control, and laboratory use.

- **FDA/CDRH 21:** CFR Parts 1040.10-11

WARNING

Using this analyzer in a manner not specified by Picarro may result in damage to the analyzer and render it unsafe to operate.

WARNING

The analyzer is not waterproof and proper measures should be taken to protect from exposure to liquid water

WARNING

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

CAUTION

The analyzer contains no user serviceable components except the particulate filter, fans, and the vacuum pump. Do not attempt repairs; instead, report all problems to Picarro Customer Service or your local distributor. Please contact Picarro if you have any questions regarding the safe operation of this equipment.

CAUTION

Do not replace the mains supply power cord with an inadequately rated cord.

CAUTION

HOT SURFACE: 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**	**This analyzer weighs 47 lbs (17.5 kg) Use the technique described below (or follow your local regulations) when lifting the analyzer.**

a. Before lifting, inspect the unit for slippery substances or sharp edges.
b. Lift with two people, one on each side of the analyzer.
c. Crouch down and stay close to the unit. Always keep your back as straight as possible.
d. Position your feet for sturdy balance. Lift with your legs, not your back.
e. Do not twist the back while carrying the unit. Rotate direction with hip joints.
f. Lower the unit by bending at the knees.

3.2   Laser Safety

⚠ **WARNING**	**This equipment is classified as a Class 1 laser product with an embedded 3B laser in accordance with EN 60825-1:2014. Do not to open the enclosure where this label is placed; there are no user serviceable parts inside.**

The following Laser Safety Label is affixed to the outer cover of the analyzer.

Figure 2: Laser Safety Label – Affixed to Outside Cover of Analyzer

⚠ **WARNING**	**The laser is a Class 3B when exposed.** **Only operate or service this device in accordance with the instructions in this guide, and only open the device in an approved laser safe service area using appropriate laser-safety glasses.**

The following **Laser Safety Label** is affixed to the inside of the analyzer:

Figure 3: Laser Safety Label – Affixed to Inside of Analyzer

![Caution symbol] **CAUTION**	**Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.**

4.   Acronyms

This manual includes various acronyms. For definitions, see below:

Table 3: Acronyms, Formulas, Units, and Symbols

Acronym	Definition
atm.	atmosphere; unit of pressure, approximately equal to atmospheric pressure at sea level. 1 atm. = 14.69595 psi (101.325 kPa)
C_2H_4O	Ethylene Oxide
CH_4	Methane
cm	centimeters
CO_2	Carbon Dioxide
CRDS	Cavity Ring-Down Spectroscopy
DAS	Data Acquisition System (the Analyzer)
EtO	Ethylene Oxide
ft.	Length in feet;1 ft. = 12" or 12 inches (30.48 cm)
GUI	Graphical User Interface
H_2O	Water, Water Vapor
HB	Hotbox
kPa	Kilopascal; unit of pressure; 1 kPa = 0.145 PSI
mm	millimeters
OD	Outside Diameter
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PSI (psi)	Pounds per Square Inch
RH	Relative Humidity
sccm	standard cubic centimeters per minute
SST	Stainless Steel
UM	User Manual
WB	Warm box
WLM	Wavelength Monitor
" (as in 1/4")	Inches
°C	degrees Celsius
‰	per mil

5. Unpacking Analyzer Components

5.1 Inspect the Shipping Boxes

Picarro products are inspected and tested before leaving the factory. Their packing containers have been designed to keep the equipment safe from damage during transit.

Inspect the condition of the boxes upon arrival. The larger box includes the analyzer and most of the accessories. Even if the outer box shows damage, the inner box holding the analyzer will protect the instrument under most circumstances.

If the equipment does appear to be damaged, photograph the damages and contact Picarro (email pictures if possible) as soon as possible.

5.2 Unpack the Shipping Boxes

This section describes the contents of the shipping boxes:

- Inspect each item to ensure it is not damaged.

- If items are missing, contact Picarro.

- Keep the shipping packages to reuse when transporting the analyzer.

- Contact Picarro for options on transporting systems to remote labs.

WARNING

This analyzer weighs 47 lbs (17.5 kg). Use the technique outlined in the General Safety section on Page 17 when lifting or moving the analyzer.

Figure 4: G2910/G2920 Box Contents

Table 4: Box One: Analyzer and Accessories

Item (qty)	Description
Analyzer (1)	Includes all the data acquisition, control, and communications hardware and firmware to perform all gas handling, spectral collection, and analysis.
AC Power Cables (1)	A power cable with connectors appropriate to your country is provided. The analyzer automatically adjusts to local voltage.
Keyboard (1)	USB keyboard.
Mouse (1)	USB mouse.
Control Cable (1)	For External Solenoid Valves.
Nut (1) and Ferrules (2)	For connecting input line to analyzer INPUT.
Document Packet (1)	Includes this manual, certificate of compliance, and Windows License.
USB Flash Drive	Contains backup software.

Table 5: Box Two: Vacuum Pump and Accessories

Item (qty)	Description
Vacuum Pump (1)	Provides vacuum required for sample gas sequencing into and out of the analyzer.
AC Power Cable (1)	A power cable with connectors appropriate to your country is provided. The pump automatically adjusts to local voltage.
Vacuum Hose (1)	Hose to connect the pump to the analyzer.
Pump Manual (1)	Detailed instructions for pump.

PICARRO

6. Installation

This section describes the setup and installation of the Picarro Analyzer. Please read and understand this section thoroughly before proceeding with the installation.

⚠️ **WARNING**	**Equipment Damage: Do not attach electrical power to or start the analyzer until after attaching and turning on the External Vacuum Pump. Do not disconnect the vacuum line while the analyzer is running. Failure to do so could result in damage to the optics.**
⚠️ **WARNING**	**Picarro sells USB enabled devices, such as GPS, which is approved for use. Please do not connect USB hubs or unapproved USB devices, other than flash drives to the computer because they can interfere with the operation of the analyzer.**
⚠️ **WARNING**	**If rack mounted, the Analyzer cannot support itself using a front rack mount kit alone. The instrument must be supported by a shelf or additional rails attached to the rack.**
⚠️ **CAUTION**	**If the analyzer has been stored at less than 10 °C, allow the components to equalize to room temperature before starting the installation process.**
📝 **NOTE**	**Take care to ensure that warm air can be exhausted from an enclosure in which the analyzer is mounted.**
⚠️ **CAUTION**	**Equipment Damage: It is imperative that the analyzer 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 analyzer will result in overheating of the analyzer causing a shutdown and potential damage. There should be 4" (10 cm) of clearance in the front and back of the analyzer.

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

6.1 Analyzer and Vacuum Setup

1. Remove the Analyzer and the External Vacuum Pump from their respective shipping containers.

2. Place the Analyzer on a bench top or flat surface. Place the External Vacuum Pump nearby or on the floor. Don't push the analyzer into position yet; there are cables to be installed on the back panel.

3. Unpack the analyzer accessories. The Certificate of Compliance and USB drive should be stored in a safe place and may be required if you contact Picarro with questions about your analyzer.

4. Remove the caps from the analyzer's INLET and VACUUM connection ports (Figure 5). Save the caps; you should reinstall them when the analyzer is stored, moved or shipped.

1. External Vacuum Port to Vacuum Pump	**9.** USB Ports (2 ea)
2. Gas Inlet	**10.** Ethernet Ports – RJ-45 (2 ea)
3. USB Ports (4 ea)	**11.** Audio In/Out Ports
4. HDMI Port	**12.** AC Power Input and Switch
5. COM 2 Port	**13.** Valve Control Port (Solenoid valves)
6. COM 1 Port	**14.** DIO (not used with this analyzer)
7. DVI-D Video Monitor Port	**15.** COM 3 Port (Rotary valve – A0311, A0311-S)
8. DVI-I Video Monitor Port	**16.** Not used

Figure 5: EtO Analyzer Back Panel

5. Set the vacuum pump input voltage to the correct level for your area by rotating the voltage selector switch located on the side of the pump next to the fuse holder (shown in Figure 6 below).

6. Remove the cap from pump vacuum inlet. Save the cap for later use. Reinstall the caps whenever the pump is stored, moved or shipped.

Power Connector and Switch

Vacuum Inlet

Input Voltage Selector

Exhaust Port

Fuse
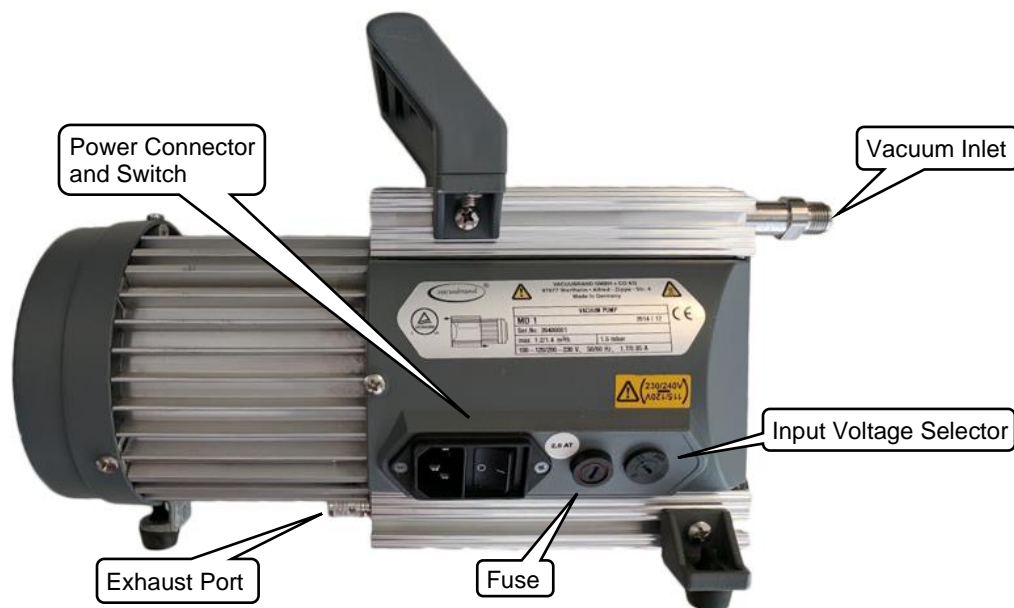
Figure 6: Pump Voltage Selection

7. Connect one end of the vacuum hose to the pump: hand tighten the nut and then use an 11/16" wrench (not included) to make an additional turn of one flat (about 60 degrees).

8. Connect the analyzer to a power source using the supplied AC power cable.

9. If desired, attach a tube to the External Vacuum Pump exhaust port and direct to a safe place for venting the mixture of sample gases.

10. Connect the External Vacuum Pump to a power source using the other AC power cable.

NOTE

The software to operate the instrument will start automatically after the operating system has loaded. The user interface will appear a few seconds after the instrument software starts. See "Startup Procedure" in Section 7.1.

6.2 Connecting to the Analyzer Inlet

Connect to the inlet of the analyzer using ¼" OD stainless steel (SST) tubing using the supplied SST ¼" inlet nut and ferrules.

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

Making a New Connection:

When using new tubing, follow these steps.

1. Place the two ferrules inside the nut as shown in Figure 7 below.

2. Loosely connect the nut to the INLET on the back panel of the analyzer about a full turn, being careful not to let the ferrules fall out.

Figure 7: Orientation of Ferrules and Nut

3. Loosely connect the nut to the INLET on the back panel of the analyzer about a full turn, being careful not to let the ferrules fall out.

4. Insert the tubing into the back of the nut, feeding it in as far as possible without deforming the tubing.

5. Hand tighten the nut.

6. Using a 5/8" wrench (not included), tighten the nut approximately seven flats (420 degrees).

Replacing a Connection

When reattaching tubing that already has a nut connected:

1. Inspect ferrules. If you see any damage, replace the ferrules and follow the directions above for making a new connection.

2. If there is no damage, hand tighten the connector to the analyzer's INLET.

3. Using a 5/8" wrench (not included), tighten the nut approximately one flat (60 degrees).

6.3   Setting Up Monitor, Keyboard, and Mouse

A video monitor (not included), keyboard, and mouse are required for monitoring device operations, viewing, or changing settings (including setting user permissions), or validating device performance.

NOTE

This device will operate under its default settings without any direct control of the internal software.

1. Connect a keyboard to one of the available USB ports.

2. Connect a mouse to one of the available USB ports.

3. Connect a monitor to one of the monitor ports. The analyzer will detect the connection and adjust the resolution to match the monitor.

4. Connect the monitor to a power source.

5. Turn on power to the monitor.

7. Analyzer Basic Operation

7.1 Startup Procedure

This section describes the steps to power on the system. These steps are sufficient for operating the instrument.

CAUTION

Always turn on the external pump before turning on the analyzer.

1. Switch on the external vacuum pump.

2. Switch on the main power to the analyzer on the rear panel.

3. Press the soft power button located on the front panel. The software will start automatically and the analyzer will display the CRDS Data Viewer window. Data Viewer features are detailed in Section 8.

4. Wait approximately 45 minutes for the system to power, initialize, and stabilize.

5. Once the cavity pressure and operating temperature are at their proper setpoints and stable, the analyzer will start measuring.

NOTE

As the instrument is starting up, it is normal for there to be a delay in reporting data. This can take several minutes depending on how long it takes for the internal temperature and pressure to reach their operating points, and it is normal during this time for some concentration readings to be negative or constant.

The data selection pull-down menus will not be populated with the appropriate items until actual data is being reported in the graph. This is typically less than 30 minutes, but depending on ambient temperature, the analyzer can take up to 1 hour to stabilize.

NOTE

The GUI heading title may vary depending on the analyzer type.
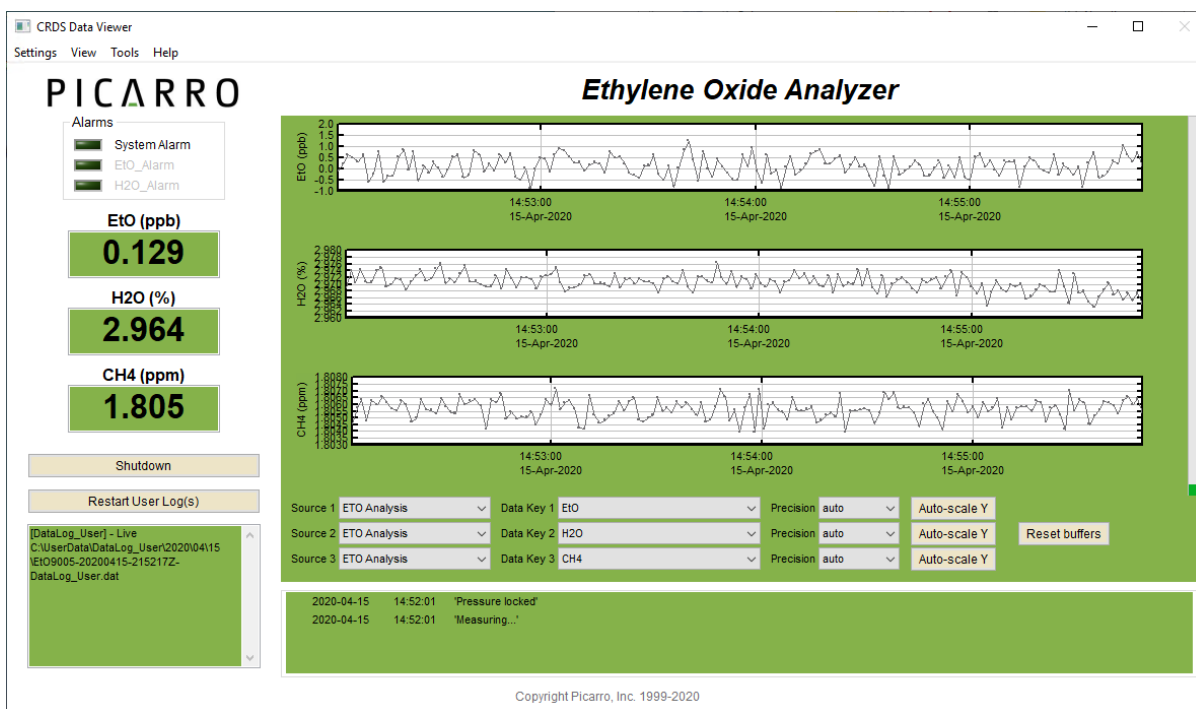
Figure 8: Picarro Analyzer GUI

7.2   Desktop Icons and Folders

On the Windows desktop, there will be the following icons and folders:

1. **Start Instrument:** When clicked, the analyzer will start measuring in the configuration that it was in when the software/analyzer was shut down.

2. **Coordinator Launcher:** Depending on the system's configuration, the coordinator program may not be included. Clicking on this icon will lead you to a window that will allow you to choose the proper coordinator to operate the peripheral module that came with your analyzer.

3. **Picarro Mode Switcher:** When clicked, you will be led to a window that will allow you to switch between various measurement modes. Most analyzer models are configured for one mode and may not include the Mode Switcher. If the analyzer has multiple modes, this allows the user to switch between them easily.

4. **Picarro Controller:** When clicked, you will be led to a useful diagnostic panel allowing the user to see the analyzer's internal temperatures, pressure, and spectroscopy in real time. This program has user-accessible functions, but it cannot change

anything related to analyzer functionality. It is intended for diagnostic purposes only.

5. **Picarro Utilities Folders:**

   a. **Data file Viewer**: When clicked, you will be led to a window that will allow you to convert between *.dat and H5 data files and to make various graphical representations of your data. The instructions on using the Data File Viewer software are described in the Appendix B

   b. **Data Recal:** When clicked, you will be led to a window that will allow you to recalibrate your data based on known, certified data.

   c. **Setup Tools:** When clicked, you will be led to a window that will allow you to edit various settings for your analyzer (See the Setup Tool in Section 9.5 of this manual for information about these settings).

6. **Diagnostic Folder**

   a. **Stop Instrument:** When clicked, you will be led to a window that will allow you to turn off the analyzer in an emergency event. Upon clicking on this icon, the following window will pop up. Please see Shutdown Procedure on page 31 to shut down the analyzer under normal circumstances.
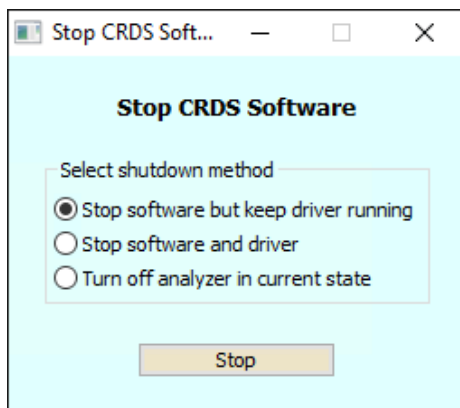
Figure 9: Stop CRDS Software Pop-up

⚠️ CAUTION	**Equipment Damage: EXCEEDING GAS INLET PRESSURE OR TEMPERATURE SPECIFICATIONS COULD RESULT IN DAMAGE TO THE INSTRUMENT. In the case of higher input pressure or flow, configuring a sampling bypass manifold system is recommended.** **Use a 'tee' at the gas inlet and either return the remainder to the main gas stream or exhaust appropriately.**

CAUTION

Equipment Damage: **Do not disconnect the AC power to the analyzer, vacuum line or the AC power to the External Vacuum Pump while analyzer is operating. Damage may be caused by current surges if power is applied while attaching or removing cables.**

7.3   Shutdown Procedure

To shut down the analyzer using the GUI:

1. Click on the "**Shutdown**" button located on the left side of the Data Viewer window.

2. A window will pop-up (Figure 10) prompting the user to confirm the shutdown. Once confirmed, the analyzer software and hardware will turn off.

3. Manually turn off the pump(s) and dry gas (only if your system requires it).

CAUTION

A flow of clean, relatively dry gas should always be directed to the instrument for several minutes prior to shutting down. Trapping a high-moisture content gas sample in the cavity can cause condensation damage to the mirrors as the instrument cools from its operating temperature.

CAUTION

Do not turn off the pump or disconnect the vacuum line while the instrument is operating.

CAUTION

FOR G2xxx ANALYZERS: If you have trouble turning off the analyzer software, do not kill the process(es) in the task manager; rather, double-click on the "Stop Instrument" icon in the Diagnostics folder on your desktop.
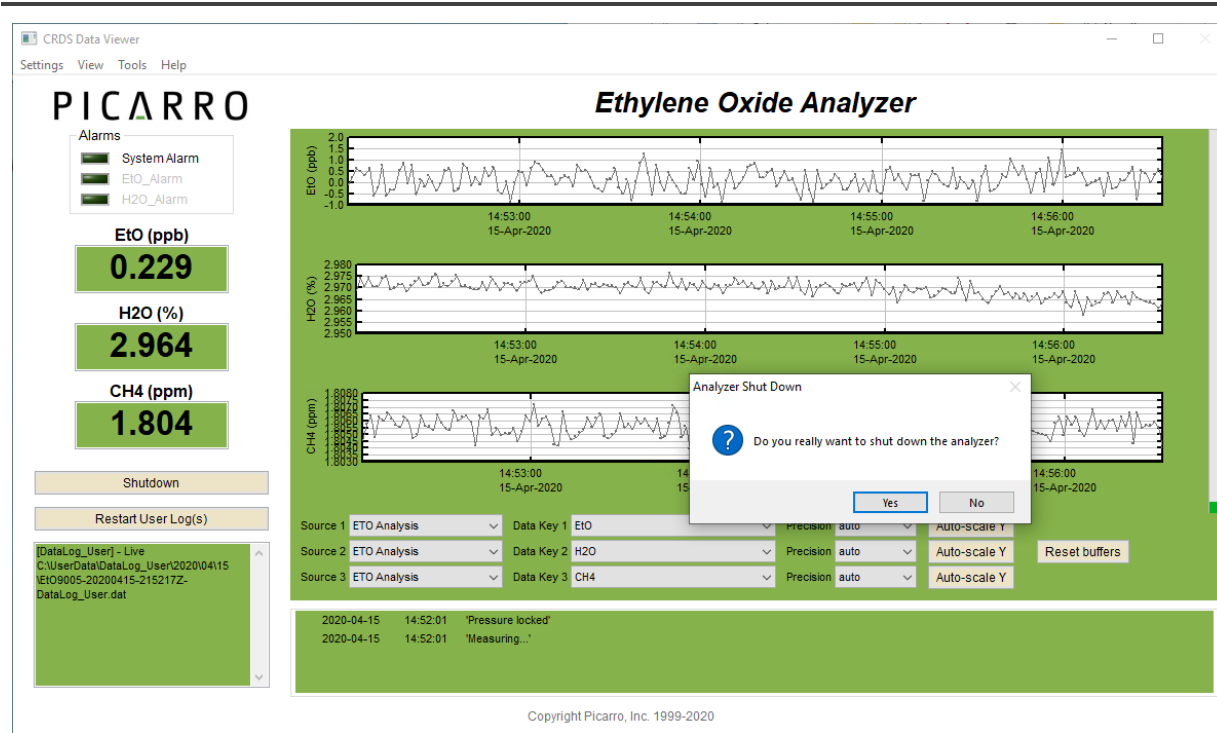
Figure 10: Shutdown Confirmation Pop-up

7.4 In Case of Electrical Power Outage

If the power to the analyzer is cut-off for any reason, the analyzer will cease operation. However, when the power is reapplied, the analyzer will restart automatically. The Picarro software tools will also properly close out previous files and open new files for data collection so that previously collected data, instrument diagnostics, and other parameters recorded up to the time of power outage are retained.

If short power outages will be a routine occurrence in your operating environment, Picarro recommends the use of an uninterrupted power supply (UPS) to prevent damaging the hardware or software.

8. List of GUI Functions

8.1 GUI Overview

The features of the Picarro analyzer GUI are identified in Figure 11 and described in the following sections.
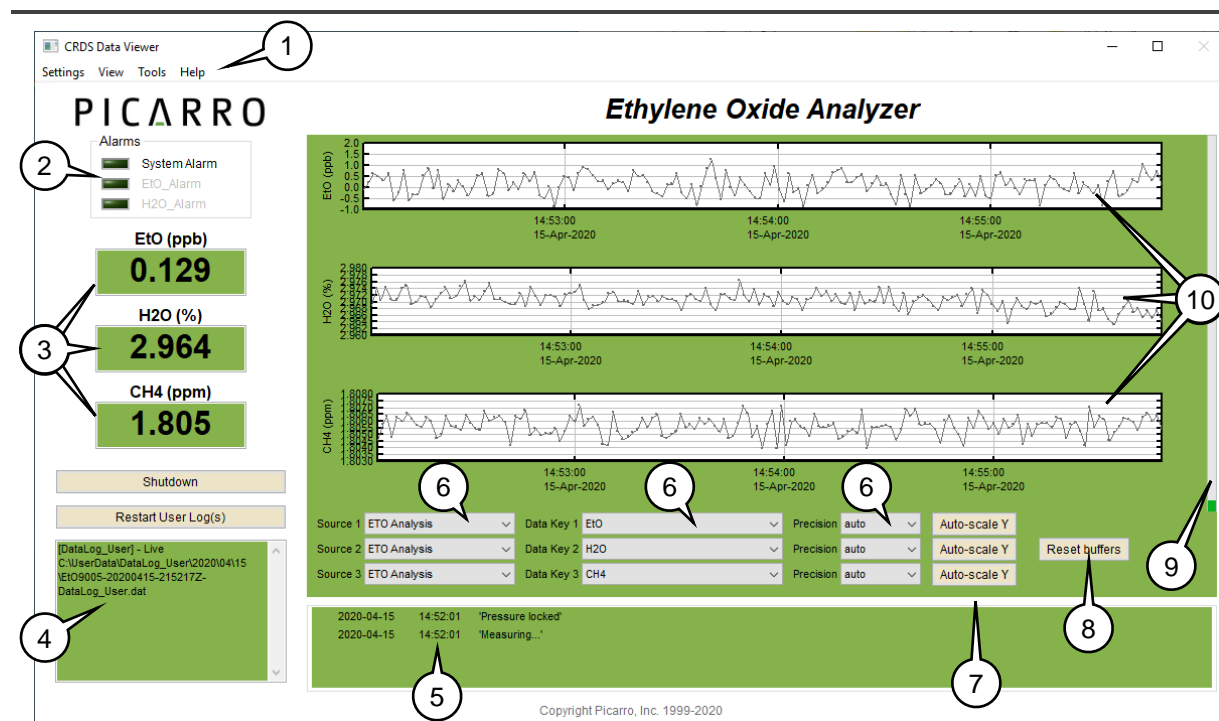
1. Settings, View, Tools, and Help menus	**6.** Data Source, Data Key, and Precision pull-down menus for data window content
2. Alarm Panel	**7.** Axis Auto Scaling
3. Digital Readouts	**8.** Reset Data Buffer
4. Data Log, Filename, and Path	**9.** Data Buffer Level Meter
5. Status Log Window	**10.** Data Windows

Figure 11: Layout of G2910/G2920 Analyzer GUI

8.2 Settings, Tools, and Help Menus

Settings Menu

Left clicking on the Settings menu pulls down a menu that has one entry 'Change GUI Mode from Standard to Service.' This is the access point to a password protected service mode where additional operational and measurement parameters are displayed. Selecting and clicking on this entry opens the Cavity Ring-Down Spectrometer Controller. This is reserved for Picarro service operators only.

View Menu

This menu item has three entries:

1. Lock/Unlock time axis when zoomed: When locked, forces the two graphs to display the same time scale during zoom.

2. Show/hide statistics: Toggles the measurement statistics display, see Digital Readouts section on Page 39 below.

3. Show/hide instrument status: Toggles the status of the instrument display.

4. Instrument Status below.

Tools Menu

This menu item has three entries:

1. **User Calibration:** Opens the user calibration window (default password is "picarro"). The password can be reset in the QuickGui.ini file in the instrument directory: "C:\Picarro\G2000\AppConfig \Config\QuickGUI\" under the section:

   `[Authorization] UserCalPassword = Picarro Show/Hide Valve`

2. **Sequencer GUI:** Toggles the display of the external valve sequencer window.

3. The calibration slope and intercept can be entered and their effects immediately were seen in the data. Please refer to the Calibration section on Page 55.

Help Menu

1. **About:** Displays the version number of the instrument.

8.3 Alarm Panel

This panel is used to monitor the status of the internal instrument alarms. These indicators are gas concentration alarms, such as "C2H4O Too High/Low" depending on instrument configuration. The gas concentration alarm LEDs are off (grayed) when the respective concentrations are below a certain value, and they are illuminated when the respective concentrations are above/below a certain value. To view the alarm set point, click on the LED and a dialog box (Figure 12) will appear indicating the alarm setting and allow the user to enable it or change the setpoint:

Figure 12: Alarm Setting Window

Type the value you wish to set the alarm to and press the "**OK**" button, or press "**Cancel**" if you do not wish to change the alarm value. If you do nothing, the dialog box will disappear, and the alarm value will remain unchanged.

8.4   Instrument status

If these parameters are enabled through the 'Show Instrument Status' entry in the 'View' Menu on the main toolbar digital readouts for Warm Box temperature, Cavity Temperature and Cavity Pressure are displayed to the left of the main trend graphs.
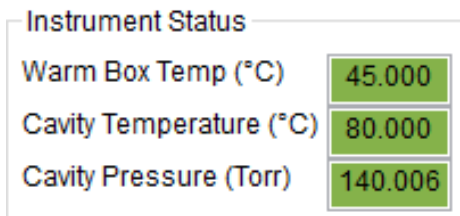
Figure 13: Instrument Status

8.5   Data Log Filename and Path

The filename and path of the active data log are displayed in this pan. The indicator is grayed-out if there is no active data log (i.e., if a new data log has not been started using the Start /Stop New Data Log Button). A new file will be generated at midnight, which will be saved to the same location as the original log file.
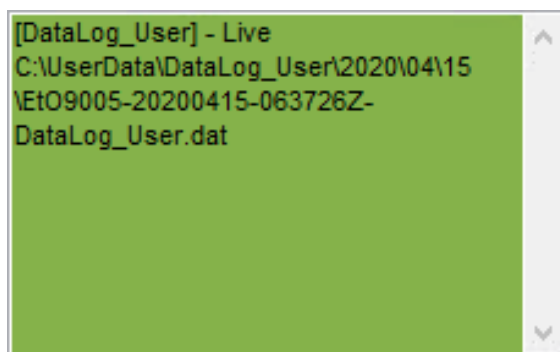
Figure 14: Data Log Filename

8.6   Data Window

The data window (Figure 15) displays a graph of any stream of data vs. system time, with a format of hh:mm:ss. The user can select which data stream is displayed using combinations from the Data Source and Data Key pull-down menus. The precision displayed can be adjusted using the "Precision" menu and Auto-scaling of the 'Y' axis is also available.
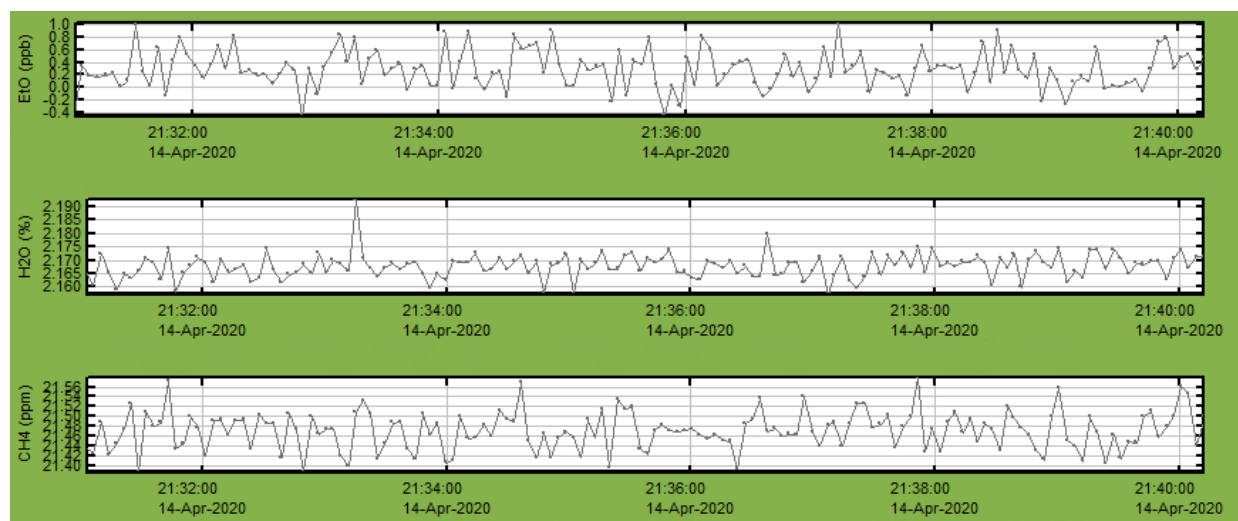
Figure 15: Data Window

Data Source and Data Key Pull Down Menus

These two menus enable selection of the data stream that is viewed in the data window. Data streams available on the GUI are gas concentrations, if 'instrument Analysis' (where instrument represents the system installed) is selected, or if "sensors" is selected, the analyzer's optical cavity pressure or temperature can be viewed as well as the nominal ambient temperature of the analyzer ("DAS temp") and the temperature of the analyzer's electronics chamber, indicated as "warm chamber temp."

Figure 16: Data Source

Precision Pulldown Menu

Click on this icon (Figure 17) to select the precision displayed on the y-axis, between 0 and 4 digits of precision or "auto." The currently selected precision is displayed during operation. This does not affect the precision of the saved data in the data log files or results files.
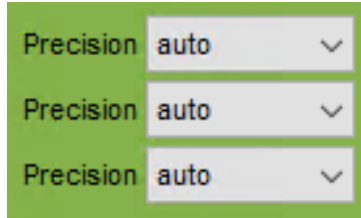
Figure 17: Precision Pulldown

Data Buffer Level Meter

The meter to the right of the Data Window indicates how much of the internal memory of the GUI is used to retain historical data collected with the instrument. There is an internal limit of a finite number of points. Once that number of data points is collected, the buffer is full, and old data is removed from the buffer as new data is collected. This buffer affects only the data displayed in the data window, not the data stored in any files. This buffer is empty upon instrument startup and can also be emptied by pressing the reset data buffer button in the lower-right-hand corner of the GUI.
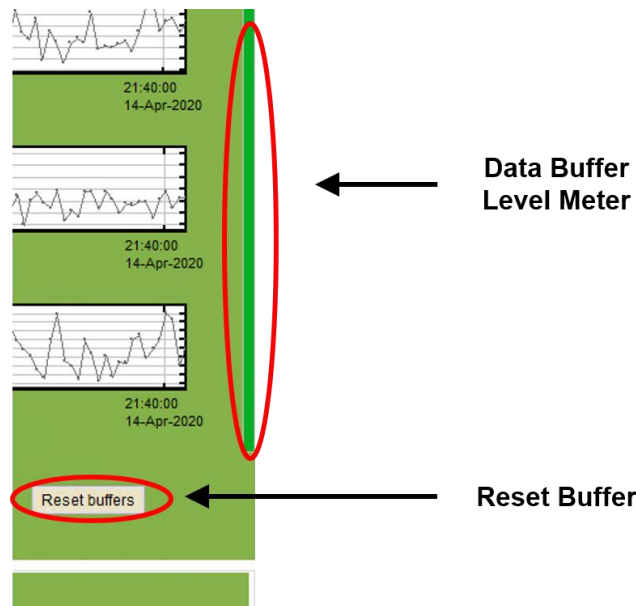
Figure 18: Data Buffer and Reset Buffer

Reset Data Buffer Button

Press this button to clear the internal data buffer of the GUI (this clears the current data traces from the graphs). This has the effect of clearing all data in the data window. Pressing this button has no effect on any of the data log files stored by the instrument.

Graph Zooming

To zoom the graph, simply drag the magnifying glass over the section to be zoomed and click/hold the left mouse button. While holding down the left button, move the mouse to create a box that covers the region of interest. When the box is properly drawn, release the left button and boxed area will automatically scale to fill the data window. To zoom back out, double-click on the left button. To auto scale, the y-axis of either graph, use the auto-scale buttons below the graph. To lock or unlock the time axis of each graph during zooming, select that menu item in the 'View' menu.
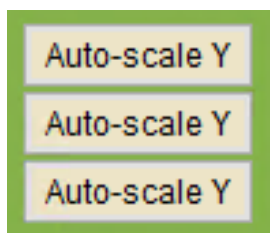
Figure 19: Graph Zooming

Digital Readouts

Displays the latest value recorded for the selected Data Key for each Data Window. Changing the Data Key modifies the Digital Readout as well as the Data Window view. If the 'Show Statistics' entry is enabled in the 'View' menu, the mean, standard deviation and slope of the data in the graph are dynamically calculated and indicated below the digital concentration readout. These numbers change to reflect statistics of whatever data is in the data window.
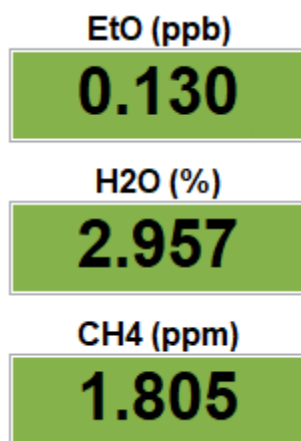
Figure 20: Digital Readouts

Start / Stop Data Log Button

The Analyzer automatically records all data collected on the instrument and saves it for later analysis. These files are called Data.dat files, which are described below in the section called File Management. In addition, the user can record a separate data log file. Press this button if you would like the instrument to start recording a separate data file. A dialog box will appear prompting you for a filename and location. Press this button again to stop recording the data file.

8.7　Status Log Window

This window displays instrument status messages, in the following form: "MM/DD/YYYY hh:mm:ss generic message text." These messages include all messages sent to the DAS front panel display. The common status log messages are:

1. Temperature Locked: WB (HB)

   The system waits for the warm box ("WB" – the temperature-controlled electronics and wavelength monitor chamber) to reach operating temperature. Similarly, the temperature of the hot box ("HB" – the temperature-controlled chamber containing the analyzer's optical cavity and gas handling system) is stabilized. This is typically the longest step in the startup sequence. The duration of this step can range from 5 to 60 minutes, depending on the ambient temperature and how much time has elapsed since the last startup.

2. Entering Measurement

   Spectral scanning has started. Concentration measurements will be available in approximately 30 seconds. The instrument will continue to scan and report concentration measurements until the instrument is shut down using the procedure below.

3. Pressure Stabilizing/Locked

   The valve control system begins to allow flow through the analyzer and stabilizes the pressure inside the cavity.

4. Measuring

   This is the normal mode of operation after startup has completed.

9. File Management

9.1 Overview

During operation, the Analyzer generates various ASCII-format text output files that are updated after each batch of concentration measurements is complete. For example, one of the user output files is named:

```
UV1xxx-YYYYMMDD-hhmmssZ-DataLog_User.dat
```

Where "UV1xxx" or similar is the instrument serial number and where Z denotes "Zulu" or GMT for time zone. The data files are created every 15 minutes.

File Name

The file name is generated from the instrument serial number, the date, and the time when the instrument was started. For example:

```
UV1123-20200410-093852Z-DataLog_User.dat
```

- **UV1123** is the instrument serial number

- **20200410** is the date, 4/10/2020, in format YYYYMMDD (to allow chronological sorting of data files).

- **093852Z** is the time the file was started, 09:38.52 am, formatted as hh:mm:ss using a 24-hour clock. Z = Zulu time = GMT

Raw User Data

The raw user data are contained in folders in the directory:
C:\UserData\DataLog_User\[year]\[month]\[day]\hour.

Data File Creation Frequency

Data files are created every 15 minutes and stored for 90 days before they are automatically deleted. The file deletion frequency and details can be modified in the file:
C:\Picarro\G2000\AppConfig\Config\Archiver\Archiver.ini. This is explained below.

Data File Archiving

During data acquisition, the analyzer creates directories to store the data, based on the date the data were acquired. After each data file has been closed (every 15 minutes) it is moved to an archive directory, and a new

file is started in the original location. The archive directory is C:\Picarro\G2000\Log\Archive\ and has subdirectories DataLog_Mailbox, DataLog_Private, and DataLog_EventLogs with files arranged by year\month\day\hour.

Additional Data for Diagnostics

There are complete data files which include additional information beyond the concentration data including parameters such as instrument temperatures and pressure, set points and spectroscopic information. This information is generally not useful to the user but can be useful for diagnostic purposes and is stored in the directory:

C:\Picarro\G2000\Log\Archive\DataLog_Private\[year]\[month]\[day]\[hour].

For more information about how to include various columns of data from the DataLog_Private in the DataLog_User files in the C:\UserData directory, please contact Picarro.

The current data file can be found in C:\Picarro\G2000\Log\DataLogger\

Within this directory, there are subdirectories for DataLog_Private and DataLog_User. Similarly, the archive directory has subdirectories arranged by file type. The subdirectories are further organized by \[year]\[month]\[day]\[hour].

Simplified Management

To keep the data files easy to manage and to limit the size of individual files and directories, the software automatically generates new files each time the instrument is powered up and at midnight each night. When new files are created at midnight GMT, their file name will contain the new date and a time of 00:00. For example, if the system were started at 10:29 am GMT on 4/10/2020 it would create a file named:

```
20200410\UV1123-20200410-102900Z-Datalog_User.dat
```

Then at midnight GMT, a new file will be created:

```
UV1123-20200410-000000Z-Datalog_User.dat
```

9.2 File Archival and Automatic Deletion of Old Files

The analyzer can automatically compress (zip) and archive old files as mentioned above. This operation is controlled by the .ini file: **C:\Picarro\G2000\ AppConfig\Config\Archiver\Archiver.ini.** For each file type, there are various items along with some recommended default settings which may vary by file type:

- Directory = C:/UserData/DataLog_User

  Optionally specifies which directory to find files to the archive.

Archiver.ini Settings

- **MaxCount = –1**

  Specifies how many files to keep. A setting of –1 indicates that there is no maximum number of files. Generally, –1 is used in conjunction with a maximum size limit, below.

- **MaxSize_MB = 1500**

  Specifies that a maximum of 1.5 GB of data is to be kept before the system begins to delete old data.

- **Compress = True/False**

  Specifies if archived files are to be zipped – recommended setting is true to save hard drive space. True means files are zipped, false means files are not zipped.

- **AggregationCount = 0**

  If compression is set to TRUE, specifies how many files to be included in each zip archive.

- **StorageMode = FIFO**

  First in first out. Specifies that old data is deleted first.

- **Quantum = 4**

  Generally, should not be changed. Specifies the files be sorted by year\month\day\hour in the archived directory structure.

Automatic File Deletion

In addition to the automatic file and directory management described above, the analyzer also automatically deletes various files specified in C:\Picarro\ G2000\AppConfig\Config\FileEraser\FileEraser.ini. There are various settings, as described below:

- **runtime_interval_hrs = 0.5**

  Specifies how often (in hours) to run the file eraser.

- **path = ../../../Log/Archive/DataLog_Private**

  Specifies which directory to look in for files to delete.

- **extension = data**

  Specifies which files having what extension are to be deleted. If empty, it deletes all files.

- **delete_time_hrs = 48**

  Specifies how long to keep files prior to deletion.

9.3   Measuring Time in Picarro Data Files

Since measurements performed by Picarro analyzers are asynchronous (they require a variable and unpredictable amount of time to complete), data reported by the analyzer is time stamped. Each independent measurement is given a time derived from the Windows™ computer system clock. This time can be reported by one or many of the following variables.

Table 6: Data Time Stamp Definitions

Variable Name	Definition	Units
DATE	The calendar date formatted as YYYY-MM-DD **Example:** April 24, 2020 is formatted as 2020-04-24	-NA-
TIME	The time of day formatted as HH:MM:SS.SS on a 24-hour clock **Example:** 4:18:53.12 PM is formatted as 16:18:53.12	-NA-
FRAC_DAYS_SINCE_JAN1	The number of days since midnight January 1 of the current year **Example:** at 3:00:00 PM on January 12 the value is 11.625	days
FRAC_HRS_SINCE_JAN1	The number of hours since midnight January 1 of the current year **Example:** at 3:00:00 PM on January 12 the value is 279.0 (=FRAC_DAYS_SINCE_JAN1*24)	hours

Variable Name	Definition	Units
JULIAN_DAYS	The number of the day of the current year **Example:** at 3:00:00 PM on January 12 the value is 12.625 (=FRAC_DAYS_SINCE_JAN1+1)	days
EPOCH_TIME	The number of milliseconds since midnight January 1, 1970 **Example:** at 3:00:00 PM on January 12 the value is 1421074800000 (= time)	ms
timestamp	The number of milliseconds since midnight January 1, 1 if the current Gregorian calendar was extended back to that time **Example:** at 3:00:00 PM on January 12 the value is 63556671600000	ms
time	The number of milliseconds since midnight January 1, 1970 **Example:** at 3:00:00 PM on January 12 the value is 1421074800000 (= EPOCH_TIME)	ms
ymd	The calendar date formatted as YYYYMMDD **Example:** August 24, 2020 is formatted as 20200824	-NA-

In Table 6 above, all times are reported in GMT (also known as Zulu time and very closely related to UTC). We express these timestamps in GMT to avoid complications during Daylight Saving Time or when instruments are moved across time zones. The accuracy of the times is of course, only as good as the accuracy of the Windows™ clock; see section Remote Data Access to learn how to automatically synchronize the computer's clock to a time standard. There are many online calculators that convert Epoch Time to local time at any time zone, as well as many functions in commonly used data analysis programs that perform the same calculations.

9.4 Column Headers

The following table provides information regarding the column headers presented in the UserData output files available on a Picarro analyzer.

Table 7: Column Header Definitions

Column Header	Definition	Units
DATE	Date of measurement	
TIME	Time of measurement (instrument time)	
FRAC_DAYS_SINCE_JAN1	Fraction of days since Jan 1 (max = 365)	
FRAC_HRS_SINCE_JAN1	Fraction of hours since Jan 1 (max = 8760)	
JULIAN_DAYS	Julian days in since Jan 1 00:00 GMT	
EPOCH_TIME	Number of seconds that have elapsed since Jan 1, 1970 GMT	
ALARM_STATUS	Binary system alarm (0 = no alarm; 1 = alarm)	
INST_STATUS	Hardware status code: after warm-up, normal operation is indicated by code 963; see *Picarro Analyzer Programming Guide Remote Command Interface* (P/N 40-0063) for details	
species	Integer code designating the molecule being measured	
ValveMask	Integer code indicating which solenoid valves are energized	
MPVPosition	Integer code for the valve position	
OutletValve	Integer controlling the flow through the proportional valve	
CavityPressure	Cavity Pressure	Torr
CavityTemp	Cavity Temperature	°C
WarmBoxTemp	Temperature of the stabilized enclosure containing the WLM	°C
EtalonTemp	Temperature measured at the wavelength monitor (WLM)	°C
DasTemp	Temperature measured on the data acquisition system board	°C
EtO	Ethylene oxide concentration	ppb
EtO_30s	30 second window average of EtO concentration	ppb

Column Header	Definition	Units
EtO_2min	2-minute window average of EtO concentration	ppb
EtO_5min	5-minute window average of EtO concentration	ppb
CO2	Carbon dioxide concentration	ppm
CH4	Methane concentration	ppm
H2O	Water vapor concentration	%
pzt_offset	Digital position of the piezoelectric element	counts
wlm_offset	Frequency offset to align spectra to model functions	cm-1

9.5   Setup Tool

In the desktop folder called Picarro Utilities, the **Setup Tool** can be launched by double-clicking on its icon. The tool allows the user to configure data file saving details, including which data elements are written to data files, digital data output (via serial port or TCP/IP), remote data delivery (via email), and general GUI properties.

Mode

Located at the bottom of the Setup Tool window, click to select the measurement mode (in this case, Ethylene Oxide Analyzer is selected).

Data Logger

The Data Logger tab (Figure 21 below) allows the user to configure various data file saving details, including which data elements are written to data files.

- **Data Columns:**

  Controls which data elements are written to data files.

- **Hours of Each Log File:**

  Controls the size of each data document.

- **Enable Mailbox Archiving:**

  Enables archiving of data in the mailbox folder: C:\Picarro\G2000\Log\Archive\DataLog_Mailbox

- **Archived Directory Structure:**

Specifies part of naming convention for data documents.

- **Total User Log Storage Size (GB):**

  Specifies the size of storage allowed for User Data (Recent Data).

After making the appropriate edits, click "**Apply**" to put changes into effect and then "**Exit**" to close the window.
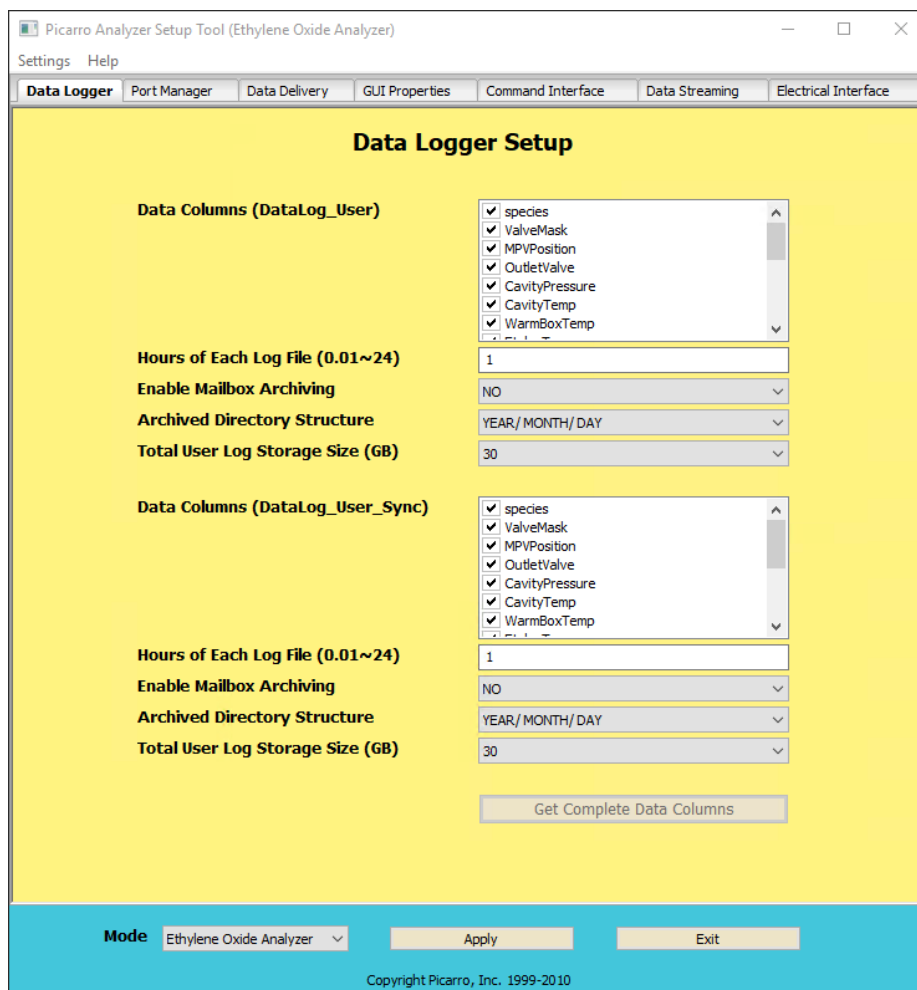
Figure 21: Setup Tool – Data Logger Tab

Port Manager

The Port Manager tab (Figure 22) allows you to control digital data output/Input via serial port or TCP/IP.

- **Data Streaming:** Specify the port for data streaming (COM1/COM2/COM3/Off)

- **Valve Sequencer MPV:** Specify the port for connecting to Valve Sequencer (COM1/COM2/COM3/Off)

- **Command Interface:** Specify the port for Command Interface (COM1/COM2/COM3/TCP/Off).

- **GPS:** Specify the port for connecting to GPS (COM1/COM2/COM3/Off)

- **Anemometer:** Specify the port for connecting to Anemometer (COM1/COM2/COM3/Off)

Make sure there are no COM port conflicts before clicking "Apply." After making the appropriate edits, click "**Apply**" to put changes into effect and then "**Exit**" to close the window.
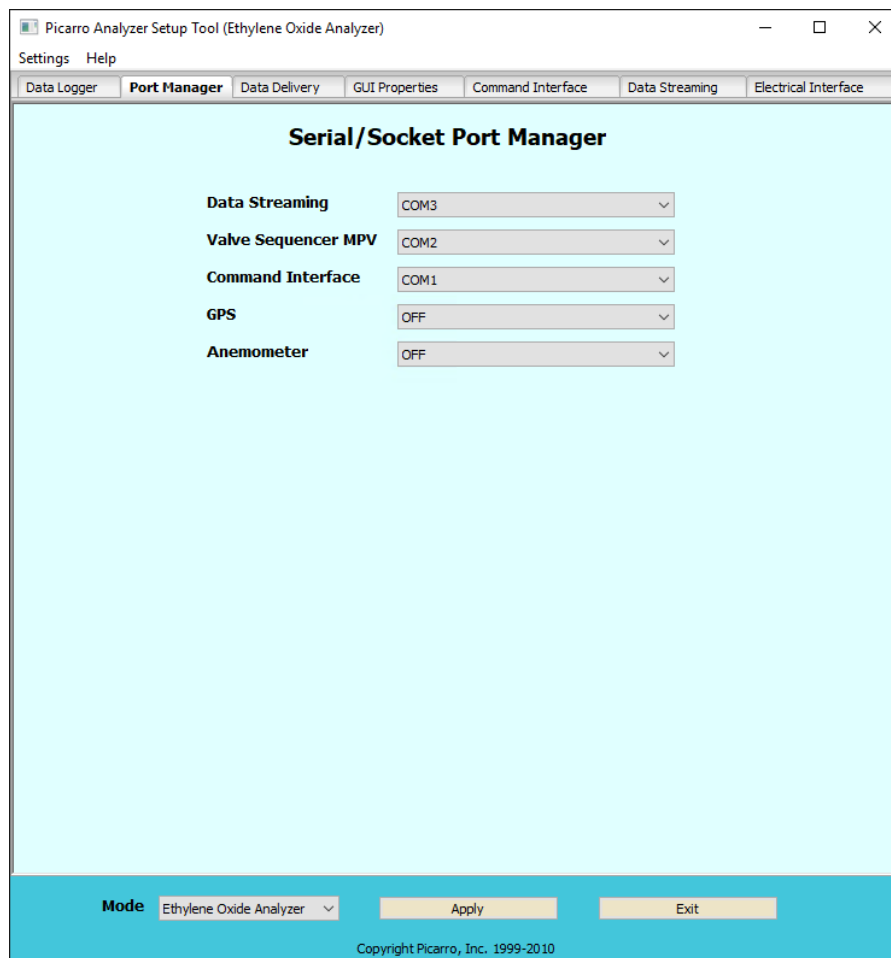
Figure 22: Setup Tool – Serial/Socket Port Manager

Data Delivery Setup

The Data Delivery tab (Figure 23) allows the user to schedule remote data delivery via email.

- **Delivery Start Time:** Time of the day when data will be sent.

- **Use SSL:** Depending on the sender's email server, the sender can activate the Secure Sockets Layer (SSL).

- **Use Authentication:** Turning this on will require the receiver to provide a password and a username to access data.

- **Server:** Enter server location.

- **User Name:** Required when Use Authentication is turned on.

- **Password:** Required when Use Authentication is turned on.

- **From:** Sender's email address.

- **To:** Receiver's email address.

- **Subject:** Subject line of the email.

- **Data Directory:** Location of the data you want email.

After making the appropriate edits, click "**Apply**" to put changes into effect and then "**Exit**" to close the window.
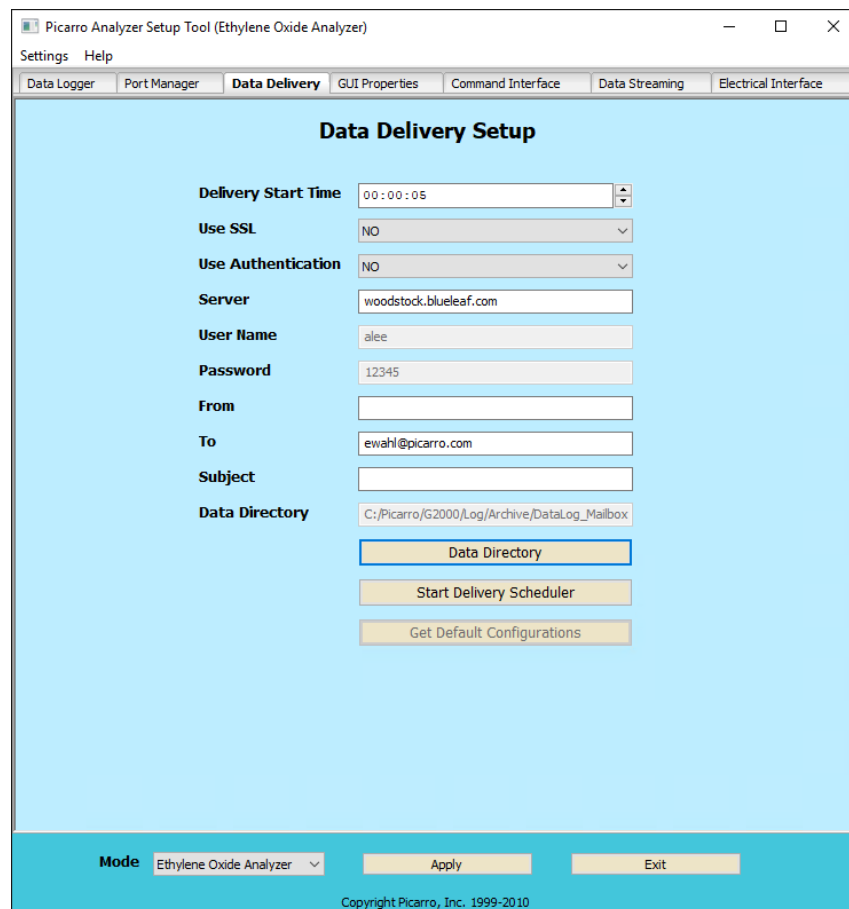
Figure 23: Setup Tool – Data Delivery Tab

Editing Main GUI Properties

The **GUI Properties** tab (Figure 24) allows you to set the number of line graphs visible on the main GUI and to enable valve sequencer control.

In this tab, you can enable control of a connected Valve Sequencer from the main GUI:

1. Click on "**Settings**" of the "Setup Tool" window, and then "**Switch to Service**" mode.

2. Choose "**Yes**" next to "Enable Control Valve Sequencer" drop down menu on the "GUI Properties" tab.

3. Click "**Apply**" to put changes into effect and then "**Exit**" to close the window.

   You should now be able to access the "Show/Hide Valve Sequencer GUI" menu from the main GUI under "Tools"
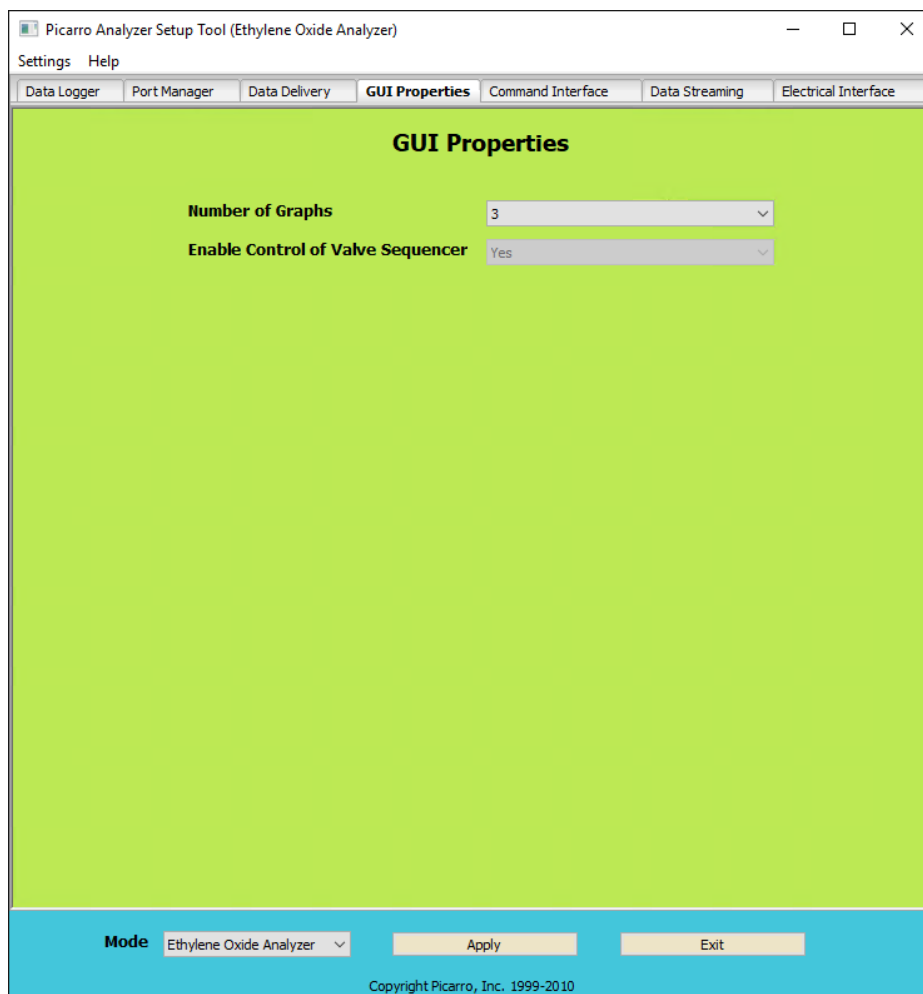
Figure 24: Setup Tool – GUI Properties Tab

Command Interface – Specifying Digital Data Output

The Command Interface tab (Figure 25) allows you to specify the data elements that are sent via COM port/TCP (specified in the Port Manager tab). Two types of data can be specified here: *Output Data Source and Output Data Columns.*

After making the appropriate edits, click "**Apply**" to put changes into effect and then "**Exit**" to close the window.
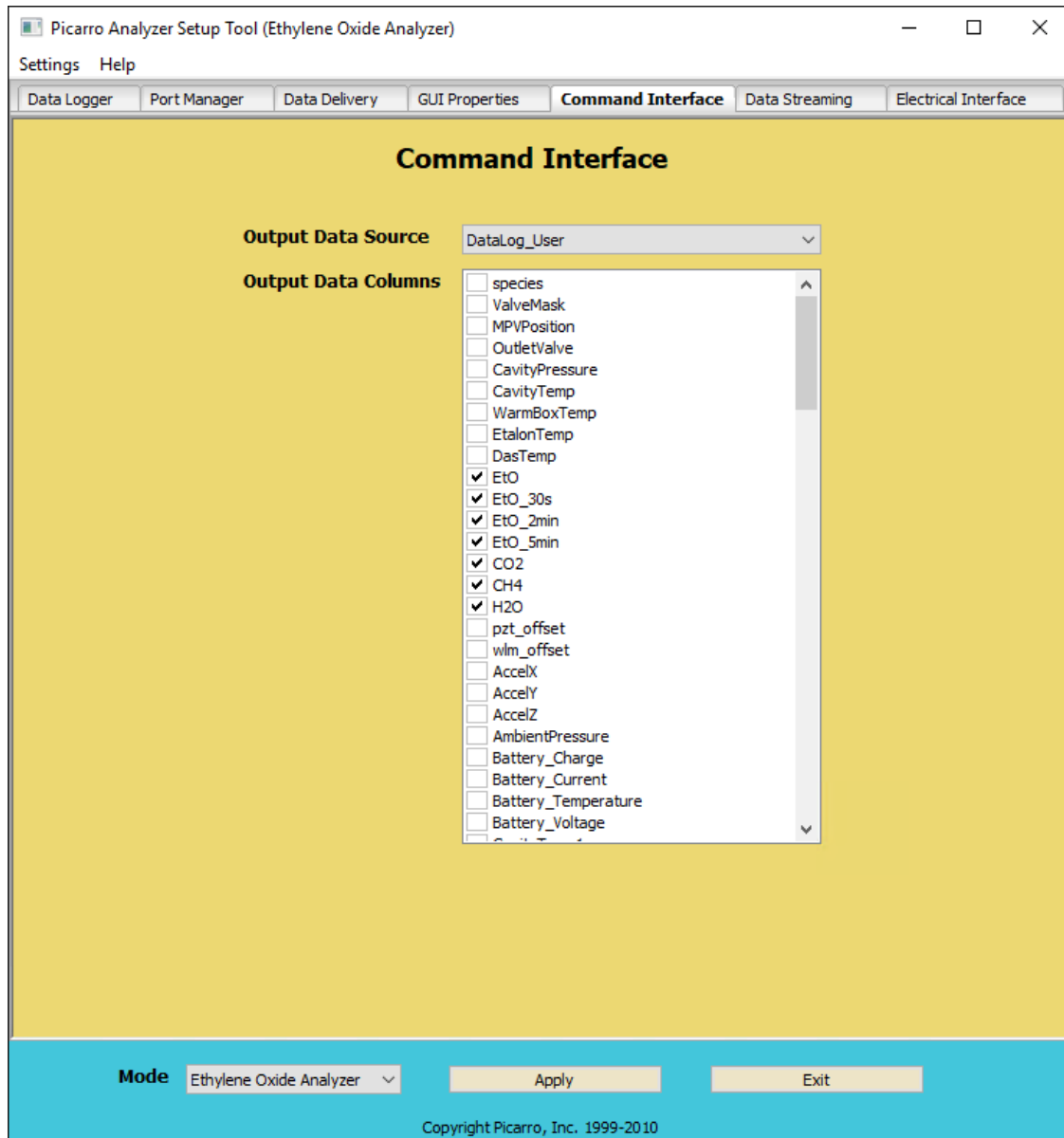

Figure 25: Setup Tool – Command Interface Tab

Data Streaming – Specifying Digital Data Output

The **Data Streaming** tab (Figure 26) allows you to specify the data elements that you want to send via COM port (specified in the Port Manager tab). Two types of data can be specified here: *Data Stream Source and Data Stream Columns.*

Data Streaming outputs data continuously, whereas the Command Interface needs commands to prompt data output.

 After making the appropriate edits, click "**Apply**" to put changes into effect and then "**Exit**" to close the window.
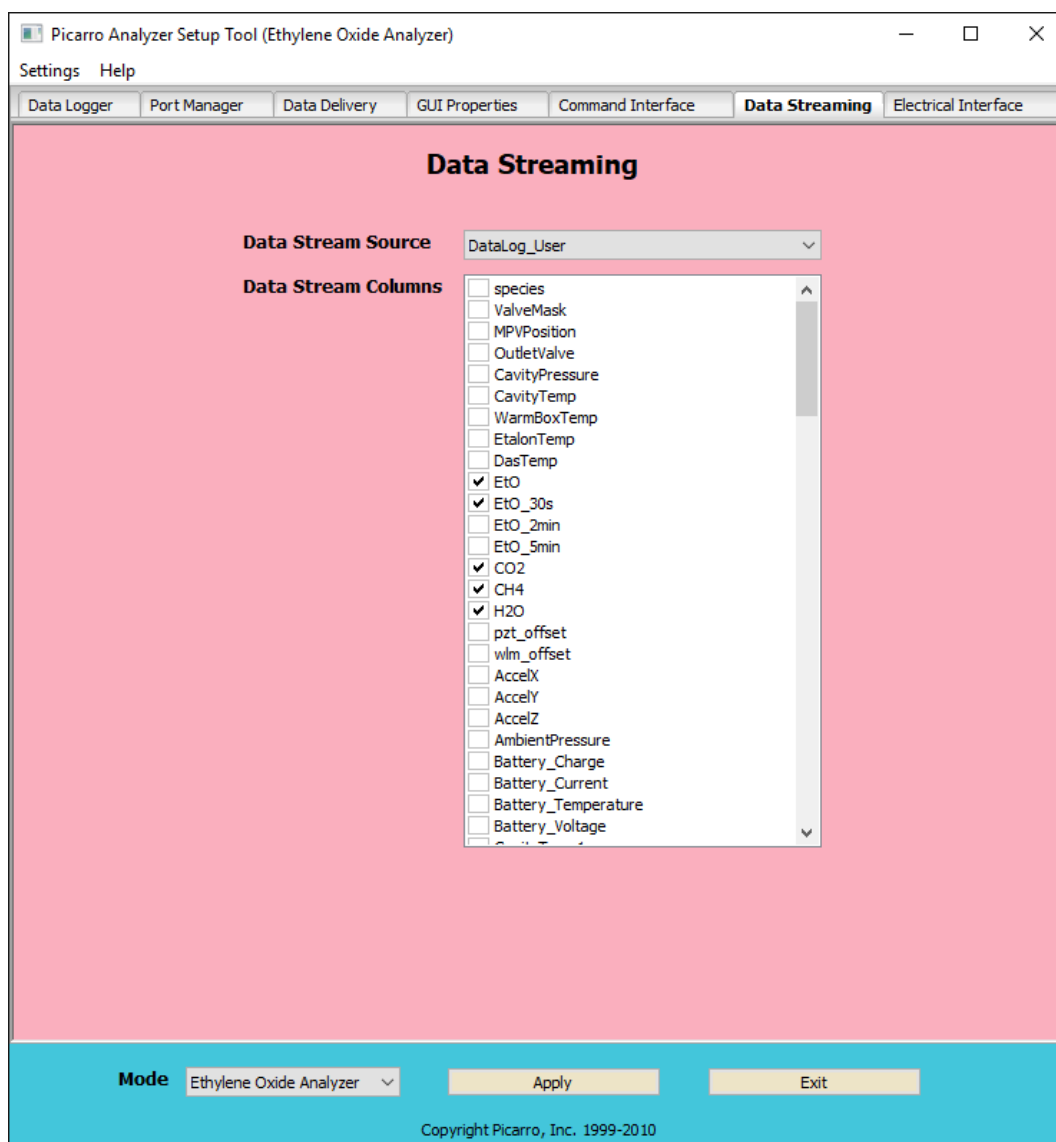

Figure 26: Setup Tool – Data Streaming Tab

Customizing Analog Output Channels

The Picarro analyzer may be optionally configured with an Electrical Interface Card (EIC) that provides up to 8 analog signals available to the user for monitoring various measurements results and analyzer parameters.

Electrical Interface

The Electrical Interface tab (Figure 27) allows you to customize each analog output channel. This tab will be disabled if your analyzer was not configured to work with an analog peripheral.

After making the appropriate edits, click "**Apply**" to put changes into effect and then "**Exit**" to close the window.
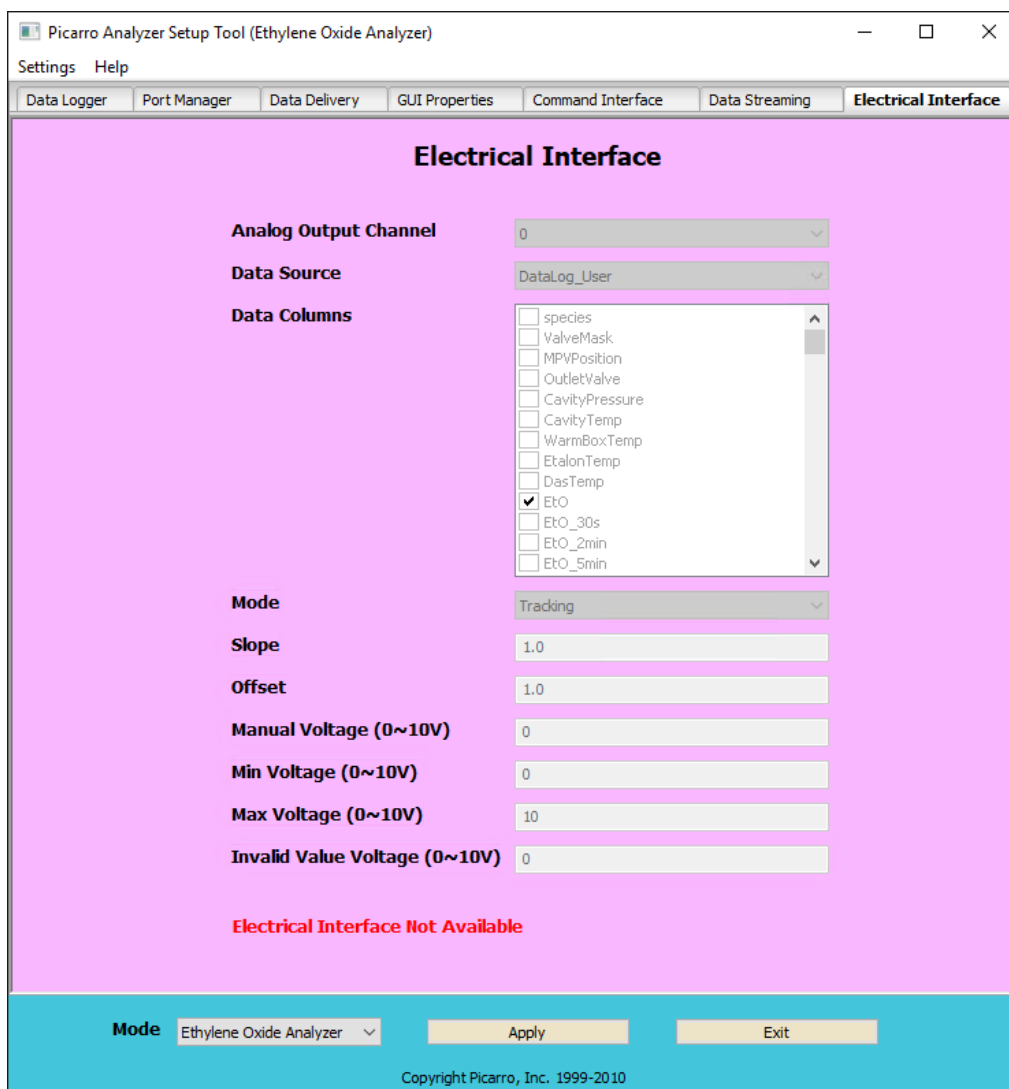

Figure 27: Setup Tool – Electrical Interface Tab

10. Calibration

The primary analytical measurement of the G2910/G2920 instrument is the concentration of C_2H_4O (Ethylene Oxide or EtO) Periodic recalibration with standards of known concentration maintains the accuracy of these quantities. Using the **Data Recal Software Utility** (described in Section 10.3, Calibration Software Utility Tools) enables the calibration constants to be tracked over time, thus enabling the user to follow system performance.

10.1 Slope and Offset

Every Picarro analyzer ships with a default user calibration value of 1 for slope and 0 for offset. While new user calibrations will likely result in changes to both, we recommend that only offset changes are applied during more frequent calibrations.

If a new slope calibration is to be applied, the user must be mindful of their experimental uncertainty. For example, a change in the slope calibration from 1 to 0.95 may not represent a change in the system's linearity but may simply reflect the experimental uncertainty. If during your slope calibration, a new value of 0.9 or 0.85 is suggested by the Data Recal tool, please repeat the measurements of your standards. In most cases, such large changes in slope are a result of uncertainty and do not indicate a bad nonlinearity of the analyzer. If your analyzer continues to suggest a large change in slope, please consult with Picarro Support before applying a new calibration.

NOTE

If you are uncertain about the state of your current slope and offset values, they can be reset back to their user default values of 1 and 0, respectively. In your Picarro GUI, navigate to:

"Tools → User Calibration → (password: picarro) →" Then change the slope and offset values of your parameter of interest to 1 and 0, respectively.

10.2 Calibration Methodology

To perform a calibration or verification of calibration, the user simply introduces the calibration standard into the analyzer for a period long enough for the analyzer to yield a stable measurement of that sample.

Calibration Setup

This section describes the connections from the analyzer to the gas tank.

- The pressure regulator at the outlet of the gas tank protects the analyzer from over-pressurizing. The pressure should be set to about 1 – 3 psi (68.9 mbar – 206 mbar).

- The toggle valve allows rapid shutoff of the gas delivery.

- Tubing is connected to the male quick-disconnect connector provided with the analyzer.

- The male connector is inserted into the inlet port of the analyzer.

To replace the gas tank:

1. Turn off the main valve on the gas tank.

2. Disconnect the pressure regulator assembly from the tank.

3. Connect the pressure regulator assembly to the next gas tank.

Measurement Time for Each Standard

The measurement period for a calibration standard is dependent upon the recorded precision of the standard gas and performance characteristics of the analyzer, using the Allan standard deviation plot.

Measuring Multiple Gas Standards

When measuring multiple gas standards, the order of the gas standard is not important. However, make sure that you measure the gas standard slightly longer than the time you determined in the previous section because the usable/effective data set will be trimmed down.

Calibration Data Processing

1. Process the calibration results from the .dat file (see File Management on Page 41) and calculate the average recorded value for each standard.

2. Plot these values versus the certified values from the gas supplier, and determine the linear relationship between the known calibration values and the analyzer's reported values. A linear best-fit equation can be calculated from the data.

NOTE

It is important to plot the analyzer's reported concentration on the horizontal axis and the gas standards' stated concentrations on the vertical axis.

The slope and intercept of the best-fit line through these points are the two values that are used to calibrate the analyzer. By determining the linear relationship between the known calibration values and the analyzer's reported concentration values in this way, a calibration offset (slope and intercept) can be calculated to add a correction term to the analyzer's factory or previous calibration.

Entering the Calibration Setting

Changing the analyzer's calibration is intended to be done infrequently. Instead of recalibrating frequently to increase the accuracy of the data, users often just verify the calibration by measuring three or more gas standards and use the same regression procedure described here to calculate an offset by which to correct their data offline. Using the following equation in the graph below, this calculation would be accomplished point-by-point by calculating the corrected data "y" using the analyzer's data "x" so that:

Data corrected = $0.9866 \cdot$ Dataraw $+ 5.268$
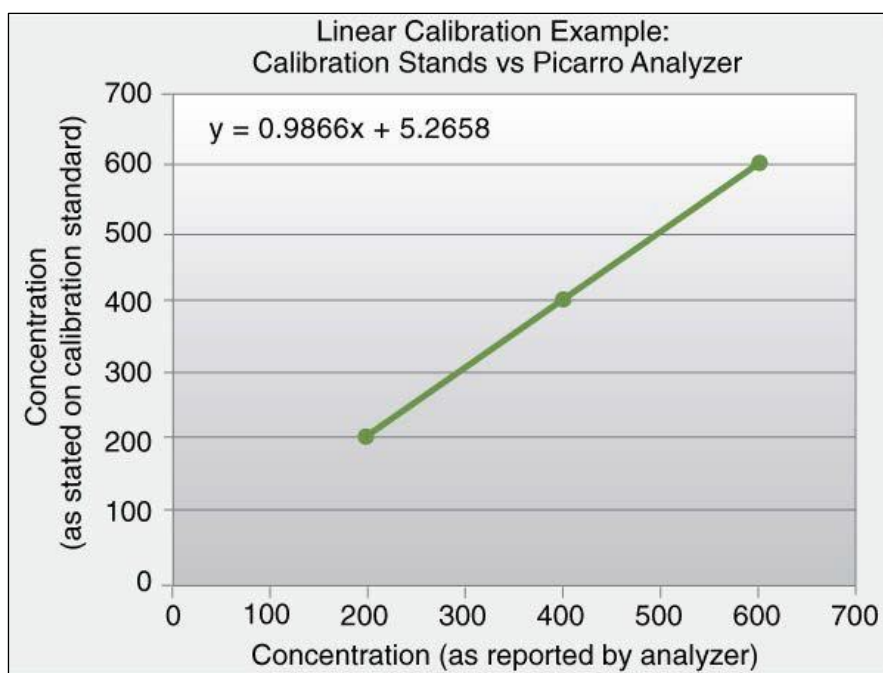
Figure 28: Linear Calibration Example

Calibration values are input into the analyzer by selecting Tools → User Calibration, and then entering the slope and intercept for each species.

NOTE

User Calibration is a password-protected form, and the default password is "picarro". This password can be reset in the QuickGui.ini file as previously described.

The calibration will take effect immediately after clicking **OK**.

How to Return to Factory Calibration

To return to the factory calibration, simply set the slope to 1 and the intercept to 0 for each species.

10.3 Calibration Software Utility Tools

Data Recal

The Data Recal software utility is designed to enable users to perform a concentration calibration or calibration verification of Picarro's gas concentration analyzer via a user-friendly interface.

Data Recal allows the input of ten calibration points. Some of these points can be used for recalibration, while the remaining points can be used as quality control calibrants. In an ideal situation, three concentration certified standards should be analyzed on the system to generate CRDS-reported values for concentration. Standards spanning and encompassing the intended sample analysis should then be used to build a standard calibration curve. Parameters of this curve will then be used to correct the instrument readings so that they match standard values. The other standards will be simultaneously used for quality control, to verify other recalibrated values against their certified values.

NOTE

The following steps illustrate the Data Recal procedure for an isotopic delta calibration. The user can follow the same steps for a concentration calibration.

Graphical User Interface (GUI)

The Picarro Data Recalibration ("Data Recal") software can be found in the "Picarro Utilities" folder on the desktop. The Data Recal software utility can be launched by double-clicking on the Data Recal Icon in the folder. Shown in Figure 29 below is a screenshot of the window that will open.

Figure 29: Data Recal Software Utility GUI

The Delta Recal Software Utility comprises three sections:

1. **Numerical Input and Selection Section** (Figure 30):

   Certified and CRDS reported values are entered in the white boxes. Standards that will be used for instrument recalibration are then selected by checking the corresponding box in the first column, labeled "Used for Recal."

Figure 30: Recalibration Section of Data Recal Software Utility GUI

2. **Calibration Output Section** (Figure 31):

    In the "**Calibration Options**" drop-down menu, you can select either an "**Offset**" or an "**Offset + Slope**." Once the new calibration parameters are calculated, the Data GUI will display the new values under the "New Calibration" column. The parameters that appear here will depend on your initial selection. When the Offset + Slope option is selected, the program also calculates a goodness-of-fit correlation coefficient (R2).
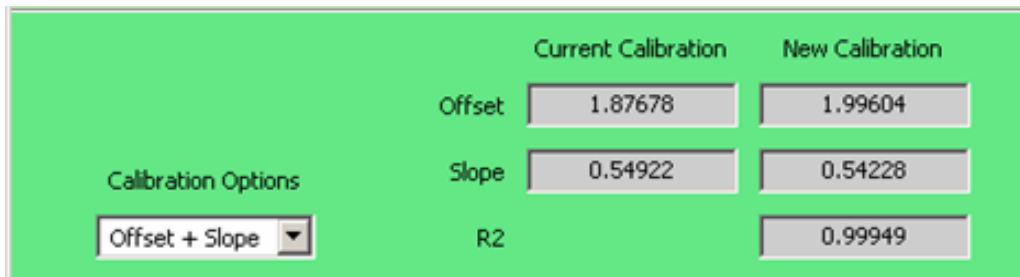
Figure 31: Calibration Output Section of Data Recal Software Utility GUI

3. **Action Selection Section** (Figure 32):

    In this section, the user can click on the compute button to calculate the new calibration parameter(s). The compute button will be grayed out until values have been entered in the Certified and CRDS reported columns (Figure 30), and at least one pair of Certified and CRDS reported values selected for the calibration. Once these values are entered or selected, the "Compute" button will be active. Click "**Compute**" to calculate the new calibration parameters. These parameters will appear in the Calibration output section of the GUI, and an asterisk "*" will be displayed at the end of the window title line (Figure 33), indicating the new change.
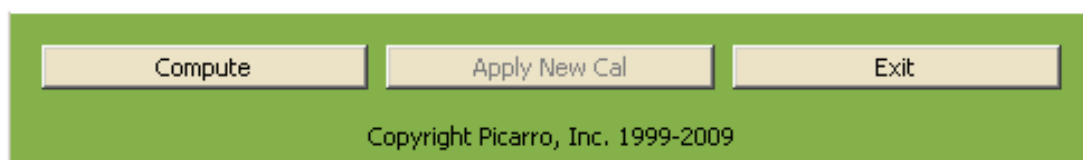
Figure 32: Action Selection Section of Data Recal Software Utility GUI

Once the calibration parameters are calculated, you can elect to graphically display the calibration and quality control (QC) standards in a graph. To do this, click "**Plot**" in the upper left corner of the window, and select "**Plot Linear Fitting**" from the drop-down menu, as shown in Figure 33 below.
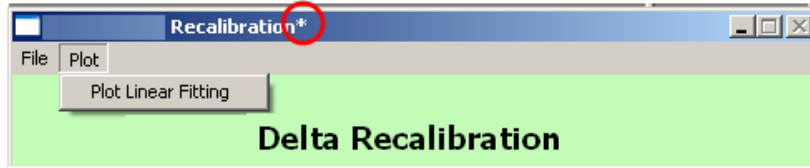
Figure 33: Delta Recalibration – Asterisk Indicating New Change

The plot that the utility will generate is shown in Figure 34; this plot will display two graphs. The top graph presents measurements for the recalibrated standards (calibration and QC), as well as a line fit through those points. The bottom graph shows the residuals, which shows how far each measurement is from the best-fit line.
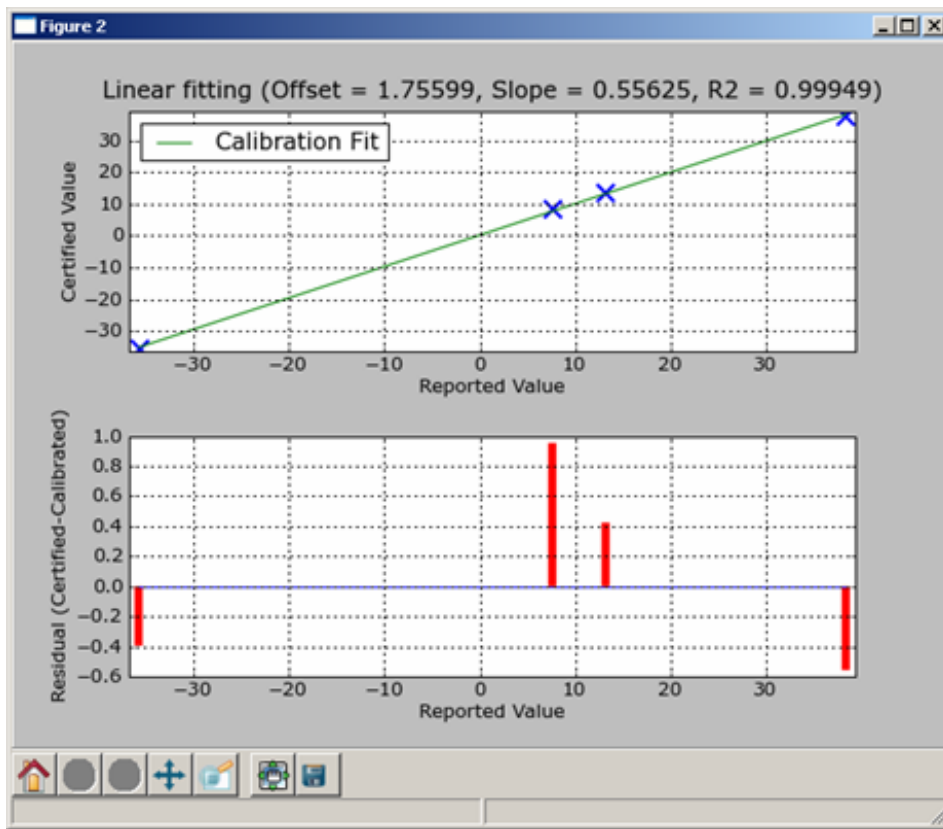
Figure 34: Slope of Delta Recalibration

If you decide to accept the new calibration values based on this plot, click on the "**Apply New Cal**" button (Figure 35 below).
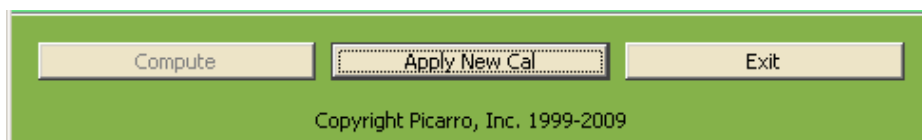
Figure 35: Apply New Calibration Slope and Intercept

You will then be prompted to enter a Calibration Password (Figure 36). **The default Calibration Password is PICARRO**.
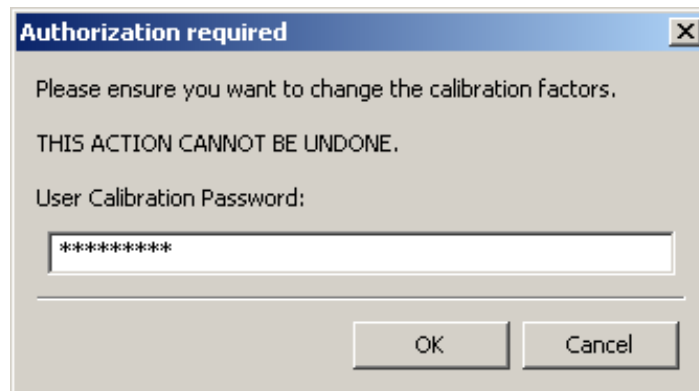
Figure 36: User Authorization Dialog

Next, a "Recalibration Confirmation" pop-up window will appear, displaying the new offset and slope (when applicable) values. This window will prompt you to confirm your choice to apply these values, to avoid any inadvertent mistakes.
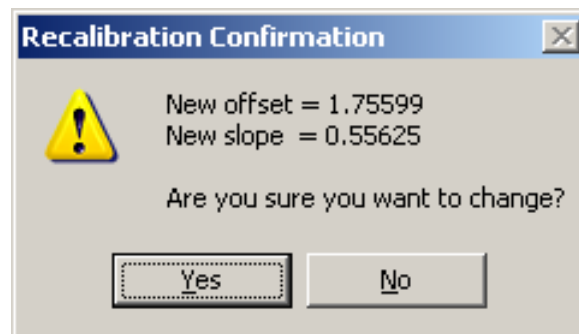
Figure 37: Calibration Confirmation Pop-up

Please note that when you click the "**Yes**" button, the newly accepted calibration parameters will take effect immediately, without the need for the instrument main GUI to be restarted.

Once you accept the new calibration parameters, the Data Recal Software Utility automatically gives you the option to save the new recalibration file (Figure 38 below). Saving these files enables you to track the instrument recalibration history.
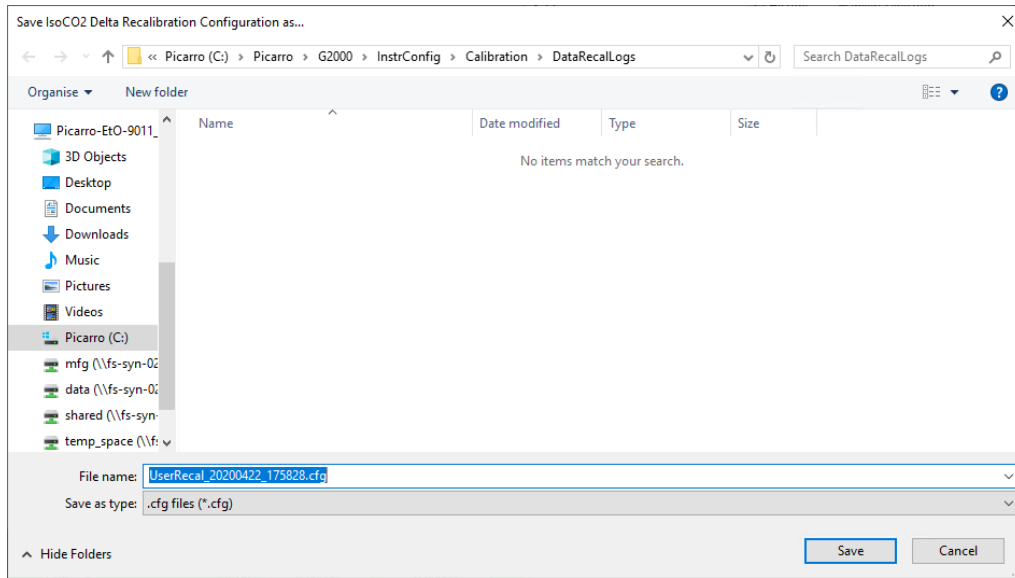
Figure 38: Delta Recalibration Save-As File Dialog

Saved files can be reloaded by clicking "**File**" in the upper left corner of the window (Figure 39) and selecting "**Load Recalibration File**."
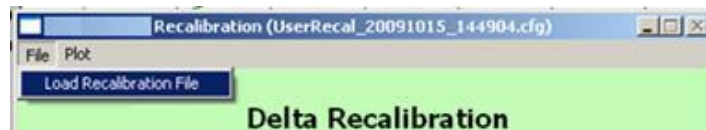
Figure 39: Delta Recalibration Load File

Next, you would select and open the file that you want to load (Figure 40).
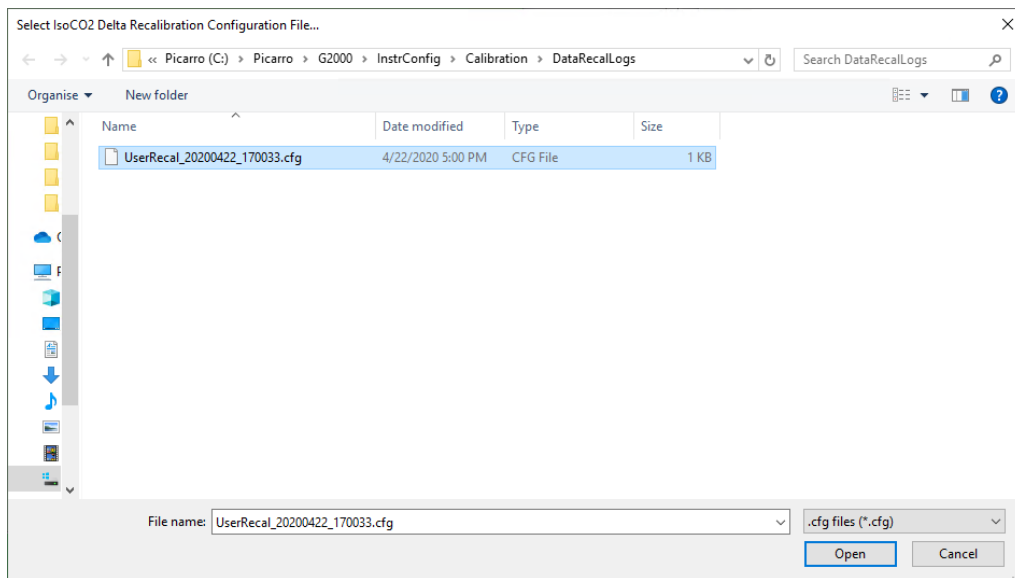
Figure 40: Delta Recalibration Load File Dialog

The recalibration file for this example will contain the information shown in Table 8.

Table 8: Delta Recal Log File

Row	Column 1	Column 2	Column 3
1	−35.6	−35.8	−35.20437
2	8.6	7.6	7.64690
3	37.5	38.4	38.05748
4	cc	1.75599	0.55625
5	nc	1.87678	0.54922 0.99949
6	option	Offset + Slope	

Rows 1 – 3: Values from each standard selected for recalibration. The first column in these rows lists the certified values, the second column lists the measured values, and the third column lists the recalibrated values. The number of rows will depend on the number of standards selected to be used for recalibration.

Row 4 – Current Calibration (cc) Row: Read from left to right, lists the current offset and current slope value.

Row 5 – New Calibration (nc) Row: Read from left to right, lists the new offset and new slope values. The third value in this row is the R^2 value, which is only displayed if the calibration option is "offset + slope."

Row 6 – Options Row: The last row displays the calibration option selected. If you choose to exit the Recal GUI before accepting the new recalibration values, you will be prompted to confirm your choice through a pop-up window (Figure 41). This window contains a warning that continuing to exit will cause the new calibration data to be lost:
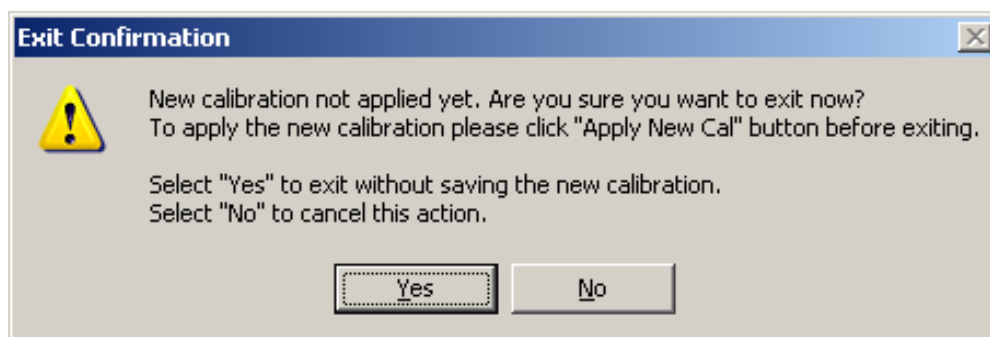
Figure 41: Recalibration Exit Confirmation Pop-up

When you are finished with the calibration, you can exit the Delta Recal software utility by clicking on the "**Exit**" button at the bottom part of the Recal GUI.
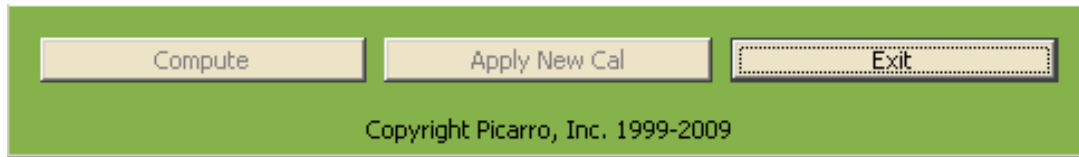
Figure 42: Exit Delta Recalibration Utility

NOTE

The Recal GUI will display an error message (Figure 43) saying the new slope value is not acceptable when one of the following occurs:

  a. **At least two entries in the Certified or CRDS reported columns contain zero-value numbers.**

  b. **These entries are selected to be used for recalibration.**

  c. **The "Offset + Slope" calibration option is selected. This error occurs because the entered values will lead to an erroneous zero-slope value.**
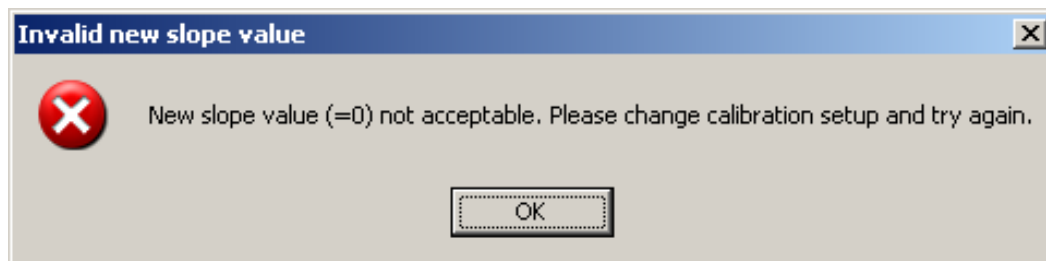
Figure 43: Invalid New Slope Value Error Message

11. Troubleshooting

The following section lists problems that may be encountered during installation and operation of the analyzer. The corresponding step-by-step procedures provide resolution in most cases. If, after attempting these procedures, the problem remains unresolved, please contact Picarro Technical Support.

11.1 Power LED on Analyzer Does Not Illuminate

Context: Turning on the analyzer by momentarily depressing its front panel power switch should apply power. The green power LED is illuminated when it detects the correct power levels.

1. Check that the AC power cord is attached and plugged into a working outlet.

2. Verify the rear on-off switch near the AC power cord is ON.

3. Press and hold the front panel power switch for at least 5 seconds as the analyzer may take several seconds to respond.

11.2 User Interface Program Does Not Start

Context: The computer may be configured to start the instrument and the associated user interface program automatically after it completes its boot-up sequence, or the program may be launched using the "Start instrument" icon on the desktop. Communications problems with the analyzer may occur if the analyzer fails to initialize correctly on power up. Should the analyzer initialization process not complete correctly, shut down the instrument by shutting down the Windows operating system on the control computer:

NOTE

Do not simply restart Windows as this does not cycle the power to the analyzer.

1. Use the Start menu, select the red Shutdown button and select "Shutdown" in the drop-down box under "What do you want the computer to do?".

2. Wait for the shutdown to complete normally and for the computer and analyzer to turn off completely.

3. After a few seconds, restart the computer by momentarily depressing the power button.

11.3 Sample Pressure Not Controlled to Appropriate Value For Concentration Measurements

Context: Under normal operation, the cavity pressure is automatically locked to the correct value by means of electronically controlled inlet and outlet valves. The message "Pressure Locked" on the front panel display and the user interface indicates that the cavity pressure is at the appropriate value. If messages stating "Pressure high" or "Pressure low" are displayed, the cavity pressure is out of its correct operating range.

1. A "**Pressure low**" message indicates that there is insufficient gas available at the inlet of the analyzer. Check the inlet plumbing to the analyzer and ensure that the pressure at the inlet is within the specifications.

2. A "**Pressure high**" message indicates that gas cannot be removed from the analyzer at a sufficient rate. Check the vacuum line between the analyzer and the power vacuum unit for leaks. Failure of the vacuum pump, injecting dilution gas at excessive pressure, or excessive pressure at the inlet can also cause this problem.

11.4 UI Program "Freezes" – Does Not Update Graphs as Data Collected.

Context: The computer may become unresponsive causing the programs that control the analyzer to stop functioning. The computer and analyzer should be shut down and restarted.

1. Resetting the computer and the instrument requires that the computer is shut down and restarted. If the computer responds to the mouse, a normal Windows shutdown may be carried out: use the Start menu, select the red Shutdown button and select "Shutdown" in the drop-down box under "What do you want the computer to do?" Wait for the shutdown to complete normally and for the computer and analyzer to turn off completely. After a few seconds, restart the computer by momentarily depressing the power button.

2. If the computer does not respond to the mouse, hold down the power switch on the front panel for a few seconds until the computer and the instrument turn off. After another few seconds, restart the analyzer by momentarily depressing the power button.

12. Service and Maintenance

12.1 Consumables and Replacement Parts

The following parts can be ordered directly from Picarro as needed over the lifetime of the analyzer. See Contact Information on Page 4.

Table 9: G2910/G2920 Replacement Parts

Part Number	Description	Expected Servicing Frequency
S1020	Particulate filter kit for input sample line	After 12 months
C0360	Desiccant Drier Kit	After 12 months
S2009	Rebuild kit for A2000 Pump	After 2-3 years
S2068	Complete fan replacement kit	After 2-3 years
A2000	External vacuum pump	After 40,000 hours

12.2 Particulate Filter Replacement

There are two inline, sub-micron particulate filters before the measurement cavity. The first is user-replaceable and replacement filters can be purchased from Picarro and installed by the user.

CAUTION

Equipment Damage: Never remove the filter that is directly attached to the cavity. Only change the filter immediately following the inlet at the back of the analyzer.

The symptoms of a clogged filter can be analyzed reporting "pressure low" or there being no flow into the instrument, causing unusual measurements. Filters can become clogged after years of use in dirty environments.

WARNING

If liquid water is accidentally sucked into the inlet line, it will clog the filter and impede the flow (usually for a few days) until it evaporates. If this occurs, it is important to NOT turn off the analyzer or replace the filter until it is dry.

The reason for this is that the increased humidity due to liquid water in the filter can cause condensation on the optics if the analyzer is allowed to cool from its operating temperature. Often, after the filter dries, the analyzer will begin functioning normally, and a filter replacement is not necessary.

Required Tools

- 2 mm Hex driver
- 9/16" open-end wrench
- 5/8" open-end wrench
- 11/16" open-end wrench

Removing the Old Particulate Filter

1. Move the analyzer to a clean work environment.

2. Using a 2 mm hex driver, remove the top lid of the analyzer by removing six M3 x 6 mm socket flathead screws.

3. Loosen and remove the 2 screws on the inner long side of the bigger box (Figure 44), then lift and open the inner cover.
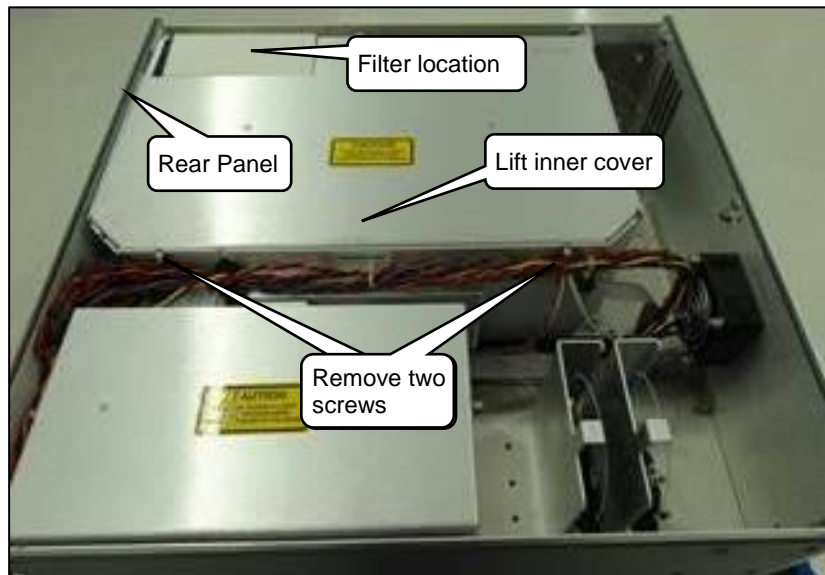
Figure 44: Opening G2910/G2920 Inner Cover

4. Remove the foam pieces as shown in Figure 45. Slide the larger foam piece toward the left side of the analyzer (as viewed from the back of the analyzer) to remove it.

5. Using a 5/8" wrench, loosen the retaining nut on the input bulkhead (about 1 full turn should be enough – See Figure 45).

6. Using a 9/16" and 11/16' wrenches, loosen input and output nuts that connect the filter to the analyzer (See Figure 46 and Figure 47).
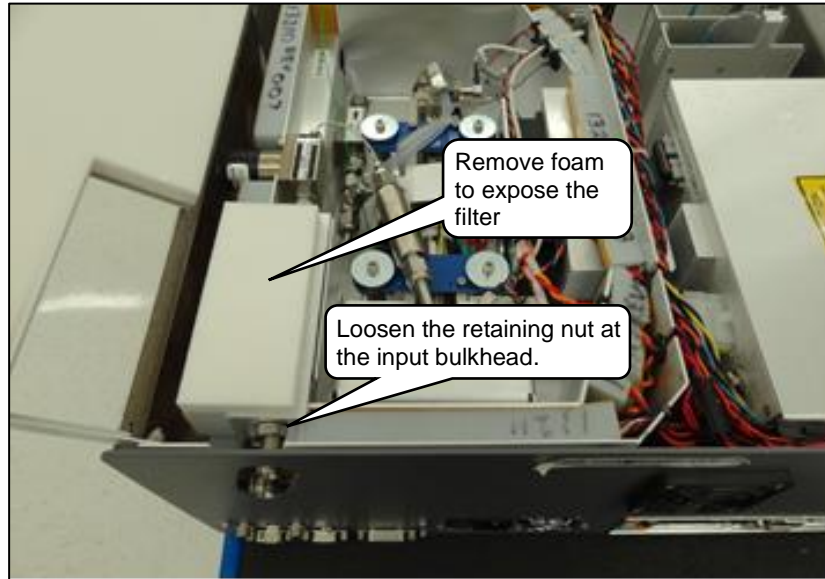
Figure 45: Foam Removal and Loosening Retaining Nut
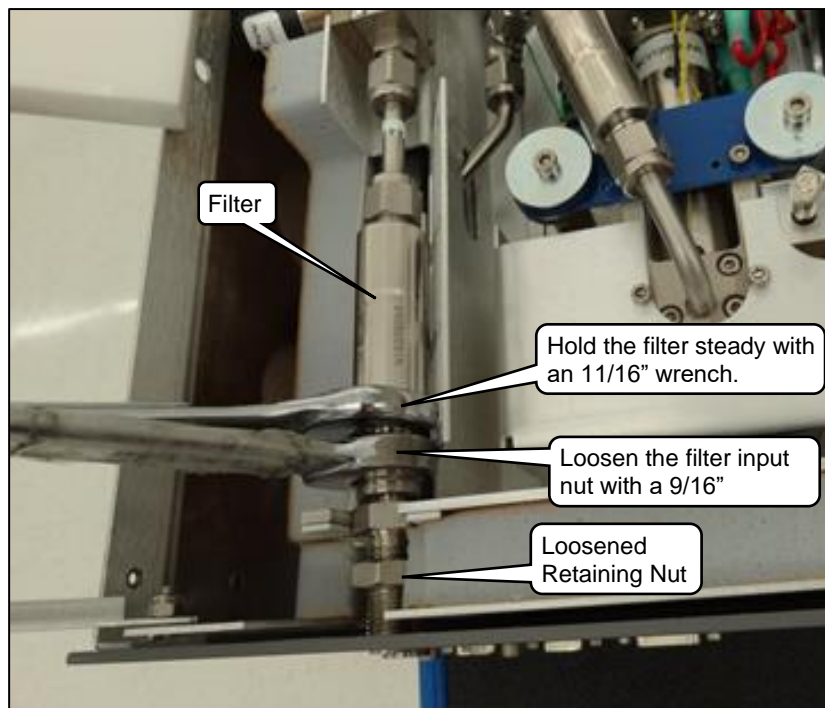
Figure 46: Loosening Filter Input Nut
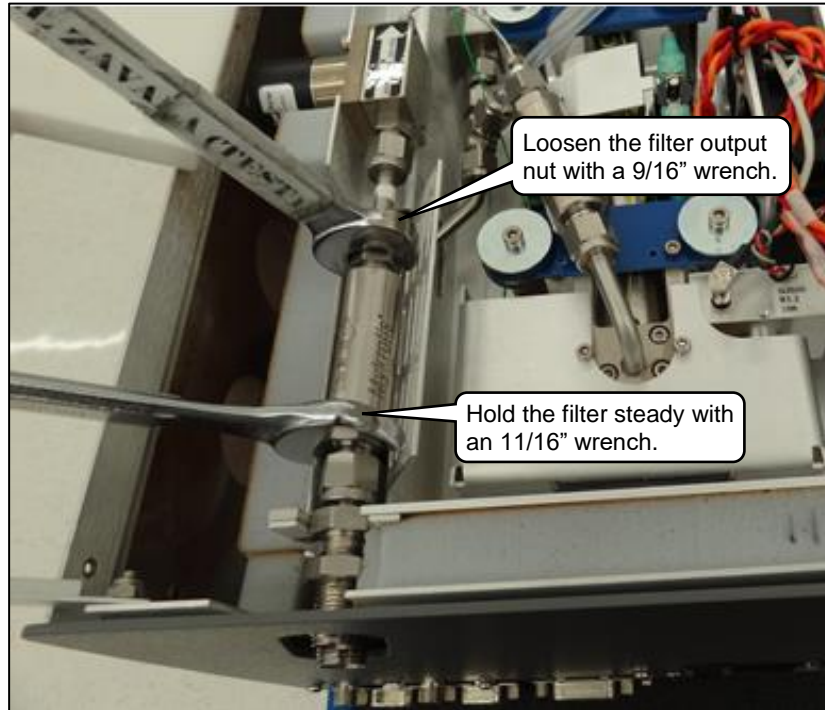
Figure 47: Loosening Filter Output Nut

7. Slide the filter slightly toward the back of the analyzer and lift it out.
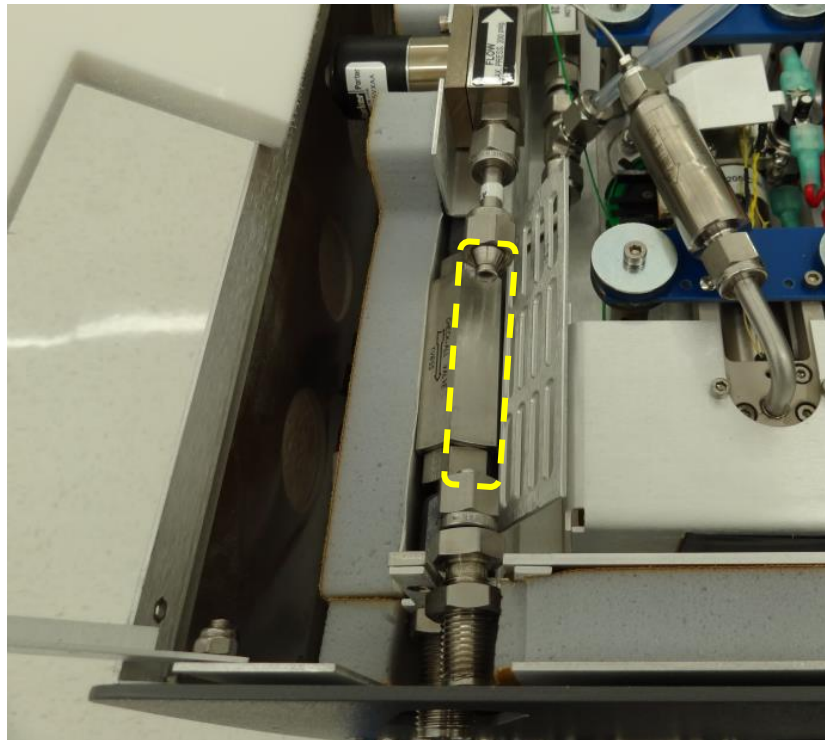
Figure 48: Filter Removed

Installing the New Filter

⚠️ **CAUTION**	When installing the new filter, to ensure proper gas flow direction, make sure the arrow on the filter is pointing away from the back panel of the analyzer as shown in Figure 49.

📝 **NOTE**	When re-attaching 1/4" Swagelok fittings, the nut should be hand-tightened and then turned an additional 1/8 of a turn using a wrench.

1. Remove new the filter from its packaging.

2. Position the new filter between the inlet and outlet fittings and attach the inlet and outlet nuts to each end. The flow direction arrow on the filter should point away from the analyzer rear panel (Figure 49).

3. Using a 9/16" and 11/16' wrenches, tighten the two nuts.
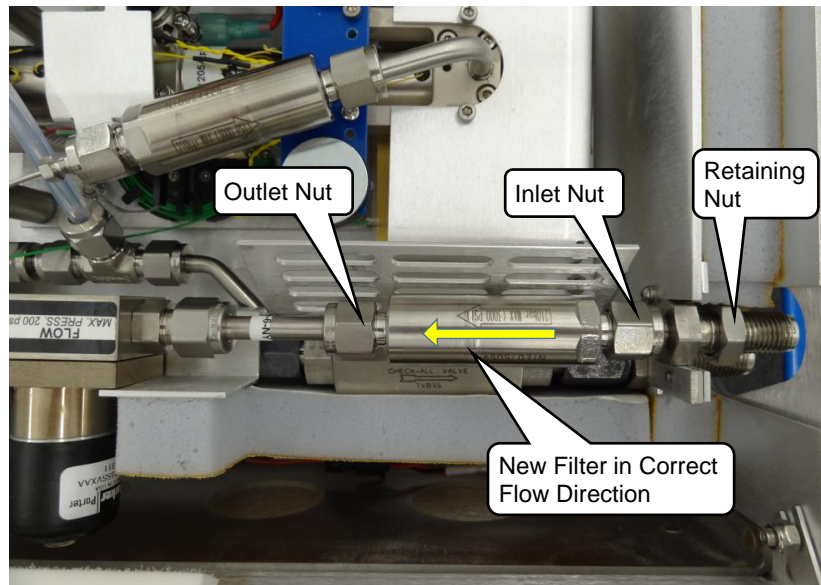
Figure 49: Filter Installation – Ensuring Correct Flow Direction

4. Using a 5/8" wrench, tighten the retaining nut at the bulkhead fitting.

5. Reposition the foam filter cover. The metal edge of the filter cover should be under the foam.

6. Close the inner lid and secure with the two screws on the inner long side of the bigger box.

7. With a 2 mm hex driver, attach the analyzer top cover with six screws.

12.3 Cleaning

Clean the outside of the analyzer with a clean dry cloth. Only certified service technicians should access or clean the inside of the analyzer.

13. Transportation and Storage

If the instrument will be transported or stored, the following procedure can be used to prepare the instrument and repack it into the original carton.

13.1 Packing the Analyzer

1. Shutdown the instrument using the shutdown button, using the "prepare for shipment" option.

2. Clean dry gas should be attached to the instrument prior to shutting down. This prevents condensation inside the system during storage or shipment.

3. Disconnect all tubing and electrical connections from the analyzer.

4. To prevent contamination and possible damage to the connector threads, place caps on all gas connections.

5. Place the analyzer in a plastic bag with a package of desiccant. Seal the bags with tape.

6. Pack the analyzer in the original shipping container ensuring that all the foam pieces are in place to protect the analyzer during shipping.

⚠️ CAUTION	**Prevent Equipment Damage: When shipping or relocating the analyzer, it is important to protect it from mechanical shocks. Failure to do so can compromise its performance. When shipping the analyzer, use its original packaging only.**

14. Limited Warranty

Picarro, Inc. warrants its Products to be free from defects in material and workmanship and to perform in the manner and under the conditions specified in the Product specifications for twelve (12) months from shipment.

This warranty is the only warranty made by Picarro with respect to its Products and no person is authorized to bind Picarro for any obligations or liabilities beyond this warranty in connection with its Products. This warranty is made to the original Purchaser only, is non-transferable and may only be modified or amended by a written instrument signed by a duly authorized officer of Picarro. Sub-systems manufactured by other firms, but integrated into Picarro Products, are covered by the original manufacturer's warranty and Picarro makes no warranty, express or implied, regarding such sub-systems. Products or parts thereof which are replaced or repaired under this warranty are warranted only for the remaining, un-expired portion of the original warranty period applicable to the specific Product replaced or repaired.

DISCLAIMER

NOTE

THE FOREGOING WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES WHETHER WRITTEN, ORAL, OR IMPLIED, AND SHALL BE THE PURCHASER'S SOLE REMEDY AND PICARRO'S SOLE LIABILITY IN CONTRACT OR OTHERWISE FOR THE PRODUCT. PICARRO EXPRESSLY DISCLAIMS ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

The Purchaser's exclusive remedy with respect to any defective Product shall be to have Picarro repair or replace such defective Product or credit the Purchaser's account, whichever Picarro may elect in its sole discretion. If it is found that any Product has been returned which is not defective, the Purchaser will be notified, and such Product returned at the Purchaser's expense. In addition, a charge for testing and examination may, at Picarro's sole discretion, be made on any Product so returned.

These remedies are available only if: **1)** Picarro is notified in writing by the Purchaser promptly upon discovery of a Product defect, and in any event within the warranty period; **2)** Picarro's examination of such Product discloses to Picarro's satisfaction that such defects actually exist and the Product has not been repaired, worked on, altered by persons not authorized by Picarro, subject to misuse, negligence or accident, or connected, installed, used or adjusted otherwise than in accordance with the instructions furnished by Picarro.

The following warranty conditions shall apply to all Picarro, Inc. products unless amended by a written instrument signed by a duly authorized officer of Picarro:

ADJUSTMENT: No electrical, mechanical, or optical adjustments to the product(s) are permitted.

PARTS AND LABOR: New or factory-built replacements for defective parts will be supplied for twelve (12) months from date of shipment of the product. Replacement parts are warranted for the remaining portion of the original warranty period. There will be no charge for repair of products under warranty where the repair work is done by Picarro, Inc.

NOT COVERED BY THE WARRANTY: Damage to any optical surface from improper handling or cleaning procedures. This applies specifically to those items subjected to excess laser radiation, contaminated environments, extreme temperature, or abrasive cleaning. Damage due to ESD, abuse, misuse, improper installation or application, alteration, accident, negligence in use, improper storage, transportation, or handling. No warranty shall apply where the original equipment identifications have been removed, defaced, altered or where there is any evidence of alterations, adjustments, removal of protective outer enclosure, any attempt to repair the product by unauthorized personnel or with parts other than those provided by Picarro, Inc.

DAMAGE IN SHIPMENT: The analyzer should be inspected and tested as soon as it is received. The product is packaged for safe delivery. If the product is damaged in any way, you should immediately file a claim with the carrier or, if insured separately, with the insurance company. Picarro, Inc. will not be responsible for damage sustained in shipment. All Picarro products are F.O.B. origin, shipped from the Picarro factory or Picarro distributor. The price of all Products, unless otherwise specifically stated, is Ex- Works, Sunnyvale, CA as defined by Incoterms, 2001. The cost of normal packaging for shipment is included in the invoiced price. Where Buyer specifies special packaging, a charge will be made to cover any extra expense.

CLAIMS ASSISTANCE: Call Picarro, Inc. Customer Service or your local distributor for assistance. Give our representative the full details of the problem. Helpful information or shipping instructions will be provided. If requested, estimates of the charges for non-warranty or other service work will be supplied before work begins.

RETURN PROCEDURE: Customers must obtain a Return Merchandise Authorization Number from Picarro, Inc. prior to returning units. Products being returned for repair must be shipped in their original shipping cartons to avoid damage.

APPENDIX A – Remote Data Access

A.1 Picarro Serial Communication

The analyzer supports an RS-232 physical command interface, which can be used to control the instrument and to retrieve concentration data. Not all features of the instrument are available on the serial interface. For details on how to use the serial command interface, please see the Programming Guide. This command set may also be used across a TCP/IP interface through an Ethernet connection. Please contact Picarro for further details.

A.2 Remote Data Access

Using the RemoteAccess.ini file, the analyzer can be configured to automatically:

- Send data from the instrument to a list of e-mail accounts.

- Measure the offset of the host computer system clock from a set of Internet time servers and (optionally) to resynchronize the clock based on this information.

The Internet connection need not be permanent and may be a dial-up connection accessible via a user-supplied USB modem. The task of sending data and/or synchronizing the clock on the analyzer is performed using the C:\Picarro\G2000\HostExe\RemoteAccess.exe program. This program can be set up to run periodically using the Windows task scheduler at a user-configurable frequency. If a dial-up connection to the Internet is employed, it is used only on demand to minimize the connection time.

Each time that the RemoteAccess.exe program runs, it appends information to a log file, which keeps a record of the results of the time synchronization and of the files sent by e-mail. The RemoteAccess.exe program is configurable by means of an initialization file, which includes information such as the login credentials for the dial-up connection, the e-mail account, and the list of time servers.

The initialization file is:

```
C:\Picarro\G2000\AppConfig\Config\UtilitiesRemoteAccess\Remote
Access.ini
```

It should be placed in the same directory as the executable RemoteAccess.exe. The file has one required section named **LOGGING** and three optional sections named **NTP**, **DIALUP**, and **EMAIL**. The logging section has a single key Logfile whose value is the path to the log file. Once this log file exceeds 64K bytes in length, it is backed up, appending a numeric extension to the file name, and a new file is opened. A total of ten backup log files are kept.

NTP

The NTP section controls querying the Internet time servers using the SNTP protocol (RFC4330) and the resetting of the clock on the host computer. If the section is not present, time synchronization is not carried out. The keys Server1, Server2, etc., are used to specify the URLs of the time servers. If the UpdateClock key is set to "true," the offset is applied to the host clock. Otherwise, the offset is recorded, but the host clock is not changed.

Email

The EMAIL section controls the sending of the data files as e-mail attachments. If the section is not present, e-mail messages are not sent. The key Directory specifies the directory that contains the data files. When the program is run, files in this directory are sent to the specified recipients and the files are deleted. To avoid problems with incomplete files, programs that place files into this directory should do so using an atomic operation, such as a rename. The Server key is set to the name of an RFC2821- compliant SMTP server that sends the e-mail messages.

The From key is the e-mail address from which the messages are sent. Note that some SMTP servers check that the source is permitted to send email while others allow any name in this field. The collection of e-mail addresses to which copies of the e-mail is sent is specified by the keys To1, To2, etc. The Subject key is used to fill the subject field in the email header and may be set to any string. Depending on the SMTP server, it may be necessary to use authentication before e-mails can be sent, as described in RFC2554. If such authentication is not needed, the key UseAuthentication is set to false. If this key is set to true, two additional keys Username and Password must also be specified for the e-mail account.

Dial-up

The DIALUP section is used if a dial-up connection to the Internet needs to be established when the program runs. If the section does not exist, a permanent connection is assumed to be available for carrying out the other tasks specified in the initialization file. The connection name key specifies the name of the dial-up connection to use, as listed under Network Connections in the Control Panel. The values of the keys Username, Password and Number are used to make the connection.

Table 10: Examples of RemoteAccess.ini File

[LOGGING]	Logfile=c:/temp/RemoteAccessLog
[NTP]	Server1=time-a.nist.gov Server2=time-b.nist.gov Server3=time-a.timefreq.bldrdoc.gov Server4=time-b.timefreq.bldrdoc.gov Server5=time-c.timefreq.bldrdoc.gov Server6=time.nist.gov Server7=time-nw.nist.gov UpdateClock=1
[DIALUP]	ConnectionName=Picarro Dialup Access Username=user Password=password Number=14085551212
[EMAIL]	Server=smtp.servername.org Directory=c:/picarro/mailbox From=instrument@picarro.com To1=recipient1@site1.com To2=recipient2@site2.com Subject=CRDS data from Silverstone instrument UseAuthentication

APPENDIX B – The Data File Viewer

B.1 Introduction

The Picarro Data File Viewer software is located in the Picarro Utilities folder on the desktop. The software allows the user to graph and to conduct statistical analysis of the raw data. Additional functions include Allan Variance plot and quadratic or polynomial fittings.

The Picarro Data File Viewer includes two main menus: File (Figure 50) and New (Figure 51).
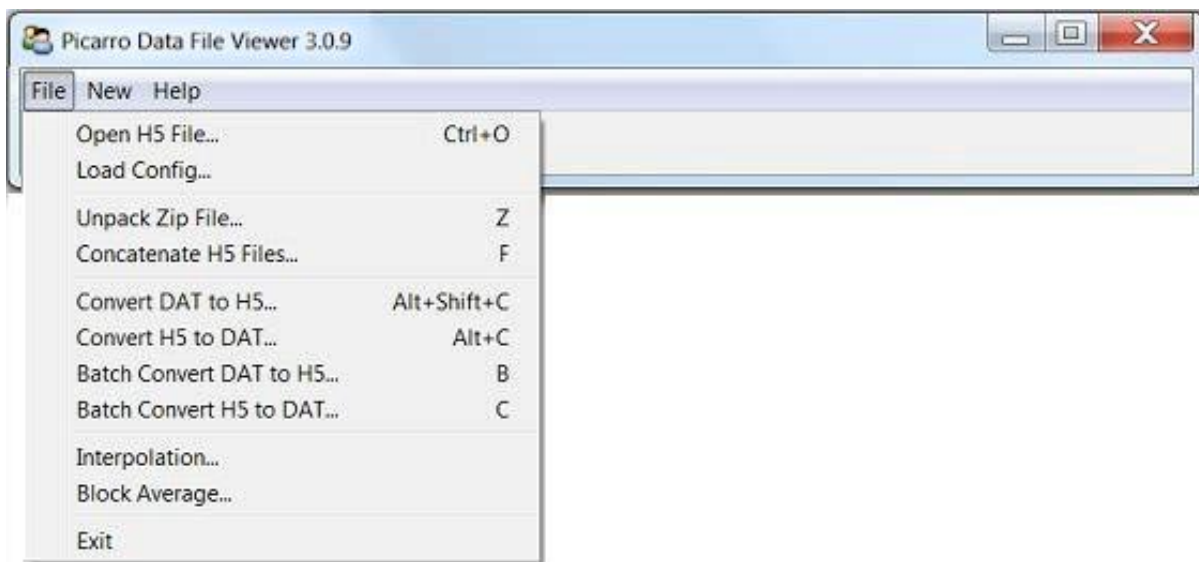
Figure 50: File Menu
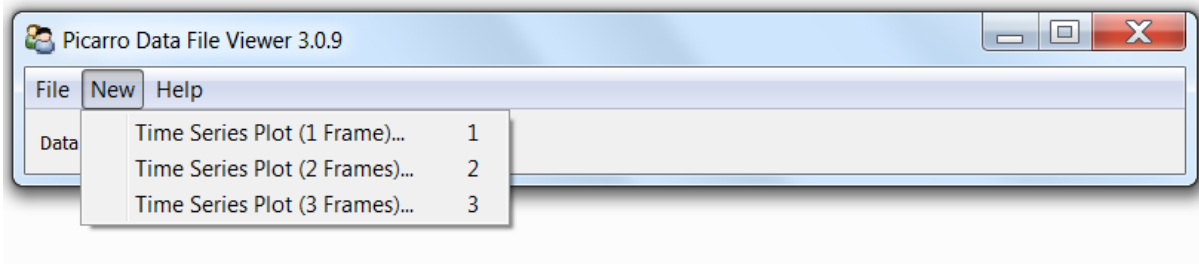
Figure 51: New Menu

B.2 The File Menu

This section describes the functions available from the Data File Viewer File menu.

Open H5

File > Open H5 File: Opens a Picarro data file (HDF5 format) for data analysis and visualization. After opening the data file, you can create a new time series plot. Refer to Section B.3, New – Time Series Plot for more information.

Load Config

File > Load Config: Loads a configuration file (ini format) to restore parameters of a workplace. Refer to Save Configuration on Page 86 for more information.

Unpack Zip File

File > Unpack Zip File: Use to concatenate all H5 files inside the zip file into a single H5 file. Refer to Concatenate H5 Files below for details.

Concatenate H5 Files

File > Concatenate H5 Files: Use to concatenate multiple files and zip archives of H5 files into a single H5 file. Navigate to the desired folder or use the **Define Date Range** button to specify a date range of files to concatenate. (See next section.)

After selecting the path of the data files, Data File Viewer will automatically search an H5 file in the specified zip/folder and look for all available variables in the H5 file. The variables are then listed in the **Select Variables** window in the left panel (as shown in Figure 52), and users can use the "**>>**" button to move variables to the right panel for concatenation.
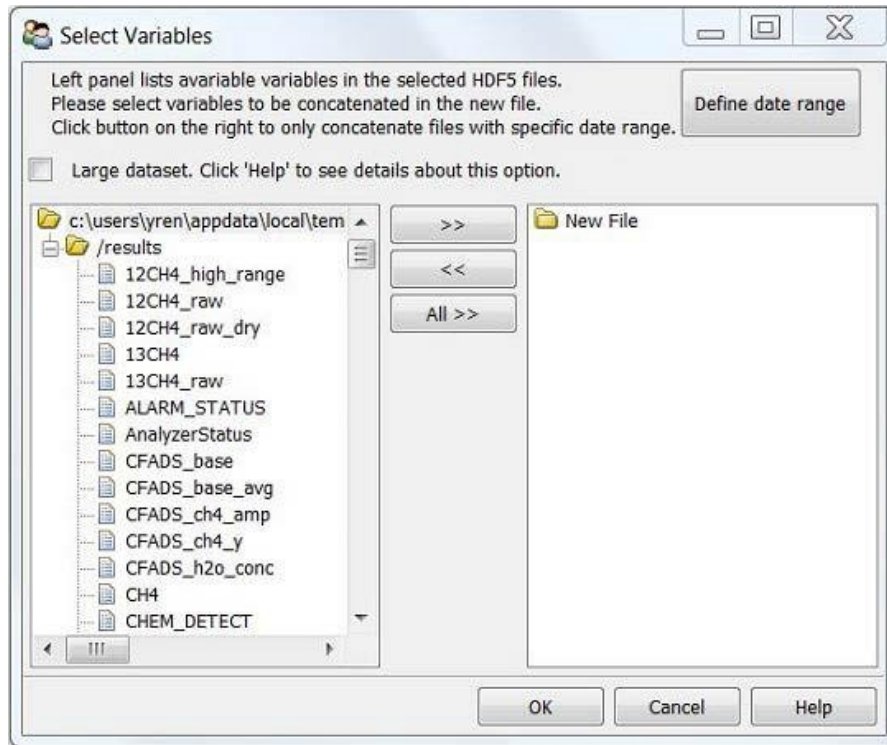
Figure 52: Select Variables Form

Define Date Range

Data File Viewer can search data files within the desired date range and then concatenate such files into an H5 file.

By default, TimeZone is set to your local time zone. However, if data were taken elsewhere, select the time zone where data were taken.

Select File > Concatenate H5 Files, then click **Define Date Range** to specify the desired date range as shown in Figure 53.

Figure 53: Define Date Range Dialog

Data files are saved in directory trees named by date and time option.

Picarro software saves data in a directory tree that is named by the creation year, month, and day as shown in Figure 54. Select this option if the target folder has this file structure. This way, Data File Viewer will only search folders within the desired date range, which can substantially reduce processing time.

Figure 54: File Structure of Data File Viewer

NOTE	**To save processing time, Data File Viewer does not open data files, but only determines data acquisition time based on the file name.**

CAUTION	**Do not define a time range for data files whose names have been changed.**

NOTE	**Data File Viewer does not concatenate data files exactly within the defined time range. This is because the time extracted from file name is different from the data acquisition time. To not miss data points, Data File Viewer expands the specified time range, so the resulting dataset normally has a wider time range than the user specification.**

Convert DAT to H5

Select **File > Convert DAT to H5 to** convert a file in DAT format to HDF5 format. These formats are described below:

- DAT format: DAT files accepted by DatViewer store tabular data (numbers and text) in plain text.

- Each line of the file is a data record. Each record consists of one or more fields separated by whitespaces.

- The first line of data file indicates column names.

- There must be a field "EPOCH_TIME" to store the acquisition epoch time (expressed as seconds since Jan 1, 1970) of the data. Otherwise, the first and second fields must be "DATE" and "TIME". The "DATE" field must have the format "mm/dd/yyyy" or "yyyy-mm-dd", and the "TIME" field must have the format "HH:MM:SS(.sss)" where (.sss) is an optional fraction of seconds.

- **HDF5 Format:** HDF5 is a data model, library, and file format for storing and managing data. (See the HDF5 Home Page on the [HDF Group](#) website for more information.) When converting DAT to HDF5 format, Data File Viewer creates a table named "results" to the contained data.

Convert H5 to DAT

Select **File > Convert H5 to DAT** to convert a file in a HDF5 format to DAT. These formats are described in Convert DAT to H5.

NOTE

Data File Viewer does not concatenate data files exactly within the defined time range. This is because the time extracted from file name is different from the data acquisition time. To not miss data points, Data File Viewer expands the specified time, column name "fineLaser-Current_1_controlOn" will be replaced with "fineLaserCurr_1_ctrlOn".

Interpolation

Interpolation describes the method for constructing data points with a range of a discrete set of known data points. Select File > Interpolation to perform interpolation on a time grid with a constant interval.

Block Average

Select **File > Block Average** to divide a dataset into small blocks based on a user-defined block size. The average is calculated for data in each block, and the results are saved in a new H5 file.

NOTE

The specified block size must be greater than the average data interval.

Because the data interval is normally not a constant (unless interpolation is performed), fluctuations in the data interval will affect block averaging if the block size is comparable to the average data interval.

B.3 New – Time Series Plot

You can specify to include create time-series plots with one, two, or three frames. New plots display in the Time Series Viewer.
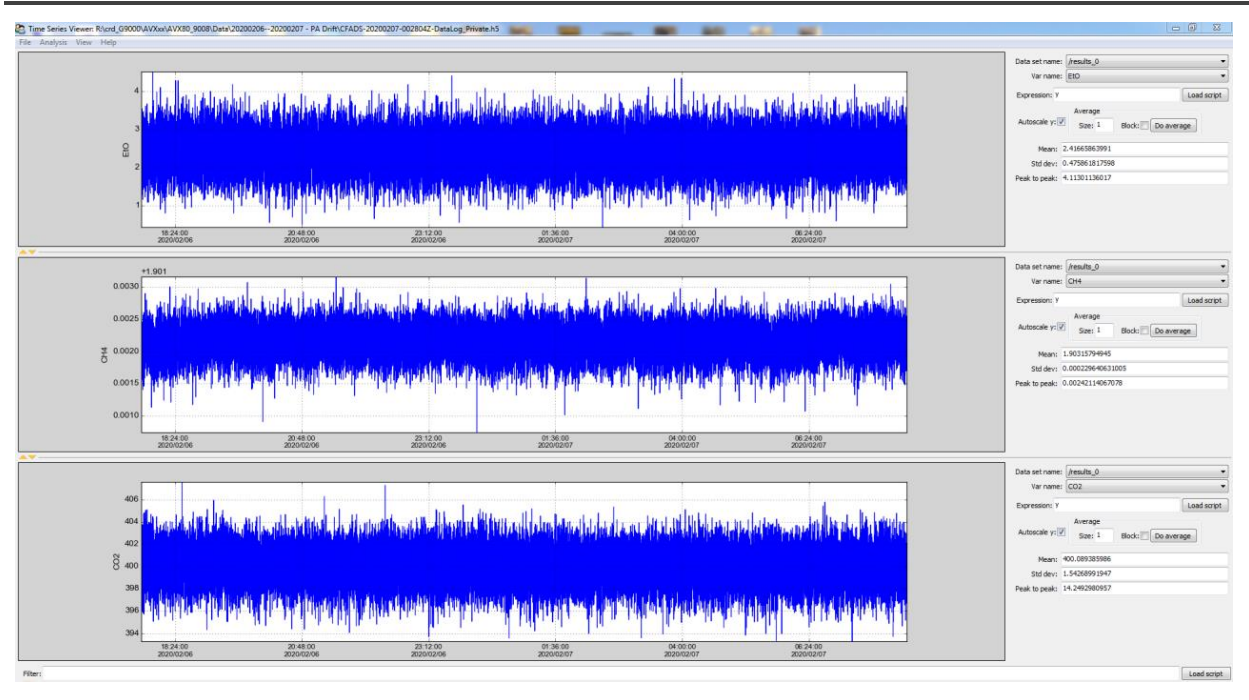
Figure 55: Time Series Viewer

The next section describes the options available on the Time Series Viewer menu bar. Refer to The Time Series Viewer Canvas on Page 89 for more information on the Time Series Viewer UI features and options.

B.4 Time Series Viewer Menus

The Time Series Viewer form includes the following menus:
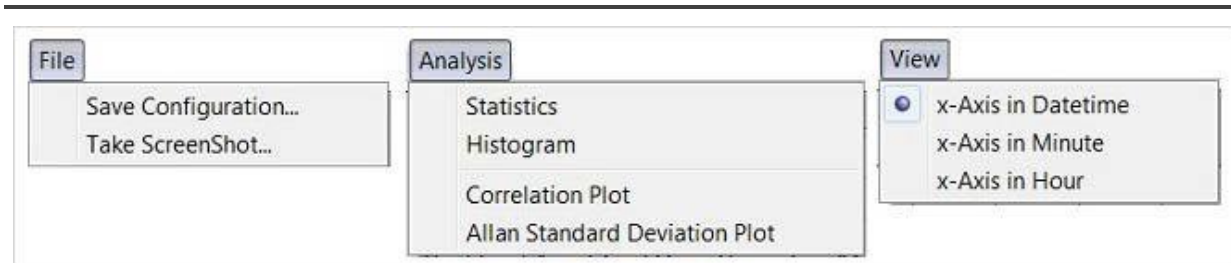
Figure 56: Time Series Viewer Menus

Time Series Viewer File Menu

Use the File menu to save a configuration or take a screenshot.
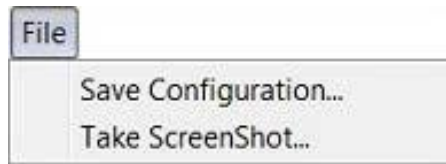
Figure 57: Time Series Viewer – File Menu

Save Configuration

Click **File > Save Configuration** to open the **Feature Capture** form. With this form, you can save figure properties, expressions, filters, and other settings to a configuration file so that it can be easily loaded in the future.
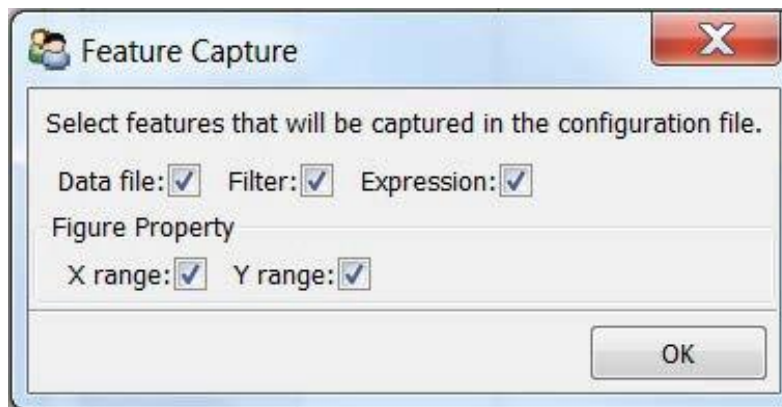
Figure 58: Time Series Viewer – Feature Capture

> ⚠ **CAUTION**
>
> **If a feature is not captured, it will be omitted when the configuration file is loaded.**

Depending on the features captured, loading a configuration file can have different effects. For example:

- If all features are captured, a saved workplace is reproduced.

- If Data file is not captured, saved parameters will be applied to the data file in memory.

- If Expression is not captured, plots will not be transformed.

- If X (Y) range is not captured, figures will be auto-scaled on the x (y) axis.

Take ScreenShot

Use **File > Take ScreenShot** to take a screenshot of the Time Series Viewer and save it as a .png to a specified file.

Time Series Viewer Analysis Menu

Use the Analysis menu to calculate statistics, generate a histogram, and to plot correlations and Allan Standard deviations.
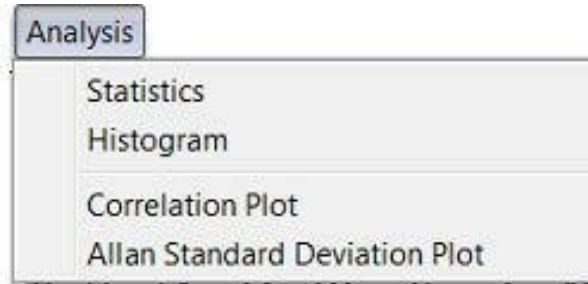
Figure 59: Time Series Viewer – Analysis Menu

Statistics

Use **Analysis > Statistics** to calculate mean, standard deviation and peak to peak for all plots in the current window.

Histogram

Use **Analysis > Histogram** to generate a histogram of data as shown in Figure 60 below.
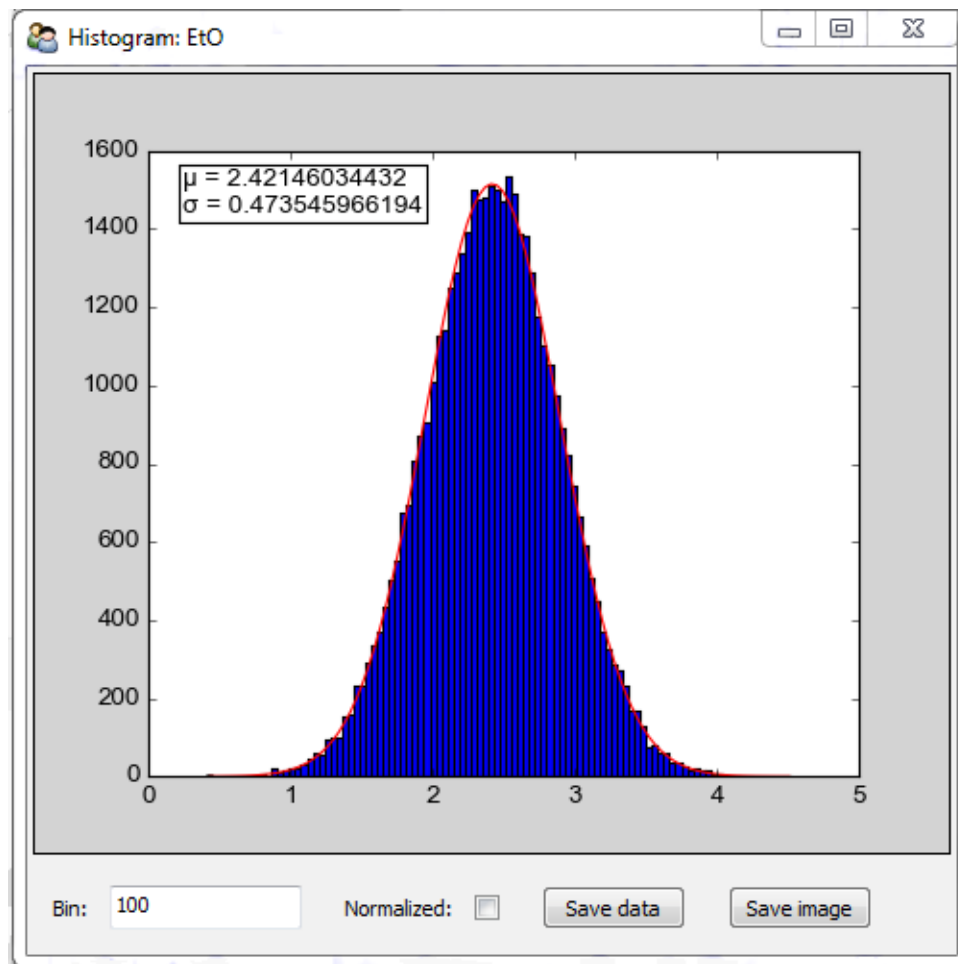
Figure 60: Histogram Window – EtO

- **Red Line:** A Gaussian function fitted to the histogram. Fitting results of μ and σ are shown in the top-left corner of the plot.

- **Bin:** Specifies the number of intervals that the range of values is divided into.

- **Normalized:** When selected, the sum of the histograms is normalized to 1.

- **Save data:** Saves histogram data to a CSV file.

- **Save image:** Saves the histogram image as a JPEG/PNG/PDF file.

Correlation Plot

Use **Analysis > Correlation Plot** to plot Y-axis data in one frame versus that in the other. This can be used when two or more frames exist in the current Time Series Plot window. See Correlation/XY Plot on Page 92 for details.

Allan Standard Deviation Plot

Use Analysis > Allan Standard Deviation Plot to create an Allan Standard Deviation plot (versus a standard deviation plot) for data in the current window. See Allan Variance Wikipedia page for more information.

Time Series Viewer View Menu

Use the View menu to view X-axis information in date-time, minute, or hour format.

Figure 61: Time Series Viewer – View Menu

NOTE

When switching from DateTime to Minute or Hour, the X-axis data is subtracted from the earliest point shown in the panel and then converted to the desired unit.

The Time Series Viewer Canvas

The Time Series Viewer canvas (Figure 62 below) is comprised of interactive graphs and a variety of configuration options.

Mouse Options and Graph Transform

The following mouse actions can be used in the canvas graphs:

- Left click and drag: Zooms into the selected area of the plot.

- Left click and drag with the SHIFT key down: Pans the plot.

- Left click and drag with CTRL key down: Zooms out from the plot.

- Left click and drag with ALT key down: Stretches the plot.

- Right-click: Opens an additional menu. Refer to Right-click Menu below in the next section.
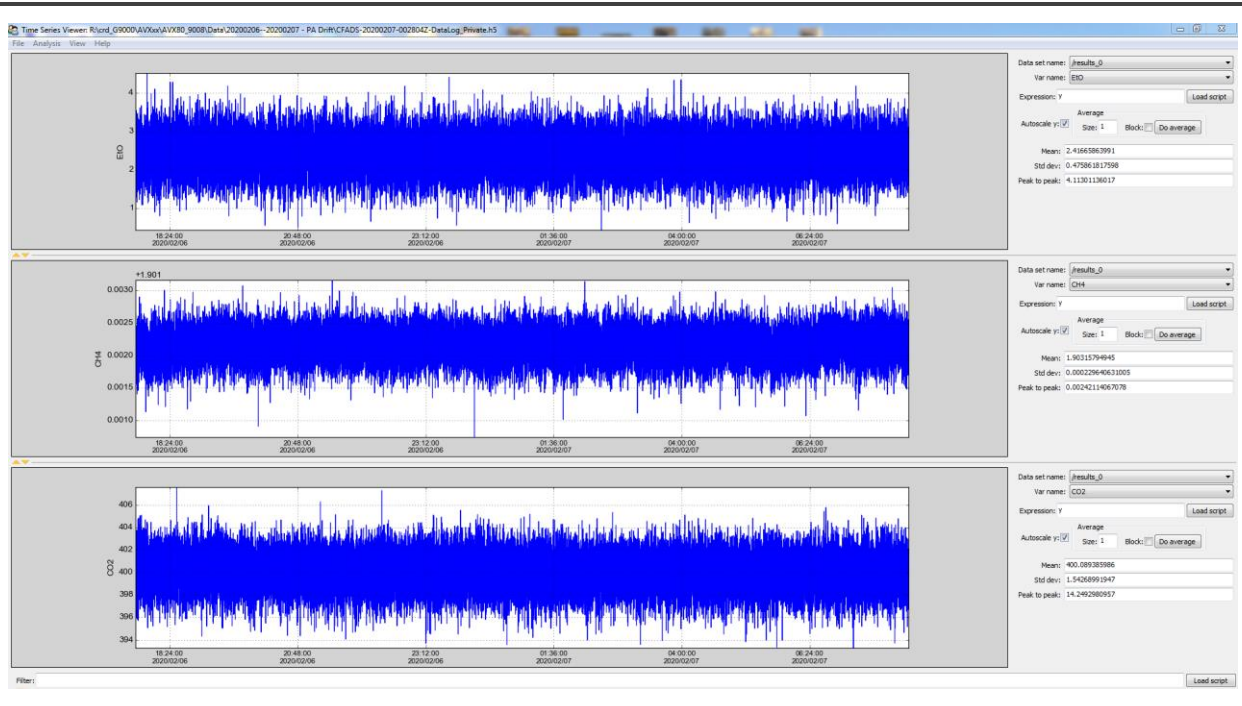
Figure 62: Time Series Viewer Canvas

Right-click Menu

Right-clicking on the canvas opens a pop-up menu:
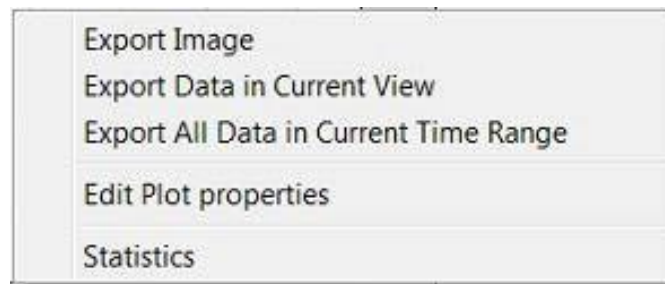
Figure 63: Canvas Right-click Pop-up Menu

Export Image: Exports the current plot as a jpeg, png, or pdf file.

Export Data in Current View: Exports only date/time and the selected variable in the current view to an HDF5 or CSV file.

Export All Data in Current Time Range: Exports all variable columns of the selected dataset in the current time range to an HDF5 file. Refer to Concatenate H5 Files on Page 81 for more information.

Edit Plot properties: Opens the **Image Editor** form (Figure 64 below), where the following options can be specified:

- **Title:** Edits the title of the plot.

PICARRO

Figure 64: Image Editor Form

- **Line:** Specifies the line pattern of the plot. If None is selected, the data points will be plotted without connecting lines.

- **Marker:** Specifies the marker type to indicate data points. If None is selected, data points will not be shown.

- **Min and Max:** Specifies the minimum and maximum of data range for the X-axis and the Y-axis.

- **x[0]:** Sets the earliest time of the dataset as the minimum of the X-axis.

- **Time zone:** Sets the time zone for date/time variables. This defaults to the local time zone.

Label: Specify a label for the X-axis and the Y-axis.

Statistics: Calculates the mean, standard deviation, and peak to peak for data in the current view.

Dataset Name and Var Name

An HDF5 file can store one or more tables. Each of these tables is called a Dataset. A table can contain one or more columns. Each column is called a variable (Var).

Use the **Dataset name** drop down to select the dataset that will be used for this time series graph. Use the **Var name** drop down to select the column in the dataset to use in the graph.

Autoscale Y

When the Autoscale Y option is selected, the Time Series Viewer will autoscale on the Y-axis to make sure that all data within the range of the X-axis is displayed.

Average

If **Block** is selected, a block average is calculated when you click the **Do average** button. Otherwise, a moving average is calculated.

For a block average, **Size** specifies block size in unit of a minute. For a moving average, **Size** specifies subset size in unit of data points.

REMINDER

Averaging is performed after the Filter and Expression are performed.

Mean, Std Dev, and Peak to Peak

The **Mean, Std dev** (Standard deviation) and **Peak to peak** fields provide all the statistical information of data in the current view.

Correlation/XY Plot

The Correlation/XY Plot window (Figure 65) includes two menu items: **File** and **Analysis**. For details about the File menu, see Save Configuration on page 86.

REMINDER

The canvas in this plot is interactive. For details about the plot canvas, see The Time Series Viewer Canvas on Page 89.
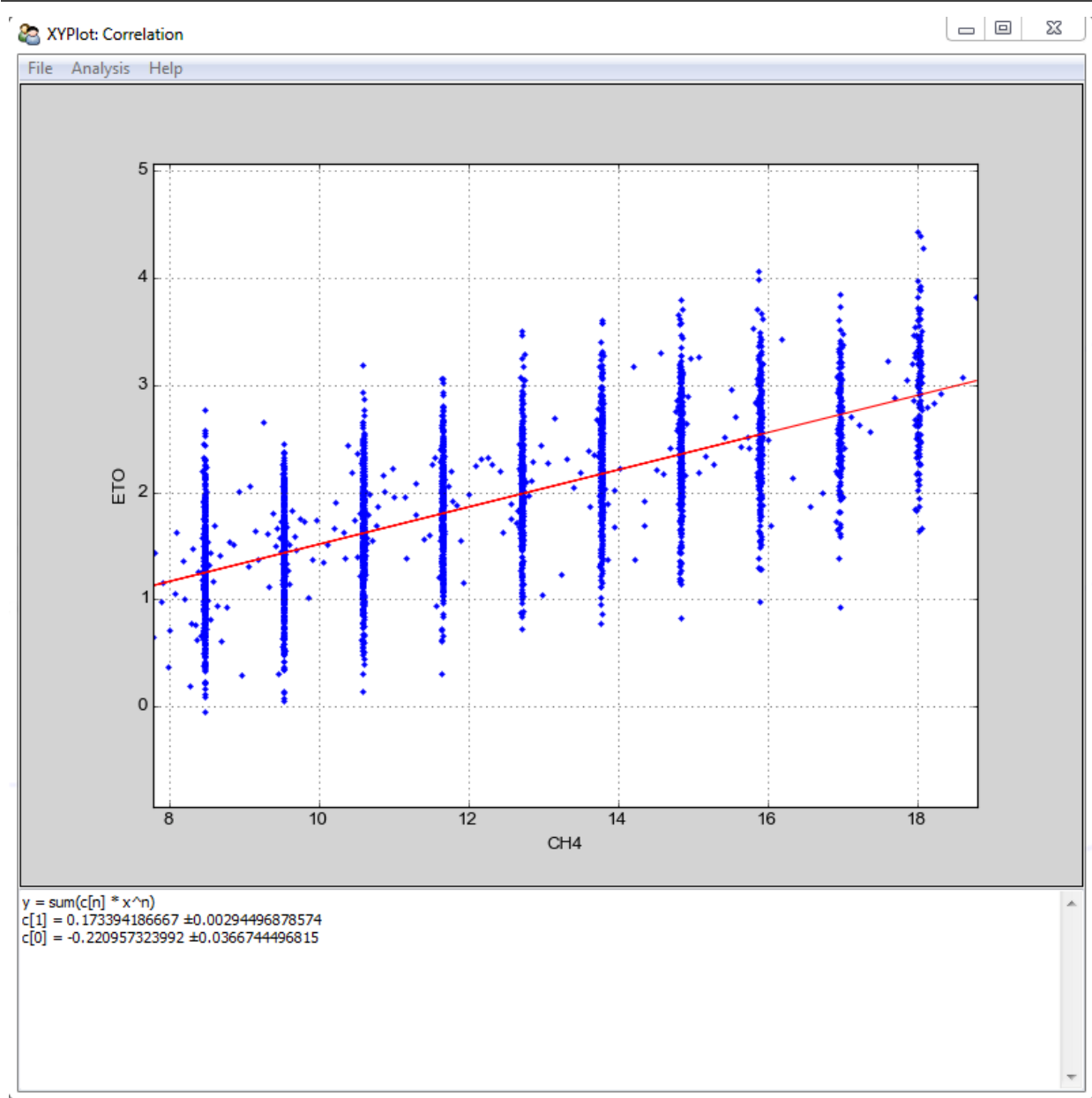
Figure 65: Correlation XY Plot

Analysis Menu

The Analysis Menu (Figure 66) includes three options: *Fitting, Integration, and Statistics.*

Fitting allows you to specify one of four fitting methods to include in the Correlation/XY plot:

1. **Linear fit:** Specifies to fit to linear function:
   $y = c_1 x + c_0$

2. **Quadratic fit:** Specifies to fit to quadratic function:

   $y = c_2x^2 + c_1x + c_0$

3. **Polynomial fit:** Specifies to fit polynomial function of degree n:

   $y = \Sigma c_nx^n$

4. **Curve fit:** Specifies to use non-linear least squares to fit an arbitrary function to data.
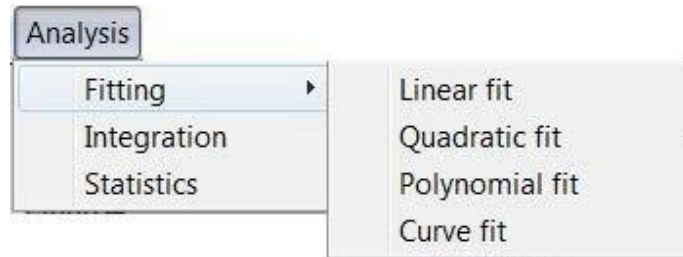
Figure 66: Analysis Menu

Integration calculates area under the curve using the composite trapezoidal rule.

Statistics calculates mean, standard deviation, and peak to peak for data in the current view.

After applying any of the above Analysis options, the results, statistics, or fitting function with coefficients are displayed in the lower portion of the Correlation Plot window (Figure 67).
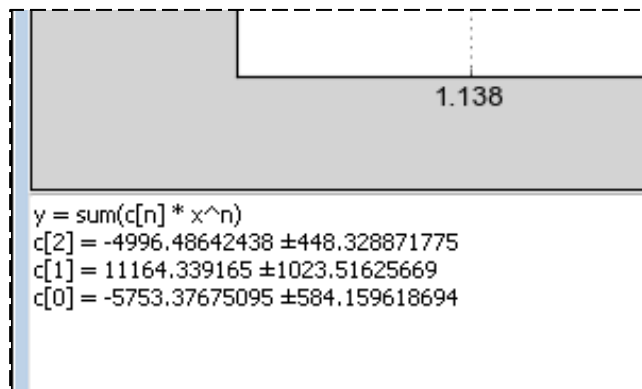
Figure 67: Results of Quadratic Fitting

APPENDIX C – External Valve Sequencer

C.1 Introduction

The Picarro analyzer can control two types of valves:

- Rotary Selector valve: digitally controlled valve used to send selected flow from one of many inputs (up to 16) into the analyzer.

- Solenoid valve(s): DC voltage powered valve with normally open (NO) and normally closed (NC) positions. These can be either 2-way or 3-way valves.

Both types of valves can be simultaneously controlled through a common software interface called the 'External Valve Sequencer described in Section C.5 which is available from the Tools menu on the GUI.

NOTE

Picarro offers a rotary valve solution with the A0311 16-Port Distribution Manifold (shown in Figure 68). The Distribution Manifold and GUI makes it easy to program the sequence and duration of sample intake from various attached sampling lines, flasks, or bags. The manifold is controlled using either the Picarro analyzer GUI or an external hand-pad (included with the A0311).

The A0311 sequentially samples up to 16 gas sources. During operation, the selected line is routed through the valve into the analyzer. The 15 lines that are not selected terminate in the valve.

For detailed instructions on integrating the A0311 with your analyzer, refer to the *A0311 16-Port Distribution Manifold User Manual* (P/N 40-0038).

Figure 68: A0311 – 16-port Distribution Manifold

NOTE

For users who require faster response performance, Picarro offers the A0311-S Fast Multipoint Sampler (Figure 69); a 16-Port Sequencer with a flow-through valve for reduced memory effects. Designed to optimize response time in the presence of reactive gases, the A0311-S uses SilcoNert coated components and an additional vacuum pump.

The sampling duration and sequence is easily programmed through the Picarro analyzer graphical user interface. This design is ideal for fast switching between different locations, large coverage areas and for specialty applications in Semiconductor, Pharmaceutical, Environmental research, and other industries. For further technical, and purchase information, please visit www.picarro.com/

For detailed instructions on integrating the A0311-S with your analyzer, refer to the A0311-S 16-Port Sequencer User Manual (P/N 40-0023).

Figure 69: A0311-S – 16-Port Sequencer – Fast Multipoint Gas Sampler

C.2 Default Configuration

For all models of Picarro analyzers, the rotary valve control is disabled in the factory default setting. The solenoid valve control, however, is ready to use by default for all solenoid valve connectors.

To configure an A0311 or A0311-S for rotary valve control, refer to **Setup Tool**; **Port Manager** in Section 9.5 for instructions to change to rotary valve configuration (the Valve Sequencer MPV field) and to ensure the correct COM port is enabled.

PICARRO

C.3 Setting Up Solenoid Valves

The Valve Sequencer software can control up to six solenoid valves. Each valve should operate using 12 VDC with a maximum quiescent current of 500 mA. This analyzer comes with a cable that can be connected to the solenoid valves.

The valve connector cable should be connected to the 15-pin connector at the lower left corner of the analyzer. There are six pairs of wires with connectors labeled V1, V2, … V6 with 2-pin female Molex connectors (Molex#43020-0200) for connection to the solenoid valves. For valves wired with matching Molex connectors, connect V1 to the solenoid valve 1, V2 to solenoid valve 2, etc. Do not connect the solenoid valve to the analyzer ground -- use only the provided electrical connectors.

C.4 Setting Up Rotary Selector Valve

The 9-pin female connector cable should be attached to its corresponding 9-pin male port (COM 2) on the analyzer. The other end of the cable connects to the 9 pin port on the A0311. Please note the 9-pin connector cable is not supplied with the instrument.

C.5 External Valve Sequencer Software

The External Valve Sequencer software allows the user to set steps in which solenoid valves are turned on/off and the rotary selector valve is set to a single position. The Picarro valve sequencer window appears below:
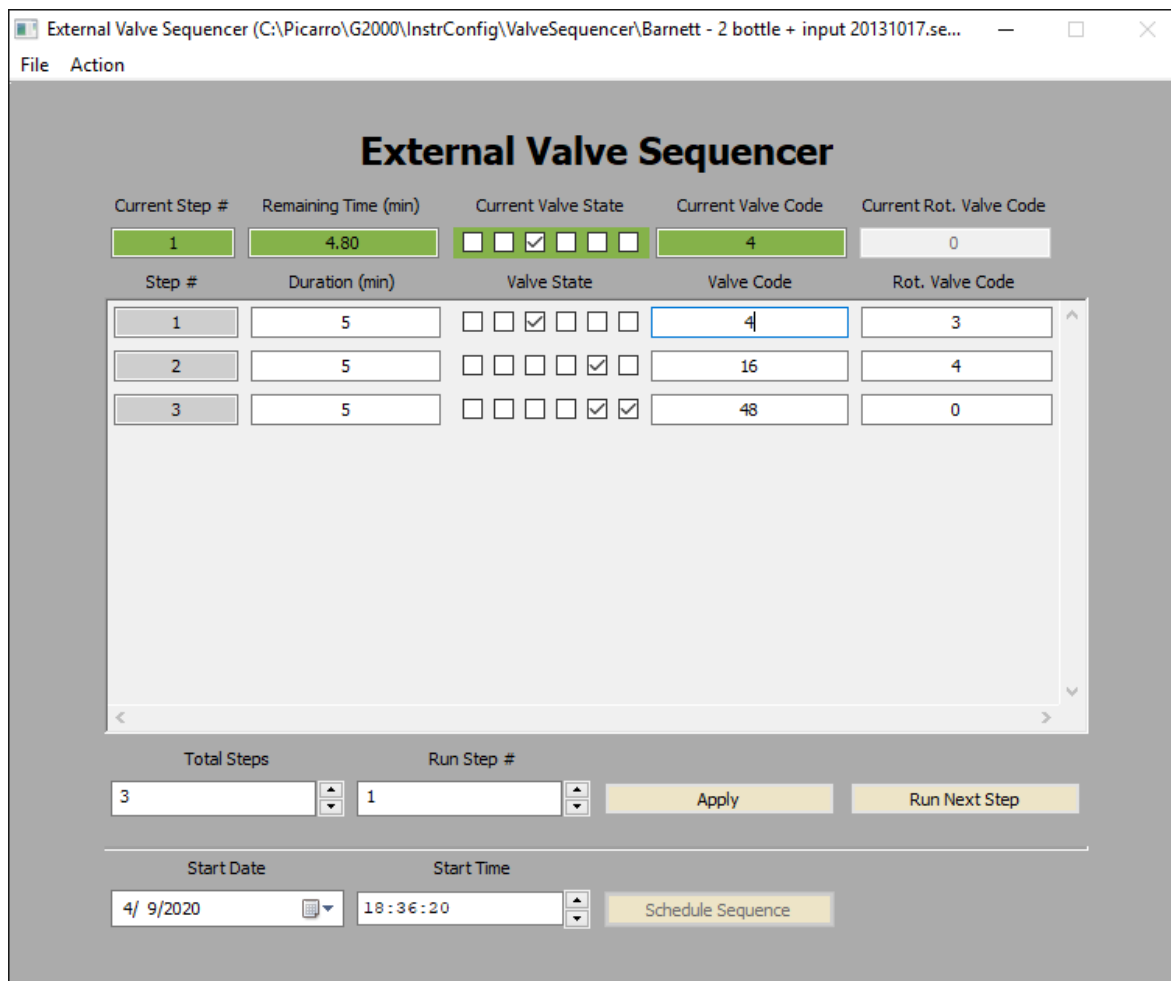
Figure 70: Valve Sequencer GUI

The current step, elapsed duration, and valve states are shown in the topmost row of the valve sequencer command window. The duration of each step is set in minutes; for example, 1 minute and 30 seconds correspond to 1.5 minutes.

Please note the number of steps correlates with the total steps in the sequence, and the count of the steps starts at "0." The first step in the sequence is designated Current Step "0," and the second step in the sequence is designated Current Step "1." The "Go to First Step" menu item under "Action" restarts the sequence from step 1.

Different sequences can be created and saved in the software. Use the "Sequence File #" field to select which file the sequence will be saved to (0 to 10 are the available choices). Click the up/down arrows to select the desired number.

C.6 Configuring a Valve Sequence

Each "step" sets the rotary valve to a single position and activates the indicated solenoid valve(s) for a set period. Multiple steps can be carried out in sequential order to switch between different gas sources, flush out a manifold, or other gas handling operation. Create the number of desired steps in the sequence by clicking the up/down arrow for "steps."

For each step, select the box for each solenoid valve to be opened. The checkmark in the "current valve state" window indicates a solenoid valve is open. Note: In this example, we assume normally closed (NC) valves are used. A check indicates current is flowing to the valve thus powering it open. The positions from left to right correspond to solenoid valves V1…V6.

The rotary selector valve position can be set in the column labeled "Rot. Valve Code." Enter the number that corresponds to the desired valve position. A value of 1 in this field corresponds to position 2 on the Valco valve. Only one rotary position can be selected per step.

Step duration is determined by the value entered in the "duration (min)" field, where the duration of the step is in minutes. If duration values are set to <0.1 minutes, they may not be carried out correctly.

The "Valve Code" column (not used with the A0311) is a configuration-dependent, read-only display field that shows the total state of that particular step in a numerical code. Should the most upper right gray box display a value of 512,256 or be grayed-out, either no rotary selector valve is connected to the instrument, or the valve is not functioning.

For each individual measurement, the analyzer makes, the valve codes and rotary valve positions corresponding to the valve state(s) at that point in time are saved alongside the concentration data.

Once the valve sequence has been programmed, it can be saved using the button "Save Valve Sequence File." The sequence will be saved under the sequence file number selected.

C.7 Loading and Running a Saved Sequence

To load a valve sequence file, select the desired "sequence file number" and press "Load Valve Sequence File." If the user has been running a different sequence from the one that was loaded, the user needs to press "Next Step" to initialize the newly selected sequence.

To run a sequence file, press "Enable Sequencer." This button will turn to "Disable Sequencer" once the sequence starts. (The sequencer should be activated if it was disabled, but not necessarily to change from one sequence to another.) The sequence will repeat itself indefinitely until disabled or the software is exited. If enabled, the sequence will continue to run after the "close sequencer window" button is pressed.

If desired, the valve sequence can be forwarded to the next step of the sequence by pressing the "run next step" button. To stop the sequencer file, use the "Start/Stop Sequencer" menu item under the "Action" menu. This will leave all valves in their current state. In some situations, it is convenient to program the last step in the sequence to be a safe or default valve state. The sequencer can be advanced to the last step should the user need to put the solenoid or rotary valves into a safe/default state. The "Reset All Valves" de-activates all valves. Using the "Hide Sequencer Interface" closes the window, but if the sequencer is enabled, it will continue to run in the background. To jump to a particular step, increment the "run step 3" and click "Apply."

Both solenoid and rotary valve codes are recorded in columns in the output data files indicating the active valve configuration respective to when data is taken. These codes can be used as event timing flags. For example, if no solenoid valves are present, the codes will be recorded regardless of whether a valve is connected or not.

Load saved sequence files by clicking File/Load Valve Sequence. All the sequence files are in:

C:\Picarro\G2000\InstrConfig\ValveSequencer\Name of the Sequence File

1. Click **Apply** to run the sequence.

    To skip the next step click **Run Next Step** (even while in middle of running a step):

2. Click on the **Action** scroll-down menu.

3. Reset all Valves by changing all the Rot. Valve Code fields to zero.

4. Click on **Go to the First Step** (Whatever the step the sequencer is at, step 1 will be played).

5. Click on **Start/Stop Sequencer (**While the sequence is running, it will read Stop Sequencer).

6. Click on **Hide Sequencer Interface** (to hide the External Valve Sequencer window).

APPENDIX D – Relative Humidity Conversion

H_2O Concentration (C) is reported in units of parts per hundred or percent (%) and is a volumetric fraction of water vapor to total (wet) gas. Via the ideal gas law, the concentration can be related to the water vapor pressure (P_W) and the total pressure (P).

$$C_{wet} = 100 \cdot \frac{P_W}{P}$$

A popular way to express volumetric concentration when working with humidity is in terms of total (dry) gas.

$$C_{dry} = 100 \cdot \frac{P_W}{(P - P_W)}$$

The two concentration definitions can be related by

$$C_{dry} = \frac{100 \cdot C_{wet}}{(100 - C_{wet})} \qquad \text{or} \qquad C_{wet} = \frac{100 \cdot C_{dry}}{(100 + C_{dry})}$$

Relative Humidity (RH) is the percentage of water vapor pressure to the saturated water vapor pressure (P_{WS}).

$$RH = 100 \cdot \frac{P_W}{P_{WS}}$$

There are several empirically generated equations that provide the saturation vapor pressure as a function of temperature (T). A simple and effective relationship for use within a temperature range of -45 °C to 60 °C is provided by the Mangus formula with coefficients adjusted by Sonntag [1].

$$P_{WS} = \alpha \cdot e^{\left(\frac{\beta \cdot T}{T + \lambda}\right)}$$

Where, α = 4.584 Torr, β = 17.62 and λ = 243.12 °C

Combining the equations shown above yields the final relationship for converting the wet and dry definitions of concentration to relative humidity.

$$RH = C_{wet} \cdot \frac{P}{\alpha} \cdot e^{-\left(\frac{\beta \cdot T}{T + \lambda}\right)} = \frac{100 \cdot C_{dry}}{\left(C_{dry} + 100\right)} \cdot \frac{P}{\alpha} \cdot e^{-\left(\frac{\beta \cdot T}{T + \lambda}\right)}$$

For example, a wet concentration of 1.5% H20 at 18.0 °C and 760.0 Torr yields a relative humidity of 73.8%.

A dry concentration of 1.5% at 18.0 °C and 760.0 Torr yields a relative humidity of 72.7%.

[1] Sonntag D.: Important New Values of Physical Constants of 1986, Vapour Pressure Formulations based on the ITS-90 and Psychrometer Formulae; Z. Meteorol.70 (1990) 5, 340-344

APPENDIX E – Introduction to CRDS Technology

Picarro analyzers use time-based, optical absorption spectroscopy of the target gases to determine concentration in a sample. They are based on wavelength-scanned cavity ring-down spectroscopy (WS-CRDS), a technology in which light travels many times through the sample, creating a very long effective path length for the light to interact with the target gas, thus enabling excellent detection sensitivity in a compact and rugged instrument.

The Picarro analyzer is comprised of two modules:

- The Analyzer contains the spectrometer, sample chamber, and a computer with a hard drive to store and analyze data. The single analyzer module controls the operation of the system and converts spectroscopic measurements into gas concentration data.

- The External Vacuum Pump draws the sample gas through the instrument.

E.1 Cavity Ring-Down Spectroscopy (CRDS)

Nearly every small gas-phase molecule (e.g., CO_2, H_2O, H_2S, NH_3) and isotopologue (e.g., $H_2^{18}O$, $^{13}CO_2$, $^{15}N^{14}N^{16}O$) uniquely absorb specific wavelengths of near-infrared light. The strength of the light absorption is related to the concentration of a molecule in a sample and the distance that light travels through the sample, called the path length.

Conventional infrared spectrometers are typically only sensitive enough to detect trace gases at levels in the part-per-million. Cavity Ring-Down Spectroscopy (CRDS), on the other hand, is one thousand to one million more times sensitive.

The increased sensitivity of CRDS is due to the design of the sample cavity and the time-based measurement. In the cavity, a series of mirrors reflects the infrared light through the sample, increasing the path length. For a Picarro cavity of only 25 cm in length, the effective path length of the cavity can be over 20 kilometers.

In Picarro analyzers, light from a single-frequency laser enters a cavity where three mirrors reflect the laser light as seen in Figure 71. The light enters through the mirror closest to the laser, bounces off the angled mirror in the lower right corner of the cavity, travels to the hemispherical mirror at the top of the cavity, bounces toward the mirror in the lower left corner of

the cavity, and then returns to the first mirror. This motion becomes a continuous traveling light wave, which is represented by the dark orange path in Figure 71.
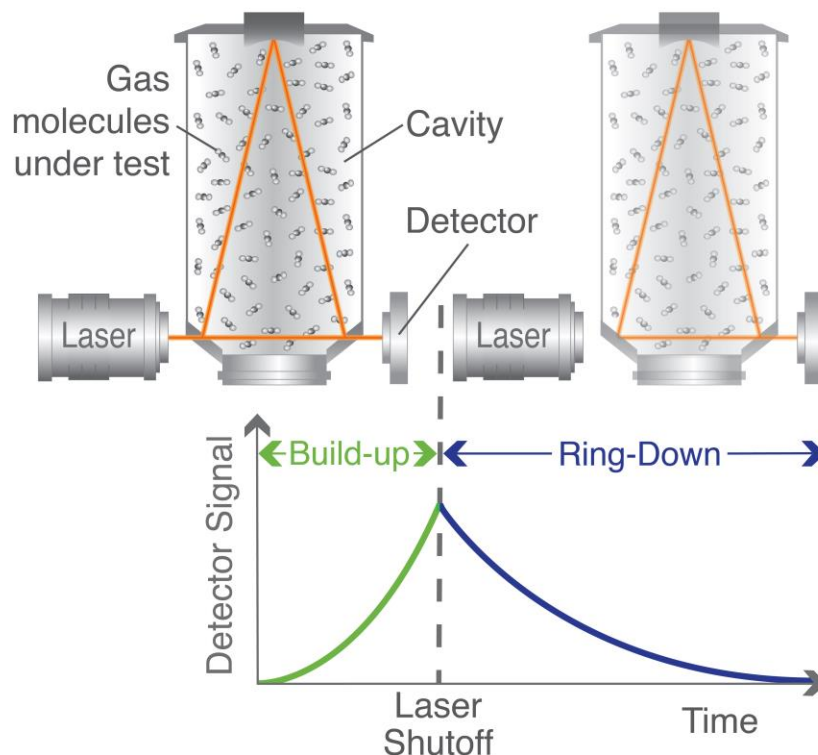

Figure 71: Schematic of Picarro CRDS Analyzer Cavity

When the laser is on, the cavity quickly fills with laser light. A small amount of the laser light is transmitted through the mirror closest to the photodetector, which turns the incident light into a signal that is directly proportional to the light intensity in the cavity.

When the photodetector signal reaches a threshold level (in a few tens of microseconds), the laser is turned off. The light contained within the cavity continues to bounce between the mirrors (about 40,000 times). Since the mirrors have slightly less than 100% reflectivity (99.999%), the light inside the cavity steadily leaks out of the cavity. The intensity of the light reaching the detector decreases, falling exponentially until it reaches zero. This decay, or "ring-down," is measured in real time by the photodetector.

E.2 Relating Ring-Down Time to Absorption Intensity

The time it takes to ring-down is inversely related to the total optical loss in the cavity, including the strength of molecular absorption at a given wavelength of light. For an empty cavity, the time it takes for the intensity to decrease by a given percent is determined solely by the reflectivity of the mirrors. A cavity containing gas that absorbs light will have a shorter ring-down time than an empty cavity. As the light circulates in a cavity with a gas sample, the molecular absorption by the gas results in a decrease of the light intensity.

Determining absorption intensity at a specific wavelength requires comparing the ring-down time of an empty cavity to the ring-down time of a cavity that contains gas (Figure 72). A cavity can be empty if it contains no gas; it will also appear empty if the molecules of the sample inside the cavity do not interact with the specific wavelength of light.

Picarro instruments gather measurements from an "empty" cavity by switching the light to wavelengths that are not absorbed by the target molecules. The analyzer subsequently measures ring-down times at wavelengths that are absorbed by the target gas. The analyzer automatically and continuously compares these two types of ring-down times, and the software uses those comparisons to calculate absorption intensities.
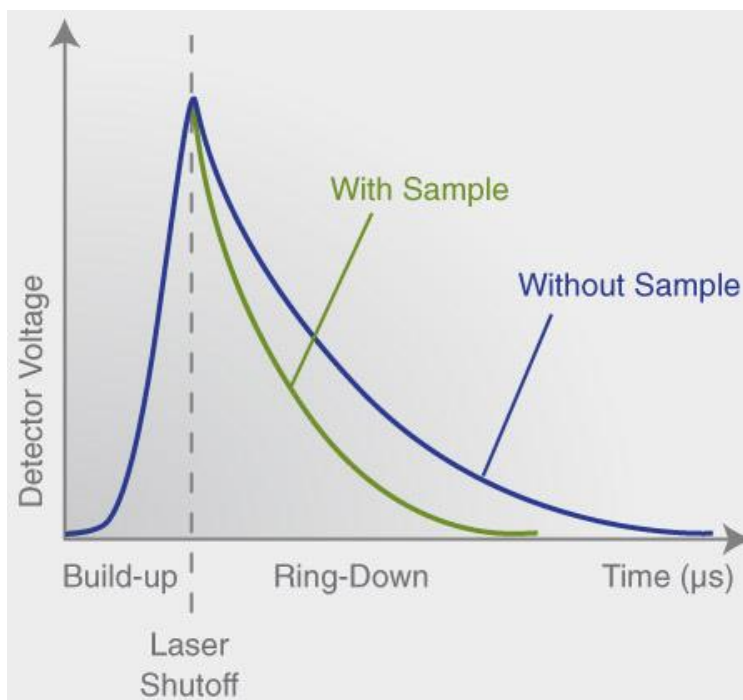

Figure 72: Light Intensity as Function of Time in CRDS System

E.3 Converting Absorption Intensity to Concentration

Plotting the absorbance at each measured wavelength generates an optical spectrum. This spectrum contains absorbance peaks that are unique to each molecule in the sample. The height of a particular absorption peak is proportional to the concentration of a molecule that generated the signal.

The height of the peak is calculated by subtracting the maximal absorbance from the baseline absorbance. Figure 73 shows a plot of ideal optical spectra with a clean, uniform baseline on either side of the absorption peak.
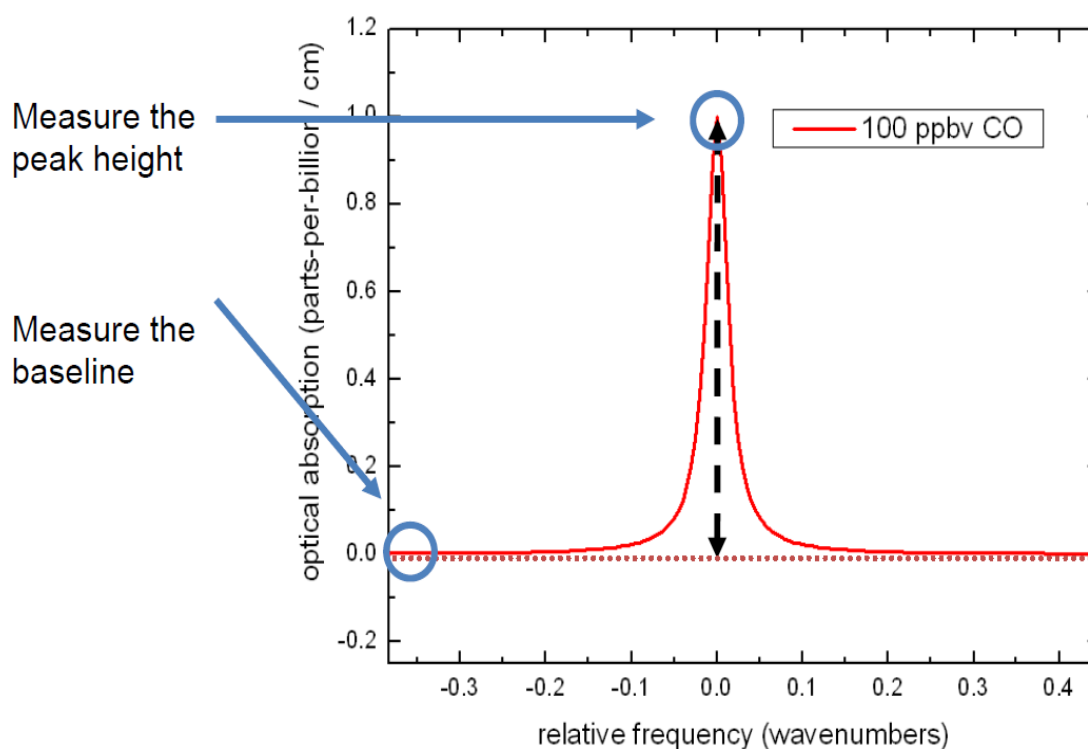

Figure 73: Absorption Spectral Curve

However, optical spectra often contain several absorption lines, nested closely together. A particular absorption peak may be visible between lines, but the absorption may not return to the baseline before it rises in response to another molecule.

Picarro analyzers calculate the baseline underneath a poorly resolved peak by modeling the absorption peaks from other surrounding molecules and subtracting contributions from neighboring peaks to the absorption intensity.

E.4 Spectral Precision and High Sensitivity Measurements

Picarro analyzers contain two features that provide high spectral precision:

- A proprietary wavelength monitor (WLM) that measures the absolute laser wavelength to a precision that is a few orders of magnitude narrower than the spectral linewidth: Picarro's patented WLM measures absolute laser wavelength to a precision more than 1,000 times narrower than the observed Doppler-broadened linewidth for small gas-phase molecules. The instruments lock the laser to the WLM, and then the monitor tunes to wavelengths known to be maximally and minimally absorbed by the target molecule. The result is closely clustered absorption intensities, measured at wavelengths just before peak absorption, at peak absorption, and just after peak absorption, as the absorbance returns to the baseline.

- Precise temperature and pressure control in the sample cavity: Accurate absorption measurements at precisely known wavelengths account for little unless the temperature and pressure of the CRDS measurement cavity are known. The observed line intensity and shape depend on the temperature and pressure inside the sample cavity. Small temperature and pressure instabilities can result in large concentration errors due to fluctuating peak heights and baselines. To completely minimize instrument measurement drift, temperature and pressure must be actively stabilized to constant values.

For precise temperature control, the sample cavity is surrounded by layers of thermally insulating material to provide a high degree of passive thermal stability. The cavity is further actively stabilized by means of a solid-state heating system locked to the output of a thermal sensor. This enables the temperature of the cavity to be within 20 mK of the set temperature.

For precise pressure control, the cavity pressure is monitored using a high-linearity pressure transducer. The system computer uses this pressure data in a feedback loop to control proportional valves that adjust the inlet and outlet gas flow of the cavity.