PICARRO

PI2910/PI2920
Ethylene Oxide Concentration Analyzer
User Manual

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Picarro Notices

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.

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1. Introduction

The PI2910 and PI2920 analyzers are designed to measure concentrations of ethylene oxide (EtO) gas. The PI2910 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 PI2920 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 PI2910 and PI2920 are different. However, the setup, method of use, and data logging are virtually identical.

NOTE

Analyzer guidelines established by Picarro are provided for optimal performance for near source and broader range measurement. These systems can be utilized outside of these recommendations with the understanding of the performance specifications and differences.

This manual is written for operators, service technicians and maintenance technicians who install, operate, and maintain the PI2910 or PI2920 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 PI2910 analyzer to a PI2920, and vice versa. The final configuration is performed during production.

1.1 Intended User

The PI2910/PI2920 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 System Overview

Analyzer

Figure 1 shows the analyzer front and back panels. More detailed information on panel features, functions, and connections are in section ***4, Hardware Setup***.

Figure 1: PI2910/PI2920 Front/Back Panels

A2000 Vacuum Pump

The A2000 vacuum pump (Figure 2) is used to maintain cavity pressure inside the analyzer. The pump should be connected and running whenever the analyzer is in use.

Figure 2: A2000 Vacuum Pump – Side Views

1.3 Analyzer Specifications

Table 1: PI2910/PI2920 Specifications

Parameter	Specification
Measurement Technique	Cavity Ring-Down Spectroscopy (CRDS)
Weight: Analyzer Weight: Pump	21.3 kg (47 lbs.) – Should be lifted by two people. A2000: 6.5 kg (14.4 lbs)
Dimensions – Analyzer	Depth: 59.9 cm (23.6” without handle) Width: 43.2 cm (17.0”) Height: 19.8 cm (7.8”) Height with Feet: 21.3 cm (8.4”)
Dimensions – A2000 Pump	Length: 27.9 cm (11”) Width: 10.2 cm (4”) Height: 19.1 cm (7.5”)
Ambient Humidity Range	< 99% RH non-condensing
Ambient Temperature Range	Operating: 0 °C to 35 °C (32 °F to 95 °F) Storage: 0 °C to 70 °C (32 °F to 158 °F)
Maximum Altitude (During operation)	3,048 m (10,000 ft)
Front/Rear Clearance	Front: 15.3 cm (6”); Rear: 15.3 cm (6”)
Primary Gases Measured	C_2H_4O Ethylene Oxide (EtO)
Other Gases Measured	CO_2, CH_4 and H_2O
Sample Flowrate	230 sccm at 760 torr (101 kPa)
Required Accessories	Included: Pump (external), Supplied by customer: keyboard, mouse, LCD monitor
Operating System Data Outputs	Linux Ubuntu 20 RS–232, Ethernet, USB, Analog (optional) 0-10 V
Installation	Benchtop or 48.3 cm (19”) rack mount
Power Requirements Startup Power Steady-state Power Mains Supply Voltage Fluctuation	100 – 240 VAC; 50 – 60 Hz (auto-sensing) <375 W at start-up, (Analyzer and Pump) 120 W (Analyzer) 150 W (A2000 Pump) ±10% of the nominal voltage
Minimum Rated Circuit Amperage	10A @ 115 VAC 5A @ 230 VAC
Liquid Ingress Protection	None

1.4 Acronyms

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

Table 2: Acronyms, Formulas, Units, and Symbols

Acronym	Definition
“ (as in 1/4”)	Inches
°C	degrees Celsius
A	Ampere Accessory (internal use). Used in model names i.e. A0302
AC	Alternating Current
AMC	Airborne Molecular Contamination
atm.	Atmosphere; unit of pressure, approximately equal to atmospheric pressure at sea level. 1 atm. = 14.69595 psi (101.325 kPa)
bar	Metric unit of pressure. 1 bar = 100,000 pascals (Pa)
BBCRDS	Broad Band Cavity Ring-Down Spectroscopy
cc	current calibration
CH_4	Methane
cm	centimeters
COM	Communication Port
CRDS	Cavity Ring-Down Spectroscopy
CSV	Comma Separated Values
CPU	Central Processing Unit
DC	Direct Current
DIO	Digital Input/Output
DVI	Digital Visual Interface
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
°F	Degrees Fahrenheit
ft.	Length in feet;1 ft. = 12” or 12 inches (30.48 cm)
GUI	Graphical User Interface

Acronym	Definition
H_2CO	Formaldehyde
H_2O	Water, Water Vapor
HDF	Hierarchical Data Format
Hz	Hertz
kg	kilograms
kPa	kiloPascal; unit of pressure; 1 kPa = 0.145 PSI
lbs	pounds
M	meters
max	Maximum
min	Minimum
mA	milliampere
mK	millikelvin
mm	millimeter / millimetre
nc	new calibration
NC	Normally Closed
NO	Normally Open
NTP	Network Time Protocol
OD	Outside Diameter
PAIAC	Phosphoric Acid Impregnated Activated Charcoal
PDF	Portable Document Format
PFA	Perfluoroalkoxy Alkane – A chemically resistant polymer, suitable for use with sticky and aggressive gases
PN	Part Number
ppb	parts per billion
ppm	parts per million
PSI (psi)	Pounds per Square Inch
PSIG	Pounds per Square Gauge
QC	Quality Control

Acronym	Definition
RH	Relative Humidity
RJ-45	Registered Jack (physical network interface)
RS232	Recommended Standard 232 (serial communication protocol)
SNTP	Simple Network Time Protocol
SCCM	Standard cubic centimeters per minute
SSL	Secure Sockets Layer
SST	Stainless Steel
TCP/IP	Transmission Control Protocol/Internet Protocol
Torr	Torricelli (unit of pressure equal to 1/760 atmosphere)
UM	User Manual
USB	Universal Serial Bus
UPS	Uninterruptible Power Supply
VAC	Volts Alternating Current
VDC	Volts Direct Current
W	Watts
WLM	Wavelength Monitor

1.5 Text Conventions

The following conventions are used in the manual.

- *Italic* text identifies screen names and emphasizes important text or certain features.
- ***Bold Italic*** text identifies section reference links.
- **Bold** text is for actions to take (such as clicking on a UI button), caution and warning statements, and text you should type or select in screens.

2. Safety

2.1 Warning Symbols

Icon notes and warnings are used throughout this manual. The purpose of these icons is to provide a visual convention to alert you of important information. They indicate dangers to either the operator or to the analyzer, and other important information.

Table 3: Warning/Information Icon Types

Icon	Description
 NOTE	**NOTE** is important information that you should be aware of before proceeding.
 WARNING	**LASER WARNING** alerts you of a laser danger.
 DANGER	**DANGER** indicates an imminently hazardous situation that, if not avoided, will result in death or severe injury.
 WARNING	**WARNING** indicates a potentially hazardous situation which, if not avoided, could result in death or severe injury.
 CAUTION	**CAUTION** alerts user of a potential danger to equipment or 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	**REMINDER** is a helpful hint for procedures listed in the text.

2.2 General Safety

CDRH Certification

This Picarro Analyzer complies with 21 CFR Chapter 1, sub-chapter J, and is classified as a Class 1 laser system when all panels and covers are on.

CE Certification

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

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

WARNING

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

CAUTION

This analyzer contains no user-serviceable components except the particulate filter, CPU fan, and A2000 vacuum pump diaphragms and valves. To order user-replaceable parts and access video replacement instructions, see section *11, Maintenance*.

Do not attempt other 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.

WARNING

If mounting in a 19” rack, this analyzer cannot support itself using a front rack mount kit alone. It must be supported by a shelf, or by user-provided “L” type support brackets.

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 exhaust the remainder of the gas stream appropriately.

WARNING

The inlet and outlet gas connectors 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.

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.

WARNING

This analyzer weighs 21.3 kg (47 lbs). 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.**

2.3 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 3: 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** (Figure 4) is affixed to the inside of the analyzer:

Figure 4: Laser Safety Label – Affixed to Inside of Analyzer

CAUTION

Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

3. Unpacking

3.1 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 damage and contact Picarro (email pictures if possible) as soon as possible.

NOTE

Keep all packing materials so the instrument can easily be returned Picarro if necessary or transported to another location.

3.2 Unpack Components

While unpacking each shipping box:

- Inspect each item to ensure it is not damaged.
- If items are missing, contact Picarro.
- Keep the shipping materials to reuse when transporting the analyzer.
- Contact Picarro for options on transporting systems to remote labs.

WARNING

The analyzer weighs 21.3 kg (47 lbs). Use the technique outlined on Page 21 when lifting or moving the analyzer.

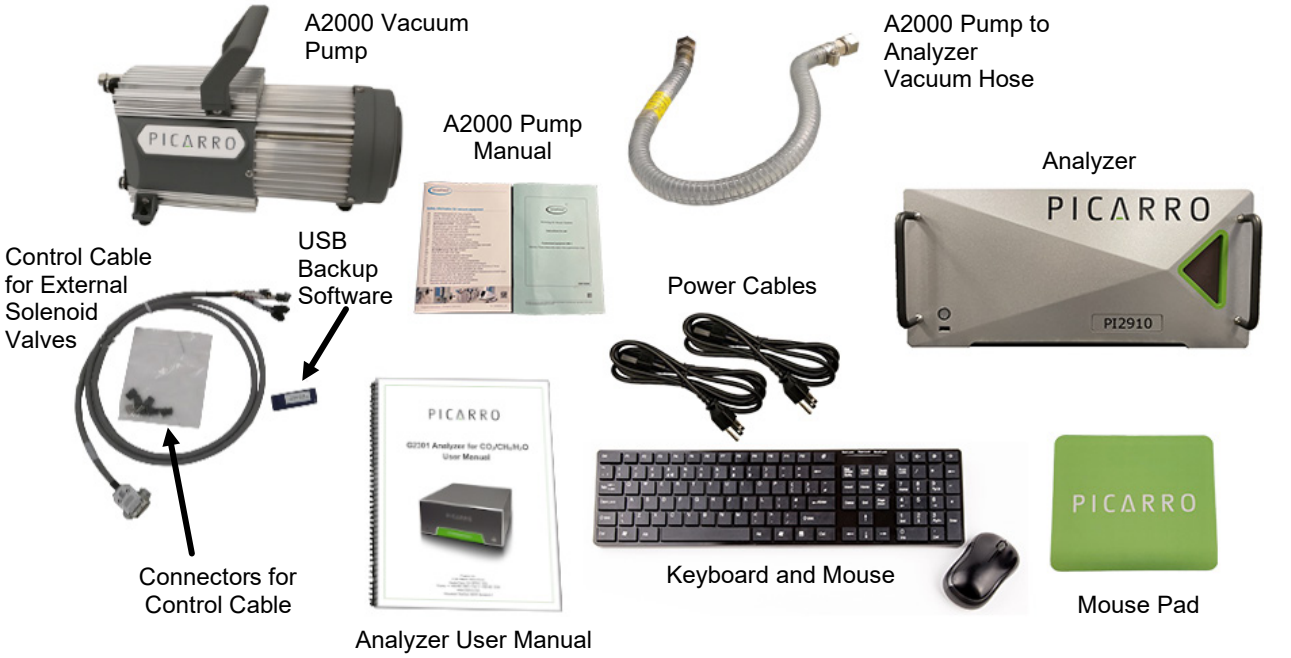


Figure 5: PI2910/PI2920 Shipping Box Contents

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. **Note:** The analyzer automatically adjusts to local voltage.
Control Cable Kit (1)	For External Solenoid Valves.
Nut (1) and Ferrules (2)	For connecting input line to analyzer gas INPUT.
Vacuum Hose (1)	Hose to connect the pump to the analyzer.
Keyboard and Mouse (1)	Monitor is not included.
USB Flash Drive	Contains backup software.
Document Packet (1)	Includes this user manual and certificate of compliance (not shown).

Table 5: Box Two: A2000 Vacuum Pump and Accessories

Item (qty)	Description
A2000 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. Note: The vacuum pump voltage must be selected. See ***Set A2000 Pump Input Voltage*** in section ***4.3***.
Pump Manual (1)	Detailed instructions for pump.

4. Hardware Setup

Read this entire section before proceeding. Some of the setup instructions in this section are model-dependent.

4.1 Items/Tools Required

- Analyzer and accessories included in shipment
- Pump (Model dependent; see specifications in ***Table 1***) and accessories included in shipment
- 5/8” open end wrench
- 11/16’’ open end wrench
- Power Cords for analyzer and pump

4.2 Installation Safety

WARNING

Two-person lift required: The analyzer weighs 21.3 kg (47 lbs). When lifting the analyzer, use the technique described on page 21 (or follow your local regulations).

CAUTION

When the analyzer is being integrated to an external system, the safety of that system is the responsibility of the assembler of that system.

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 certain USB enabled devices, such as GPS, which are approved for use. Do not connect USB hubs or unauthorized USB devices (except flash drives, mice, and keyboards) to the USB ports. Unauthorized USB devices may interfere with the normal functioning of the analyzer.

Warning

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

CAUTION

Lines connected to the 1/4” Swagelok sample inlet connector must not exceed 15 PSIG of pressure.

CAUTION

During installation, do not position the analyzer so that it is difficult to operate the electrical disconnecting device (such as an emergency off (EMO) switch or breaker).

WARNING

If mounting in a 19” rack, this analyzer cannot support itself using a front rack mount kit alone. It must be supported by a shelf, or by user-provided “L” type support brackets.

CAUTION

Use the AC power cables supplied with the analyzer or a similarly rated cable. Check with Picarro technical support if you have questions about power cable replacement. An inadequately rated power cable can result in equipment damage.

CAUTION

Cords shall be RATED for the maximum current for the equipment and the cable used shall meet the requirements of IEC 60227 or IEC 60245. Cords certified or approved by a recognized testing authority are regarded as meeting this requirement. The connector type used should be: IEC320 C13.

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. Do not place the pump or the instrument in any enclosure without providing adequate forced air flow.

Do not plug or block any perforations in the chassis of the instrument. Do not put anything near the instrument that will impede the air flow. 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 6” (15 cm) of clearance in the front and back of the analyzer.

To determine if the ventilation is adequate in an enclosure, monitor the temperature of the air near the instrument and adjust ventilation so that the ambient temperatur3e is within specification. As a guide, the ambient temperature of the air around the instrument cannot exceed the specifications listed below.

Thermal Specifications	Min	Max	Description
Ambient Operating Temperature	0 °C	35 °C	Worst-case environmental limits (unless otherwise specified)

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.

4.3 Analyzer Preparation

Ventilation Considerations

The instrument and pump require adequate ventilation in order to function properly. Do not plug or block any perforations in the chassis of the instrument. Don't place anything near the instrument that will impede the air flow.

Positioning

1. Remove the analyzer and the external vacuum pump from the shipping container.
2. Install the analyzer in a rack or place it on a cart or table.
3. Place the external vacuum pump near the analyzer in a rack, or on a cart or table.
4. Unpack the analyzer accessories (vacuum line, cable kit, manual, and certificate of compliance).

NOTE

Store the certificate of compliance in a safe place. It may be required if you contact Picarro for service or questions.

5. Remove the caps from the analyzer **SAMPLE** inlet and **VACUUM** connection ports.
6. Remove the caps from the pump vacuum inlet (and exhaust port if using an A0702 or S2000 pump). Save the caps for reuse in case the analyzer and pump is stored, moved, or shipped.

Set A2000 Pump Input Voltage

7. If using an A2000 vacuum pump, set its 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 (Figure 6).

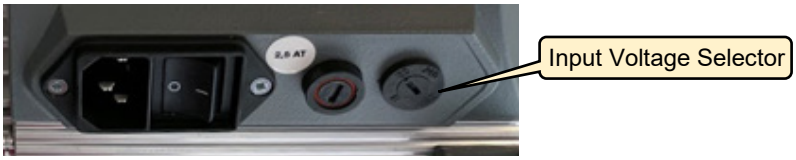


Figure 6: Vacuum Pump Voltage Selection

4.4 Connections – A2000 Pump and Gas Inlet

Follow instructions in this sect ion when using an A2000 pump with your analyzer.

Pump Connections

Refer to Figure 7 when using an A2000 pump with your analyzer.

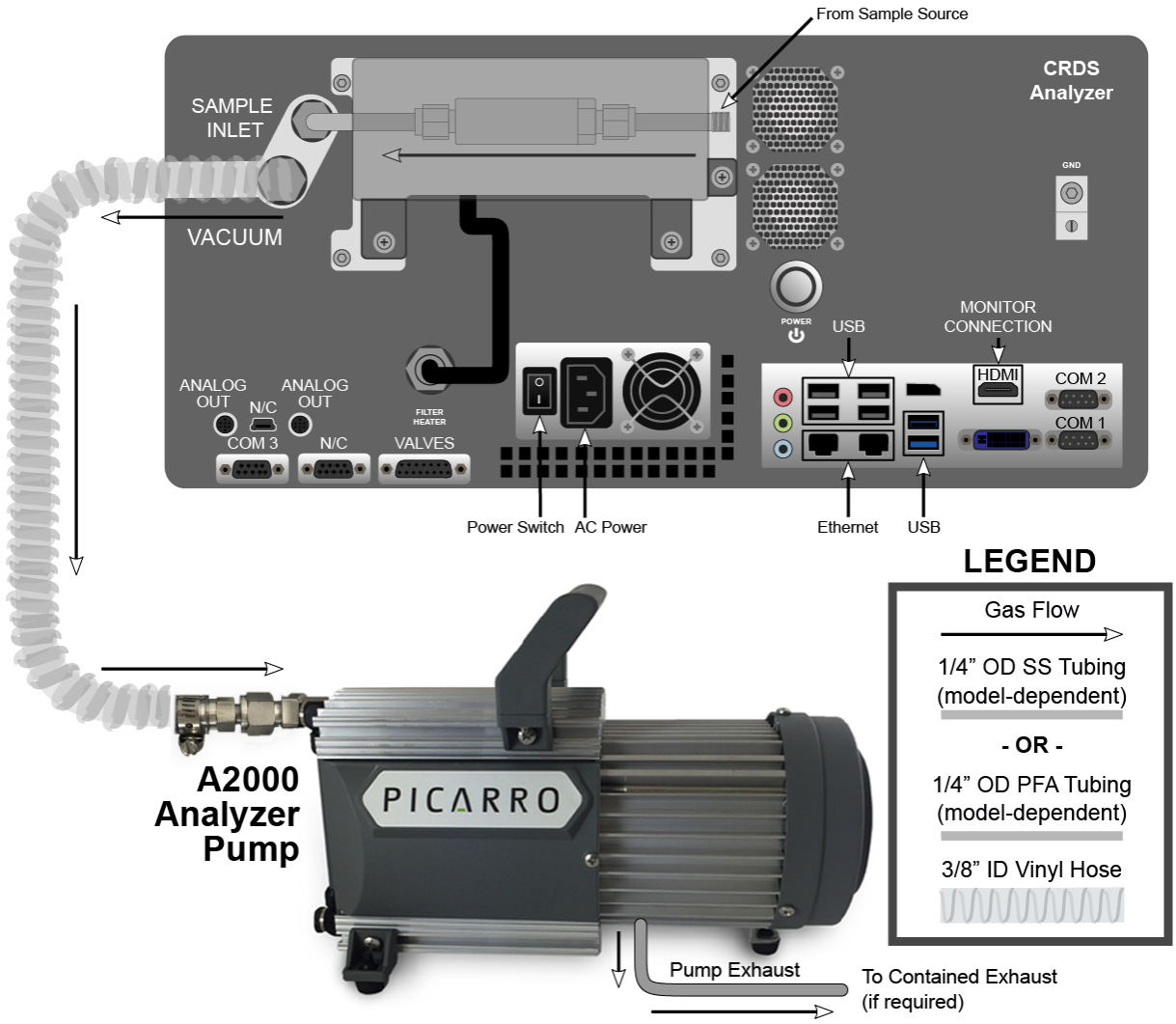


Figure 7: Analyzer Setup with A2000 Pump

CAUTION

When working with hazardous gases, remove the pump exhaust muffler and adapt a tube to the vacuum pump exhaust port (shown in Figure 6) and direct the exhaust to a safe place for venting the mixture of sample gases. For instructions, see *APPENDIX D – Setting up Contained Exhaust Flow*.

1. Connect the provided vacuum line between the analyzer port labeled **VACUUM** and the pump vacuum inlet.
2. If working with hazardous gases, see APPENDIX D – for instructions on directing the pump exhaust to a safe venting environment.

Sample Gas Inlet Connections

There are two types of sample Inlet connections which are model-dependent.

- Analyzers that have stainless steel (SST) sample inlet connectors.
- Analyzers that have PFA sample inlet connectors.

Sample Gas Inlet Connection (SST Tubing

3. Use 1/4” OD SST tubing and connector sets to connect from sample source to the sample inlet.
4. Place the two ferrules inside the nut as shown below.

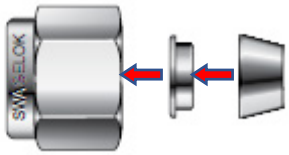


Figure 8: Orientation of Inlet Nut and Ferrules

5. Loosely connect the nut to the INLET on the back panel of the analyzer, being careful not to let the ferrules fall out.
6. Insert the tubing into the back of the nut and through the ferrules, feeding it in as far as possible without deforming the tubing.
7. Hand tighten the nut.
8. Using a 9/16" wrench (not included), tighten the nut 1-1/4 turns.

When reconnecting SST tubing:

9. Inspect the ferrules. If you see any damage, replace the ferrules and follow the directions above for making a new connection.
10. If there is no damage, hand tighten the connector to the analyzer sample inlet.
11. Using a 9/16" wrench, tighten the nut 1/6 of a turn (60°).

Sample Gas Inlet Connection (PFA Tubing)

When making a new PFA gas inlet connection:

1. Use 1/4” OD PFA tubing and connector sets to connect from sample source to the sample inlet.
2. Place the two PFA ferrules inside the PFA nut as shown in Figure 9.

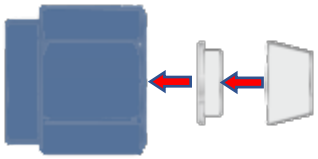


Figure 9: Orientation of Inlet Nut and Ferrules

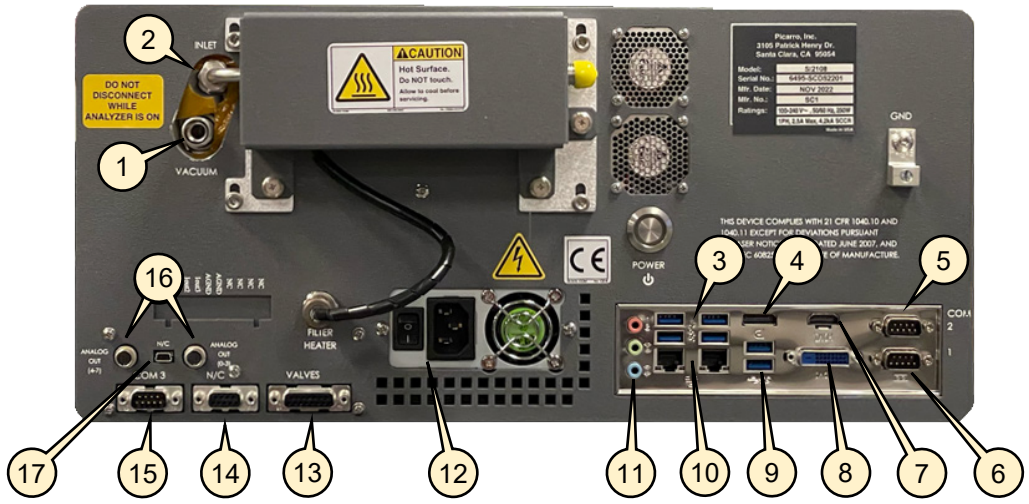
3. Loosely connect the nut to the INLET on the back panel of the analyzer, being careful not to let the ferrules fall out.
4. Insert the tubing into the back of the nut and through the ferrules, feeding it in as far as possible without deforming the tubing.
5. Hand tighten the nut.
6. Using a 5/8" wrench, tighten the nut 1-1/6 turns (1 full turn plus another 60°).

When reconnecting PFA tubing

1. Inspect the 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 sample inlet.
3. Using a 5/8" wrench, tighten the nut 1/6 of a turn (60°).

4.5 Electrical Connections

Refer to Figure 10 for connection points.



1. External Vacuum Port to Vacuum Pump	**10.** Ethernet Ports – RJ-45 (2 ea)
2. Gas Sample Inlet	**11.** Audio In/Out Ports
3. USB Ports (4 ea)	**12.** AC Power Input and Power ON Switch
4. Display Port	**13.** Valve Control Port (Solenoid valves)
5. COM 2 Port (Rotary valve – A0311, A0311-S)	**14.** DIO (Not connected)
6. COM 1 Port	**15.** COM 3 Port (Connected but typically not used.)
7. HDMI Video Monitor Port (typical)	**16.** Analog EIC Output (Optional upgrade)
8. DVI-I Video Monitor Port	**17.** USB for Logic Board (Not connected)
9. USB Ports (2 ea)	

Figure 10: Annotated Back Panel Diagram

1. Connect a monitor to one of the DVI monitor ports at the back panel. The analyzer will detect the connection and adjust the resolution to match the monitor.
2. Connect a mouse and keyboard to a pair of USB ports.
3. Connect the provided AC power cable from the analyzer to the power source.

NOTE

The analyzer has a universal power supply that automatically adjusts to power sources ranging from 100-240 VAC, 50/60 Hz, 10 A max.

NOTE

The A2000 pump does not automatically adjust to power sources. If using the A2000 vacuum pump, ensure its input voltage is set 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 (see Figure 6).

4. Check that the A2000 pump voltage input switch is set correctly.
5. Connect the provided AC power cable from the vacuum pump to the power source.
6. If used, connect the valve cable from the analyzer back panel to any solenoid valves.
7. If used, connect rotary valve (A0311, A0311-S) to COM2 with its provided serial cable.

4.6 Manifold Compatibility

The selection of an A0311 or A0311-S manifold depends upon the user's needs. The A0311-S manifold flushes all inactive lines providing the most instantaneous measurements when switching to the next pre-purged position. However, it also pulls more total flow from all positions, which all users may not require or desire. The A0311-S has short portions of PFA Teflon, which can have memory effects if a user sees very high and low concentrations in the same position.

The A0311-S is the more responsive choice for EtO applications, but some users may prefer the A0311. For more information, see Appendix D - External Valve Sequencer. If additional help is required, contact mailto:support@picarro.com to discuss with a technical representative.

5. Analyzer Basic Operation

This section explains how to operate the analyzer using the GUI. It describes system startup, shutdown, and recovery procedures, desktop features. GUI Functions are detailed in section ***6, List of GUI Functions***.

WARNING

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

CAUTION

During operation, do not position the analyzer so that it is difficult to operate the electrical disconnecting device (such as an emergency off (EMO) switch or breaker).

NOTE

The illustrations shown in this chapter are for example only. What is shown on your instrument is dependent on the model analyzer in use and may differ.

5.1 Startup

1. Make sure the pump vacuum hose is connected between the analyzer and pump.

CAUTION

Always turn on the external pump before powering up the analyzer. This ensures a safe start-up sequence.

2. Verify the power cable to vacuum pump is plugged in.
3. Switch power on at the pump.
4. Verify the power cable to the analyzer is plugged in.
5. At the analyzer back panel, press the main power switch to the **ON** (“**I**”) position.
6. If needed, press the round **Soft Power** button on the front panel. The indicator LED will illuminate green.

   The **Picarro Launch Pad** user interface displays and the **CRDS Data Viewer** (Figure 11) automatically starts within 30 seconds. For more information about the CRDS Data Viewer features, see section ***6.1, GUI Overview***.

The analyzer will not begin producing data until the cavity temperature and pressure have reached their operational set points. A message will display in the Status Log window (see Figure 11, bottom panel) when each set point is reached. An explanation of the most common status log messages can be found in section ***6.10, Measurement Status Log***.

Data will be saved automatically once the analyzer starts to produce data. The data in the GUI is the continuous real time read out from the analyzer. User data is stored in:

/Home/Picarro/I2000/Log/DataLogger/DataLog_User/YYYY/MM/DD, where Y=year, M=month, D=day. Further details can be found section ***8***, ***File Management***.

In order to measure discrete samples (such as individual gas bags) or from multiple locations (when switching valves draw in ambient air from different heights) a separate software window (coordinator) is used to control the sample source and match the corresponding real time read out with the sample source. Depending on system configuration, coordinator programs may not be included.

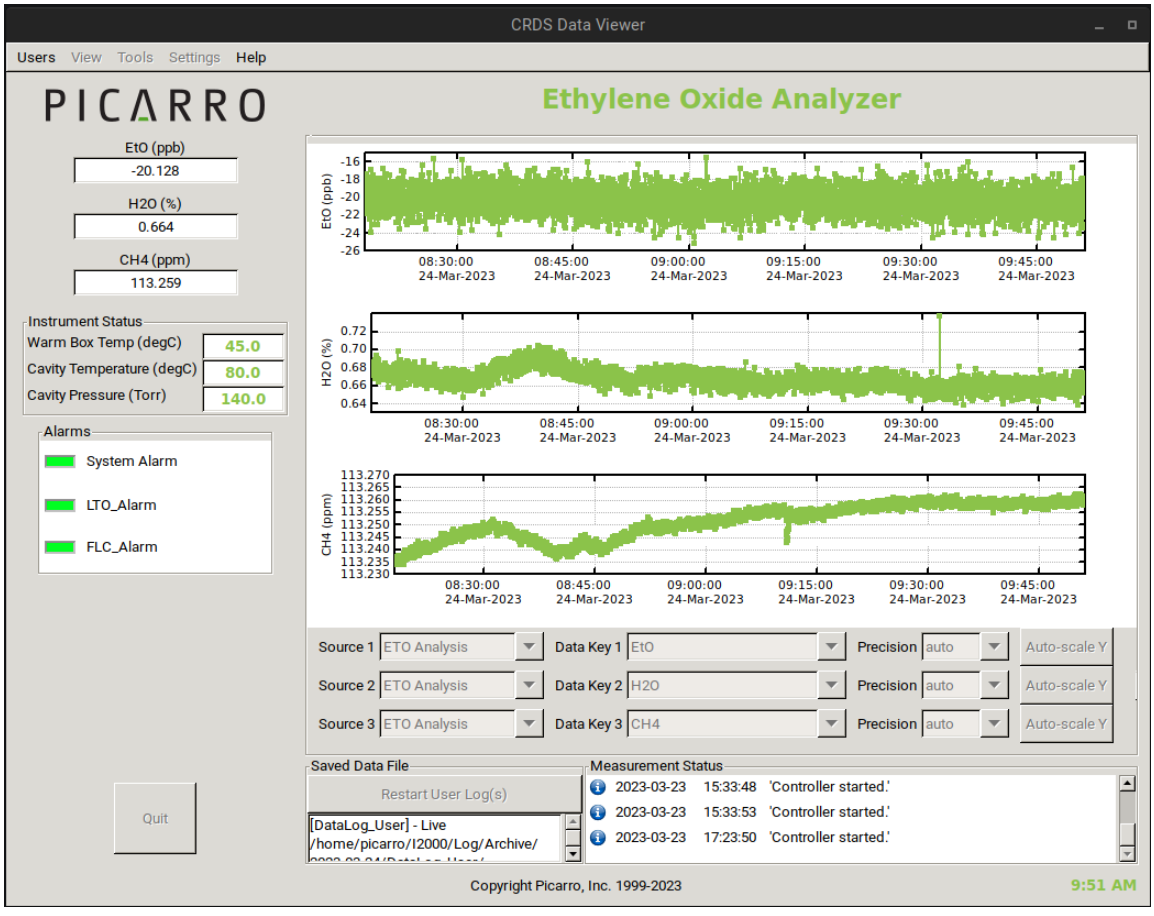


Figure 11: Picarro Analyzer GUI

5.2 Shutdown

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.

1. With the pump still running, switch to a source of clean, dry gas at the sample inlet and allow it to run until the water channel reading on the GUI falls below 0.2% (2000 ppm). This will prevent any damage from condensation to the cavity surfaces. This dry gas may be from a tank (target 2-3 PSIG pressure) or from a desiccant column like the DrieRite column, C0360, sold on store.picarro.com).
2. From the **CRDS Data Viewer** select the **Quit** button located in the lower left corner of the window.
3. A message displays () prompting the user to confirm the shutdown. Once confirmed, the CRDS Data Viewer turns off.

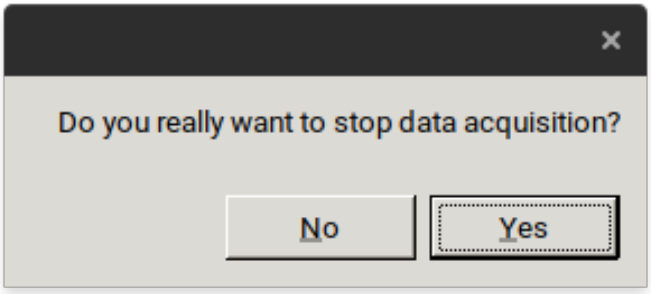


Figure 12: Stop Data Acquisition/Shutdown Confirmation Dialog

4. From the **Picarro Launch Pad** select **Power Off** to tun off the hardware.
5. Manually turn off the pumps and dry gas (only if system requires it).

NOTE

Leave any dry gas or desiccant attached to the inlet during this process.

6. When the instrument fans audibly turn off, and when the green power button light on the front of the instrument turns off, shut off the pump manually from the rocker switch located on the pump.

5.3 Analyzer Restart after Electrical Power Outage

If 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 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 are common in the user location, Picarro recommends using an uninterrupted power supply (UPS) to protect the data stream and the health of the cavity.

5.4 Picarro Launch Pad

The Picarro Launch Pad is the entry point for starting and using the analyzer. It provides access to the CRDS Data Viewer, tools, settings, and administrative controls for the instrument such as managing user accounts. This section provides an overview of the Picarro Launch Pad's key features with additional information throughout this manual.

NOTE

Note Picarro Launch Pad features vary depending on user account types. Each section describes the account type that is required for each of the main menu options.

Home Menu

Account Type: All Users

The Picarro Launch Pad automatically starts in Guest account mode and displays the home menu upon startup of the analyzer. Note several options are not accessible until you login with a user account. The Home menu options are provided, as shown in Figure 13.

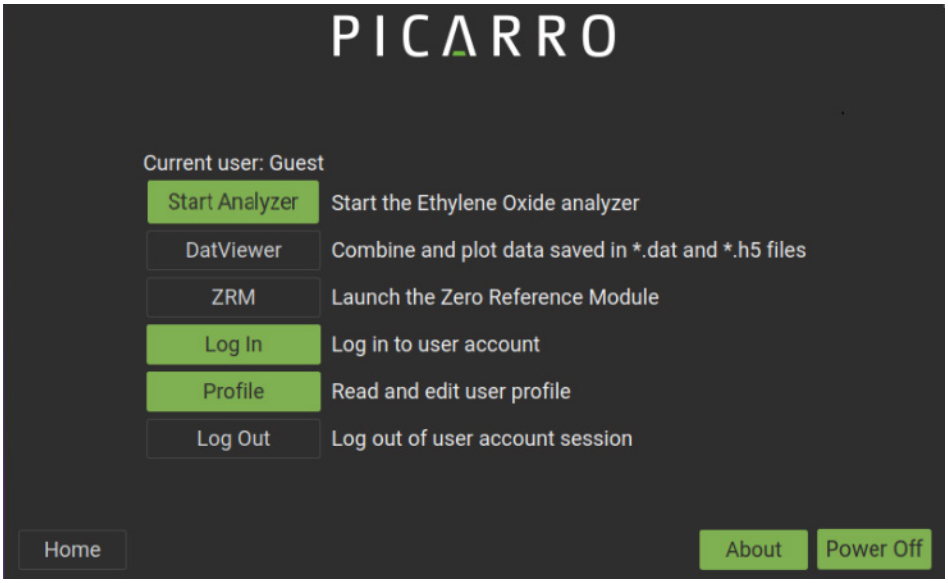


Figure 13: Picarro Launch Pad/Home Menu

- **Start Analyzer** – Starts the ethylene oxide analyzer and launches the CRDS Data Viewer.
- **Data Viewer** – When clicked, a window opens that allows you to convert between *.dat and H5 data files and to make various graphical representations of your data over time periods longer than what is available in the software buffer. The instructions on using the Data File Viewer software are described in ***APPENDIX A – Setup Tools and Communication.***

  Note requires login to the Picarro Launch Pad.

  ZRM – Launches the Zero Reference Module (optional peripheral). Note requires login to the Picarro Launch Pad. For more information, see the ***A0601 Zero Reference Module User Manual***.

  Log In – Provides access to the Picarro Launch pad and tools associated with a specified user account. Note options vary with different types of user accounts.
- **Profile** – Provides access to the User Management Tool to allow regular users to change their own password and administrators to manage user accounts. Note requires a password to obtain entry. For more information, see ***View My Profile*** and ***User Management.***
- **Log Out** – Concludes the user account session.

Tools Menu

Account Type: Operators, Technicians, and Administrators

The Tools menu provides additional utilities for the instrument and include the following options as shown in Figure 14.

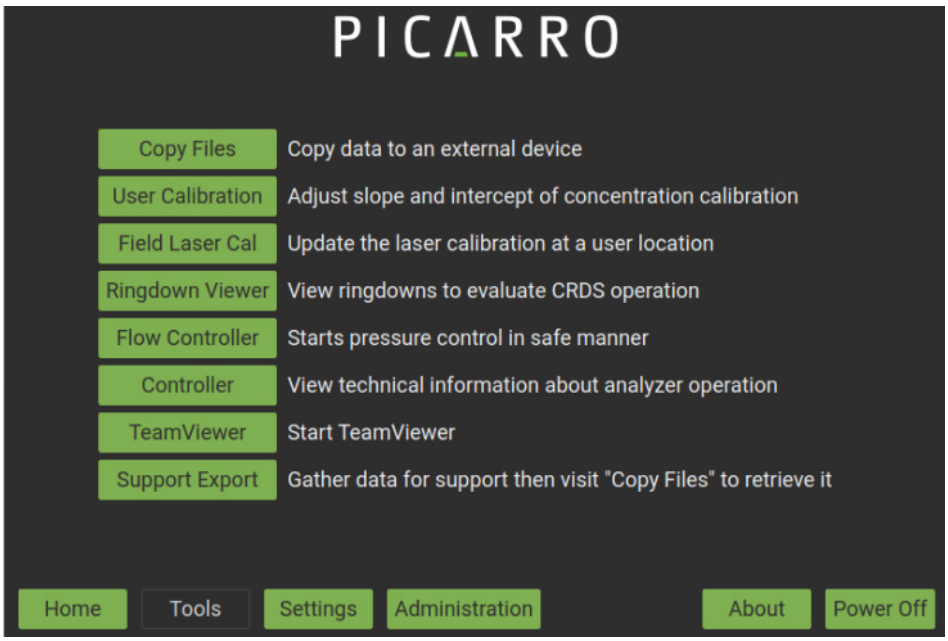


Figure 14: Picarro Launch Pad/Tools Menu

- **Copy Files** – Allows data to be copied to an external device. Requires technician or administrator permissions.
- **User Calibration** – Allows adjustment of slope and intercept for concentration calibration to maintain accuracy. For more information, see ***Chapter 9 Calibration***.
- **Field Laser Cal** – Launches the SGDBR calibration utility to update the laser calibration.
- **Ringdown Viewer** – Provides visual ring-downs for evaluation of CRDS operations.
- **Flow Controller** – Safely starts pressure control to bring the cavity to the setpoint pressure.
- **Controller** – Displays the Cavity Ring-Down Spectrometer Controller to view technical information about the analyzer operation.
- **TeamViewer** – Starts TeamViewer for remote access and remote control of the analyzer. Can also aid in file transferring and customer support.
- **Support Export** – Opens the CRDS Diagnostic Data Collector tool to curate support data for troubleshooting.

Settings Menu (Setup Tools)

Account Type: Technicians and Administrators

The Settings menu provides various configuration options for the analyzer and is described in detail in ***APPENDIX A – Setup Tools and Communication***.

Administration Menu

Account Type: Administrators

The Administration menu provides the following options as shown in Figure 15.

Figure 15: Picarro Launch Pad/Administration Menu

- **Windowed Mode** – Displays the Picarro Launch Pad and utilities as windows within the user interface.
- **Network** – Provides configuration of network settings.
- **Clock** – Sets the time of the hardware clock.
- **User Accounts** – Provides access to the User Management Tool for managing user accounts, security settings and user history. Requires a password to obtain entry. For more information, ***Chapter 7 User Management***.
- **System Backup** – A mechanism for backing up or restoring system settings.
- **Toggle Modbus** – Allows enabling and disabling of the Modbus interface for configuration of the communication protocol.
- **Launch Shell** – Opens a command line interface.

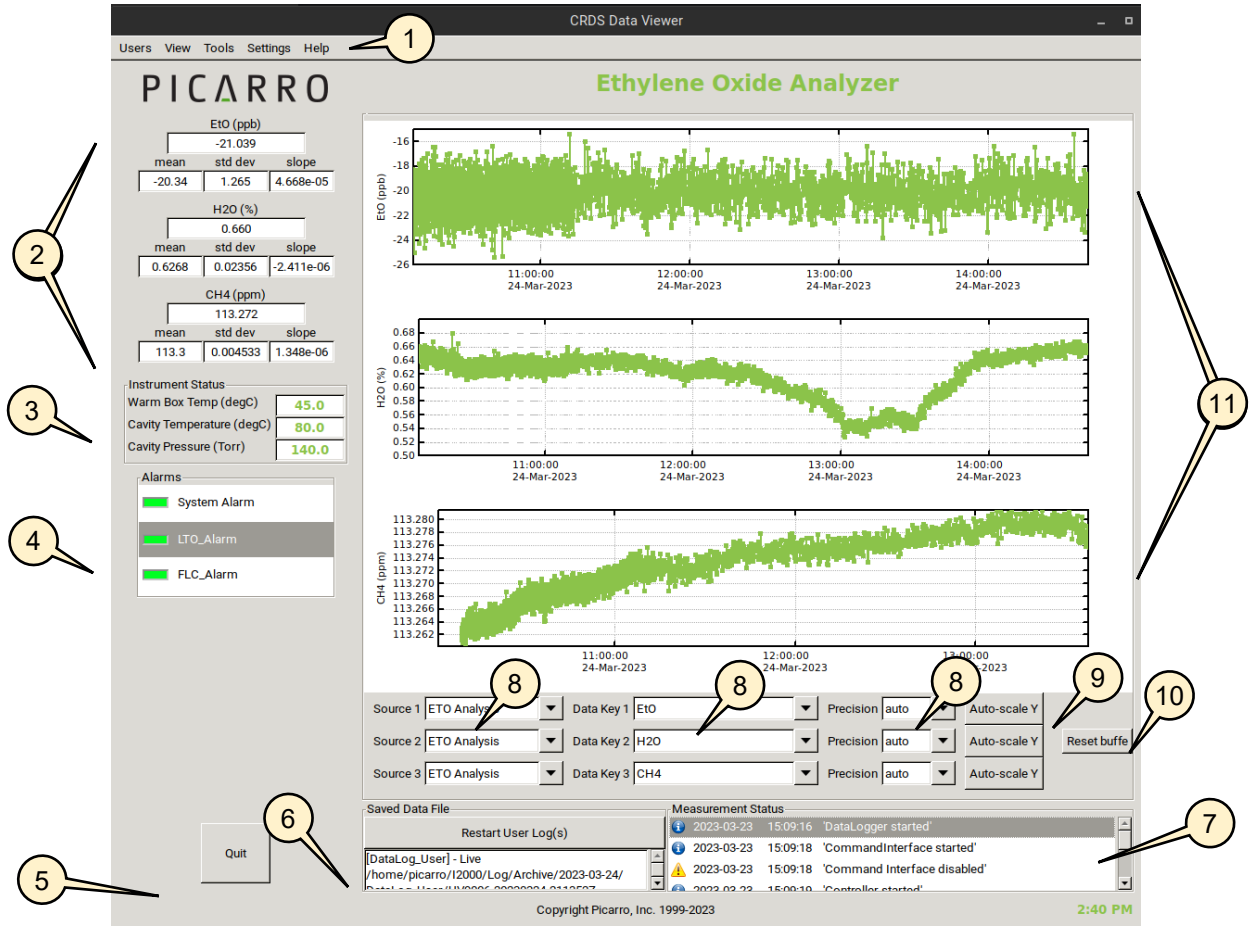
6. List of GUI Functions

NOTE

The illustrations shown in this chapter are for example only. What is shown on your instrument is dependent on the model analyzer in use and may differ.

6.1 GUI Overview

The features of the GUI in Figure 16 are described in the following sections.



1. Users, View, Tools, Settings, and Help menus
2. Digital Readouts and Statistics
3. Instrument Status
4. Alarms Panel
5. Quit Button
6. Restart User Logs and Data Log (filename, path)
7. Status Log Window
8. Data Source, Data Key, and Precision pull-down menus for data window content
9. Axis Auto Scaling
10. Reset Data Buffer
11. Data Windows

Figure 16: Layout of PI2910/PI2920 Analyzer GUI

6.2 Users, View, Tools, Settings, and Help Menus

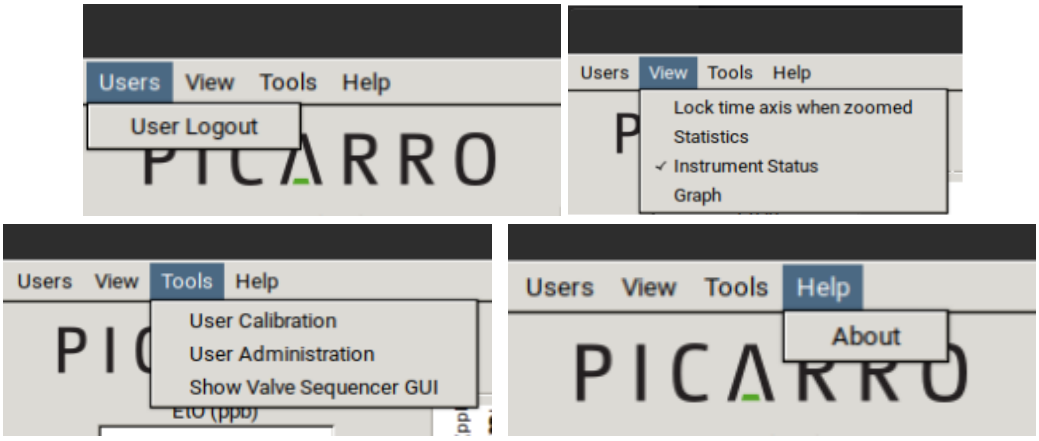


Figure 17: Menu Toolbar Options

Users Menu

- **User Login** – Provides access to the CRDS Data Viewer. If you do not have an account one can be created by an administrator.

View Menu

This menu item has three entries:

- **Lock time axis when zoomed/Unlock time axis** – When locked, forces the two graphs to display the same time scale during zoom.
- **Statistics** – Toggles the measurement statistics display, see the section *Digital Readouts*.
- **Instrument Status** – Toggles the instruments status display. See the section *Instrument Status*.
- **Graph** – **Number of Graphs:** Set the desired number of line graphs to be visible on the CRDS Data Viewer. Note the data buffer resets when the number of graphs are changed.

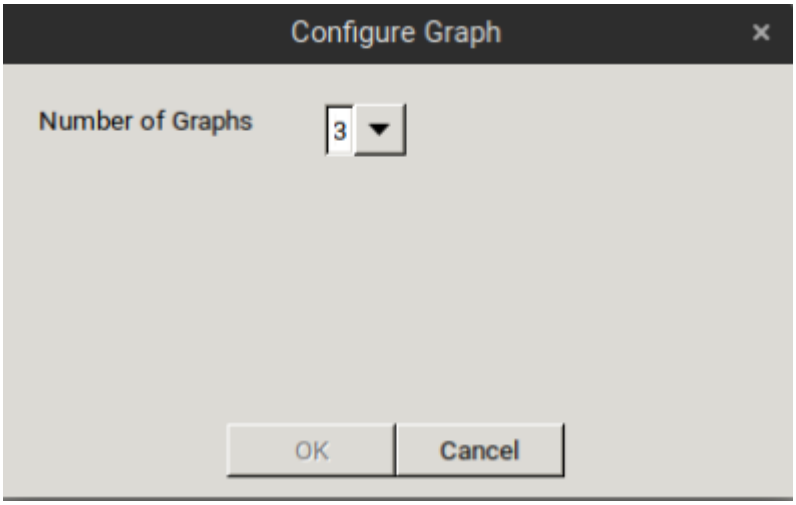


Figure 18: Configure Graph Window

Tools Menu

This menu item has three entries:

- **User Calibration** – Opens the password protected user calibration window (default password is picarro).

  Calibration slope and intercept can be entered, and their effects immediately seen in the data. See section 9, Calibration for more information.

- **User Administration** – Provides access to User Management options for managing user accounts, policies, viewing histories and profliles.
- **Show Valve Sequencer GUI** – Toggles the display of the external valve sequencer window (user may need to hit alt-tab to bring it to the front).

Settings Menu

This menu item has a single entry called GUI. When selected it provides the **GUI Properties** window (18) which allows you to set the number of graphs displayed and to enable the control of Valve Sequencer from the main GUI.

Help Menu

- **About** – Displays the software release version of the instrument.

6.3 Alarms Panel

This panel is used to monitor the status of the internal instrument alarms. These indicators are gas concentration alarms, such as “H2CO Too High/Low” depending on instrument configuration. The gas concentration alarm icons are off

(grayed) when the respective concentrations are below a certain value, and they are illuminated red when the respective concentrations are above/below a certain value.

CAUTION

High/low alarm settings are not intended as a safety measure as configured at the factory, either with respect to human health or the health of the analyzer. It is up to the customer to determine the meaning and level of a "high" or "low" value based on their application.

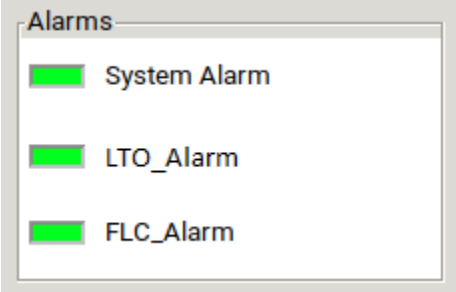


Figure 19: Alarm Panel

To view the alarm set point, click on the **Alarm Icon** and a dialog box will appear indicating the alarm setting and allow the user to enable it or change the setpoint.

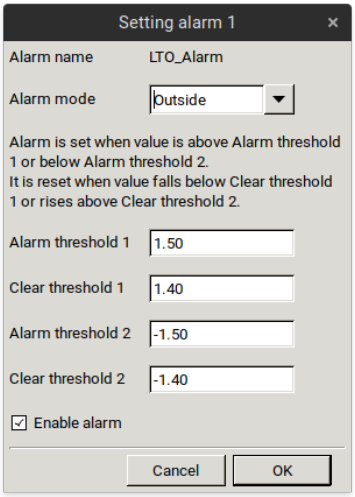


Figure 19: Alarm Settings Dialog

Type the value you wish to set the alarm to and click the **OK** button or **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. The units are those that appear in the GUI graph.

6.4 Digital Readouts

Displays the latest value recorded for the selected Data Key for each Data Window. Changing the Data Key changes the Digital Readout as well as the Data Window view. If the **Statistics** entry is enabled in the **View** menu, the mean, standard deviation and slope of the data in the graph is dynamically calculated and indicated below the digital concentration readout. These numbers change to reflect statistics of whatever data is in the data window. **Zooming** into a section of existing data will show the statistics statically for that time period, while the digital readout above the statistics continues to update with the latest value. See ***6.12, Graph Zooming*** for more information.

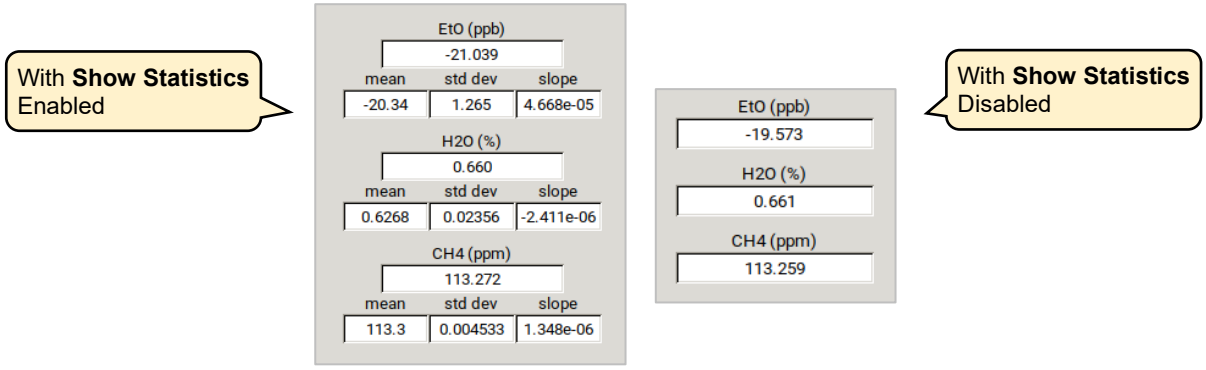


Figure 20: Digital Readouts Panel

6.5 Instrument Status

If the parameters are enabled through the **Instrument Status** entry in the **View** menu on the main toolbar, digital readouts for Warm Box temperature, Cavity Temperature and Cavity Pressure are displayed below the digital readouts panel.

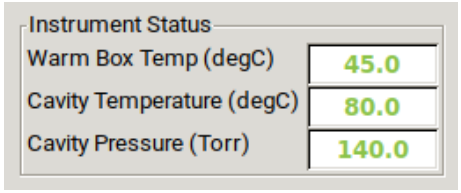


Figure 21: Instrument Status Panel

6.6 Quit and Restart User Log(s) Button

Figure 22: Quit/Restart User Log(s)

Restart User Log(s) Button

The Analyzer automatically records all data collected on the instrument as .dat files. These are described further in section ***8, File Management***.

To start a new data file (time-coded to the current second), click the **Restart User Log(s)** button. The new file name should be visible beneath the button in a few seconds.

Data Log Filename and Path

The filename and path of the active data log is displayed in this pane. The indicator is grayed-out when there is no active data log before gas measurement reporting begins. A new file is generated when the instrument starts reading gas concentrations, (e.g., “153719”) and subsequently at 1-hour increments (e.g., “163719”, “173719”). A new day folder (e.g., “2021\07\16”) will be generated at midnight, as will month and year folders at the appropriate times.

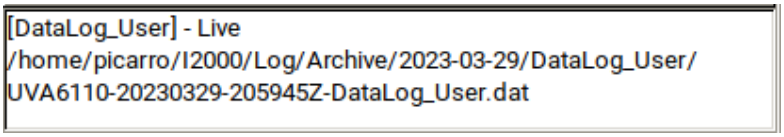


Figure 23: Data Log Filename and Path Panel

6.7 Data Window

The data window displays a graph of any stream of data vs. system time, with a format of hh:mm:ss. The user can select which data streams are displayed using combinations from the **Data Source** and **Data Key** pull down menus. The precision displayed can be adjusted using the **Precision** menu. Auto-Scaling of the **Y-axis** is also available. Clicking any Autoscale button autoscales its Y-axis if the plot hasn’t done this automatically.

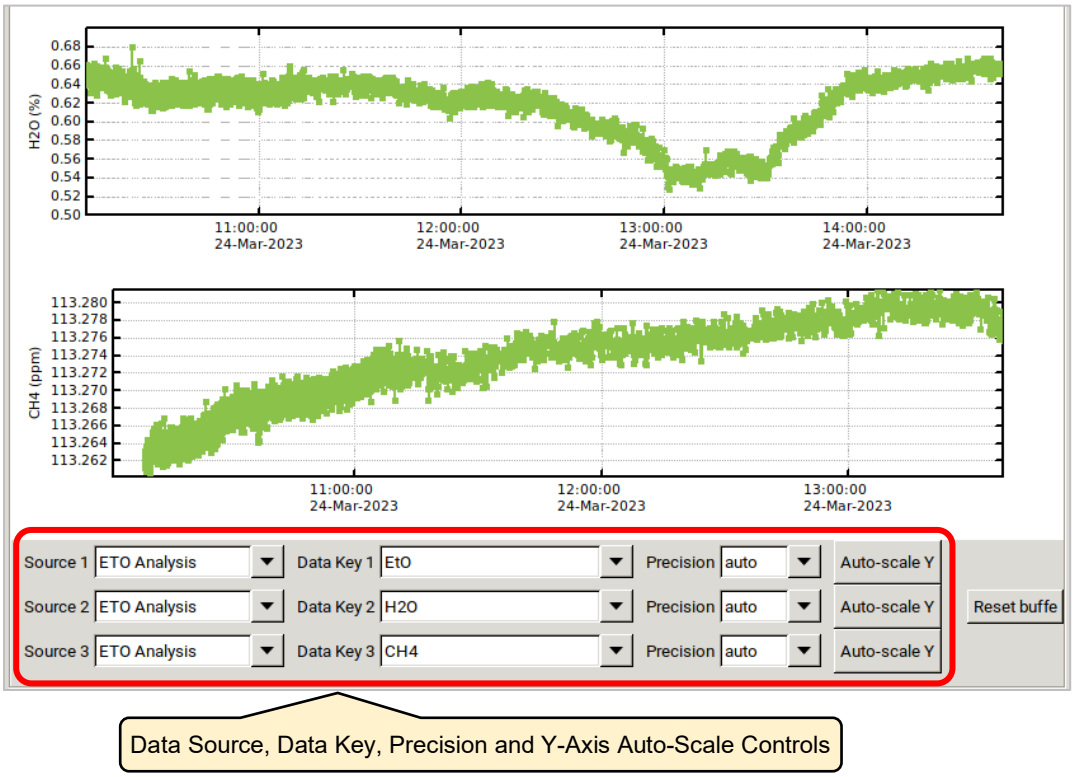


Figure 24: Data Window Panel

6.8 Data Source and Data Key Pull Down Menus

Data Source and Data Key menus (Figure 25) enable selection of the data stream that is viewed in the data window.

- Gas concentrations: If ‘EtO Analysis’ (where EtO) represents the system installed) is selected.
- Sensor Readings: If “Sensors” is selected, the analyzer’s optical cavity pressure or temperature can be viewed, as well as the temperature of the electronics of the analyzer (“DASTemp”, not directly controlled), and the temperature of the analyzer’s wavelength monitor, indicated as “WarmBoxTemp.”

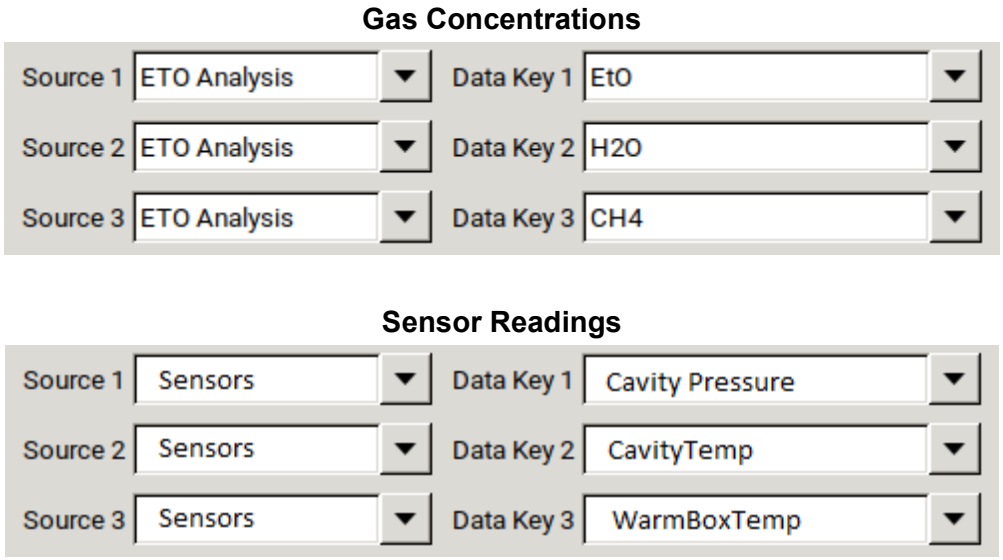


Figure 25: Data Source and Data Key Pull Down Menus

6.9 Precision Pulldown Menu

Click on the pull-down 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. Auto precision is sufficient for nearly all applications.

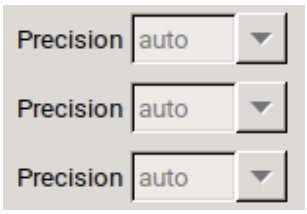


Figure 26: Precision Pull-down Pane

6.10 Measurement Status Log

This window displays instrument status messages, in the following form: **YYYY,MM,DD hh:mm:ss,** then '**Generic message text**'.

Common Status Log Messages

Following are the most common messages that appear:

- **Pressure Stabilizing/Locked: Displayed when** the valve control system begins to allow flow through the analyzer and stabilizes the pressure inside the cavity.
- **Temperature Locked: WB (HB): When the temperatures of the warmbox (wavelength monitor) and hotbox (cavity) have stabilized.**

  This is typically the longest step in the startup sequence. **Startup:** Depending on ambient temperature, the analyzer and its hotbox temperature set point, this step may take as little as 20, or as much as 60 minutes. **Restart:** If the instrument is only stopped briefly, this may take a few seconds to a few minutes.
- **Preparing to Measure:** 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.
- **Measuring:** This is the normal mode of operation after startup has completed.

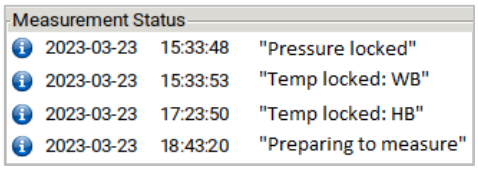


Figure 27: Analyzer Status Log

6.11 Reset Buffer Button

Click 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.*

6.12 Graph Zooming and Panning

Zooming In/Out

To zoom in on a specific region of the graph, move the cursor to the area of interest, **click/hold** the left mouse button, **then drag** as desired to create a box that covers the region of interest (see Figure 28). When the box is drawn, release the left button and the boxed area will automatically scale to fill the data window.

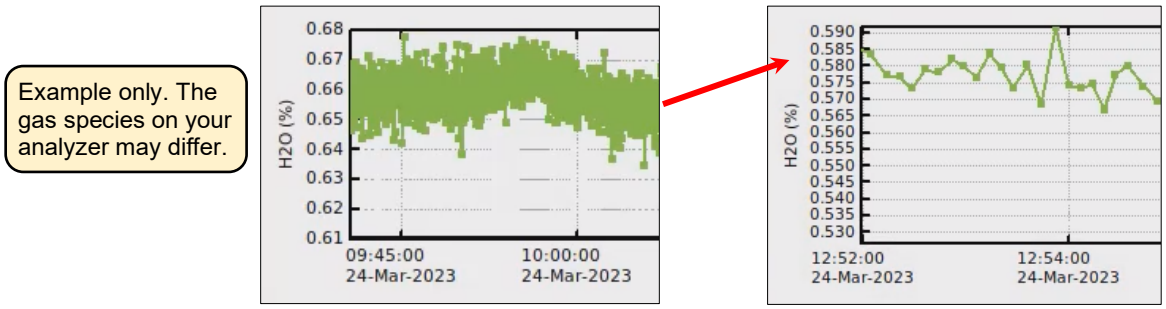


Figure 28: Data Graph Zoom Function

To zoom back out to see all data in the buffer, **double-click left button** within the graph display. **To zoom out indefinitely**, right click. Right clicking multiple times zooms out further. **To auto scale** the y-axis of either graph, use the auto-scale buttons below the graph.

To Zoom the X and Y axes: hold down the control button and move the cursor up/down or left/right using the right mouse button.

Lock/Unlock Time Axis

Zoom and pan features are often useful when time axes are locked, and the user wishes to align the Y axis in multiple plots. To lock or unlock the time axis of each graph during zooming, from the **View** menu, select **Lock time axis when zoomed** or **Unlock time axis**.

Planning

To pan the data in the X or Y axis: hold down the control button and drag the cursor using the left mouse button.

7. User Management

7.1 Overview

User management includes:

- Managing user accounts, such as adding users and changing passwords.
- Setting user policies, such as password requirements and session duration.
- Viewing and saving user histories.

There are three user roles defined in the system: operator, technician, and administrator. The permissions are as follows:

Table 6: User Accounts/Functions

Function	Not Signed In	Operator	Technician	Administrator
View Data Viewer	•	•	•	•
Set Alarms		•	•	•
Configure Data Viewer (partial)		•	•	•
Quit Measuring		•	•	•
Quit (software shutdown)		•	•	•
Configure Data Viewer (full access)				•
User Management				•

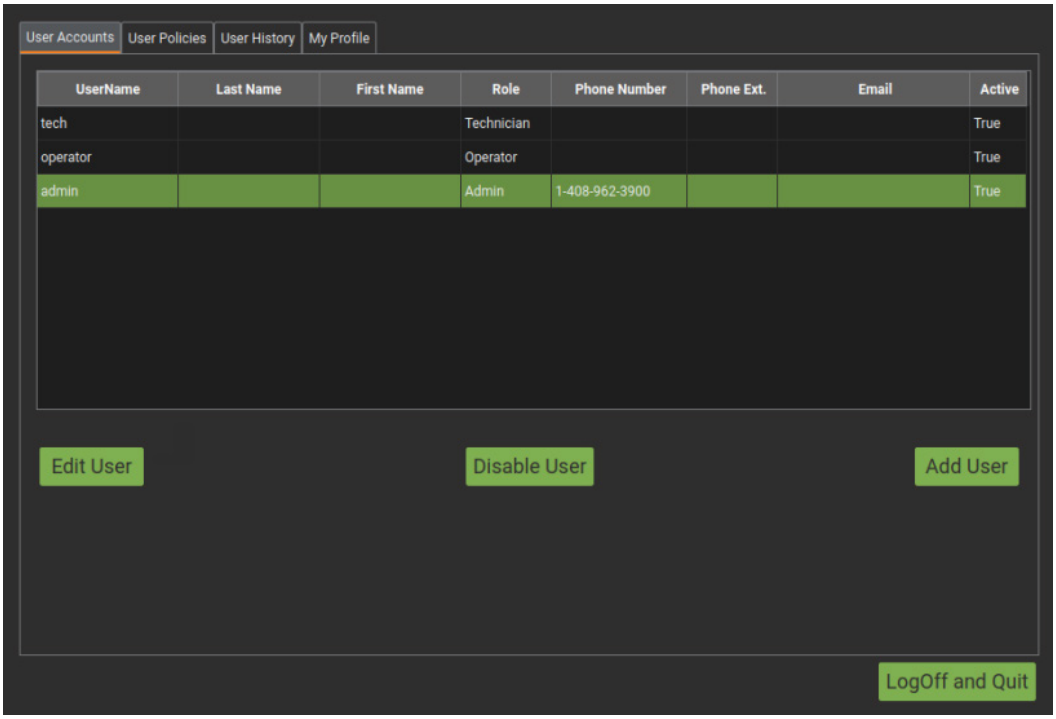
User management settings are available from the **Tools** menu in the Data Viewer or by using the **Picarro Launch Pad**. Use one of the following procedures.

From the Data Viewer:

1. From the **Users** menu, select **User Login.**
2. Login as an administrator (default user name is admin; default password is admin).
3. From the **Tools** menu, select **User Administration** to view the User Management window as shown below.

From Picarro Launch Pad:

1. Login to the **Picarro Launch Pad** as an administrator (default user name is admin; default password is admin).
2. Select **Administration** and **User Accounts**.
3. From the **User Management Tool** login as an administrator (default user name is admin; default password is admin).
4. The **User Management** window displays.



The User Management window has four tabbed states: User Accounts, User Policies, User History and My Profile.

Figure 29: User Management Window

7.2 Manage User Accounts

From the User Accounts tab, perform any of the following tasks:

- Add new users
- Disable users
- Change user passwords
- Change user roles

NOTE

The default user names that are shipped with the analyzer are tech, operator, and admin. The default passwords are tech, operator, and admin, respectively. User names and passwords are both case sensitive.

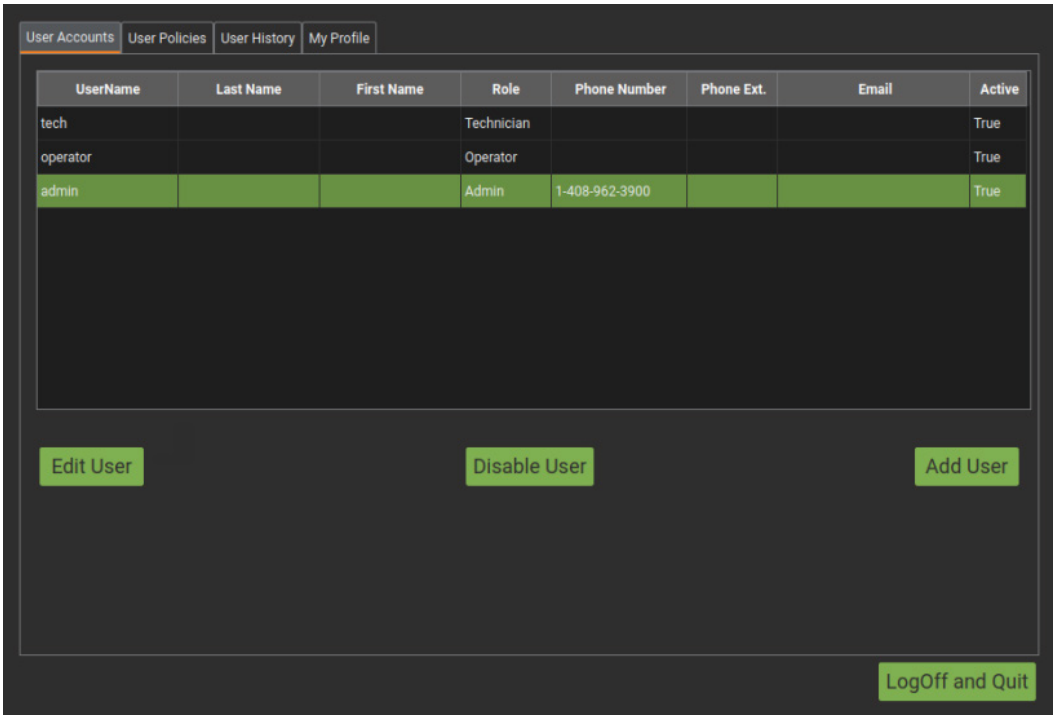


Figure 30: User Accounts Tab

To change a Password

1. In the **User Management** window, click the **User Accounts** tab.

   From the list of users, click the user you want to change from the Edit User dialog.

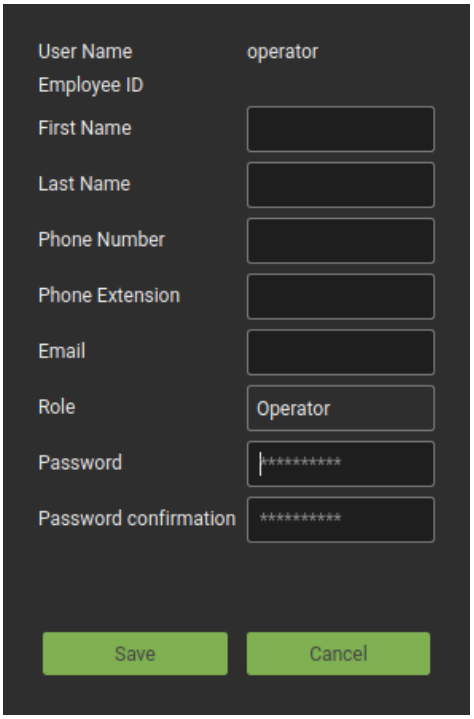


Figure 31: Change Password

3. In the **Password** field, enter the new password.

   Passwords are case sensitive. Additional rules for passwords can be set in the User Policies tab (see page 57).

4. In the **Password Confirmation** field, re-enter the password.

5. Click **Next** to save the password

NOTE

To change your own password for your account, see *View My Profile*.

To Change a User's Role

1. In the User Management window, click the **User Accounts** tab.
2. From the list of users, click the user you want to change from the Edit User dialog.
3. From the **Role** field, select the new role and click **Save**.

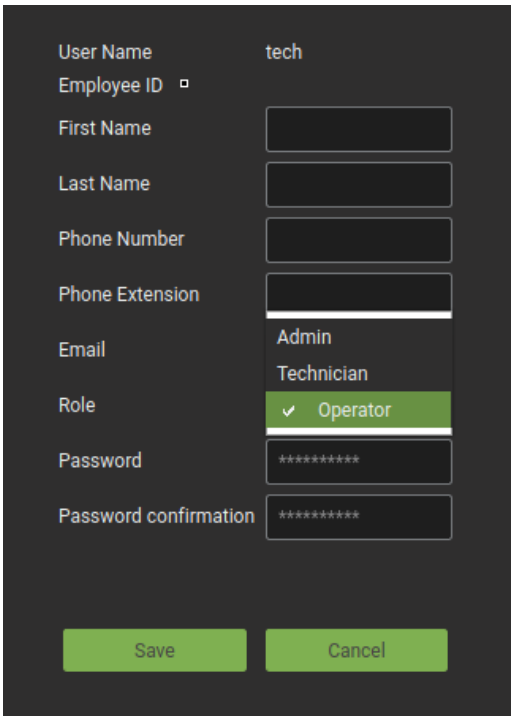


Figure 32: Change Roles

To Disable a User Account

Users cannot be deleted from the system, but they can be disabled so they will not have access to the software.

1. In the User Management window, click the **User Accounts** tab.
2. From the list of users, click a user name.
3. Click **Disable User**; this will prompt you to confirm your choice.
4. Click **OK** to confirm the action.

To Add a User

1. In the User Management window, click the **User Accounts** tab.
2. Click **Add User**; this will display the Add User screen.

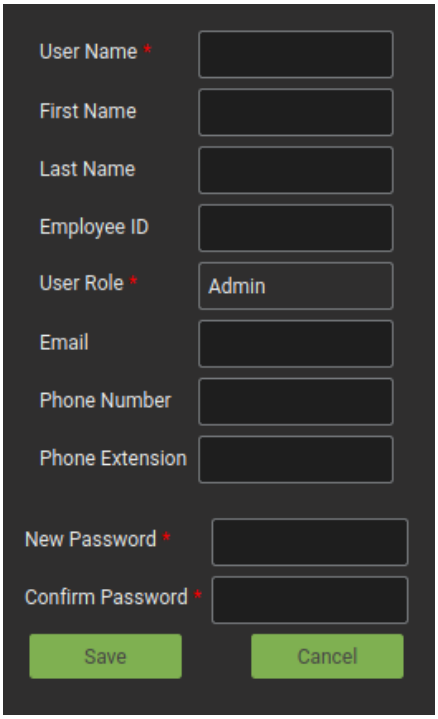


Figure 33: Add User

3. Fill in the fields in the Add User window.
4. Click **Save** to open the New User Account dialog.
5. Review the user information and click **OK** to accept or **Cancel** to go back and edit the information.

Set User Policies

1. In the User Management window, click the **User Policies** tab.

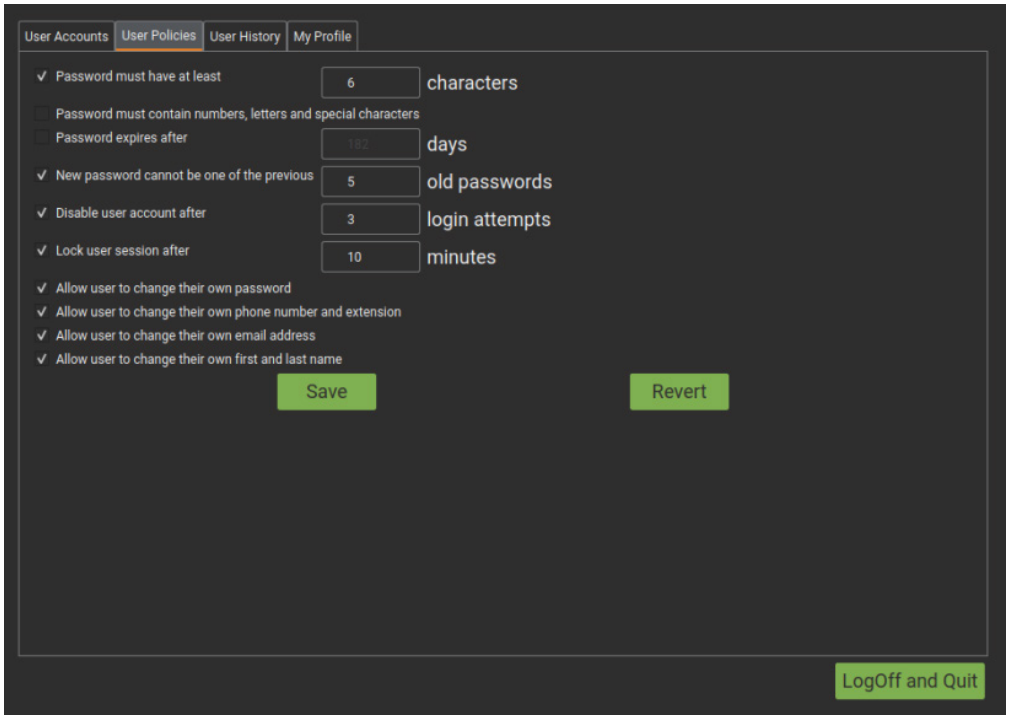


Figure 34: User Policies Tab

2. Make the changes you want. The following table provides descriptions for the various user policies.

Table 7: User Policies

Policy	Description
Password length	Specify that the length of passwords (6–15 characters) or turn off the length requirement.
Password complexity	When selected, all *new* passwords must have at least one number, one letter, and one special character. This will not impact existing passwords.
Password expiration	When selected, any passwords that reach the selected maturity will expire. Any user signing in with an expired password will be required to create a new password.
Previous passwords	When set, prevents a user from reusing a recent password. The system can remember up to 10 old passwords.

Policy	Description
Limit login attempts	Tell the system to disable a user account after a set number of failed password attempts. The failed attempts are counted until the user successfully logs in. Once disabled, an admin will have to enable the account.
Lock session	When set, the system will automatically logoff any user after a set period of inactivity, requiring the user to sign in again.
Change password	Allows the user to change their own password.
Change phone number	Allows the user to change phone number and restrictions.
Change email	Allows user to change their email address.
Change name	Allows the user to change first and last name.
Save user actions	When enabled, user actions (such as logging in) will be saved in the User History.

3. Click **Save**. If you typed an incorrect value and want to undo any changes and revert back to the last saved configuration, click **Revert**.

View User History

1. In the User Management window, click the **User History** tab to see a list of all the logged events.

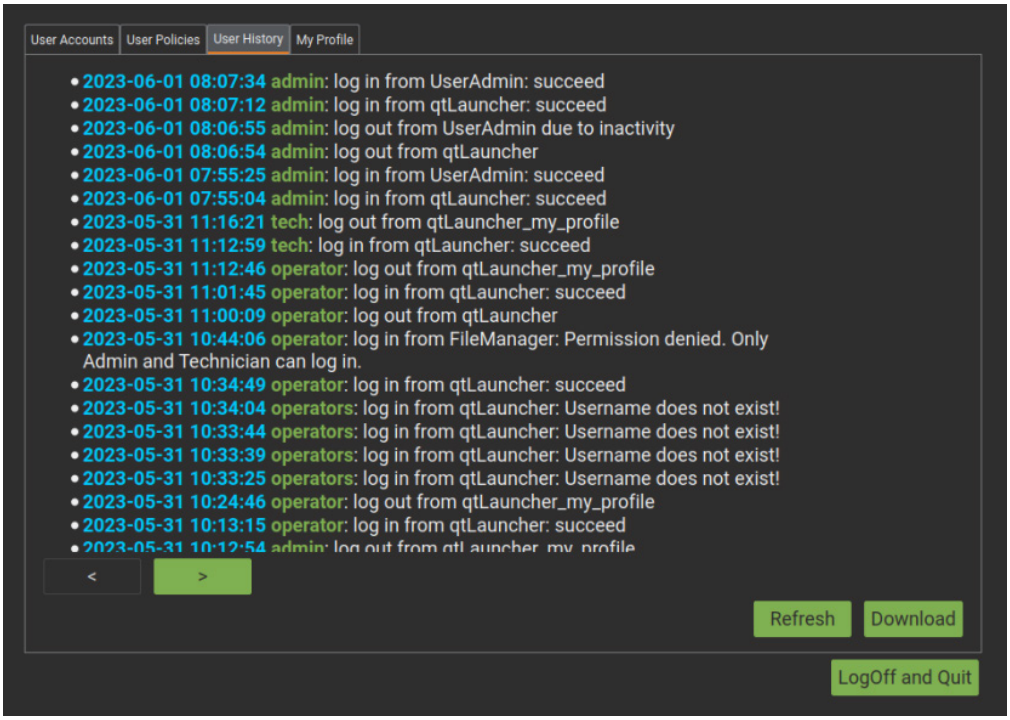


Figure 35: User History Tab

2. Click the **<** and **>** buttons to navigate through the history (if the button is grayed out, then there are no additional pages).
3. To make sure the content is up to date, click **Refresh**.
4. To copy the user history onto a USB drive, click **Download**. This will direct you to the File Manager, which will prompt you to login again. See page 48 for details on copying files from the analyzer

View My Profile

The My Profile tab provides information about the user that is currently logged into the system. The change password, phone number, email and name options are available to the user if these settings were enabled in the User Policies tab by an administrator. The user can use these options to edit their own profile information.

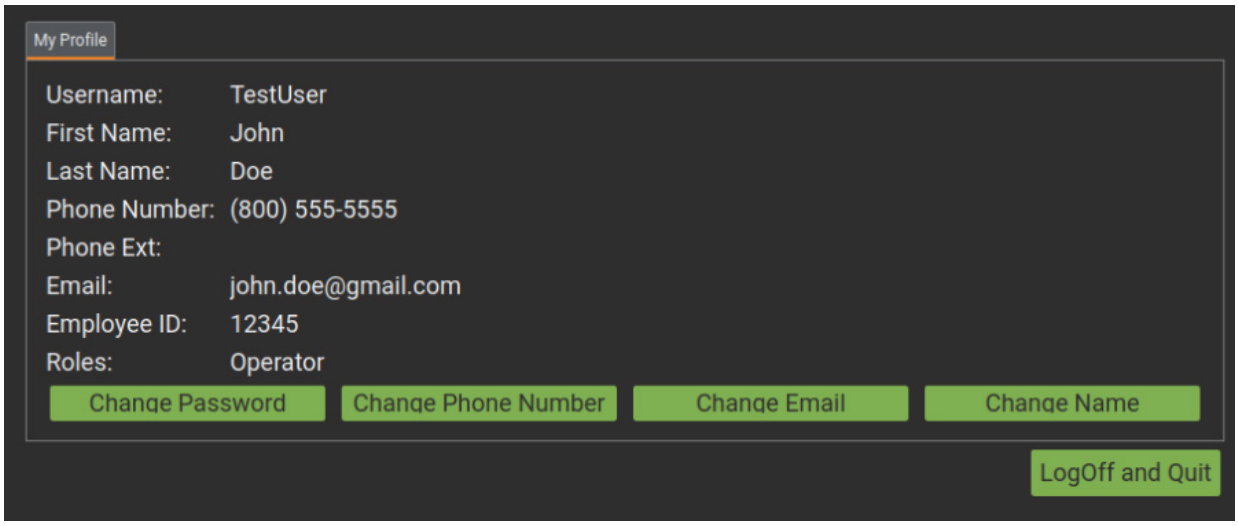


Figure 38: My Profile Tab

8. File Management

The Picarro Analyzer generates ASCII-format text output files that are updated after each batch of concentration measurements is complete. The data files are stored primarily in DataLogger folders and are also mirrored in folders which retain more situational data. Some analyzers also produce discrete measurements stored in separate isotope data folders. All user data is ultimately archived, compressed, and retained, either shortly after the measurements or at a later point, to optimize space on the hard drive.

8.1 Data Archive

The archive directory is:

/Home/Picarro/I2000/Log/Archive

and has subdirectories:

DataLog_Private, **DataLog_User**, **EventLogs,** and **WBCAL** with files arranged by **year\month\day\hour**.

The Data Logger files are in a simple text format (white-space delimited) with a DAT file extension. By default, each file stores one hour of data.

Using the **Data Logger Setup Tool**, the user can select and customize the data columns, file length, total storage size and folder structure for the user data logs. For more information, see ***Data Logger***.

Certain instruments may contain additional sub-folders under: /Home/UserData relating to time synced file formats, soil flux, or GPS data, among others. If the user has any questions about this file structure, they can contact Picarro Support.

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 following directory:

/Home/Picarro/I2000/Log/Archive/DataLog_Private
/[year]/[month]/[day]/[hour]

The archive files are in a HDF5 format, a more efficient data storing format with an .h5 file extension.

8.2 Data File Name

The file name is generated from the analyzer serial number, the date, and the time when the file was started. The specific time stamp will depend upon the time the instrument was started and began measuring sample gas, so files seldom begin exactly at the top of the hour. For example:

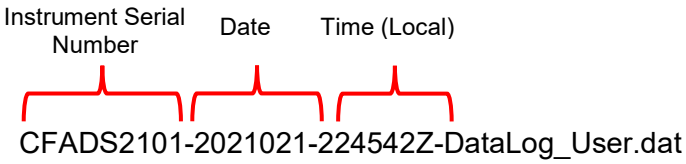


Figure 36: Example Data File Name

- **CFADS2101** is the analyzer serial number
- **20210201** is the date, in format *yyyymmdd* (to allow chronological sorting of data files).
- **224542** is the time the file was started in the computer's local time 22:45:42, formatted as *hhmmss* using a 24-hour clock. Note that the time stamp of samples within the file is usually recorded in UTC (GMT) relative to the local time. For example, an analyzer in California will usually have a time stamp (UTC) within the file that is 8 hours ahead of the time stamp in the file name itself (UTC - 8).

8.3 File Archiving

Picarro instruments will not delete data. Some instruments will, however, compress and archive older data to conserve hard drive space. Raw data file archiving frequency and details can be modified in the file:

Home/Picarro/I2000/AppConfig/Config/Archiver/Archiver.ini.

CAUTION

To avoid losing data, discuss with Picarro support before attempting any changes to the Archiver.ini file.

For each file type, there are various items along with some recommended default settings which may vary by file type:

- **Directory = */Home/Picarro/I2000/Log/Archive***

  Optionally specifies which directory to find files to archive.

- **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 archive 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 archived first.

- **Quantum = 4**

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

9. Calibration

9.1 Introduction

Periodic recalibration with standards of known concentration maintains the accuracy of your analyzer. Using the **Data Recal Software Utility** (described in section ***9.4, Direct Calibration Through the Data Recal Tool (Recommended)***) enables the calibration constants to be tracked over time, thus enabling the user to follow system performance.

9.2 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.

A rule of thumb with Picarro analyzers is that their linearity seldom drifts more than 5% in either direction over many years, so a recalibrated slope of <0.95 or more than 1.05 typically reflects not instrument drift, but the uncertainty in the other components of a calibration, e.g., reference materials, gas delivery, or sample handling materials compatibility.

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, checking for any leaks or dilution, confirming regulators are fully flushed before use, and confirming that you've taken the certified rather than target value on your calibration cylinders. In most cases, such large changes in slope are a result of these sorts of biasing effects, and do not indicate a lack of repeatability in the analyzer. If your analyzer continues to suggest a large change in slope, please consult with Picarro Support before applying a new calibration.

While the user can expect non-reactive gases (including surrogate gases which are traceable to primary standards) to be quite repeatable to better than 5% from use to use, the same is not always true of reactive gases. Gases like ammonia are typically certified with significantly larger uncertainty terms, and standards are expected to degrade, often significantly, over months or years. Accordingly, the overall health of an analyzer (e.g., laser or sensor drift) should be assessed by the non-reactive species reported when high quality reactive gas standards are not available or trusted.

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. From the Picarro Launch Pad, navigate to Tools and User Calibration.

Then change the slope and offset values of your parameter of interest to 1 and 0, respectively.

9.3 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, typically five-minute measurement of that sample.

WARNING

When calibrating with hazardous, corrosive, explosive, or otherwise dangerous gases, the user should follow best practices for reducing personal exposure, including locating the instrument and pump near or in a vacuum hood, and/or venting pump exhaust flow into a vacuum hood or dump line

Calibration Setup

Connections from the analyzer to the gas tank

- Always use a two-stage regulator capable of delivering 2-3 PSIG. Picarro recommends e.g., the Y12ASC445A590-AG Stainless Steel regulator from Airgas. This regulator offers a 0-30 PSIG range, which requires caution when directly connecting the instrument and cylinder, but also allows users the flexibility to use the cylinder with mass flow controllers. Always ensure the calibration pressure is set carefully before connecting to the instrument directly, and consider adding a bleed tee to avoid excess pressure buildup.
- The pressure regulator at the outlet of the gas tank protects the analyzer from over-pressurizing. The pressure should be set to about 2 – 3 PSIG (0.14 bar – 0.2 bar).
- The toggle valve allows rapid shutoff of the gas delivery.
- Tubing is connected to the male inlet bulkhead thread on the back with the analyzer.
- If the user is either moving a regulator from tank to tank, placing a regulator on a cylinder for the calibration, or calibrating for reactive gases, they should flush their regulator fully 2-3 times before use. Follow the tutorial located on the Picarro website Video Gallery. If you are viewing this manual on PDF, click HERE to go directly to the video. Otherwise, navigate to the video by following these instructions:
    a. In your web browser, enter **https://www.picarro.com/**, hover over the **Support** dropdown and select **Document Library**. The

Document Library homepage will open.

b. Click on the **Video** button near the top of the page.

c. When the video page opens, click on the **Flushing Regulators** link to view the video.

CAUTION

Failure to flush the regulator fully will typically result in a long, slow stabilization process that may take an hour or more for values that differ greatly from ambient air, or the gas from a previous tank.

When switching between tanks**:**

1. Ensure you are in a well-ventilated setting, and that all gases are contained within a fume hood.
2. Disconnect the tubing from the instrument inlet.
3. Turn off the main cylinder valve on the current cylinder.
4. Bleed down the pressure in the regulator using best practices, typically by disconnecting the line from the regulator to the instrument, and increasing the delivery pressure until both gauges have dropped to zero.
5. Disconnect the pressure regulator from the tank.
6. Connect the pressure regulator assembly to the next gas tank,
7. Flush the regulator with the new gas, following the instructions mentioned in the previous section.
8. Set the delivery pressure back to 2-3 PSIG.

9.4 Direct Calibration Through the Data Recal Tool (Recommended)

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. Ideally, three concentration-certified standards, or a single standard blended with diluent air to three concentrations, should be used for calibration checks. Standards spanning and encompassing the intended sample range should be used to build the standard calibration curve. Parameters of this curve will then be used to correct the instrument readings to match the standard cylinder values.

NOTE

The following steps illustrate the Data Recal procedure for concentration measurements. The user can follow the same steps for isotope measurements, if working with a Picarro isotope analyzer.

Running Calibration Standards for Direct Calibration

1. With the first standard hooked up to the inlet (typically starting with the lowest concentration), navigate to the main Picarro GUI, and watch until the calibration tank values have stabilized. Ensuring that **Show Statistics** is selected from the **View** menu, zoom in on a 5-minute stable period for a given gas species, and write down in a lab book or new text file the reported Mean concentration value from the left hand side of the screen for each species being calibrated.
2. When complete for the first tank, remove the tank from the instrument inlet and close the cylinder and/or on/off toggle valve.
3. Connect up the next **cylinder and** repeat the above steps for the remaining cylinders.

Graphical User Interface (GUI)

The **Picarro Data Recalibration** (Data Recal) software is located from the **Picarro Launch Pad**, **Tools** menu. The Data Recal software is launched by clicking **User Calibration** button and displays as shown in the following figure.

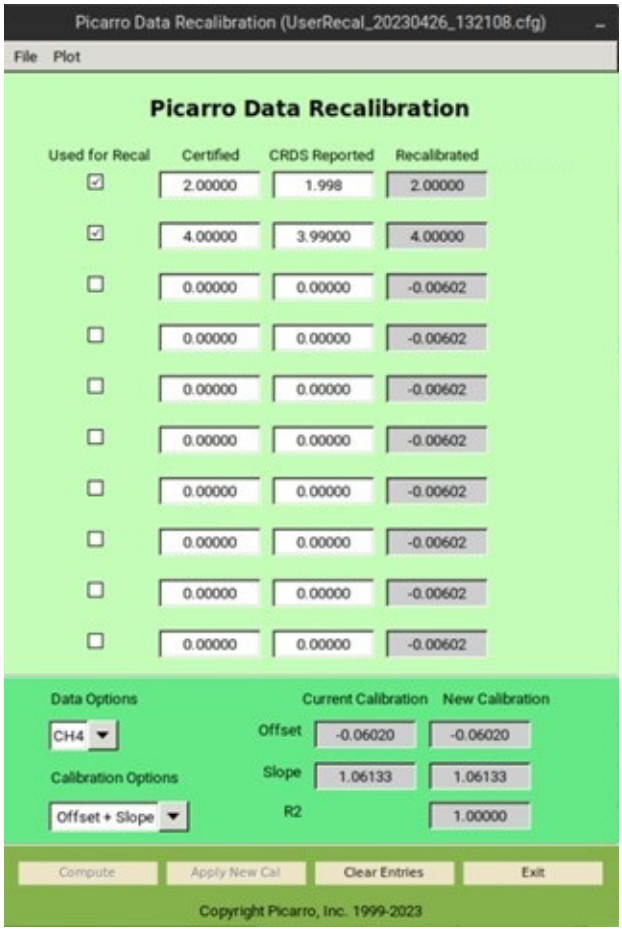


Figure 37: Data Recal Software Utility GUI

The Data Recal Software Utility consists of three sections:

1. **Numerical Input** and **Selection** sections (Figure 38):

   Start with the first gas being calibrated, e.g., CO2.

   a. Under **Certified**, enter the certified value for the tank, as characterized by the manufacturer. Importantly, ensure that you do not simply enter the target concentration requested upon purchase. While a tank can occasionally be delivered at exactly the target concentration, this is very rare. Typically, the certified value will have more significant figures, e.g., 103.1 ppm, rather than 100 ppm. The example in the image below is notional, and thus uses round numbers.

   b. Under **CRDS reported**, enter in the values noted down in a lab book/text file in the previous section corresponding to each calibration tank. Be sure to check the **Used for Recal** checkbox on the left so that the program knows to use the certified and CRDS reported values in the calibration curve.

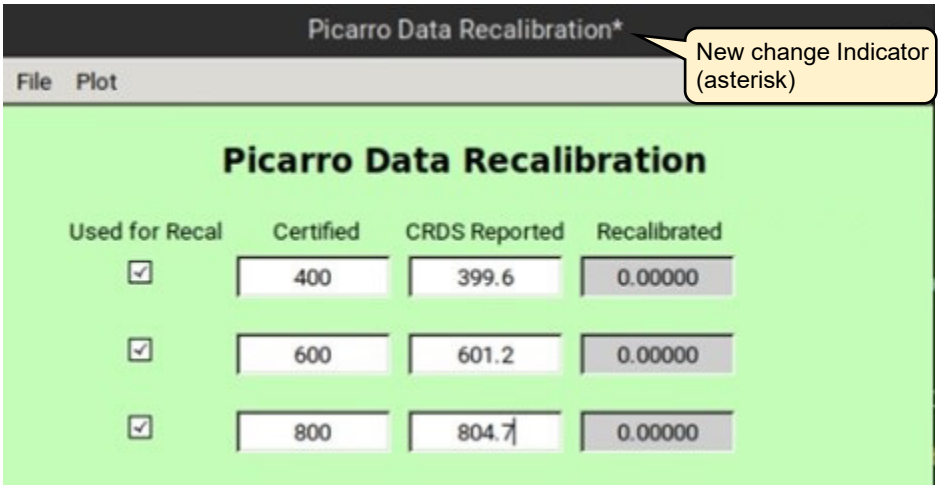


Figure 38: Recalibration Section of Data Recal Software Utility GUI

2. **Calibration Output** section (Figure 39):

   In the **Calibration Options** drop-down menu, the user can select either an **Offset** or an **Offset + Slope**.

   When using multiple standards, **Offset and Slope** are appropriate. Selecting **Offset** only is appropriate for single point scaling adjustments, e.g., for re-zeroing an analyzer.

   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 the user's initial selection. When the **Offset + Slope** option is selected, the program also calculates a goodness-of-fit correlation coefficient (R2).

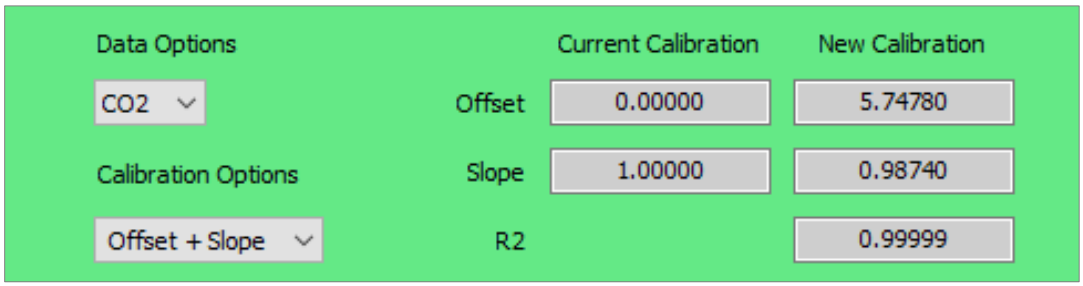


Figure 39: Calibration Output Section of Data Recal Software Utility GUI

3. **Action Selection** section (Figure 40):

   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 38), 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 38), indicating the new change.

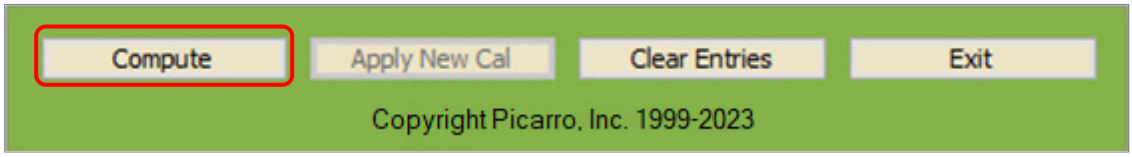


Figure 40: Action Selection Section of Data Recal Software Utility GUI

Once the calibration parameters are calculated, the user 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 41 below.

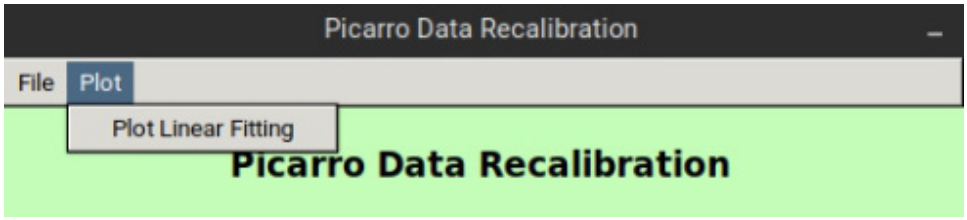


Figure 41: Data Recalibration – Plot Linear Fitting

The plot that the utility will generate is shown in Figure 42; this plot will display two graphs. The top graph presents measurements for the recalibrated standards (calibration and QC), as well as a line fitting through those points. The bottom graph shows the residuals, which shows how far each measurement is from the best-fit line.

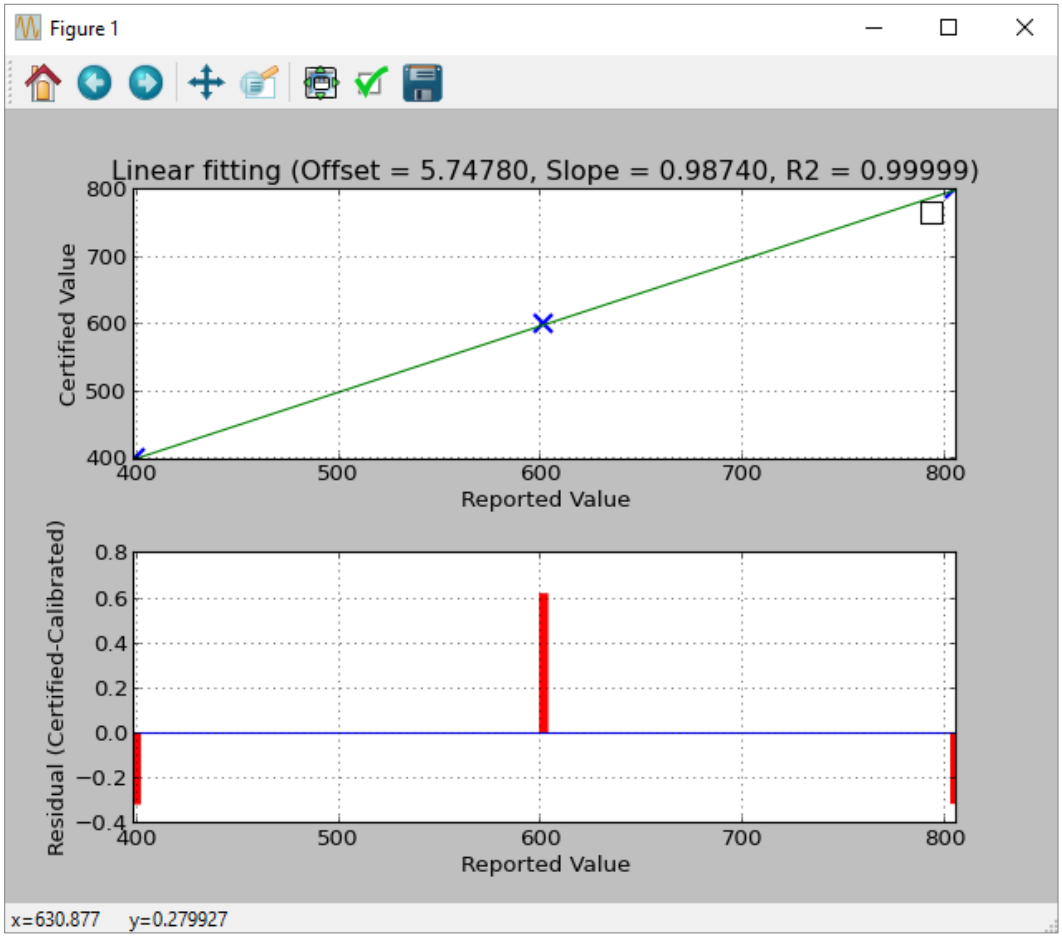


Figure 42: Slope of Data Recalibration

If the user decides to accept the new calibration values based on this plot, they may click on the **Apply New Cal** button (Figure 43).

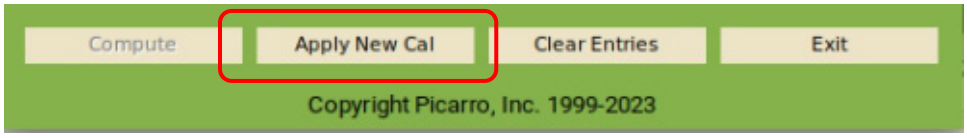


Figure 43: Apply New Calibration Slope and Intercept

The user will then be prompted to enter a Calibration Password (Figure 44). The default Calibration Password is **picarro**, all lower case.

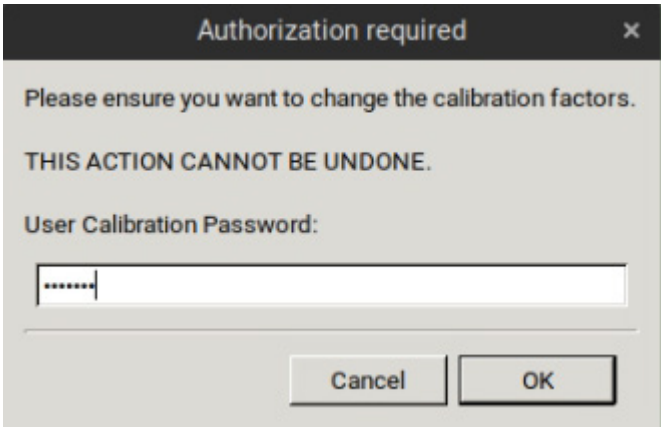


Figure 44: User Authorization Dialog

Next, a **Recalibration Confirmation** pop-up window will appear, displaying the new offset and slope (when applicable) values. This window will prompt the user to confirm their choice to apply these values, to avoid any inadvertent mistakes.

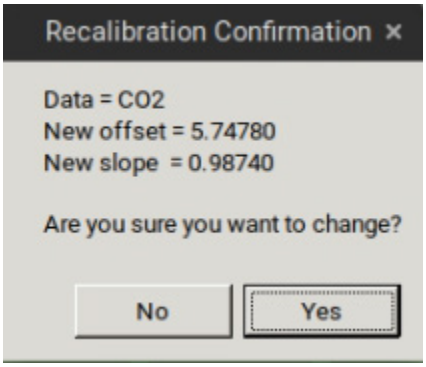


Figure 45: Calibration Confirmation Pop-up

When the user clicks the **Yes** button, the newly accepted calibration parameters will take effect immediately, without the need for the instrument main GUI to be restarted.

Once the user accepts the new calibration parameters, the **Data Recal Software Utility** automatically gives them the option to save the new recalibration file (Figure 46 below). Saving these files enables the user to track the instrument recalibration history.

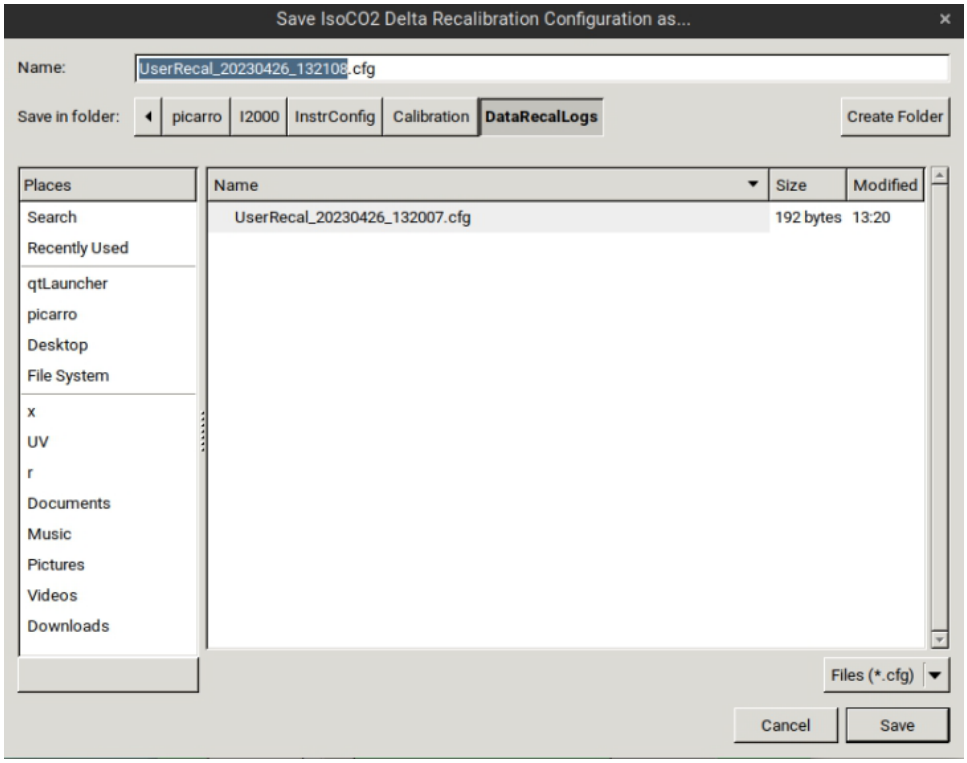


Figure 46: Data Recalibration Save-As File Dialog

The recalibration file for this example would contain the information as shown in Figure 47 below.

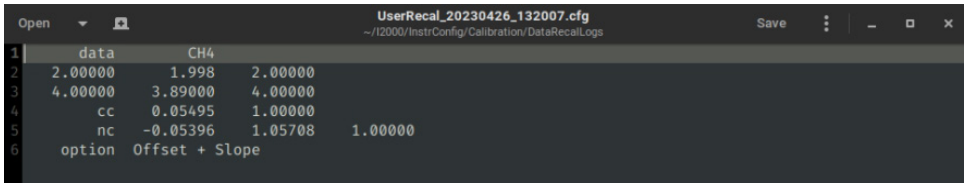


Figure 47: Data Recal Log File Example

Rows 2 – **4: 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 5 – **Current Calibration (cc) Row:** Read from left to right, lists the current offset and current slope value.

Row 6 – **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 R2 value, which is only displayed if the calibration option is **Offset + Slope**.

Row 7 – **Options Row:** The last row displays the calibration option selected.

If the user chooses to exit the Recal GUI before accepting the new recalibration values, they will be prompted to confirm their choice through a pop-up window (Figure 48). This window contains a warning that continuing to exit will cause the new calibration data to be lost:

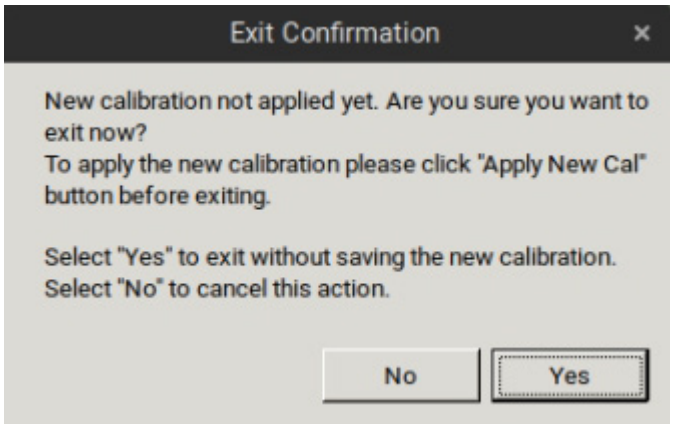


Figure 48: Recalibration Exit Confirmation Pop-up

When the user is finished with the calibration, they can either click **Clear Entries** at the bottom of the screen, and begin entering values for the next gas species, ensuring to select the right variable from the **Data Options** dropdown, or they can exit the Data Recal software utility by clicking on the **Exit** button.

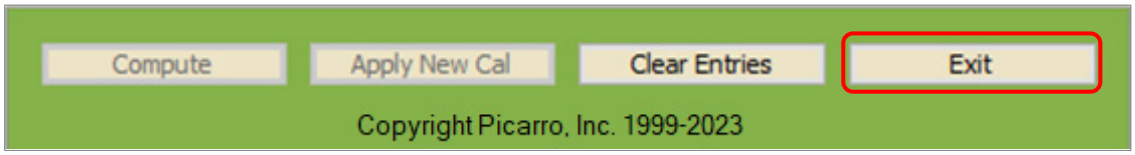


Figure 49: Exit Data Recalibration Utility

NOTE

The Data Recal will display an error message indicating the new slope value is not acceptable when one of the following occurs:

- **At least two entries in the Certified or CRDS reported columns contain zero-value numbers.**
- **These entries are selected to be used for recalibration.**
- **The "Offset + Slope" calibration option is selected. This error occurs because the entered values will lead to an erroneous zero-slope value.**

Loading a Previous/Stored Calibration

Saved calibration configurations can also be reloaded by clicking **File** in the upper left corner of the window (Figure 50) and selecting **Load Recalibration File**.

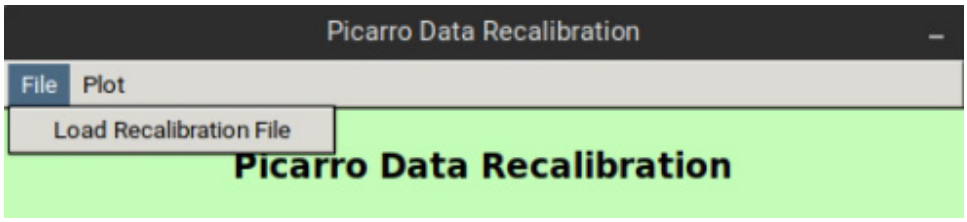


Figure 50: Data Recalibration Load File

From the load file dialogue, the user may select and open the file they wish to load (Figure 51).

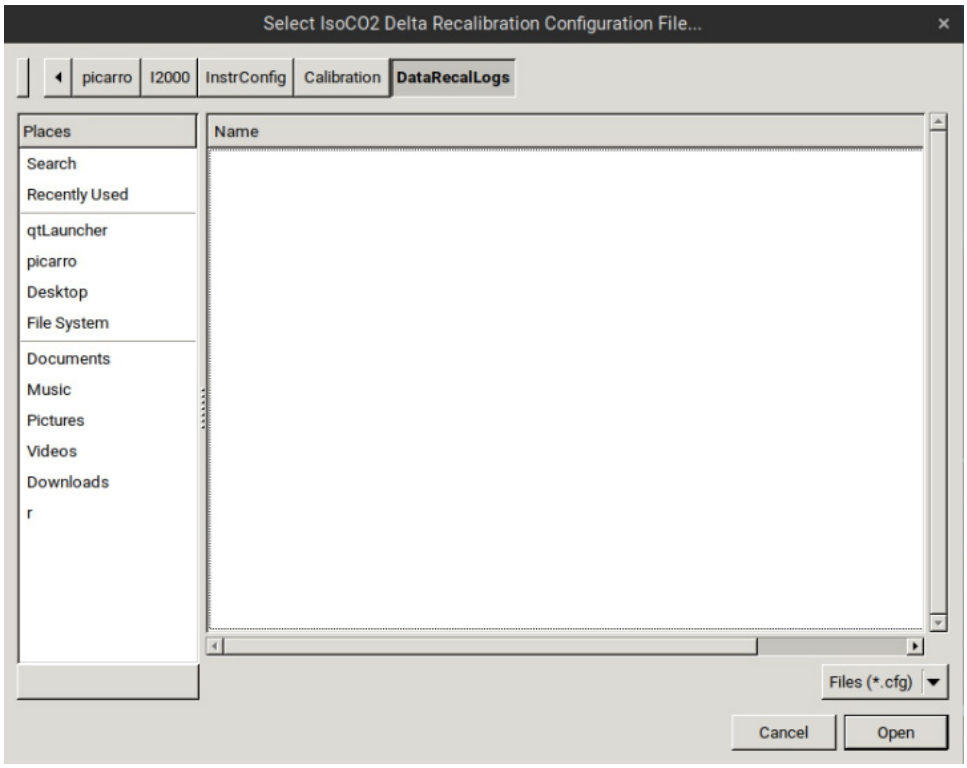


Figure 51: Data Recalibration Load File Dialog

9.5 Calibration Data Processing (less common, less direct option)

1. The user may process the calibration results from a given .dat file(s) (see ***File Management*** on Page **Error! Bookmark not defined.**) 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 in Figure 52 below, this calculation would be accomplished point-by-point by calculating the corrected data "**y**" using the analyzer's data "**x**" so that:

$Data_{corrected} = 0.9874 \times Data_{raw} + 5.7478$

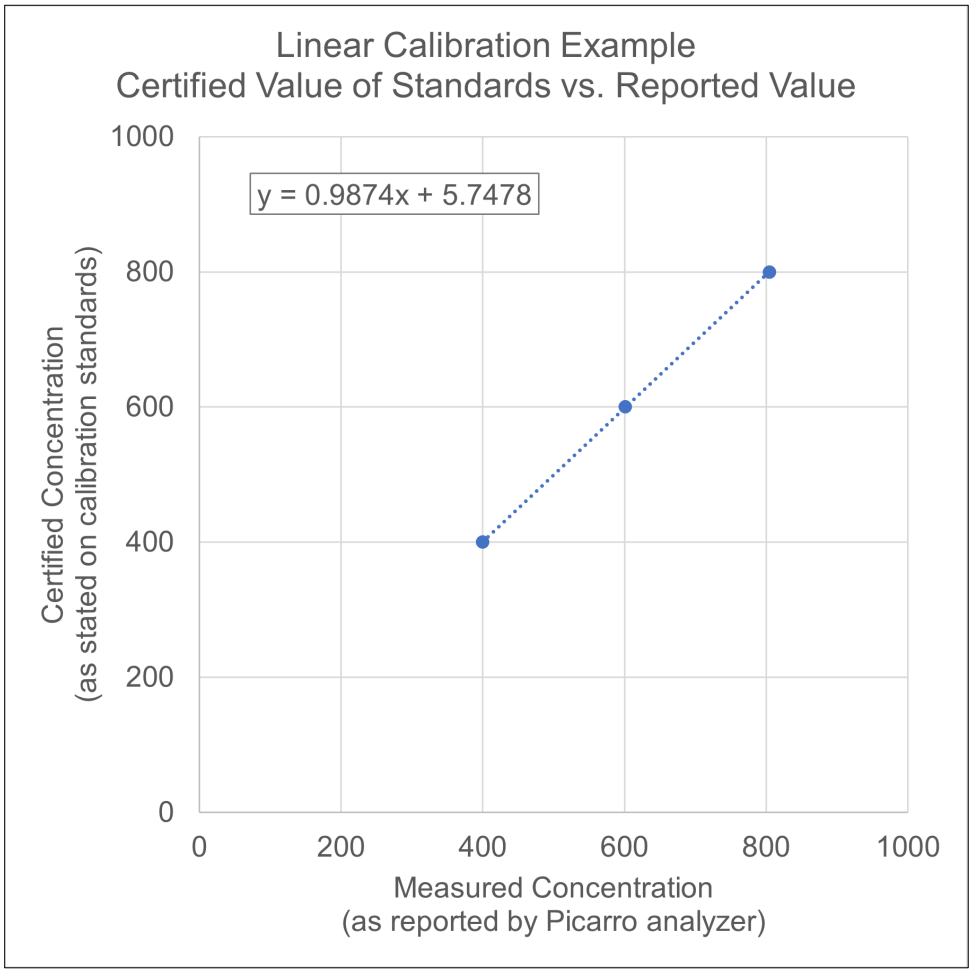


Figure 52: Linear Calibration Example

Calibration values are input into the analyzer by selecting **Tools**, **User Calibration** from the Picarro Launch Pad, 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**.

Returning the Instrument to its Factory Calibration

To return the instrument to its the factory calibration, within the **Calibration Tool**, simply set the slope to 1 and the intercept to 0 for the desired species. This returns the instrument to its factory settings, though this does not ensure that the system will read exactly as it did when it left the factory if a small amount of drift has accumulated over a period of time.

9.6 Detailed Picarro Calibration Guide

For more detail on calibrating a Picarro analyzer, refer to the ***Calibration Guide for Picarro Analyzers***. This document can be downloaded by either clicking the link below or entering the URL in a web browser.

https://www.picarro.com/sites/default/files/Calibration-Guide-Picarro-analyzers-Rev1.pdf

10. 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 Customer Service at (408) 962-3990 or support@picarro.com.

10.1 Power LED on Analyzer Does Not Illuminate

Context: Turning on the analyzer by momentarily depressing its back 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. Check that the rear on-off switch near the AC power cord is in the ON position (**I**).
3. Press and hold the front panel power switch for at least 5 seconds as the analyzer may take several seconds to respond.

10.2 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. Should either of the messages “Pressure high” or “Pressure low” be displayed, the cavity pressure is out of its correct operating range.

1. The “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. Check for blockages in the lines, or regulators that are turned off, especially by removing all items upstream of the inlet to see if the pressure returns to the specification. If removing plumbing from upstream of the instrument inlet doesn’t work, the inlet particulate filter may need to be replaced. See section ***11, Maintenance*** for more information.
2. The “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. Maintenance

The advanced, rugged design of Picarro Analyzers provides stable, long-term operation with minimal service or maintenance. With the exception of the following items, the analyzer and pump are not user serviceable. Should either appear to malfunction, please refer to the Troubleshooting Guide or contact Picarro Support.

As described below, users may obtain preventive maintenance components as part of a service plan, as part of a designated PM kit, or individually from the Picarro store.

11.1 Service Plans

In addition to basic telephone and email support and remote diagnostics, service plans include an annual preventive maintenance kit and can be purchased by contacting sales@picarro.com. The three service plans are as follows:

- **W3101 Essential Service Plan:** Free yearly maintenance kit; 50% discount on Field Replaceable Parts; 10-20% Discounted factory repair. See data sheet for complete terms and conditions.
- **W3102 Premium Service Plan:** Free yearly maintenance kit; Extended warranty; Free factory repair; Free Field Replaceable Parts. See data sheet for complete terms and conditions.
- **W3103 Commercial Service Plan:** Free yearly maintenance kit; Extended warranty; Free factory repair; Free Field Replaceable Parts; Loaner instrument; Free yearly prevention maintenance visit; Complimentary remote refresher training. See data sheet for complete terms and conditions.

11.2 Preventive Maintenance Kits

Preventive maintenance kits can be purchased by contacting support@picarro.com. The maintenance kits include the following elements:

Replacement CPU Fan; particulate filter (Stainless Steel or Teflon); dust filter; replacement screws for instrument cover panels; Ball-Point Hex L-Keys; Anti-Static Wrist Strap.

For the P2910 analyzer, Picarro recommends:

- **S3092:** Yearly Maintenance Kit for GHG, L2xxx, and EtO
- **S3093:** Yearly Maintenance Kit for PI2114
- **S3094:** Yearly Maintenance Kit for HAPs G2xxx User-Replaceable Hardware

11.3 User-replaceable Hardware – Individual Components

Inlet Particulate Filter

The inlet particulate filter is user-replaceable. Use the following links to order replacements and to find an instructional video and supporting maintenance document.

Picarro Store Ordering Links:

- **Stainless Steel Filter:** For all models except those that measure HF, NH_3, CH_2O, HCl and H_2O_2

  S1020 Particulate Filter Kit – If viewing this manual as a paper hard copy, enter the following URL in your browser:

  http://store.picarro.com/For-Analyzer/Parts/Particulate-filter-kit-all-models-except-HF-NH3.html

- **Teflon Filter:** For models that measure NH_3, HF, CH_2O, HCl and H_2O_2

  S1021 Particulate Filter Kit – If viewing this manual as a paper hard copy, enter the following URL in your browser:

  http://store.picarro.com/For-Analyzer/Parts/Particulate-filter-teflon-for-NH3-HF._3

Filter Replacement Instructional Video and Document:

- **Filter Replacement Instructional Video:** https://vimeo.com/375518688

  This video covers replacement of both stainless steel and Teflon filters. Note that this video does not currently cover replacement of externally mounted particulate filters.

- **Filter Replacement Maintenance Guide:** https://www.picarro.com/support/documents/inlet_particulate_filter_maintenance_guide

  This guide covers replacement of both stainless steel and Teflon filters for analyzer models that have either internally or externally mounted filters.

A2000 Pump Rebuild Kit

The pump rebuild kit is the only component not currently sold as part of a preventive maintenance kit because the replacement frequency is not strictly annual (frequency depends on pump usage).

The A2000 pump diaphragms and valves are user-replaceable. Use the following link to order rebuild kits and to find the instructional video and supporting maintenance document.

- Pump Rebuild Kit: Used with SI2xxx, G2xxx analyzers (except Flight and Flux analyzers)

  S2009 Rebuild Kit for A2000 Vacuum Pump – If viewing this manual as a paper hard copy, enter the following URL in your browser:

  http://store.picarro.com/For-Analyzer/Pump/Rebuild-kit-for-Picarro-A2000-vacuum-pump.html

A0702 Pump Rebuild

The A0702 recirculation pump (if used with your analyzer) is not user serviceable. Instead, these pumps may be exchanged once they reach the end of their diaphragms' operational life. Please contact support@picarro.com to coordinate this exchange.

11.4 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.

12. Transportation and Storage

If the analyzer will be transported or stored, use the following procedure to prepare and repack it into the original packaging.

CAUTION

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.

12.1 Shutdown and Preparation

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. See section *5.2, Shutdown* for specific shutdown instructions for your model analyzer.

1. Click on the **Quit** button located on the left side of the Data Viewer window.
2. A window displays (Figure 53) prompting the user to confirm the shutdown. Click **Yes** to continue with the shutdown process.

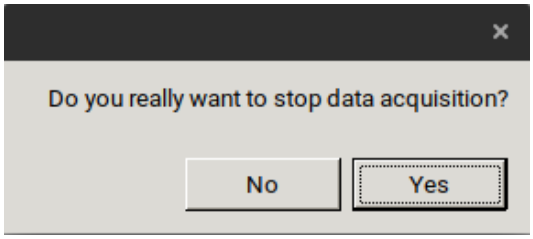


Figure 53: Stop Data Acquisition/Shutdown

Confirm the level of water vapor prior to shutdown. Click **No**, if the analyzer was dried before shutdown. Click **Yes**, if the analyzer requires dry gas to reduce the moisture content.

Once confirmed, the analyzer software and hardware will turn off.

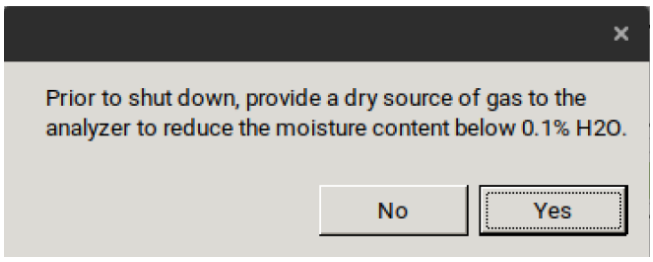


Figure 54: Reduce Moisture Content/Shutdown

3. Manually turn off the pump(s) and dry gas (if used).
4. Disconnect all tubing and electrical connections from the analyzer.
5. To prevent contamination and possible damage to the connector threads, place protective caps on all gas connections.

12.2 Packing

1. Place the analyzer in a plastic bag with a package of desiccant. Seal the bags with tape. If shipping the pump, do the same for it.
2. Pack the analyzer and pump in the original shipping containers ensuring that all the foam pieces are in place to protect the analyzer during shipping.

APPENDIX A – Setup Tools and Communication

A.1 Picarro Analyzer Settings and Tools

The **Picarro Analyzer Setup Tools** is accessed by using the **Picarro Launch Pad** and **Settings** button. These set of tools allow 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), and optionally configured electrical interface for additional measurement monitoring.

NOTE

You must be logged in as a technician or administrator to access the Setup Tools under Settings.

The settings of the Setup Tool are explained in the next pages in brief. A more in-depth description of the material is provided in the subsequent section. If you have any questions about the Setup Tool, please contact Picarro or refer to Picarro Community for further details.

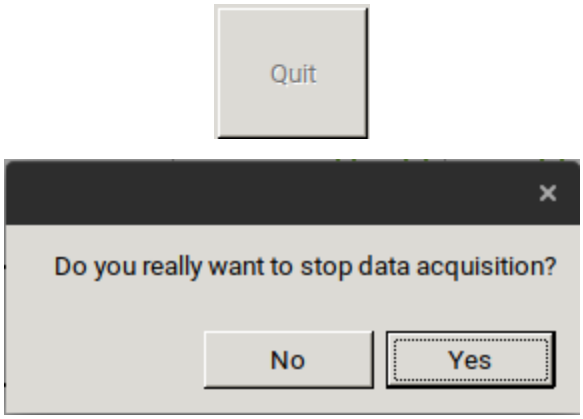
https://www.picarro.com/support/community

Figure 55: Analyzer Setup Tools

NOTE

Before running any of the setup tools, the instrument software must be stopped.

From the CRDS Data Viewer, select the Quit button and click Yes when prompted to stop data acquisition. The Setup Tool options are now active.



Serial Port

Configure the ASCII **Serial Port** by setting the Data Out and Command Interface parameters that are used for RS-232 serial communication.

The following options are provided:

- **Port:** Indicates the desired communication port.
- **Baudrate**: Specifies the rate at which bits are transmitted.
- **Data Bits**: Specifies the number of data bits to transmit.
- **Stop Bits**: Specifies the number of bits used to indicate the end of a byte.
- **Parity**: Indicates the type of parity checking.
- **Enable Serial Port**: Enables or disables the communication port specified in the **Port** field.

After making the appropriate edits, click **Save** to put changes into effect and then **OK** to close the window. For more information about Serial Communication, see ***Picarro Serial Communication.***

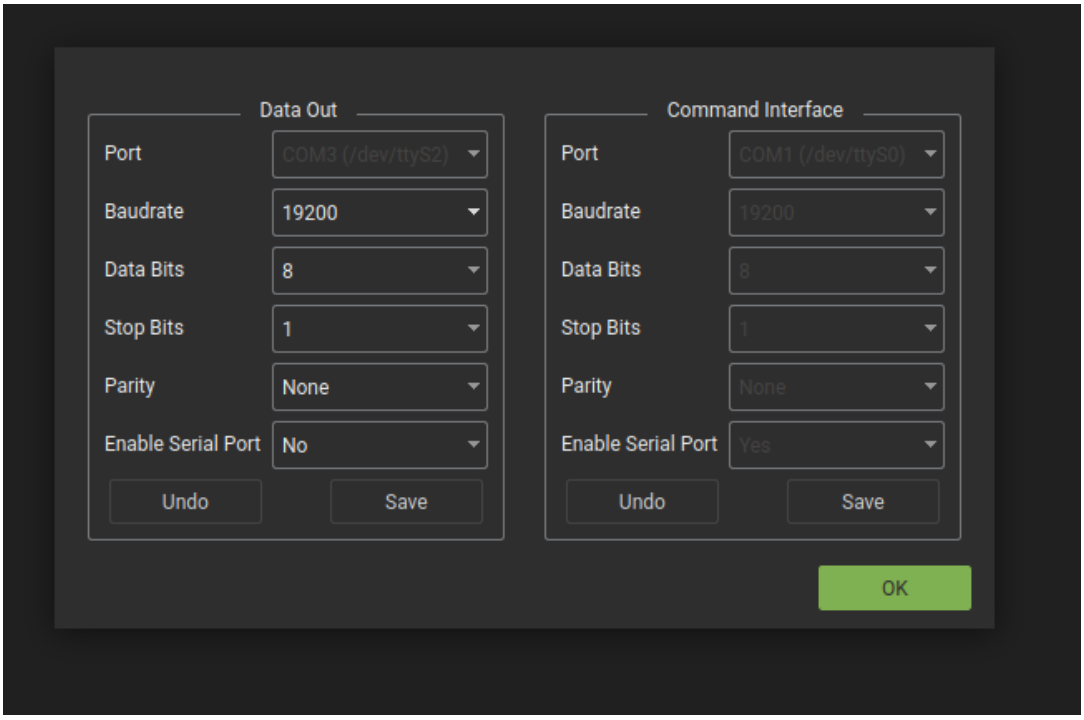


Figure 56: Serial Port Settings

Port Manager

The **Port Manager** allows you to control digital data output/Input via serial port or TCP/IP.

On this window, you can specify:

- **Data Streaming:** The port you want your data to stream through (COM1/COM2/Off)
- **Valve Sequencer MPV (Multi Position Valve):** The port you want to connect your MPV to (COM1/COM2/Off)

  For more information on the configuring for external valves, see ***APPENDIX E – External Valve Sequencer***.

- **Command Interface:** (COM1/COM2/TCP/Off).

  Make sure there are no COM port conflicts before clicking **Save**.

After making the appropriate edits, click **Save** to put changes into effect and then **OK** to close the window.

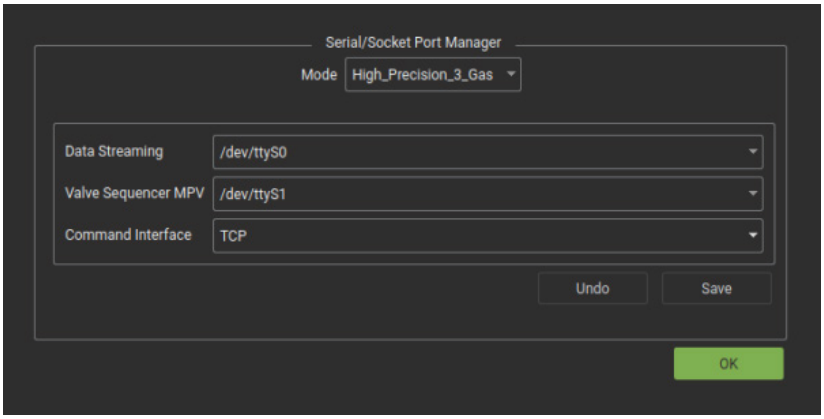


Figure 57: Serial/Socket Port Manager Settings

Command Interface – Specifying Digital Data Output

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

Output Data Source:

- Datalog_User
- DataLog_User_Sync (Relevant only for Flux G2311-f analyzers).

Output Data Columns:

- The data columns are output in the order they are checked, e.g., CH_4, comes before CO_2. Command Interface enables an external device to send a set of predetermined commands to a Picarro analyzer. The Picarro returns data or metadata on the basis of the command received.

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

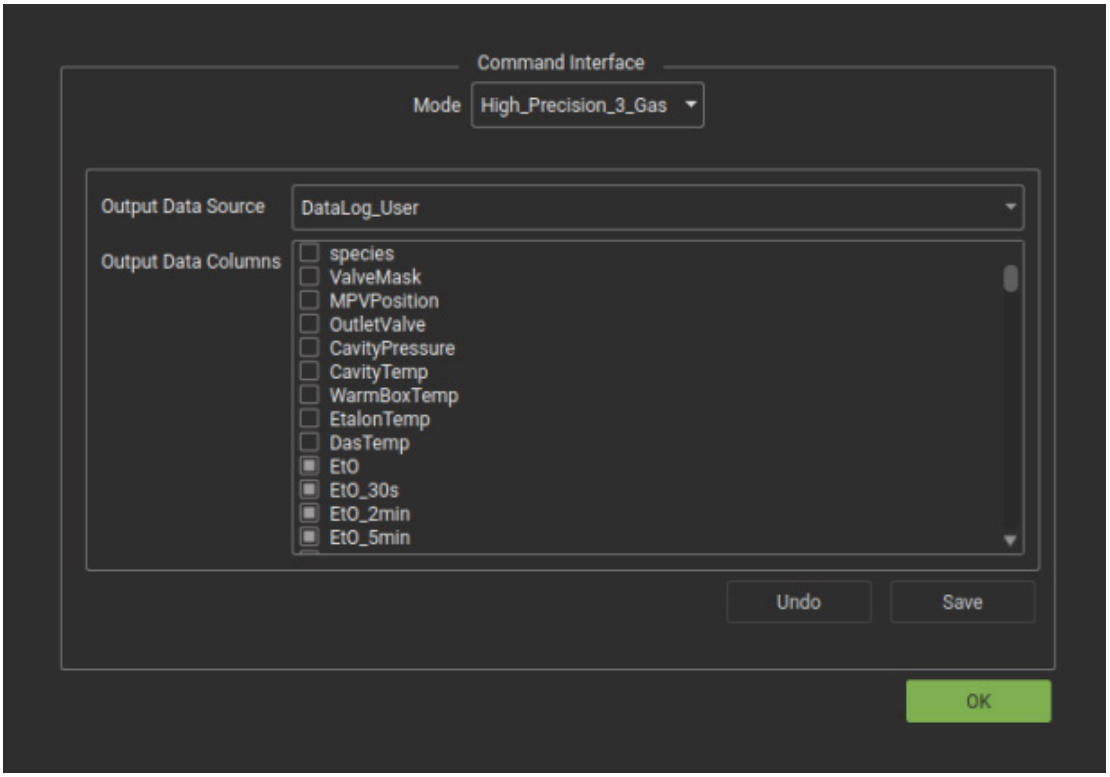


Figure 58: Command Interface Settings

Data Streaming – Specifying Digital Data Output

The **Data Streaming** allows you to specify the data elements that you want to send via COM port (specified from the **Port Manager**). Two types of data can be specified here:

Output Data Source:

- Datalog_User
- DataLog_User_Sync (Relevant only for Flux G2311-f analyzers).

Output Data Columns:

The data columns are output in the order they are checked, e.g., CH_4, comes before CO_2. Command Interface enables an external device to send a set of predetermined commands to a Picarro analyzer. The Picarro returns data or metadata on the basis of the command received.

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

After making the appropriate edits, click **Save** to put changes into effect and then **OK** to close the window.

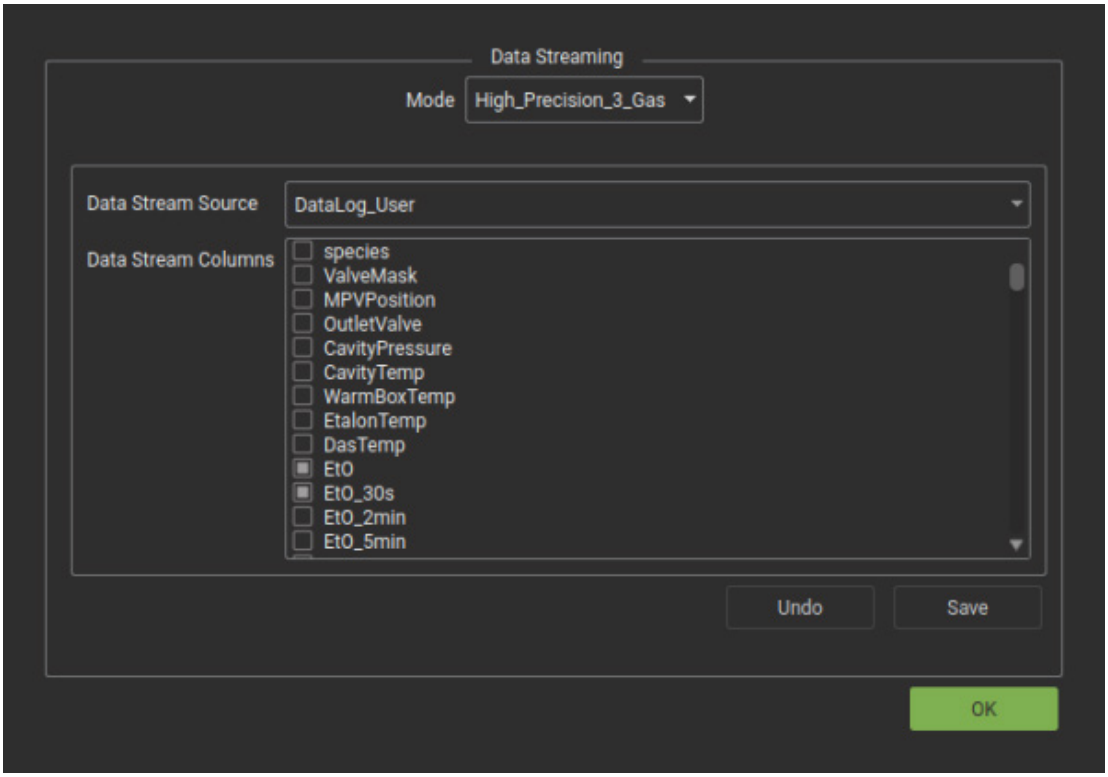


Figure 59: Data Streaming Settings

Electrical Interface – 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.

The **Electrical Interface** allows you to customize each analog output channel.

After making the appropriate edits, click **Save** to put changes into effect and then **OK** to close the window.

NOTE

This window will be disabled if your analyzer was not configured to work with an analog peripheral.

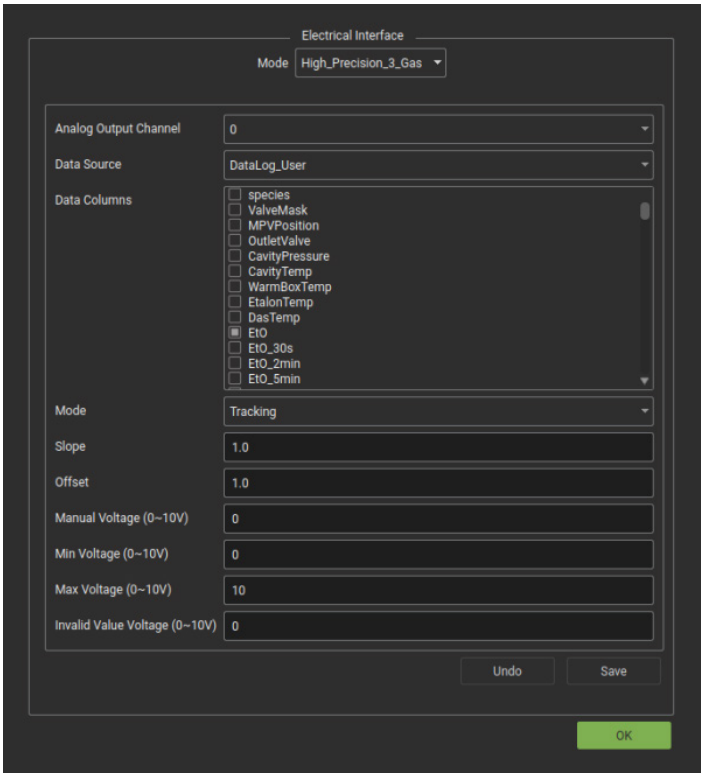


Figure 60: Electrical Interface Settings

Data Logger

The **Data Logger** 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 – */Home/Picarro/I2000/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).
- **Mode:** Changes the way the analyzer fits and displays data in the data viewer on the basis of gas matrix, species reported, precision, and dynamic range.

After making the appropriate edits, click **Save** to put changes into effect and then **OK** to close the window.

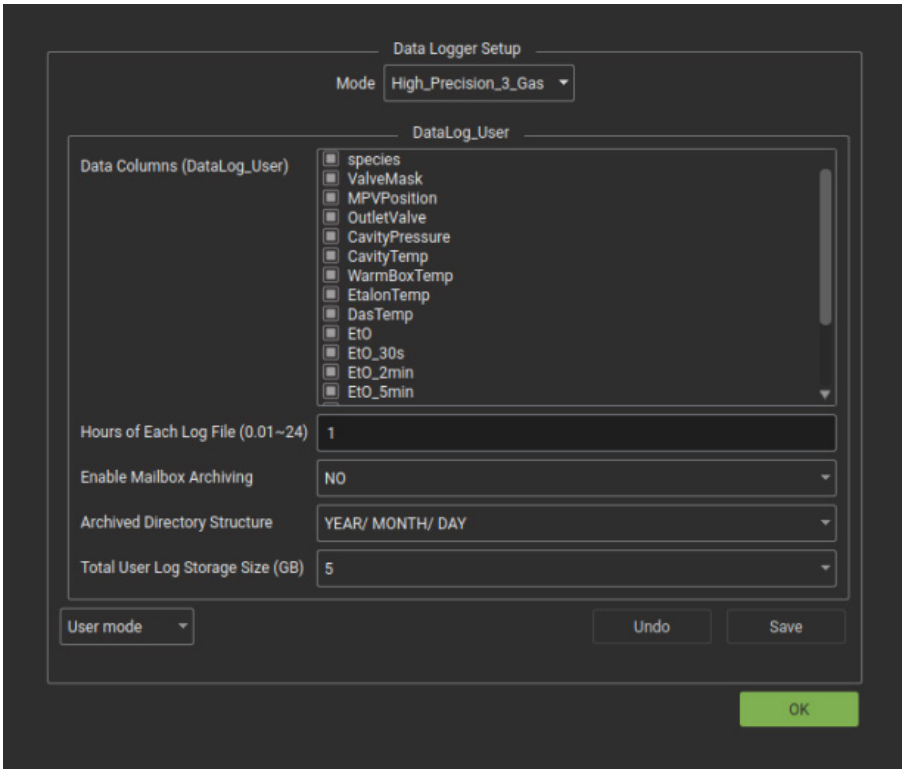


Figure 61: Data Logger Setup Settings

A.2 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 using the serial command interface, please see the Picarro Analyzer ***Remote Interface Programming Guide***.

To Download:

1. Go to ***https://www.picarro.com/***.
2. Under the ***Support*** tab (near the home page upper-right corner), select ***Document Library***.

NOTE

Registration/Login Required: Access to online User Manuals is available to all registered Picarro customers with login credentials. If you do not yet have an account, please email us at support@picarro.com to request access to the document library.

3. When the Document Library page opens, enter the search terms, "*Remote Interface*" in the ***Search*** field.

4. In the results, click on the link titled "***Remote Interface Programming Guide 40-0063***" to open the manual in your browser. From there you can also download and save it to your PC.

This command set may also be used across a TCP/IP interface through an Ethernet connection. Please contact Picarro for further details if needed.

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 */Home/Picarro/I2000/HostExe/RemoteAccess.exe* program.

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:

/Home/Picarro/I2000/AppConfig/Config/UtilitiesRemoteAccess/RemoteAccess.ini

It should be placed in the same directory as the executable *RemoteAccess.exe*. The file has one required section named **LOGGING** and optional sections named **NTP** and **EMAIL**. The logging section has a single key Logfile whose value is the path to the log file. Once this log file exceeds 64 Kbytes 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.

APPENDIX B – Modbus Communication

B.1 Enabling Modbus

To utilize Modbus as a communication protocol it must first be enabled from the **Picarro Launch Pad** through the **Administration** menu and using the **Toggle Modbus** button.

NOTE

This requires you to be logged in as an administrator. If you do not have administrator privileges, contact your admin to enable the Modbus option.

Use the following procedure to enable the Modbus button.

1. Login as administrator and click **Settings** and **Toggle Modbus**.

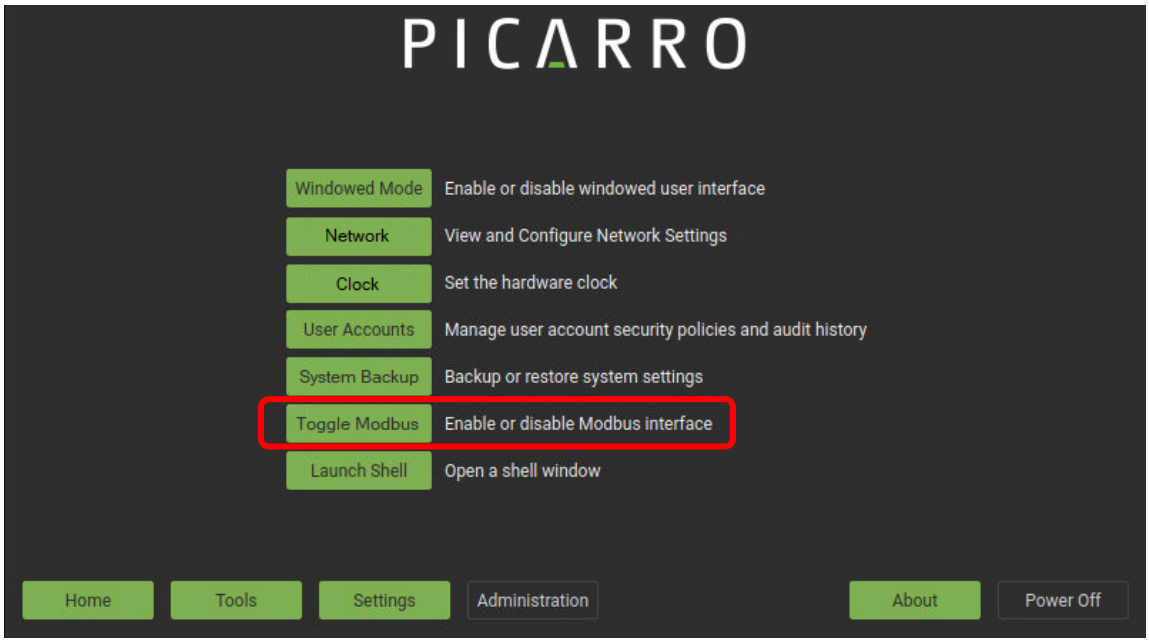


Figure 62: Toggle Modbus

2. Click **OK** to enable Modbus.

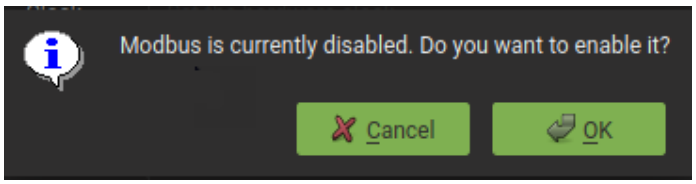
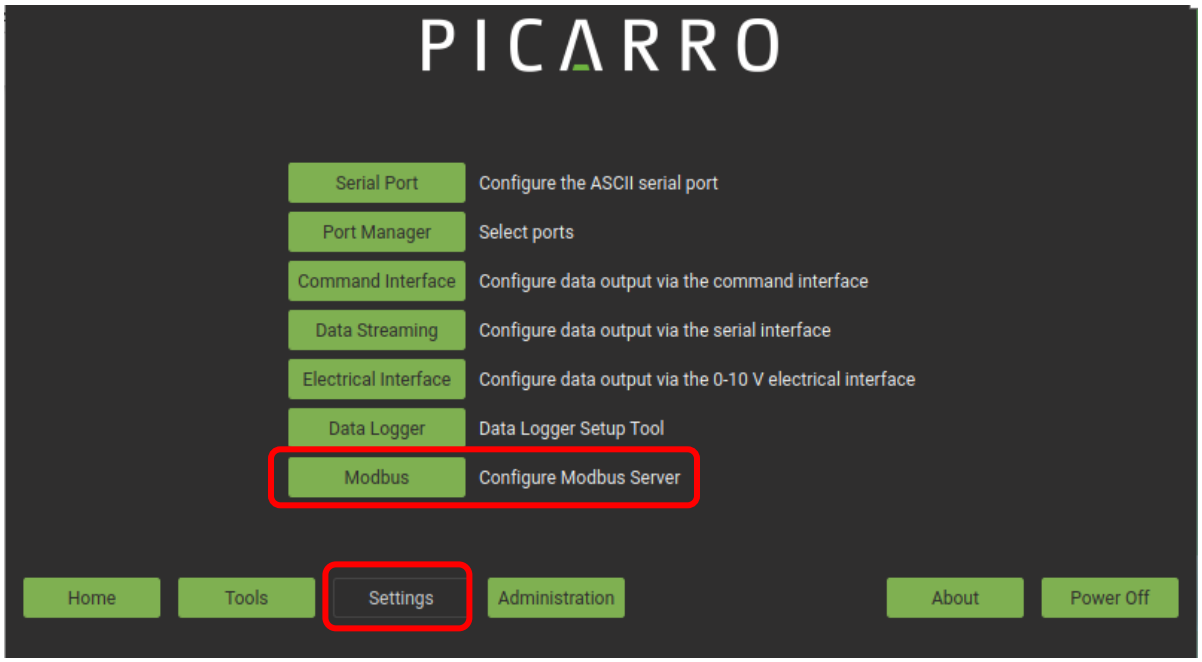


Figure 63: Enable Modbus

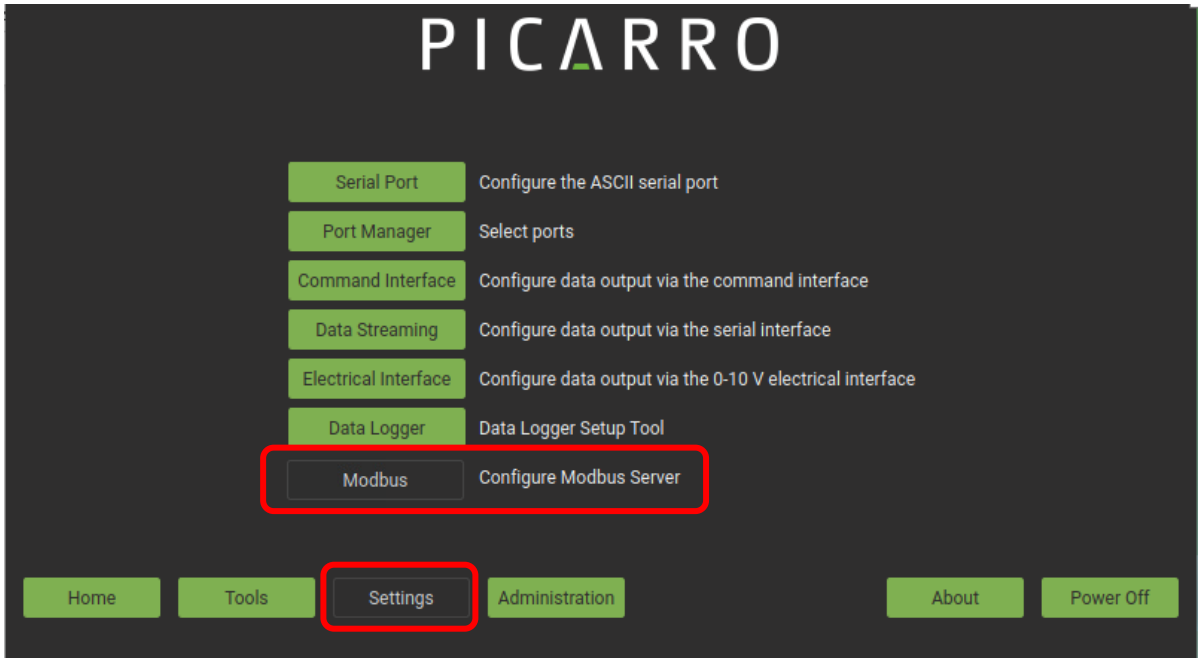
3. Restart the system.

   After restarting the system with the **Toggle Modbus** option enabled the **Modbus** button in the **Settings** menu becomes active and allows for configuration of the Modbus server (Figure 63).

Modbus Enabled on Configuration Screen (Settings menu)



Modbus Disabled on Configuration Screen (Settings menu)



*If the Modbus button does not appear on the configuration screen, it means that feature has not been enabled.

Figure 64: Analyzer Configuration Screen for Modbus Access

B.2 Configuring for Modbus Communication

1. From the **Settings** menu, click the **Modbus** button to configure the Modbus server as shown in Figure 64.

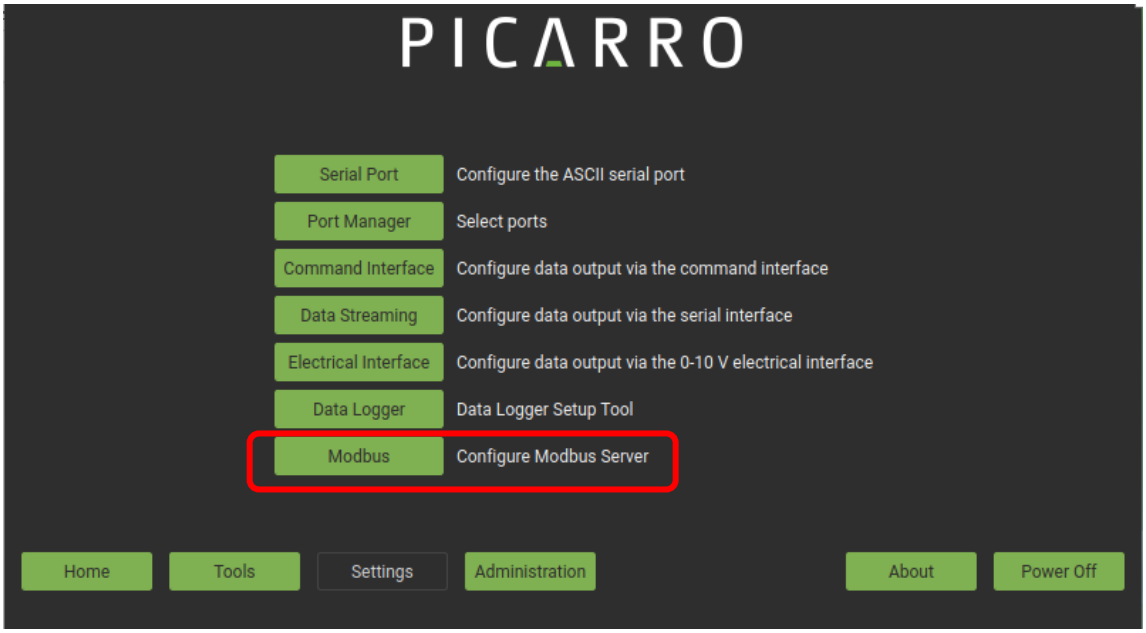


Figure 65: Settings/Modbus Configuration

NOTE

If a Modbus button does not appear in the Configuration menu, then Modbus communications must be enabled before Modbus can be configured. For more information, See the previous section *Appendix B.1 Enabling Modbus*.

This displays the Modbus Settings window shown in Figure 65. From the Modbus Settings window the following configuration options are available:

- The analyzer's Slave ID
- Modbus Communication Protocol: TCP/IP or RTU (For more information and notes, see Section B.2, Modbus Data Registers Overview and Setup.)
- TCP Port designation (if TCP/IP is selected)

Additionally, the window displays the CommandInterface Status. However, if Modbus Type is set to "RTU", then the CommandInterface on COM 1 is disabled.

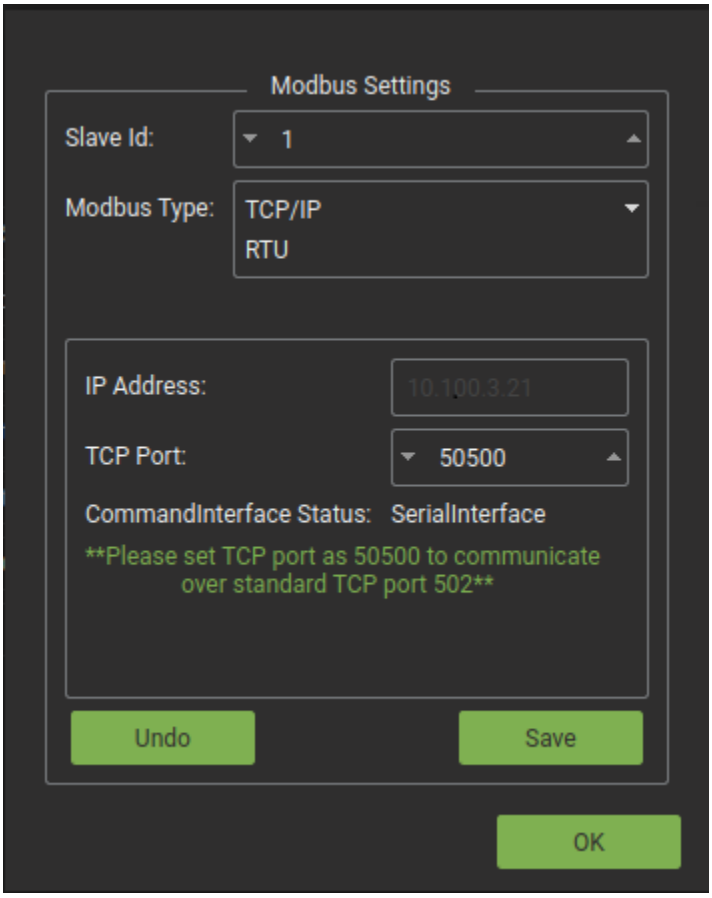


Figure 66: Modbus Settings Window

B.3 Modbus Data Registers Overview and Setup

This section describes the basic types of MODBUS data registers and setup information.

Table 8: MODBUS Register Types

Name	Size	Access
Input Register	16 bits	Read-only
Holding Register	16 bits	Read-write
Discrete Input	1 bit	Read-only
Coils	1 bit	Read-write

Setup Notes for Modbus TCP

- MODBUS is configured for TCP/IP on port 50500.
- When MODBUS is configured on port 50500, communication is also possible via port 502.
- If MODBUS is configured as TCP/IP and the IP address of analyzer is changed, the user needs to restart the Host application to run MODBUS with the updated IP address.
- MODBUS over TCP/IP will not support privileged ports (0 to 1023), except for port 502.

Setup Notes for Modbus RTU

- MODBUS RTU uses the analyzer's COM1 port.
- To establish connection between Master and Slave over MODBUS RTU, user needs to establish connection using "Straight Through Cable".
- When MODBUS is configured for RTU, CommandInterface on COM1 will be disabled.

B.4 Modbus Register Maps Overview

- Data returned is in big endian format if it utilizes more than one Modbus register.
- If input register functionality is not available for a given analyzer type, the instrument will return value as "NaN" for float values and "False" for 1-bit registers.
- Memory map is continuous memory. If a user tries to read a register address for which functionality is not available, it will return "0". For example, reading address 0 for coil registers will return "0" since the address does not exist.
- If a user tries to read a register address outside of maximum register memory map, the request will return an exception. For example, reading address 156 for coil register will return exception code "0x02" (Illegal address).
- System time is in "milliseconds Since 0001-01-01 AD".

B.5 Input Register Map

Most of the readings in Picarro analyzer are the float type and need 32-bit data. Each parameter utilizes 2 registers, out of which the first one will be storing MSB and the second one will be storing the LSB of the float number.

NOTE

All entries are floats unless otherwise noted.

Table 9: Input Registers

Address	Description	Units	Type	Comments
1-6	Time stamp		String	Long value return as 12byte string. Date will be in format YYMMDDHHMMSS
7-8	EtO Concentration	ppb	Float	
9-10	EtO_ID	unitless	Float	Gas ID code 19 identifies gas at register 7 as EtO
11-12	EtO, 30sec trailing average	ppb	Float	
13-14	EtO, 2min trailing average	ppb	Float	
15-16	EtO, 5min trailing average	ppb	Float	
17-18	EtO, max (full scale range)	ppb	Float	Value is 100,000 ppb or 100 ppm
19-20	EtO, min	ppb	Float	Value set to 0
21-22	Concentration CH4	ppb	Float	
23-24	CH4_ID	unitless	Float	Gas ID code 04 identifies gas at register 21 as CH4
25-26	CH4, 30 sec trailing average	ppb	Float	
27-28	CH4, 2min trailing average	ppb	Float	
29-30	CH4, 5min trailing average	ppb	Float	

Address	Description	Units	Type	Comments
31-32	CH4, max (full scale range)	ppm	Float	Value is set at 200 ppm
33-34	CH4, min	ppm	Float	Value is set to 0
35-36	Concentration of H20	%	Float	Water is measured in absolute %, not to be confused with relative humidity
37-38	H2O_ID	unitless	Float	Gas ID code 00 identifies gas at register 35 as H2O
39-40	H2O, 30sec trailing average	ppm	Float	
41-42	H2O, 2min trailing average	ppm	Float	
43-44	H2O, 5min trailing average	%	Float	
45-46	H2O, max (full scale range)	ppm	Float	Value is 50,000 (5%)
47-48	H2O, min	ppm	Float	Value is set at 0
63-64	Concentration of CO2	ppm	Float	
65-66	CO2_ID	unitless	Float	Gas ID code 03 identifies gas at register 63 as O2
67-68	CO2, 30sec trailing average	ppm	Float	
69-70	CO2, 2min trailing average	ppm	Float	
71-72	CO2, 5min trailing average	ppm	Float	
73-74	CO2, max (full scale range)	ppm	Float	Value is 1000 ppm
75-76	CO2, min	ppm	Float	Value set to 0
77-78	Reserved			
79-80	Reserved			
81-82	Reserved			
83-84	Reserved			

Address	Description	Units	Type	Comments
85-86	Reserved			
87-88	Reserved			
89-90	Reserved			
91-92	Reserved			
93-94	Reserved			
95-96	Reserved			
97-98	Reserved			
99-100	Reserved			
101-102	Reserved			
103-104	Reserved			
105-106	Reserved			
107-108	Reserved			
109-110	Reserved			
111-112	Reserved			
113-114	Reserved			
115+116	Reserved			
117-118	Reserved			
201-202	Cavity Pressure	Torr	Float	
203-204	Cavity Temperature	deg C	Float	
205-206	DAS Temperature	deg C	Float	
207-208	Etalon Temperature	deg C	Float	
209-210	Warm Box Temperature	deg C	Float	
211-212	Outlet Valve	dig counts	Float	
213-214	Instrument cal slope, EtO		Float	
215-216	Instrument cal offset, EtO		Float	

Address	Description	Units	Type	Comments
217-218	User cal slope, EtO		Float	
219-220	User cal offset, EtO		Float	
221-222	Instrument cal slope, CH4		Float	
223-224	Instrument cal offset, CH4		Float	
225-226	User cal slope, CH4		Float	
227-228	User cal offset, CH4		Float	
229-230	Instrument cal slope, H2O		Float	
231-232	Instrument cal offset, H2O		Float	
233-234	User cal slope, H2O		Float	
235-236	User cal offset, H2O		Float	
245-246	Instrument cal slope, CO2		Float	
247-248	Instrument cal offset, CO2		Float	
249-250	User cal slope, CO2		Float	
251-252	User cal offset, CO2		Float	
253-254	Reserved			
255-256	Reserved			
257-258	Reserved			
259-260	Reserved			
261-262	Reserved			
263-264	Reserved			
265-266	Reserved			

Address	Description	Units	Type	Comments
267-268	Reserved			
269-270	Reserved			
271-272	Reserved			
273-274	Reserved			
275-276	Reserved			

Address	Description	Type	Comments
386	Error Code	Integer 16	Error for each control command of COIL • NO_ERROR = 0 • ERROR_HANDLER_ERROR = 1 • ERROR = 2 • NO_SUDO_USER_PRIVILEGE = 3 • NO_USER_EXIST = 7 • USERNAME_PASSWORD_INCORRECT = 9 • USER_DISABLED = 10 • ADMIN_RIGHT_REQUIRES = 11 • PASSWORD_LENGTH_ERROR = 12 • PASSWORD_FORMATE_ERROR = 13 • PASSWORD_REUSE_ERROR = 14
387	Measurement Status	Integer 16	ledState = 0 red, system error, gas conc. measurements invalid ledState = 1 solid yellow, need service, gas conc. measurements might be ok ledState = 2 blinking yellow, not in reporting mode by system ok, like during warmup ledState = 3 green, system ok, gas conc. measurements accurate
388	baselineValueZeroed	Integer	
390	ALARM_WORD_1	Float	
392	InletValve	Float	
394	ST_STATUS	Float	
396	interval	Float	
398	flaserc10_90range	Float	
400	Laser_T1_offset	Float	

B.6 Discrete Input Register Map

NOTE

All entries are floats unless otherwise noted.

Table 10: Discrete Input Registers

Address	Description
1	Master System Status
6	Pressure locked
7	Cavity temperature locked
8	Warm box temperature locked
73	Incomplete EtO Spectrum
74	Incomplete CH4 Spectrum
75	Reserved
76	Reserved
77	Reserved
78	Reserved
79	Reserved
80	Reserved
81	Bad EtO Baseline
82	Bad CH4 Baseline
83	Reserved
84	Reserved
85	Reserved
86	Reserved
87	Reserved
88	Reserved
89	Reserved
90	Reserved
91	Reserved
92	Reserved

Address	Description
93	Reserved
94	Reserved
95	Reserved
96	Reserved

B.6 Holding Register Map

Table 11: Holding Registers

Address	Description	Type	Comments
1-4	System time	Integer	Integer representing milliseconds from 1AD January 1st to now
5-8	User Name	String	
9-12	Password	String	
201-202	User data 1	Float	
203-204	User data 2	Float	
205-206	User data 3	Float	
207-208	User data 4	Float	
209-210	User data 5	Float	
211-212	User data 6	Float	
213-214	User data 7	Float	
215-216	User data 8	Float	
217-218	User data 9	Float	
219-220	User data 10	Float	
221-222	User data 11	Float	
223-224	User data 12	Float	
225-226	User data 13	Float	
227-228	User data 14	Float	
229-230	User data 15	Float	
231-232	User data 16	Float	
233-234	User data 17	Float	

Address	Description	Type	Comments
235-236	User data 18	Float	
237-238	User data 19	Float	
239-240	User data 20	Float	

B.7 Coil Register Map

Table 12: Coil Register Map

Address	Description	Comments
115	Shutdown Host	Writing to this bit register will park the instrument.
116	Quit host application	
117	Shutdown Instrument	Writing to this bit register will park the instrument and shutdown the analyzer.
151	Get system time	After this please read Sync Time holding register
152	User login (Coming in near future)	Before executing this command, user needs to set user name and user password holding register
155	Update user password (Coming in near future)	Before executing this command follow the steps below: 1. Login as admin using User Login functionality if not logged in already. 2. Set user name and password holding register.
156	User logout (Coming in near future)	
201	Get User data 1	
202	Set User data 1	
203	Get User data 2	
204	Set User data 2	
205	Get User data 3	
206	Set User data 3	
207	Get User data 4	
208	Set User data 4	

Address	Description	Comments
209	Get User data 5	
210	Set User data 5	
211	Get User data 6	
212	Set User data 6	
213	Get User data 7	
214	Set User data 7	
215	Get User data 8	
216	Set User data 8	
217	Get User data 9	
218	Set User data 9	
219	Get User data 10	
220	Set User data 10	
221	Get User data 11	
222	Set User data 11	
223	Get User data 12	
224	Set User data 12	
225	Get User data 13	
226	Set User data 13	
227	Get User data 14	
228	Set User data 14	
229	Get User data 15	
230	Set User data 15	
231	Get User data 16	
232	Set User data 16	
233	Get User data 17	
234	Set User data 17	
235	Get User data 18	
236	Set User data 18	
237	Get User data 19	
238	Set User data 19	

Address	Description	Comments
239	Get User data 20	
240	Set User data 20	


NOTE

- Data is in big-endian format if it utilizes more than one Modbus register.
- If input register functionality is not available for analyzer type, analyzer will return value as NaN for float values.
- Registers in Red are coming in near future.
- Memory map is continuous memory, so if user try to read address for which functionality is not available it will return 0 (for example reading address 0 for coil register).
- If user tries to read address outside of maximum register memory map, request will be exception (for example reading address 156 for coil register).

B.8 Gas ID Map

The Gas ID input registers return a two-digit code to identify the gas species being measured.

Table 13: Gas ID Map

Address	Species	Description
00	H_2O	Water
03	CO_2	Carbon dioxide
04	CH_4	Methane
19	C_2H_4O	Ethylene Oxide

APPENDIX C – Data File Viewer

C.1 Quick Start Guide

The following sections introduce the user to all possible functionalities of the Data File Viewer in detail. This section describes the most common, simple use case.

The Data File Viewer software allows the user to concatenate multiple one-hour files into one larger file, enabling the user to observe trends over several days of measurements.

1. To start, translate the UserData files from DAT to H5. The Batch Convert option (B) allows user s to select any folder containing instrument data from a given day.

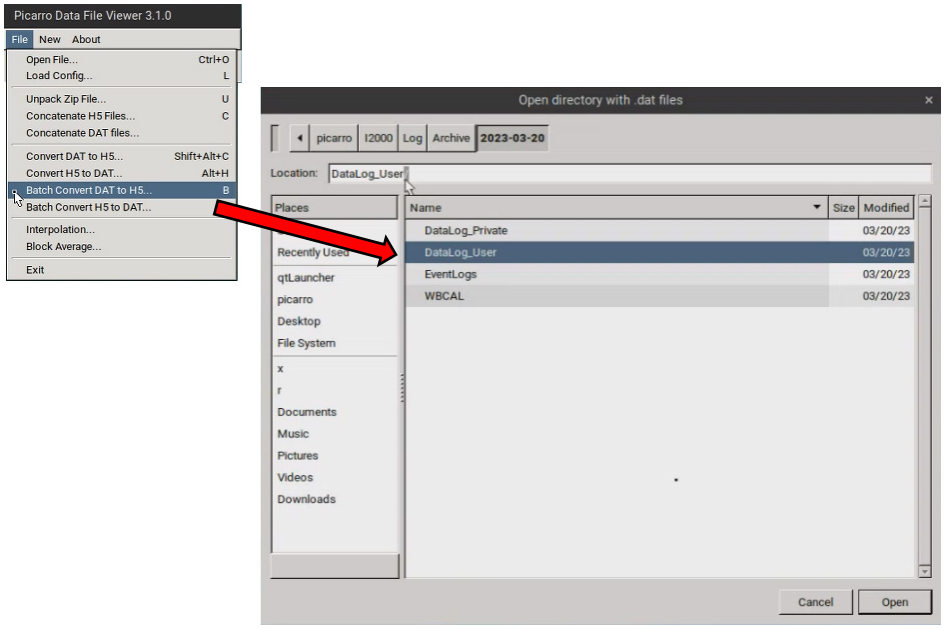


Figure 56: Batch Convert DAT to H5 – Navigation

2. In the source folder there are now copies of the original files translated into the H5 format.
3. From **File** menu select **Concatenate H5 Files** (C) to combine the H5 files into a time series. Take care to select exactly the same folder in the file viewer window.
4. In the Select Variables window, click **All** to move over all variables for concatenation. If concatenating large records, the user can instead select only a few variables by clicking the variable name on the left dialogue, and clicking the double arrow button. Confirm by clicking **OK**. ().

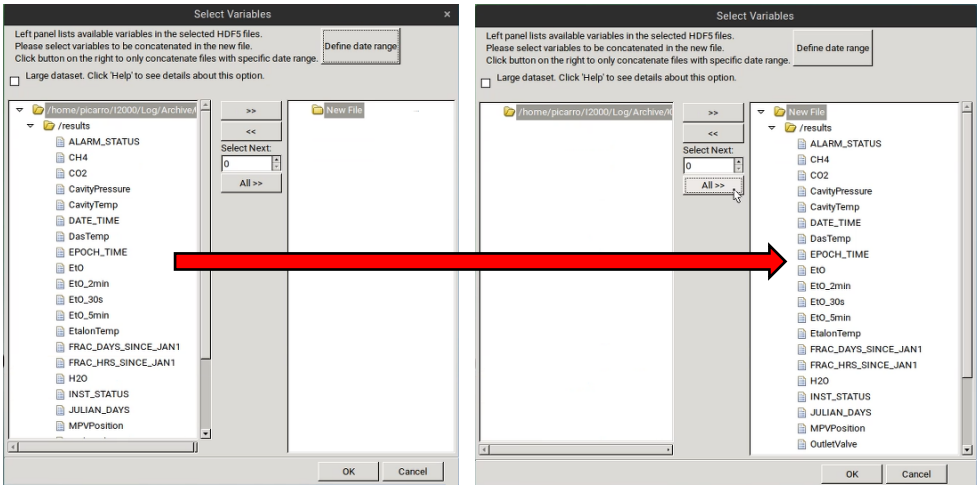


Figure 57: Selecting Variables for Concatenation

5. The user will then be asked to confirm the file name for the concatenated data. The default location is the parent folder for the selected day, and the filename by default describes the time span of the measurements within. Successful concatenation is indicated by the filename automatically being displayed in the main data file viewer window as shown in Figure 59.

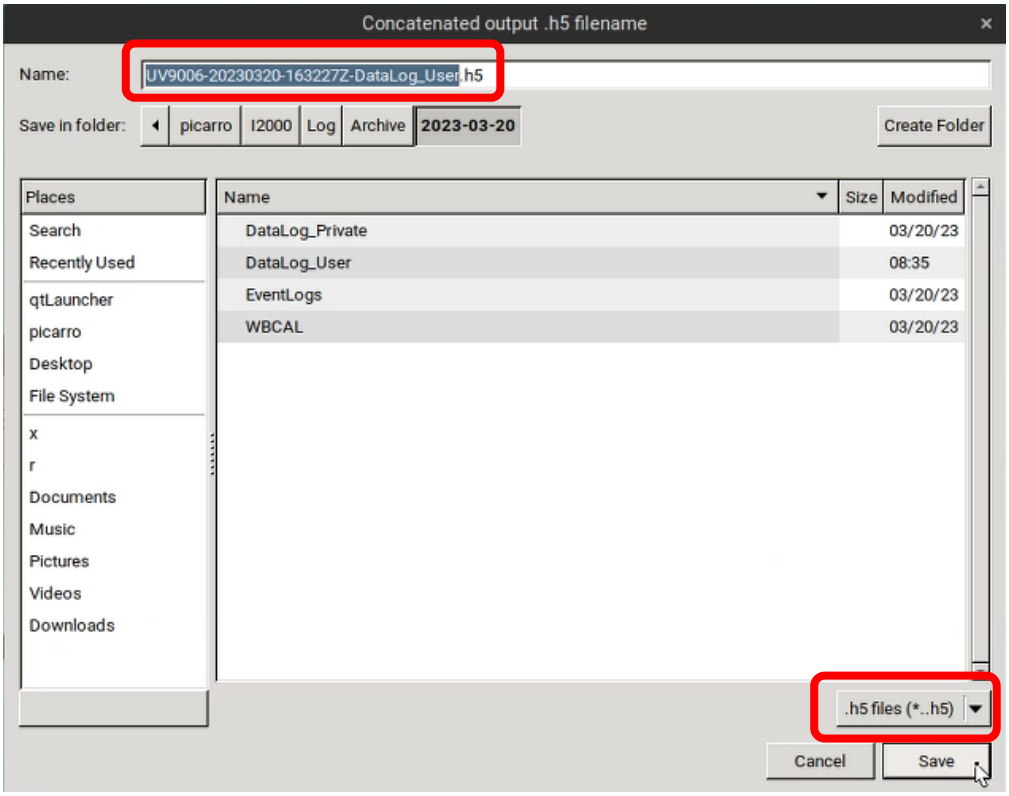


Figure 67: Concatenated Output .h5 Filename

NOTE

You can concatenate several days into one larger file, either by following steps 1-3 for selected folders, or by copying all their DAT files into a new folder and performing steps 1-5 just once.

6. With the file now opened, the user can select how many **Time Series** to display on the screen.

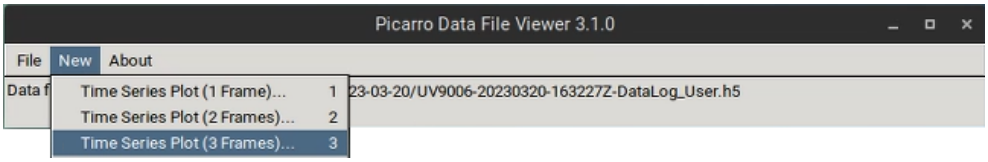


Figure 68: Time Series Selection Options

7. In the new window that displays, select the variables from the **Var Name** dropdown on the right of each plot. Deselect **Autoscale y** if the data stream has a large amount of variability in the Y-axis.
8. Please read the following sections to learn more about features of the Data File Viewer.

C.2 Data File Viewer Overview

The Picarro Data File Viewer software is located from the **Picarro Launch Pad**, **Home** menu. This software allows you 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 and New (Figure 68).

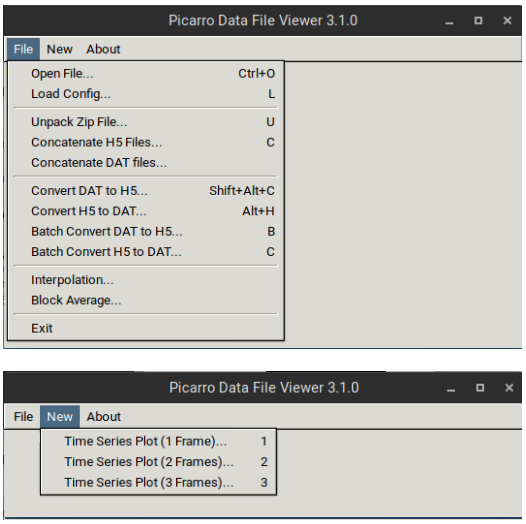


Figure 69: Picarro Data File Viewer – File and New Menus

C.3 File Menu

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

Open File

File > Open 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 ***C.4, 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*** for more information.

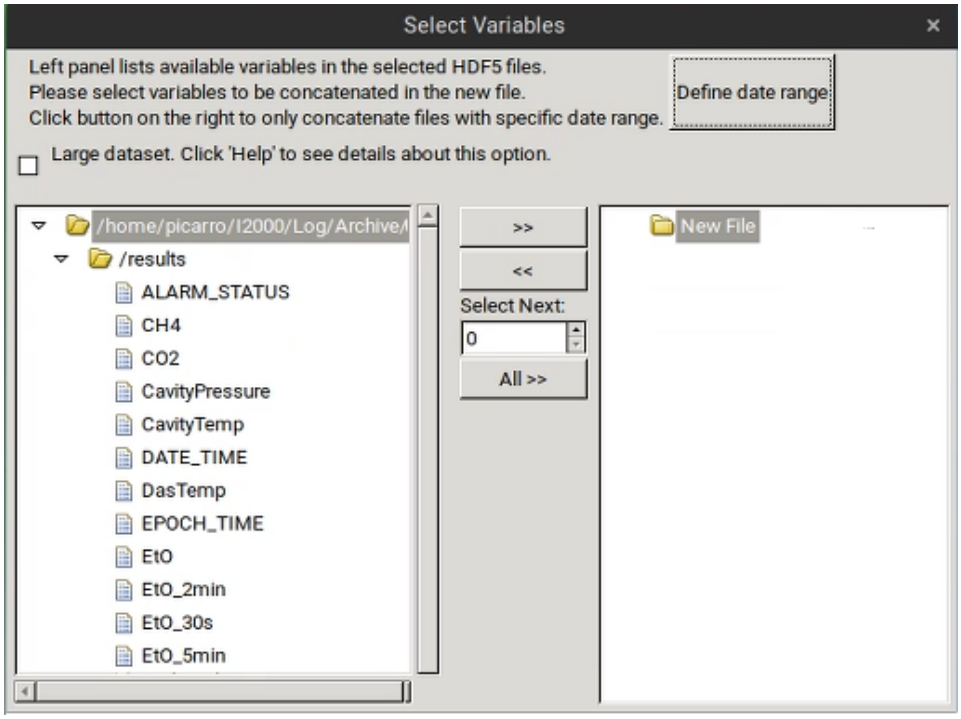
Unpack Zip File

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 69), and users can use the **>>** button to move variables to the right panel for concatenation.



Note: this screenshot is for example only. The species selections shown on your analyzer may vary.

Figure 70: 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 was taken.

Select File > Concatenate H5 Files, and click **Define Date Range** to specify the desired date range as shown in Figure 70.

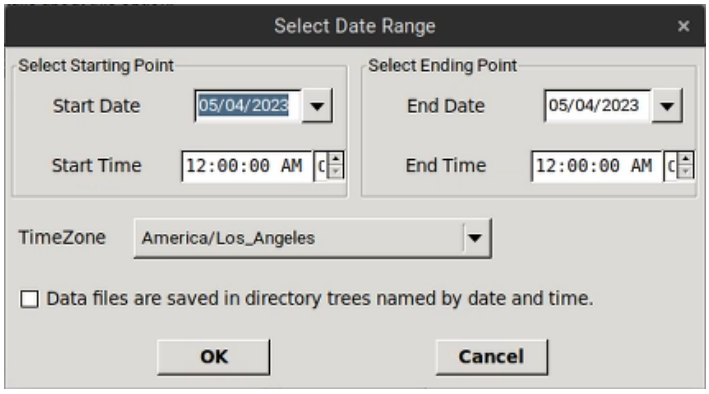


Figure 71: Define Date Range Dialog

Picarro software saves data in directories that are named by the creation year, month, and day as shown in Figure 703. **Select Data files are saved in directory trees named by date and time** option if the target folder has this file structure. This allows Data File Viewer to only search folders within the desired date range, which can substantially reduce processing time.

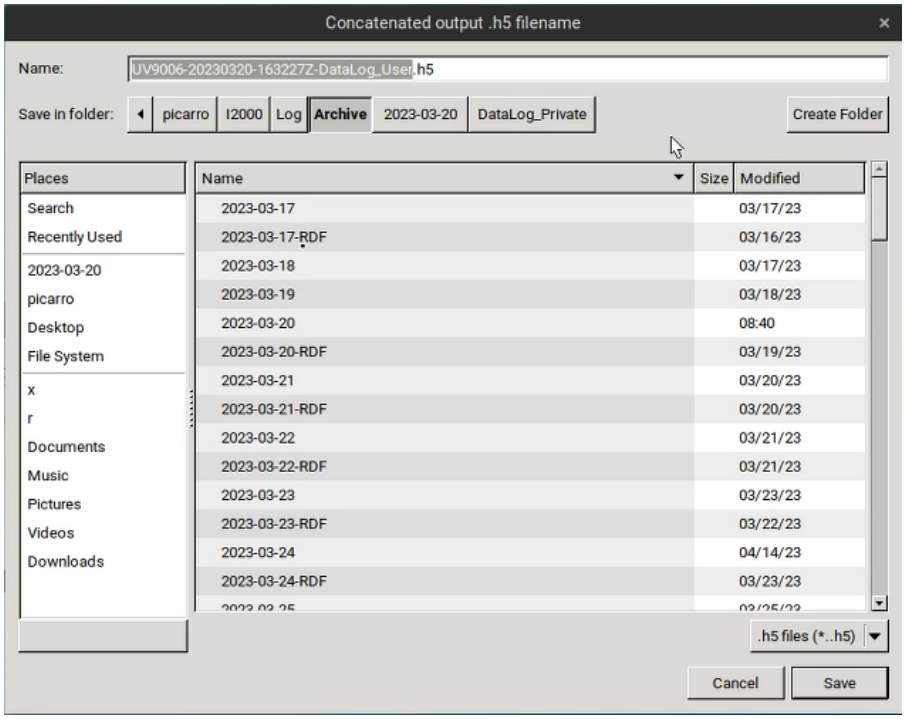


Figure 72: File Structure of Data File Viewer

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 the 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 https://www.hdfgroup.org/ 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 range.

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.

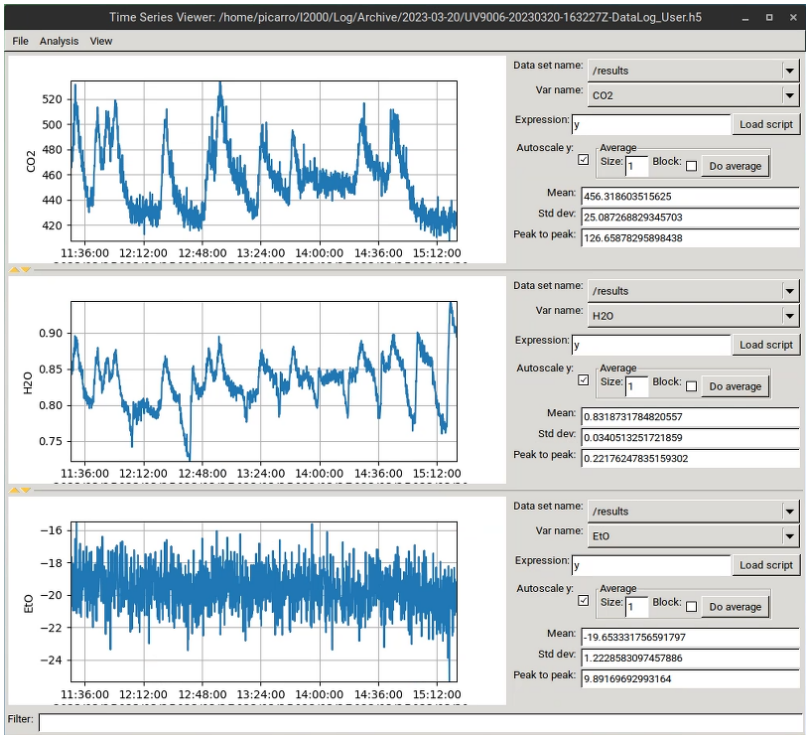
NOTE

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.

C.4 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.



Note: this screenshot is for example only. The species shown on your analyzer may vary.

Figure 73: Time Series Viewer

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

C.5 Time Series Viewer Menus

The Time Series Viewer form includes the following menus:

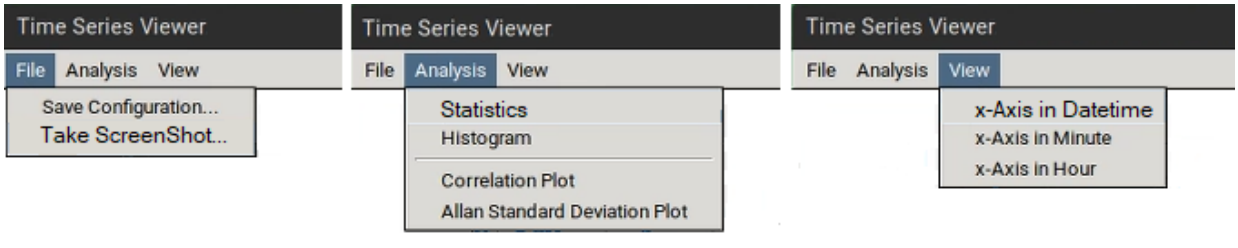


Figure 74: Time Series Viewer Menus

Time Series Viewer File Menu

Use the **File** menu to save a configuration or take a screenshot.

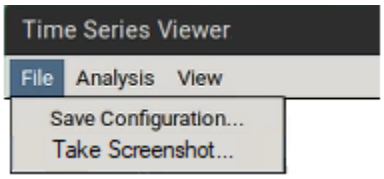


Figure 75: Time Series Viewer – File Menu

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.

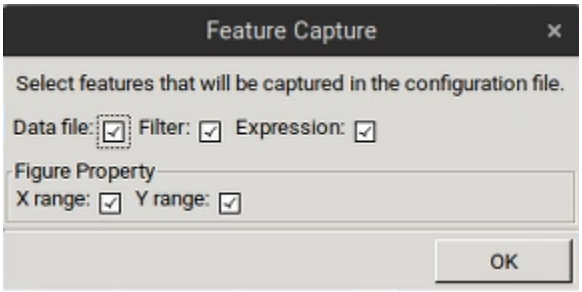


Figure 76: Time Series Viewer – Feature Capture

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 a data file is not captured, saved parameters are applied to the data file in memory.
- If an expression is not captured, plots will not be transformed.
- If X (Y) range is not captured, figures are 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.

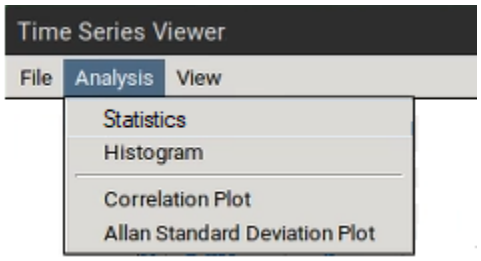


Figure 77: Time Series Viewer – Analysis Menu

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 77 below.

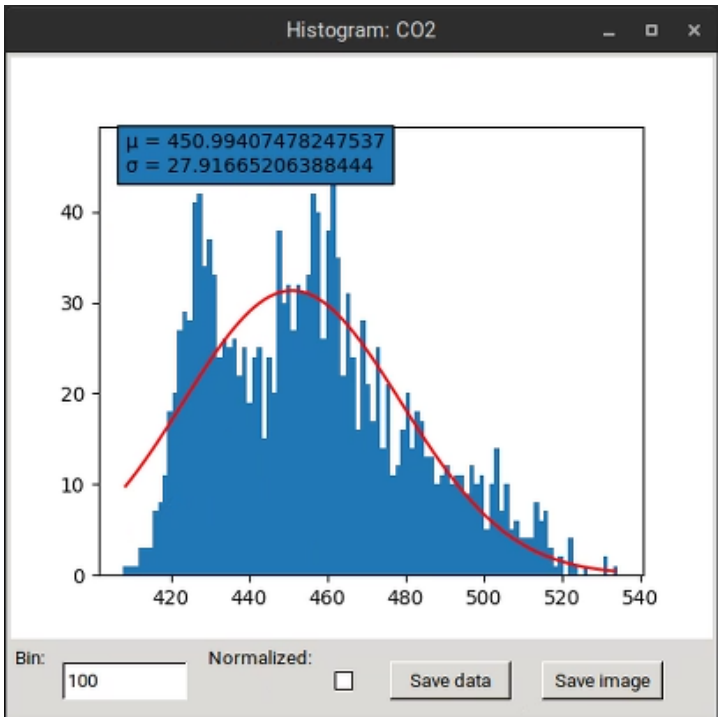


Figure 78: Histogram Window – CH4

Histogram Window Features

- **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 the section, ***Correlation Plot*** on Page 122 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.

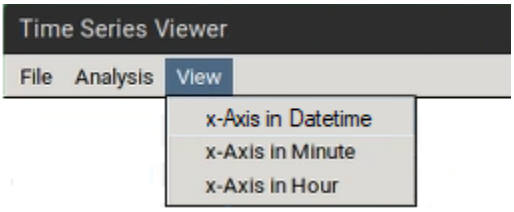


Figure 79: Time Series Viewer – View Menu

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.

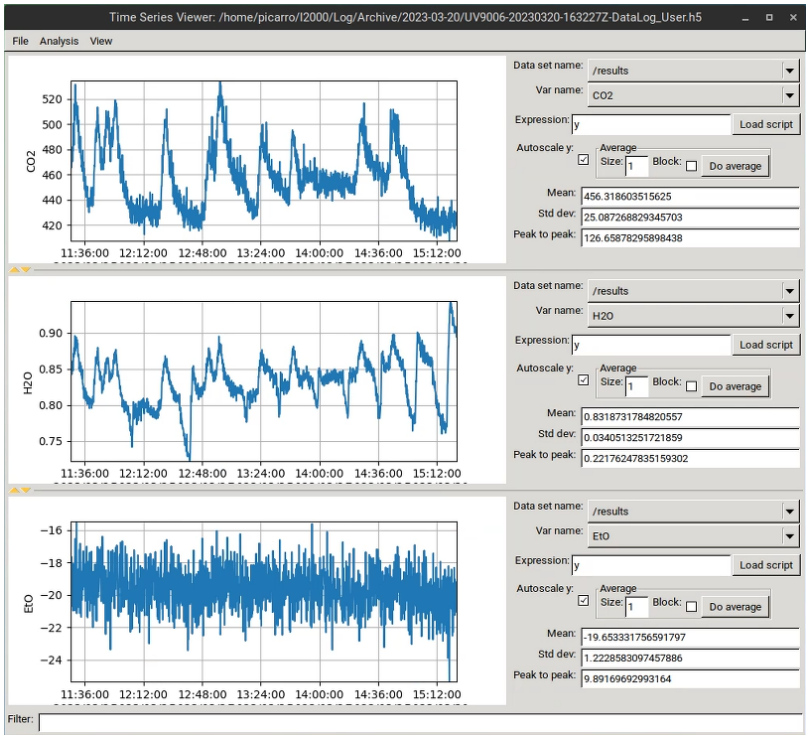
The Time Series Viewer Canvas

The Time Series Viewer canvas (Figure 79 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 the Right-click menu below in the next section.



Note: this screenshot is for example only. The species shown on your analyzer may vary.

Figure 80: Time Series Viewer Canvas

Right-click Menu

Right-clicking on the canvas opens a pop-up menu:

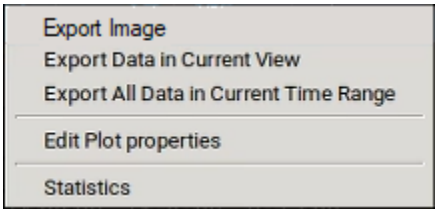


Figure 81: Canvas Right-click Pop-up Menu

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** (below), where the following options can be specified.

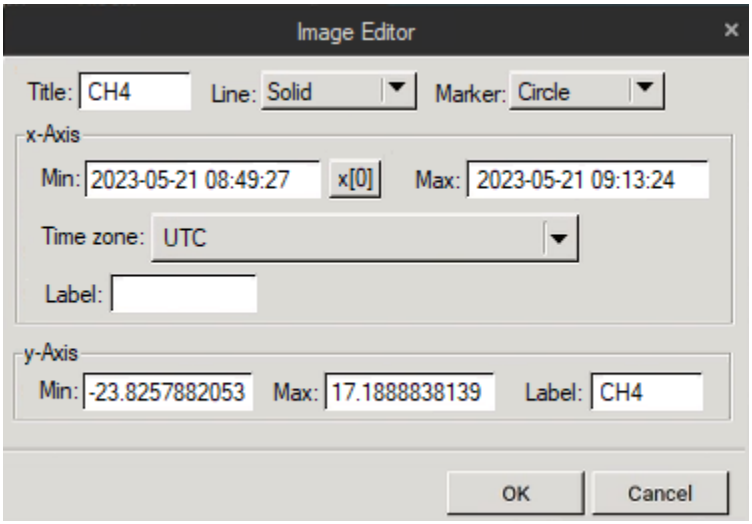


Figure 82: Image Editor Form

Image Editor Form Options:

- **Title:** Edits the title of the plot.
- **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.
- **x-Axis: Min and Max:** Specifies the minimum and maximum date range for the X-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 labels for the X-axis and the Y-axis.
- **y-Axis: Min and Max:** Specifies the minimum and maximum of data displayed on the Y-axis.

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 (Figure 82) to select the dataset that is used for this time series graph. Use the **Var name** drop down to select the column in the dataset to use in the graph.

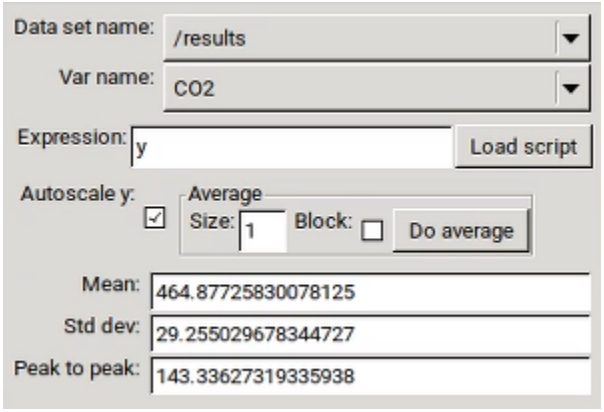


Figure 83: Time Series Viewer Dataset Options

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. This feature can make it hard to see small signals when large signals blow the Y axis out, so it is often advisable to deselect this checkbox for dynamic or spikey datasets.

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 (Figure 82) provide all the statistical information of data in the current view.

Correlation/XY Plot

The Correlation/XY Plot window (Figure 83) includes two menu items: File and Analysis. For details about the File menu, see ***Save Configuration*** and ***Take Screenshot*** on page 121.

REMINDER

The canvas in this plot is interactive. For details about the plot canvas, see *The Time Series Viewer Canvas* on Page 122.

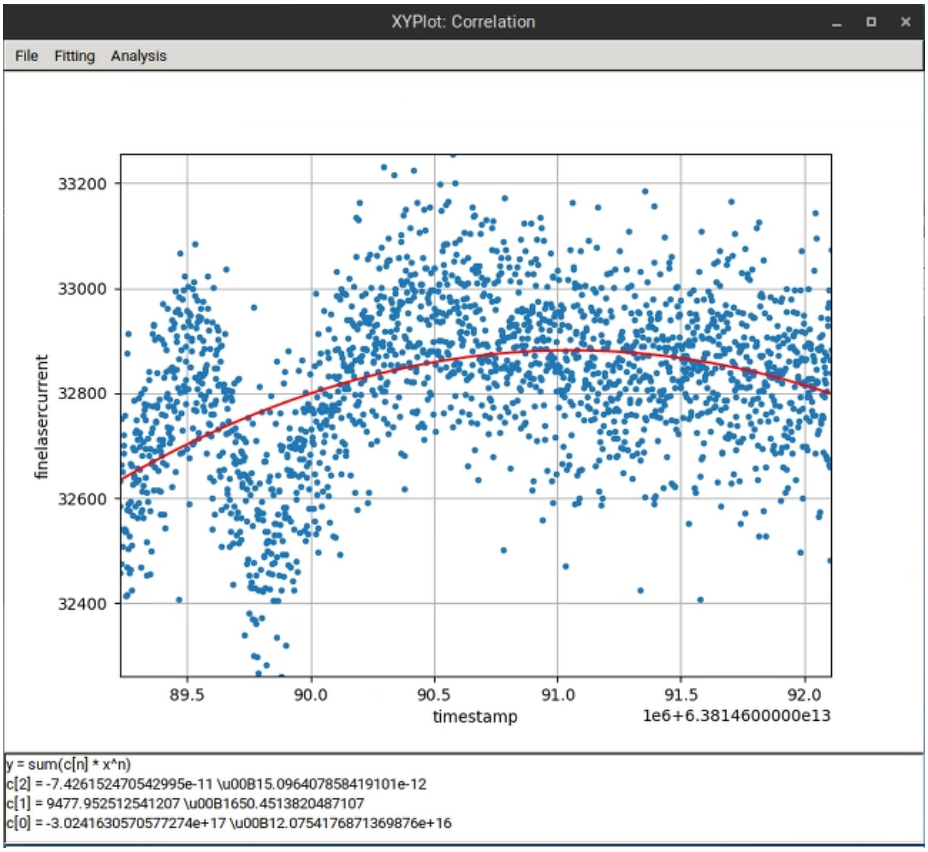


Figure 84: Correlation XY Plot

Fitting Menu

The Fitting menu (Figure 85) includes three options: **Fitting, Integration**, and **Statistics.**

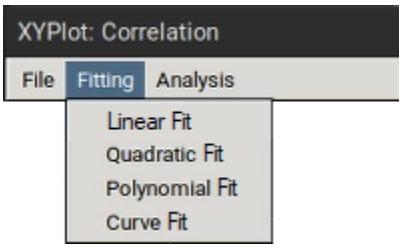


Figure 85: Fitting Menu

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

- **Linear Fit:** Specifies to fit to linear function:

  y = c1x + c0

- **Quadratic Fit:** Specifies to fit to quadratic function:

  y = c2x2 + c1x + c0

- **Polynomial Fit:** Specifies to fit polynomial function of degree n:

  y = Σcnxn

- **Curve Fit:** Specifies to use non-linear least squares to fit an arbitrary function to data.

Analysis Menu

The Analysis menu has two options: **Integration** and **Statistics**.

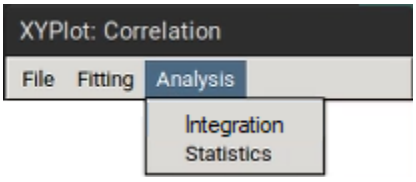


Figure 86: Analysis Menu

- **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 86).

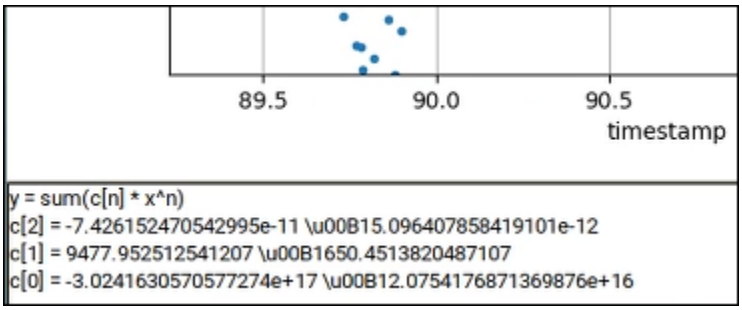


Figure 87: Results of Quadratic Fitting

APPENDIX D – Setting up Contained Exhaust Flow

D.1 Introduction

The A2000 vacuum pump is shipped with a noise dampener attached to the exhaust port. When a hazardous gas exhaust line from the pump is needed, it requires replacing the noise dampener with an adapter that allows a 1/4” OD exhaust tubing connection. Use the following instructions if installing a pump exhaust line.

Figure 88: A2000 Pump Vacuum and Exhaust Ports

D.2 Tools and Parts Required

- Long flathead screwdriver (6” x 5/16” recommended)
- 9/16” open end wrench
- Swagelok ISO parallel thread adaptor 1/4"-1/8” SS-400-1-2RS (Picarro PN 22928)
- Swagelok gasket SS-2-RS-2V (Picarro PN 22929)
- 1/4" tubing and stainless-steel ferrule set
- Snoop leak-detection fluid or similar soap solution

D.3 Directions

1. Remove the noise dampener fitting from the bottom of the pump using a long flathead screwdriver (Figure 88).

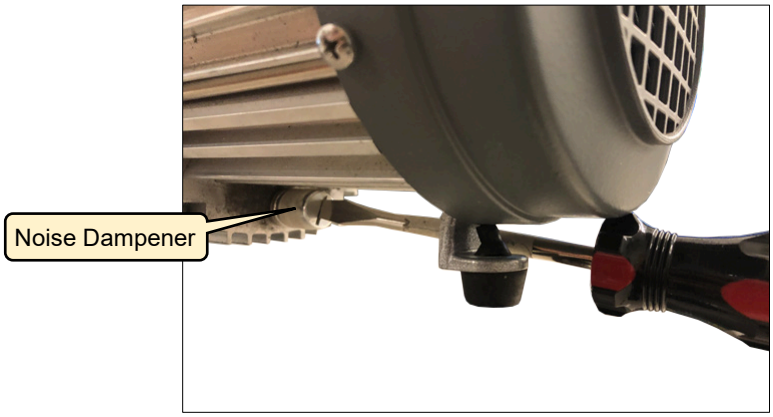


Figure 89: Pump Noise Dampener Removal

2. Slide the adapter gasket PN 22929 onto the adapter fitting PN 22928 (Figure 89), screw it into the pump exhaust port, and then tighten it 1/4 turn using a 9/16” wrench.
3. Remove the Swagelok nut and ferules from the adapter fitting to ensure their orientation is as shown below, then loosely reattach to the adapter.
4. Slide the 1/4” exhaust tubing into the Swagelok nut and ferules until the tubing is fully seated, then using a 9/16" wrench, tighten the nut approximately seven flats (420 degrees).

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

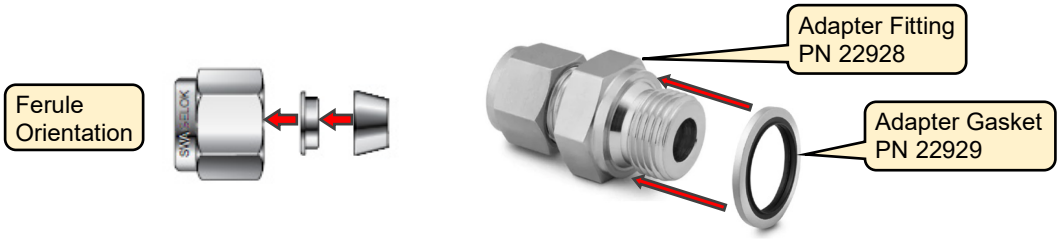


Figure 90: Pump Exhaust Line Adapter Fittings

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

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

APPENDIX E – External Valve Sequencer

E.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 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 ***E.7)*** which is available from the Tools menu on the GUI.

Picarro offers two rotary valve and two solenoid valve solutions:

- **A0311**, 16-Port Distribution Manifold
- **A0311-S**, 16-Port Distribution Manifold (Silco) which is optimized for use with sticky and reactive gases.
- **S3112**, 3-Way stainless steel solenoid valve with 1/4” fittings
- **S3136**, 3-Way stainless steel solenoid valve with 1/8” fittings

E.2 A0311 16-Port Distribution Manifold

Compatibility

The A0311 () is broadly compatible with most Picarro analyzers except for those with known surface and chemical compatibility issues (such as the G2103, SI2103, SI2108, SI2104, SI2205, G2307, G2509, and PI2114).

Function

The A0311 and External Valve Sequencer 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 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.

NOTE

For detailed instructions on integrating the A0311 with your analyzer, refer to the *16-Port Manifold, User Manual, Including A0311, A0311-S, A0310* (P/N 40-0038).

Figure 91: A0311 – 16-port Distribution Manifold

E.3 A0311-S 16-Port Distribution Manifold (Silco)

Compatibility

The A0311-S (**Error! Not a valid bookmark self-reference.**) is broadly compatible with all Picarro analyzers but is optimized for use with sticky and reactive gases in the following platforms, nominally:

- G2103, SI2103, SI2108, SI2104, SI2205, G2307, G2509, and PI2114

Function

For users who require faster response performance, the A0311-S is a 16-Port distribution manifold 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, PFA tubing, and an additional vacuum pump.

The sampling duration and sequence is easily programmed through the Picarro External Valve Sequencer GUI. This design is ideal for fast switching between different locations for specialty applications in Semiconductor, Pharmaceutical, Environmental research, and other industries.

NOTE

For detailed instructions on integrating the A0311-S with your analyzer, refer to the *16-Port Manifold, User Manual, Including A0311, A0311-S, A0310* (P/N 40-0038).

Figure 92: A0311-S – 16-Port Sequencer – Fast Multiport Gas Sampler

E.4 Valve Control Configurations

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

To configure an analyzer for operation with an A0311 rotary valve, the user must first confirm that the COM port chose on the back of the instrument for connection to the rotary valve is consistent with the COM port specified in the **Setup Tool**. Refer to located in section ***1*** for instructions to change to rotary valve configuration (the Valve Sequencer MPV field) and to ensure the correct COM port is enabled.

CAUTION

Only use supported 12V, <500 mA, solenoids (listed above in section *E.1*). Using unsupported solenoids may result in damage to the power board.

E.5 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. Most analyzers come with a valves cable that can be connected to the solenoid valves, and if not, one can be purchased by contacting support@picarro.com.

CAUTION

Be careful to avoid shorting the solenoid valve output pins, as this will blow the relays on the power board, requiring a costly replacement.

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.

E.6 Setting up a Rotary Selector Valve

The (null modem) 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 – only as part of the A0311 kit.

E.7 External Valve Sequencer Software Overview

The External Valve Sequencer software allows the user to define a sequence of (repeating) steps within which rotary valve positions and/or solenoid valve positions can be defined uniquely at each step.

Opening the Sequencer

From the CRDS Data Viewer, **Users** dropdown menu login using your username and password. Then, from the **Tools** drop-down menu, select **Show Valve Sequencer GUI**. The Picarro valve sequencer window displays (Figure 92), but typically sitting behind the main GUI. Hitting alt-tab brings the Valve Sequencer GUI to the front.

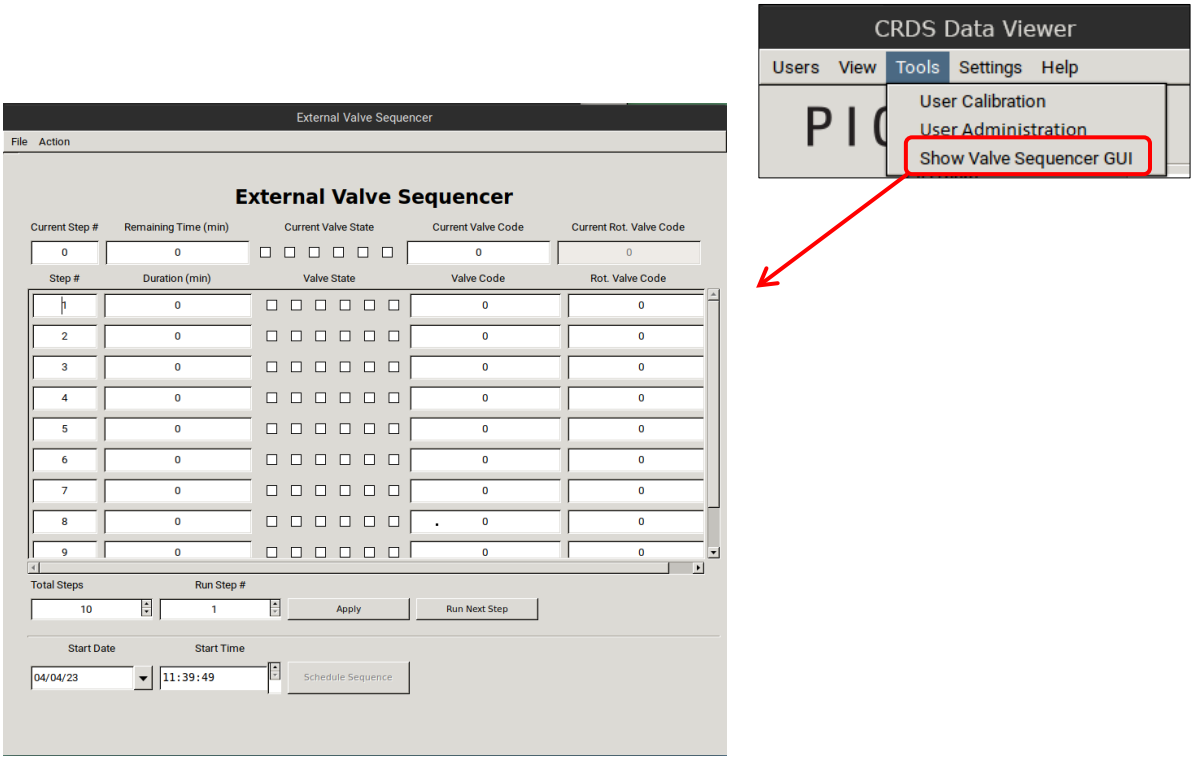


Figure 93: Launching the Valve Sequencer GUI

Valve Sequencer UI Menus

The sequencer GUI provides the dropdown menu choices shown here.

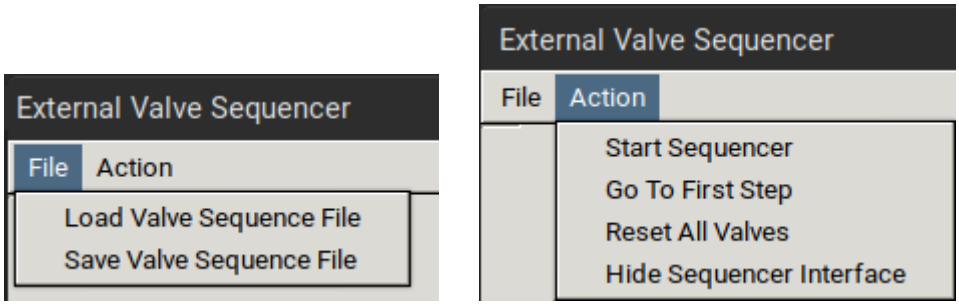


Figure 94: Valve Sequencer UI Dropdown Menus

For the following functional descriptions, Figure 94 shows a full view of an example sequencer UI.

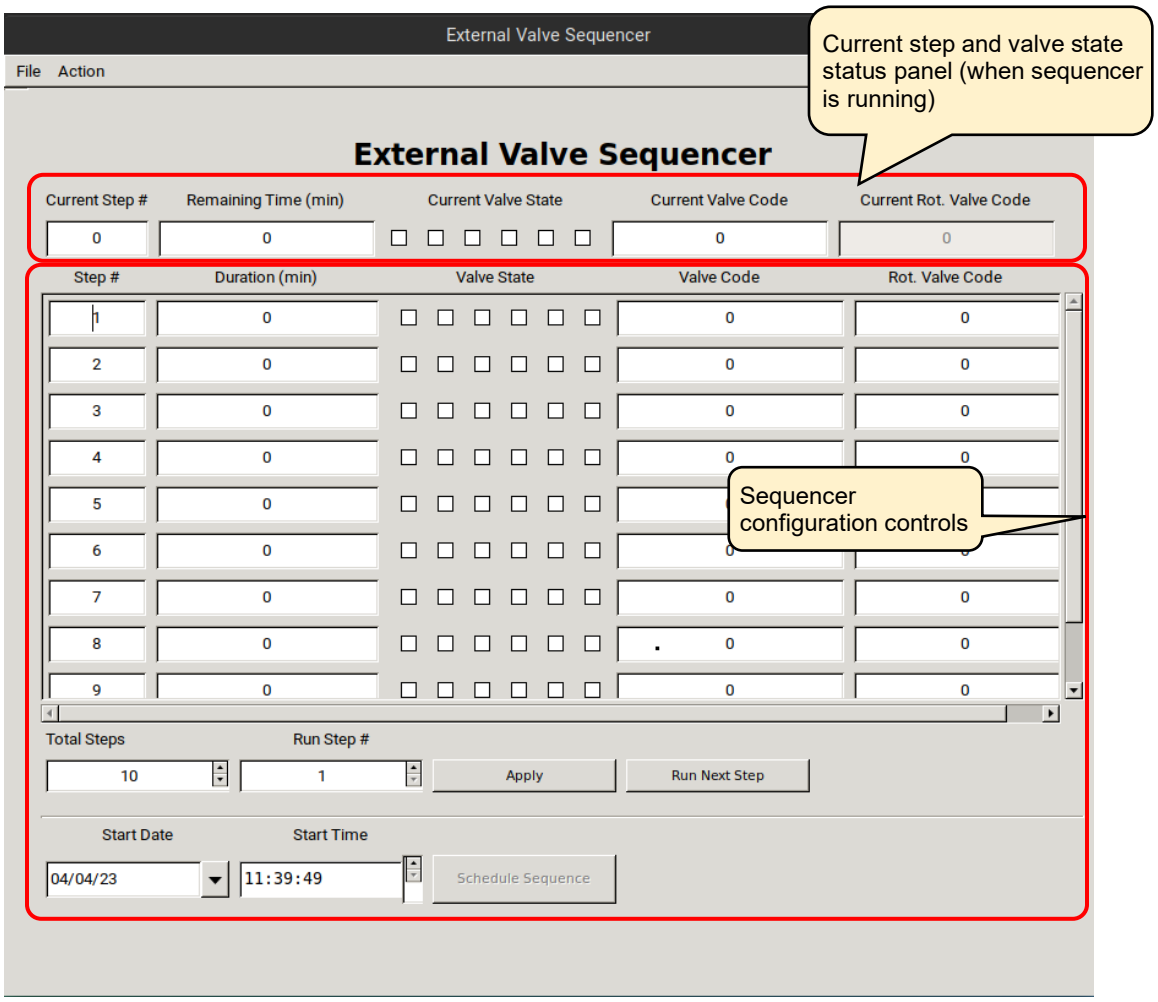


Figure 95: External Valve Sequencer UI

The **Current Step #**, the **Remaining Time (min)**, and the **Current Valve State** are shown in the topmost row of the valve sequencer command window. The duration of each step is set in decimal minutes; for example, 15 seconds would be entered in as 0.25 minutes.

While a sequence is inactive, **Current Step #** will typically read "**0**." Once the user has selected **Start Sequence** from the **Action** menu, or once the user has hit **Apply** from the GUI, the **Current Step** value will change to 1, corresponding to the first step defined below it, and will continue through the steps, returning to Step 1 once the last step is completed.

If a user wishes to perform a set of steps only once, they may set a final step with a very long duration, or wait until the sequence is finished, and at the end of the last step, click **Stop Sequence** from the **Action** menu.

Under **Action**, the **Go to First Step** menu item restarts the sequence from step 1. When the first step in the sequence starts, the “Current Step” value will change to “1”. This will begin the sequence if the sequence is currently active.

E.8 Programming and Saving a Valve Sequence

Each “step” in the sequence can be used to set the rotary valve to a given position or activate selected 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 to perform other gas handling operations.

1. Create the number of desired steps in the sequence by clicking the up/down arrow for **Total Steps**.
2. 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 set to its “normally closed” value in the case of a 3-way, or to its “open” value in the case of a 2-way on/off valve. The positions from left to right correspond to solenoid valves V1 to V6.
3. 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 **1** on the rotary valve. Only one rotary position can be selected per step.
4. The upper right box, **Current Rot. Valve Code**, displays the current value while a sequence is active. It should be white if a rotary valve is connected, turned on, and detected by the software. If the box is grayed out, the rotary valve is not detected (if so, consult your rotary valve manual).
5. For each step, set the desired **Duration**. This 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 accurately.
6. The **Valve Code** column (not used with the rotary valves) is a configuration-dependent, read-only display field that shows the total state of that particular step in a numerical binary sum of form $2^{(\text{Valve Number}-1)}$. When powered, the following valve values are produced, and then added together for the final Valve Code.

   Valve 1 Powered = $2^{(\text{Valve number}-1)} = 2^{(1-1)} = 1$

   Valve 2 Powered = $2^{(\text{Valve number}-1)} = 2^{(2-1)} = 2$

   Valve 3 Powered = $2^{(\text{Valve number}-1)} = 2^{(3-1)} = 4$

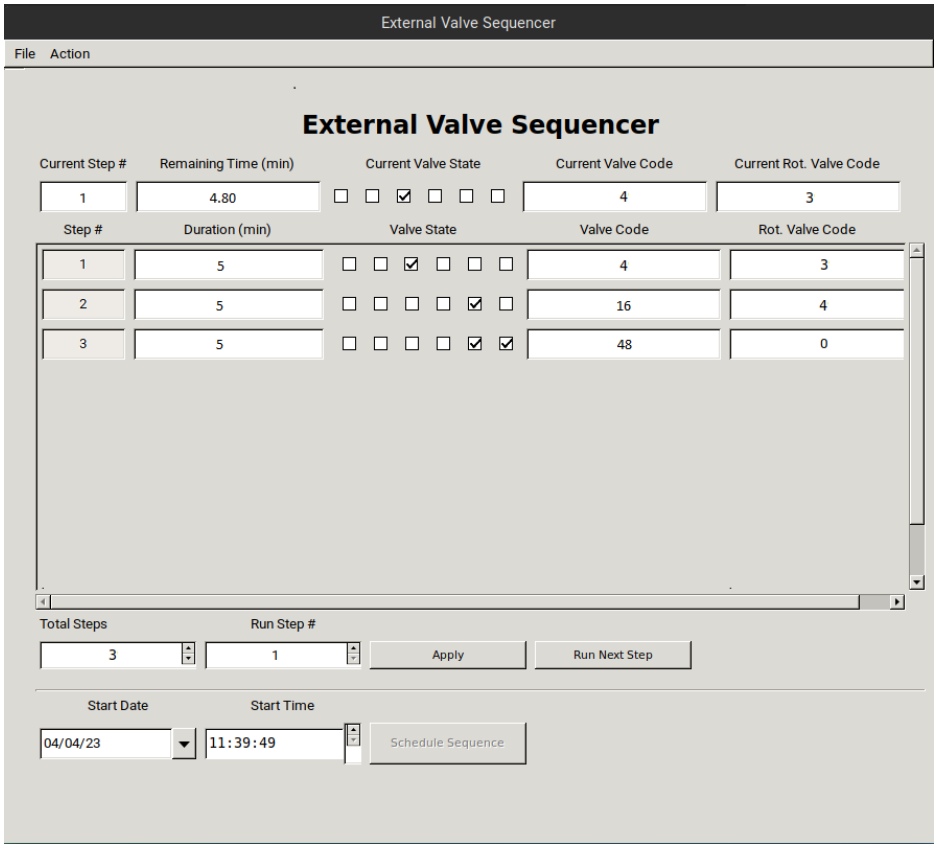
   Valve 4 Powered = $2^{(\text{Valve number}-1)} = 2^{(4-1)} = 8$

   Valve 5 Powered = $2^{(\text{Valve number}-1)} = 2^{(5-1)} = 16$

   Valve 6 Powered = $2^{(\text{Valve number}-1)} = 2^{(6-1)} = 32$

The maximum displayable value is 63 (=1+2+4+8+16+32), when valves 1-6 are all powered. All other combinations of valves are unique binary sum values which denote the specific combination of any of the six valves.

This **Valve Code** value active at a particular point in time can be shown in the main Picarro software GUI as **SolenoidValves** or sometimes **ValveMask** (this may require going to **Settings > Service Mode >** password **picarro)**. The Rotary valve code can be displayed as **MPVPosition**.



Above is a 15 minute sequence, currently on position 1, using solenoid valves only, in positions 3, 5, and 6 to determine flow path.

Figure 96: Example 15 Minute Sequence

7. Once the valve sequence has been programmed, it can be saved by selecting **Save Valve Sequence File** under the **File** menu (Figure 93). The sequence may be saved with any name the user chooses.

E.9 Loading and Running a Saved Sequence

Loading a Saved Sequence

1. Under the **File** menu, select **Load Valve Sequence**.

   All the sequence files are in:

/Home/Picarro/I2000/InstrConfig/ValveSequencer/Name of the Sequence File

2. To load an existing valve sequence file, select the desired sequence name**.**

   If the user has been running a different sequence from the one that was loaded, the user needs to press **Run Next Step** to initialize the newly selected sequence, or alternately go to **File > Go To First Step** and **Start Sequencer**.

Running a Sequence

1. Under the **Action** menu, select **Start Sequencer**.

   This selection will change to **Stop 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.

2. Once the sequencer is running, the user can select **Hide Sequencer Interface** under the **Action** menu; the sequence will continue to run even with the UI hidden, and will automatically continue if the instrument ever loses power from the wall and restarts after power is restored. (However, the timing of the sequence will be offset relative to the intended cadence.)

3. To bring the sequencer interface back into view, from the main Picarro GUI, go to **Tools** > **Show/hide Valve Sequencer** again.

Skipping Steps or Advancing to a Particular Step

If desired, the valve sequence can be forwarded to the next step of the sequence by clicking the **Run Next Step** button on the UI. To jump to a particular step, increment the **Run Step #** field and click **Apply**.

Stopping the Sequencer

1. Under the **Action** menu, select **Stop Sequencer**.

   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.

2. Should the user need to put the solenoid or rotary valves into a safe/default state, the sequencer can be advanced to the last step using the **Run Next Step** button.

Resetting Valves

Under the **Action** menu, selecting **Reset All Valves will** deactivate/reset all valves to their default state.

Valve Sequencer Data Records

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 as long as the variable is selected from the **Picarro Launch Pad**, **Settings**, **Data Logger Setup**, **Data Columns** window.

If the desired variable is not available, select **Service Mode** and then select the value from the variables that populate into the **Data Columns** window and click **Save**. Note the changes will take effect after the software restarts.

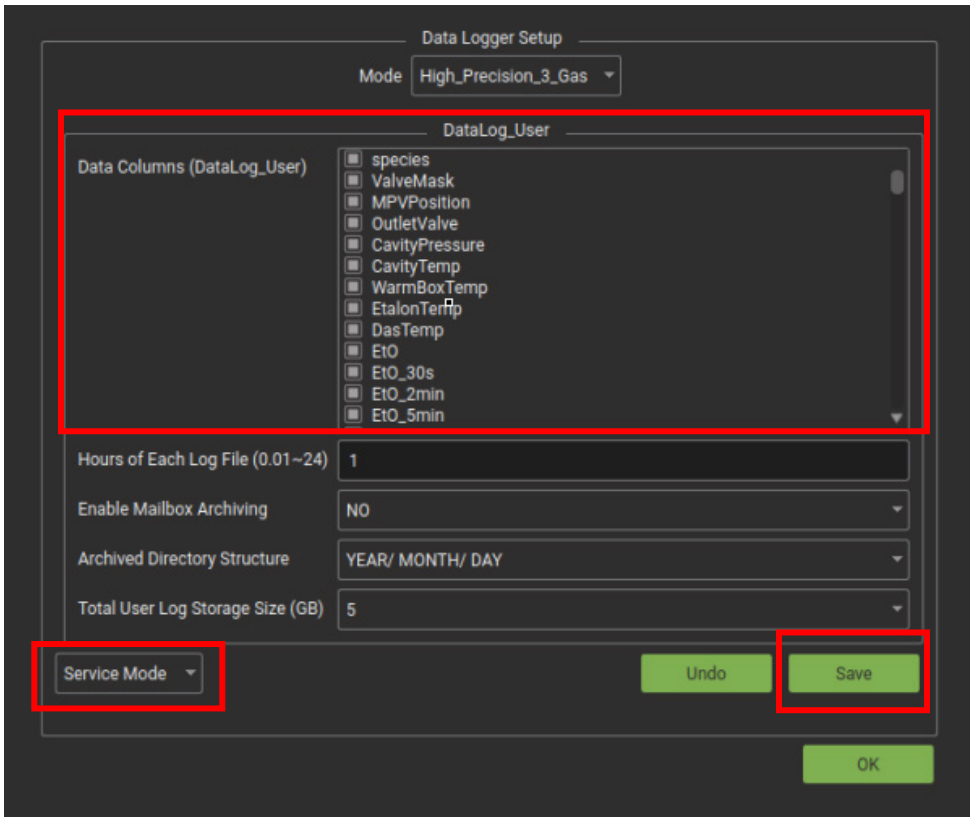


Figure 97: Data Logger Service Mode

If no solenoid valves are present, the codes will be recorded regardless of whether a valve is connected.

If no steps are defined, and no sequence is active, these values will display **0**.

E.10 Scheduling a Sequence

Users may schedule a sequence to start at a particular time in the future, often at the top of the hour, or at midnight for a recurring sequence with an hourly or daily cadence. The **Schedule Sequence** button is typically greyed out when the user shows the valve sequencer because the start time has passed. To begin a run in the future, select the desired date under **Start Date**, and the desired time under **Start Time**. When both values are in the future, the Schedule Sequence button will become active, and the user may click it. When the scheduled time arrives, the sequence will start itself automatically.

APPENDIX F – 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.

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

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 G – 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.

G.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 98. 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 98.

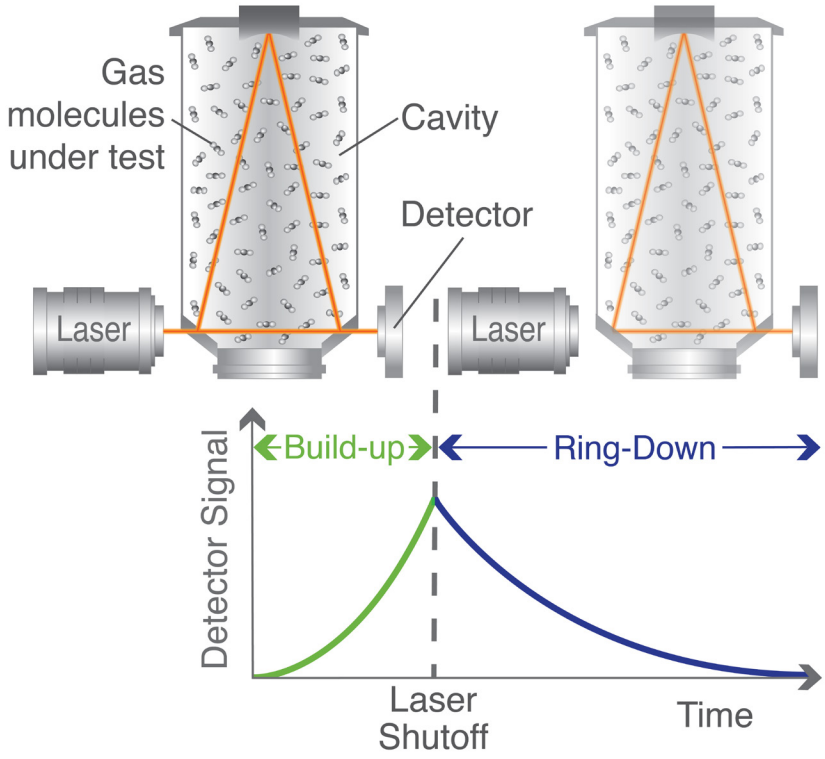


Figure 98: Schematic of Picarro CRDS Analyzer Cavity

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.

G.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 99). 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.

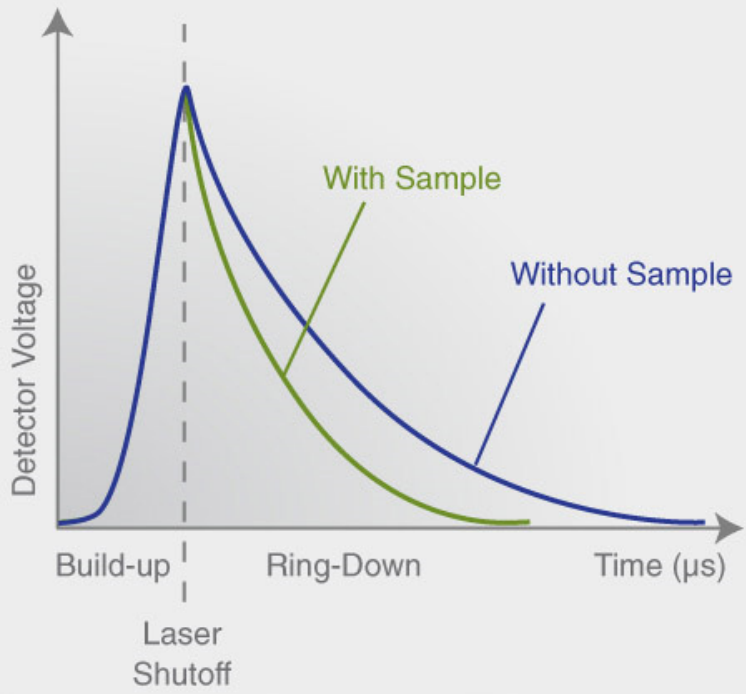


Figure 99: Light Intensity as Function of Time in CRDS System

G.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.

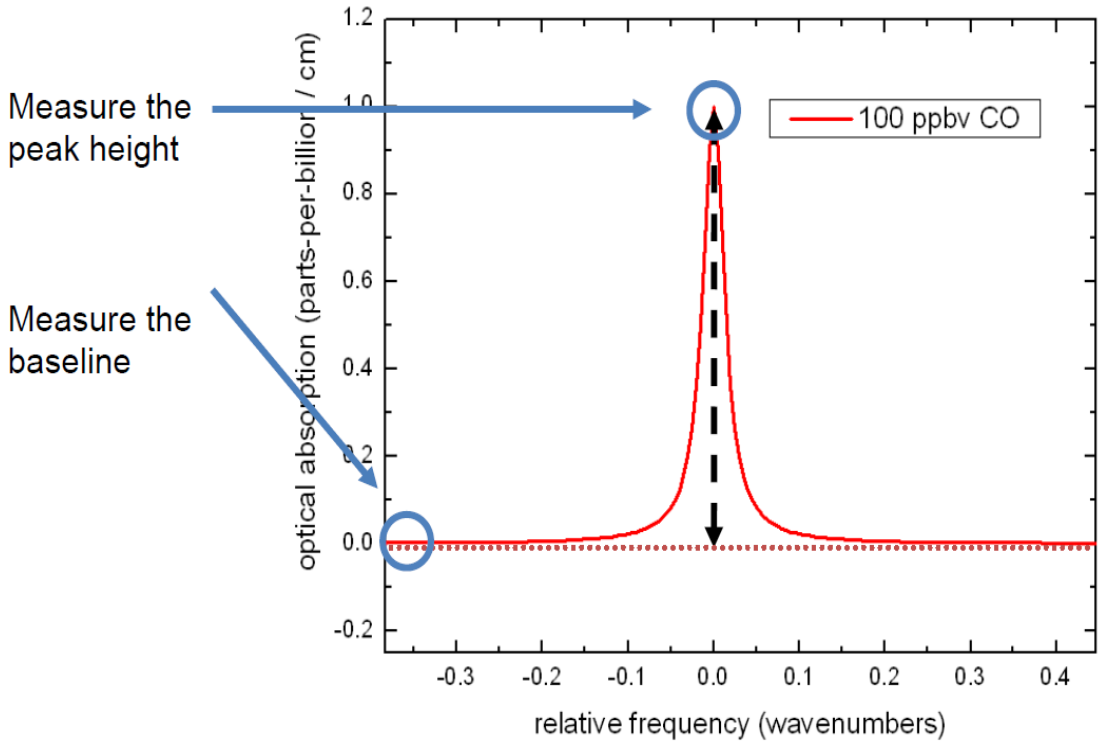


Figure 100: Absorption Spectral Curve

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.

G.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.

APPENDIX H – 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.

WARRANTY DISCLAIMER

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 - Your 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, 2020. 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.