PICARRO

G2103/G2308/G2508/G2509 Analyzer User Manual

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

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

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

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1. Introduction

1.1 Intended Use

The G2103, G2308, G2508, and G2509 analyzers measure concentrations of N_2O, NH_3, H_2O, CH_4 and CO_2 simultaneously and precisely using Picarro's patented Cavity Ring-Down Spectroscopy (CRDS) technology. The analyzers can be deployed in a lab or in the field, allowing *in-situ* ppb and ppm analysis of ambient/trace concentrations variously of N_2O, CO_2, NH_3, CH_4, and H_2O.

The analyzers enable simultaneous measurements with negligible drift over months of operation. They feature Picarro's unique algorithms to correct for the dilution and spectroscopic broadening effects of H_2O vapor, reporting N_2O, CH_4, and CO_2 as both whole air and dry mole fractions.

This manual groups together the G2103 fast ammonia instrument with the family of G2000 N_2O analyzers because of similarities in the dynamics of measuring ammonia gas (all but the G2308 measure NH_3).

Throughout this manual, you will see the following icons that help distinguish whether a piece of text is relevant to one, two, three, or all of the analyzers discussed:

G2103	The black icon identifies material pertaining to the G2103
G2308	The teal blue icon identifies material pertaining to the G2308
G2508	The green icon identifies material pertaining to the G2508
G2509	The red icon identifies material pertaining to the G2509
G2508 G2308	***Note that Grayed out versions of the G2308 and G2508 icons refer to use cases that are compatible, but not typical.***

Table 1 below compares the features of each model.

Table 1: G2103/G2308/G2508/G2509 Feature Comparison

	G2103	G2308	G2508	G2509
Species Measured	NH_3, H_2O	N_2O, CH_4, H_2O	N_2O, CO_2, NH_3, CH_4, H_2O	N_2O, CO_2, NH_3, CH_4, H_2O
Flow Rate	> 1.5 SLPM	230 SCCM	230 SCCM	1.3 SLPM
Ammonia 10-90 Response Rate	Standard, 120 secs	N/A	>2 min	<2 min
High Methane Range (up to 800 ppm)	NA	NA	By upgrade request	Standard
Ammonia range	Guaranteed 0–500 ppb; Operational 0–10 ppm; Extended 0–50 ppm (Optional)	N/A	0-2 ppm	0-2 ppm
Supported Modes	G2103	G2308	G2308, G2508, G2608, G2508 HR Methane	G2508, G2508 HR CH4 (both with FR ammonia) G2509 fast NH_3.*
O_2 sensor upgrade?	No	Yes	Yes	No
Recirculation Possible?	Limited cases**	Yes, with A0702 pump	Yes, with A0702 pump	Limited cases**
Gases Compatible with Recirculation	NA	N_2O, CH_4	N_2O, CH_4, CO2	NA
Sample Handling	Low reactivity material***	All SS	All SS	Low reactivity material***
Typical Applications	Indoor and atmospheric air quality, Livestock facilities, Vehicle emissions	Soil flux, Ambient measurement	Soil flux, Ambient measurement	Ambient indoor measurement, Livestock facilities
Inlet Filter	S1021 Teflon	S1020 Stainless Steel	S1020 Stainless Steel	S1021 Teflon
Inlet Connector (Swagelok)	¼" PFA	¼" Stainless Steel	¼" Stainless Steel	¼" PFA
Recommended Multiposition valve	A0311-S	A0311	A0311	A0311-S

***** N_2O values valid when NH_3 <2 ppm.

**Leak-tightness and pump diaphragm emissions not guaranteed—only appropriate for recirculation in large spaces with appropriate pump outlet fittings (not provided).

*** Inlet filter Teflon; inlet manifold SS; tubing Teflon, cavity SilcoNert-coated.

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: G2308/2508 Front/Back Panels

Pump Compatibility

The G2308 and G2508 instruments are fully compatible with low-leak recirculation using the A0702 pump and associated tubing and hardware. The G2509 has sample handling downstream of the cavity that makes it less compatible with this form of recirculation. Accordingly, we recommend A2000 pump broadly for the G2509 and G2103 instruments. The A2000 pump can be set up to recirculate using an outlet fitting (see ***APPENDIX C – Setting up Contained Pump Exhaust Flow*** for more information), with the caveat that the pump is not certified to be leak free or non-reactive. Accordingly, recirculation should only be done into large vessels where a small leak or contamination isn't of material concern. Likewise, the A0702 pump can and could be connected to the G2509 instrument, but its purpose as a low-leak, low-reactivity device is partially offset by the lack of equivalent sample handling in the G2509 instrument build. For simplicity, in this manual we refer the user to sections about the A2000 for the G2103, G2308, G2508, and G2509 instruments, and the A0702 for the G2308 and G2508 only.

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. This pump can be used with the G2103, G2308, G2508, and G2509 analyzers. Typically, it is used with G2103 and G2509.

Figure 2: A2000 Vacuum Pump – Side Views

A0702 Recirculating Vacuum Pump

The A0702 Pump can be used with the G2308 and G2508 instruments to measure gas concentrations in a recirculating closed system with extremely low leak rates and well-controlled pump materials compatibility. This makes it ideal for monitoring gas evolution from soils, vegetation, or living organisms.

Picarro has not tested ammonia measurement accuracy using the A0702 recirculation pump.

Figure 3: A0702 Recirculating Vacuum Pump

1.3 Analyzer Specifications

NOTE

Check your order to determine which specifications listed below apply to your system.

Table 2: G2103/G2308/G2508/G2509 Specifications

Parameter	Specification
Measurement Technique	Cavity Ring-Down Spectroscopy (CRDS)
Weight: Analyzer Weight: Pump	20.9 kg (46 lbs.) – Should be lifted by two people. A2000: 6.5 kg (14.4 lbs) G2103 G2308 G2508 G2509 A0702: 4.5 kg (9.8 lbs) G2308 G2508
Dimensions - Analyzer	Depth: 44.5 cm (17.5”) Width: 43.2 cm (17.0”) Height: 17.8 cm (7.0”) Height with Feet: 19.1 cm (7.5”)
Dimensions – A2000 Pump G2103 G2308 G2508 G2509	Length: 27.9 cm (11”) Width: 10.2 cm (4”) Height: 19.1 cm (7.5”)
Dimensions – A0702Pump G2308 G2508	Length: 34.3 cm (13.5”) Width: 19.1 cm (7.5”) Height: 14 cm (5.5”)
Ambient Humidity Range	< 85% RH non-condensing
Ambient Temperature Range	Operating: 10 °C to 35 °C (50 °F to 95 °F) Storage: -10 °C to 50 °C (14 °F to 122 °F)
Maximum Altitude (During operation)	3,048 m (10,000 ft. – Operation)
Front/Rear Clearance	Front: 15.3 cm (6”); Rear: 15.3 cm (6”)
Primary Gases Measured G2103 G2308 G2508 G2509	 NH_3, CO_2,H_2O N_2O, CH_4, H_2O N_2O, CO_2, NH_3, CH_4, H_2O N_2O, CO_2, NH_3, CH_4, H_2O

Parameter	Specification
Sample Flowrate (at 760 torr (101 kPa)	230 SCCM G2308 G2508 1.3 SLPM G2509 >1.5 SLPM G2103
Required Accessories	Included: Pump (external), keyboard, mouse Supplied by Customer: LCD monitor
Operating System Data Outputs	Windows 10 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; 47 – 63 Hz (auto-sensing) <375 W at start-up, (Analyzer and Pump) 120 W (Analyzer) 150 W (A2000 Pump) 60 W (A0702 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 3: Acronyms, Formulas, Units, and Symbols

Acronym	Definition
atm.	atmosphere; unit of pressure, approximately equal to atmospheric pressure at sea level. 1 atm. = 14.7 psi (101.3 kPa)
cm	centimeters
CO_2	Carbon Dioxide
CH_4	Methane
CRDS	Cavity Ring-Down Spectroscopy
DAS	Data Acquisition System (the Analyzer)
ft.	Length in feet;1 ft. = 12” or 12 inches (30.48 cm)
FR	Fast response
GUI	Graphical User Interface
H_2O	Water, Water Vapor
HP	High Precision (typically while measuring lower concentration)
HR	High Range (typically resulting in lower precision)
kPa	Kilopascal; unit of pressure; 1 kPa = 0.145 PSI
mm	millimeters
N_2O	Nitrous Oxide
NH_3	Ammonia
OD	Outside Diameter
PFA	Perfluoroalkoxy – A chemically resistant polymer, suitable for use with sticky and aggressive gases
ppb	parts per billion
ppm	parts per million
PSI (psi)	Pounds per Square Inch
PSIG (psig)	Pounds per Square Inch Gauge (above ambient pressure)

Acronym	Definition
RH	Relative Humidity
SCCM	Standard cubic centimeters per minute
SST	Stainless Steel
UM	User Manual
WLM	Wavelength Monitor
“ (as in 1/4”)	Inches
°C	degrees Celsius

1.5 Text Conventions

The following conventions are used in the manual.

- *Italic* text identifies screen names and to emphasize 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 important information. They indicate dangers to either the operator or to the analyzer, and other important information.

Table 4: 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	R**EMINDER** 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.

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

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

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 20.9 kg (46 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 4: 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 5) is affixed to the inside of the analyzer:

Figure 5: 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.

Based on the model ordered, the shipment may consist of one, two or three separate boxes.

Table 5: Shipping Box Quantities by Model

Analyzer Model (Typical)	Boxes	Description
G2103 G2308 G2508 G2509	2	Box 1: Analyzer Box 2: A2000 pump
G2308 G2508	3	Box 1: Analyzer Box 2: A0702 pump (if included in order) Box 3: Vacuum lines for A0702 pump (Refer to Recirculation Pump Manual 40050)

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 20.9 kg (46 lbs). Use the technique outlined on Page 23 when lifting or moving the analyzer.

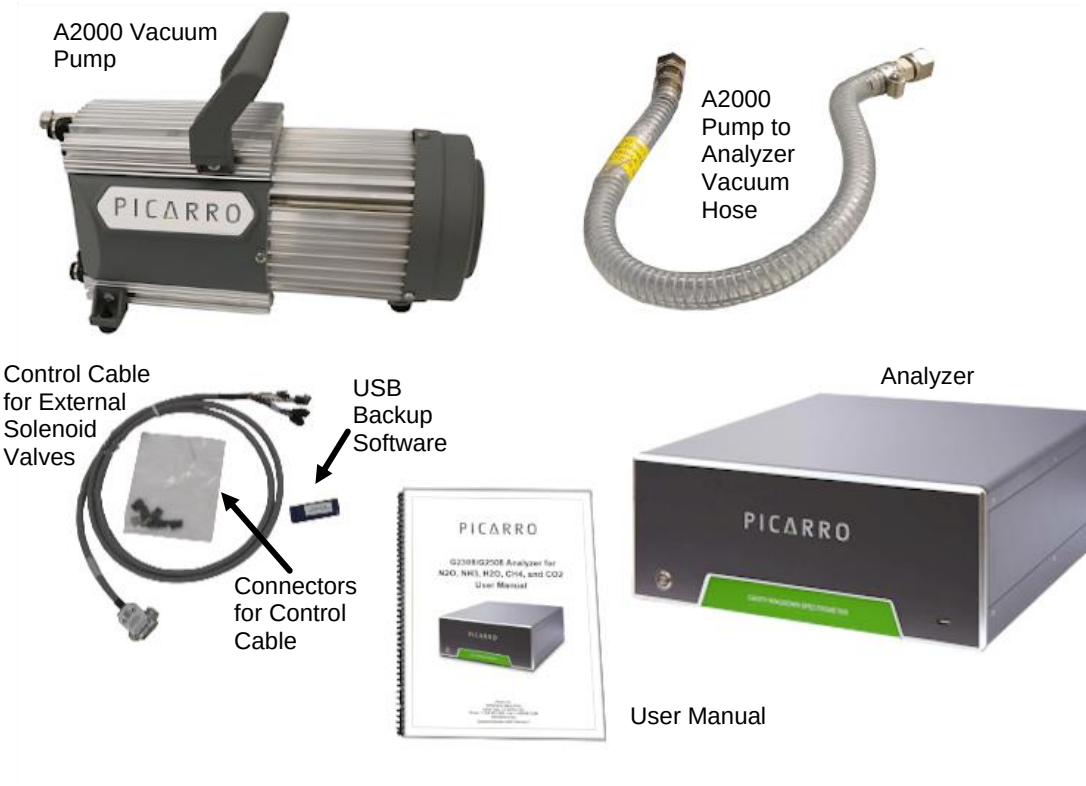


Figure 6: G2103/G2308/G2508/G2509 Shipping Box Contents

Table 6: 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.

Item (qty)	Description
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).

NOTE

Box 2 contents differ depending on analyzer model ordered.

Table 7: Box Two: A2000 Vacuum Pump and Accessories (Typical for G2103 and G2509)

Item (qty)	Compatibility	Description
A2000 Vacuum Pump (1)	G2509 G2508 G2308 G2103	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.

Table 8: Box Two: A0702 Pump (for G2308/G2508)

Item (qty)	Compatibility	Description
A0702 Vacuum Pump (1)	G2508 G2308	Used with the G2308 and G2508 instruments to measure gas concentrations in a recirculating closed system.
Ni/Ag gaskets (10)		Gaskets for VCR connections

Item (qty)	Compatibility	Description
A/C Power Cable (1)		For pump power
1/4” VCR to 1/4" Tube Fitting Adapter (1)		For connection to analyzer Sample Inlet
1/4" VCR to 3/8” Tube Fitting Adapter (1)		For connection to analyzer Vacuum Port
NPT 1/8” Male to 1/4" VCR Male Adapter, (2)		For connections to sample chamber Inlet and Outlet
Swagelok VCR Manual (1)		
Pump User Manual (1)		A0702 Closed System Measurement Package User Manual (PN 40050)

Figure 7: A0702 Pump and Accessories (Box 2 and 3)

Table 9: Box Three – A0702 Additional Parts

Item (qty)	Compatibility	Description
A0702 Vacuum Lines	G2508 G2308	Vacuum lines for A0702 recirculation pump: 24” flexible stainless-steel bellows tubing VCR, 1/4” OD (Qty 2) 12” flexible stainless-steel bellows tubing VCR, 1/4” OD (Qty 1) (Refer to A0702 User Manual, PN 40050)

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 2***) and accessories included in shipment
- 5/8” open end wrench (for G2103 and G2509)
- 9/16’’ open end wrench (for G2308 and G2508)
- 11/16’’ open end wrench
- Power Cords for analyzer and pump

4.2 Installation Safety

WARNING

<u>Two-person lift required</u>: The analyzer weighs 20.9 kg (46 lbs). When lifting the analyzer, use the technique described on page 23 (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

<u>Equipment Damage</u>: 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 temperature 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	10 °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 8).

Figure 8: Vacuum Pump Voltage Selection

4.4 Connections – A2000 Pump and Gas Inlet

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

Pump Connections

Refer to Figure 9 when using an A2000 pump with your analyzer.

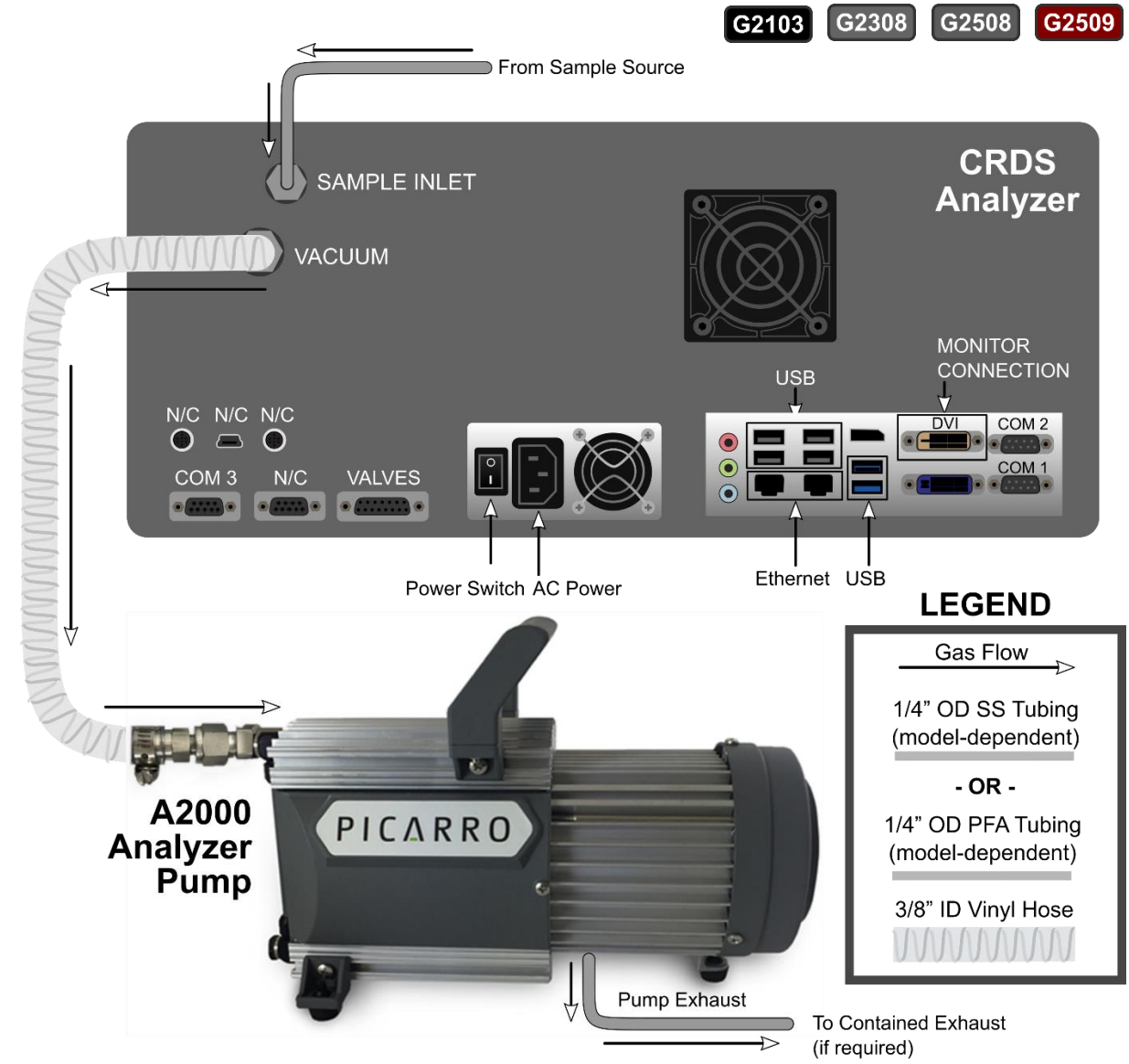


Figure 9: Analyzer Setup with A2000 Pump

CAUTION

When working with hazardous gases, remove the pump exhaust muffler and adapt a tube to the vacuum pump exhaust port (shown in Figure 8) and direct the exhaust to a safe place for venting the mixture of sample gases. For instructions, see *APPENDIX C – Setting up Contained Pump 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 C – for instructions on directing the pump exhaust to a safe venting environment.

Sample Gas Inlet Connection (SST Tubing)

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

- G2103 and G2509 analyzers have PFA sample inlet connectors.
- G2308 and G2508 analyzers have stainless steel sample inlet connectors.

When making a new SST gas inlet connection: G2308 G2508

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

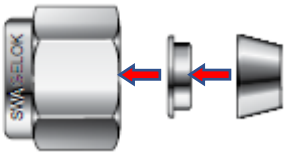


Figure 10: Orientation of Inlet Nut and Ferrules

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 9/16" wrench (not included), tighten the nut 1-1/4 turns.

When reconnecting SST tubing: G2308 G2508

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 9/16" wrench, tighten the nut 1/6 of a turn (60°).

Sample Gas Inlet Connection (PFA Tubing)

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

- G2103 and G2509 analyzers have PFA sample inlet connectors.
- G2308 and G2508 analyzers have stainless steel sample inlet connectors.

When making a new PFA gas inlet connection: G2103 G2509

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 10.
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: G2103 G2509

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 Connections – A0702 Pump and Gas Inlet

Follow instructions in this section when using an A0702 pump with your analyzer.

Pump and Gas Inlet Connections

Refer to Figure 11 when using an A0702 pump with your analyzer.

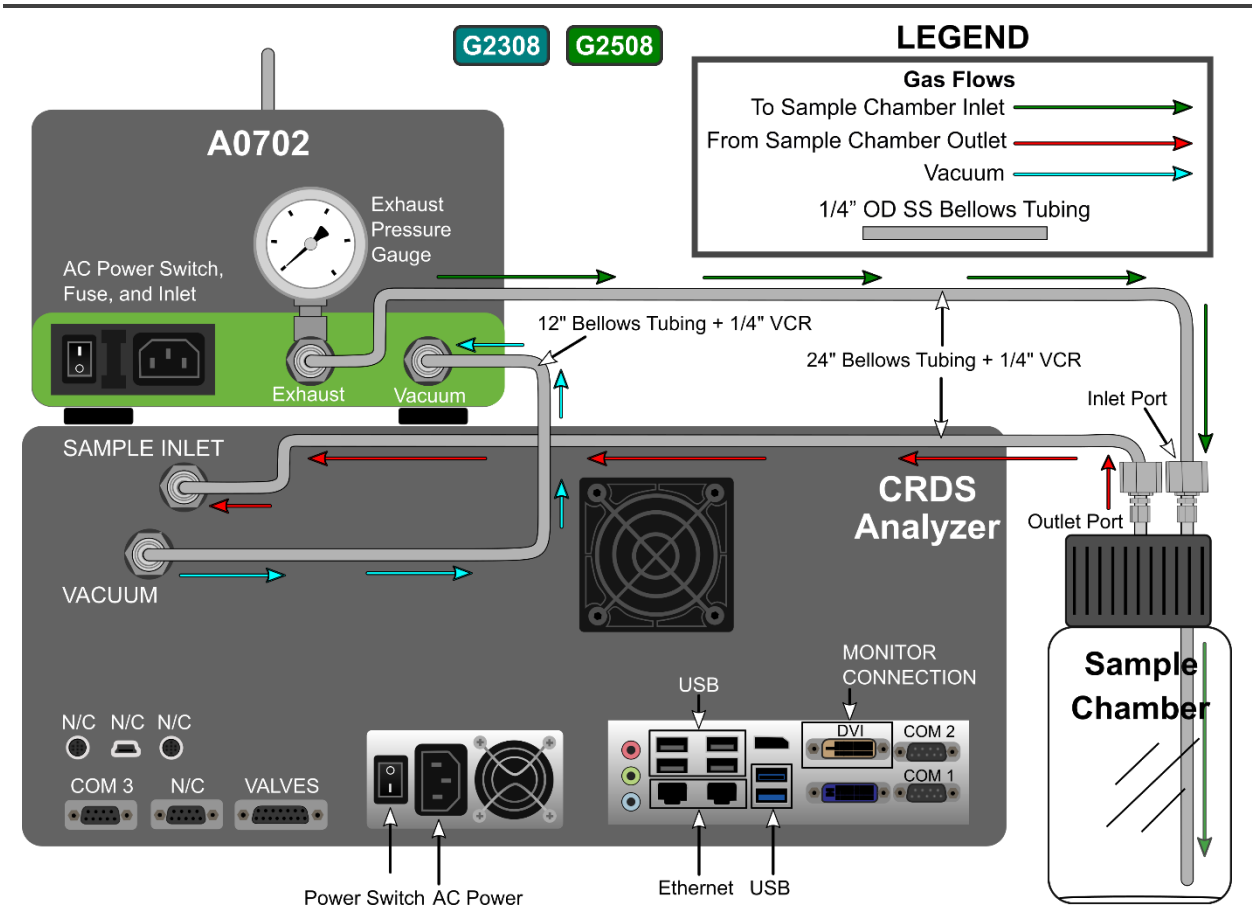


Figure 11: Analyzer Setup with A0702 Pump (G2308/G2508)

1. Attach the 1/4" VCR to 3/8” tube adapter to the analzyer VACUUM port.
2. Attach the 1/4" VCR to 1/4” tube adapter to the analzyer INLET port.
3. Attach the two 1/4” VCR to 1/8” NPT Male adapters to the Sample Chamber Inlet and Outlet ports.
4. For the following steps, insert a *new* 1/4” Ni/Ag gasket (Swagelok NI-4-VCR-2) into each VCR nut before connecting (Figure 12).

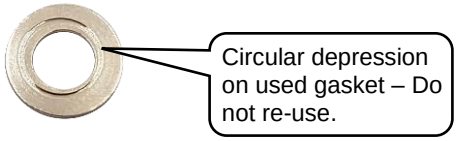
   To Connect and Tighten:

   a. Turn the nut until finger-tight.

   b. Use a 3/4” wrench (backed with a 5/8” wrench) to tighten the nut an additional 1/8 turn.

CAUTION

Always use a new gasket whenever reconnecting VCR fittings. A used gasket can be identified by a circular depression on the surface:



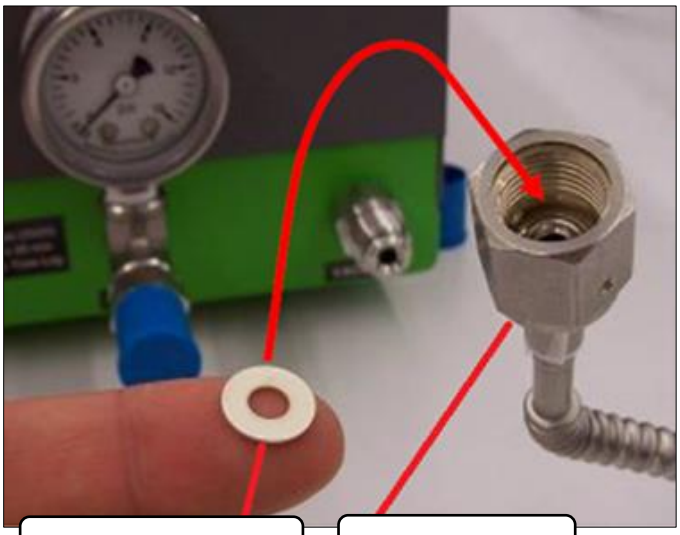


Figure 12: Insert New Gasket into VCR Nut

5. Connect the 12” flexible stainless steel line between the analyzer **Vacuum** port and the A0702 **Vacuum** port. Ensure a new VCR gasket is inserted into each VCR female fitting.
6. Connect one of the 24” flexible stainless steel lines between the analyzer **Inlet** port and the sample chamber **Outlet** port. Ensure a new VCR gasket is inserted into each fitting.
7. Connect the other 24” flexible stainless steel line between the A0702 **Exhaust** port and the sample chamber **Inlet** port. Ensure a new VCR gasket is inserted into each fitting.

4.6 Electrical Connections

Refer to Figure 13 for connection points.

1. External Vacuum Port to Vacuum Pump	**10.** Ethernet Ports – RJ-45 (2 ea)
2. Gas 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 (Only for PAL autosamplers; not used with this instrument; not connected)
6. COM 1 Port	**15.** COM 3 Port (Connected but typically not used.)
7. DVI-D 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 13: 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 8).

The A0702 has a power supply that automatically adjusts to power sources ranging from 100-240 VAC, 50/60 Hz, 10A max.

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 or A0311-S) to COM2 with its provided serial cable.

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, and 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 software will start automatically, and the analyzer will display the CRDS Data Viewer window (Figure 14). Data Viewer features are detailed in Section 6.1.

The analyzer will not begin producing data until the cavity temperature and pressure have reached their operational set points. A message will be displayed in the Status Log window (see Figure 14, bottom panel) when each set point is reached. An explanation of the most common status log messages can be found in ***Section 6.10, Status Log Window***.

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:

C:\Userdata\DataLog_User \YYYY\MM\DD, where Y=year, M=month, D=day. Further details can be found Section 7, 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.

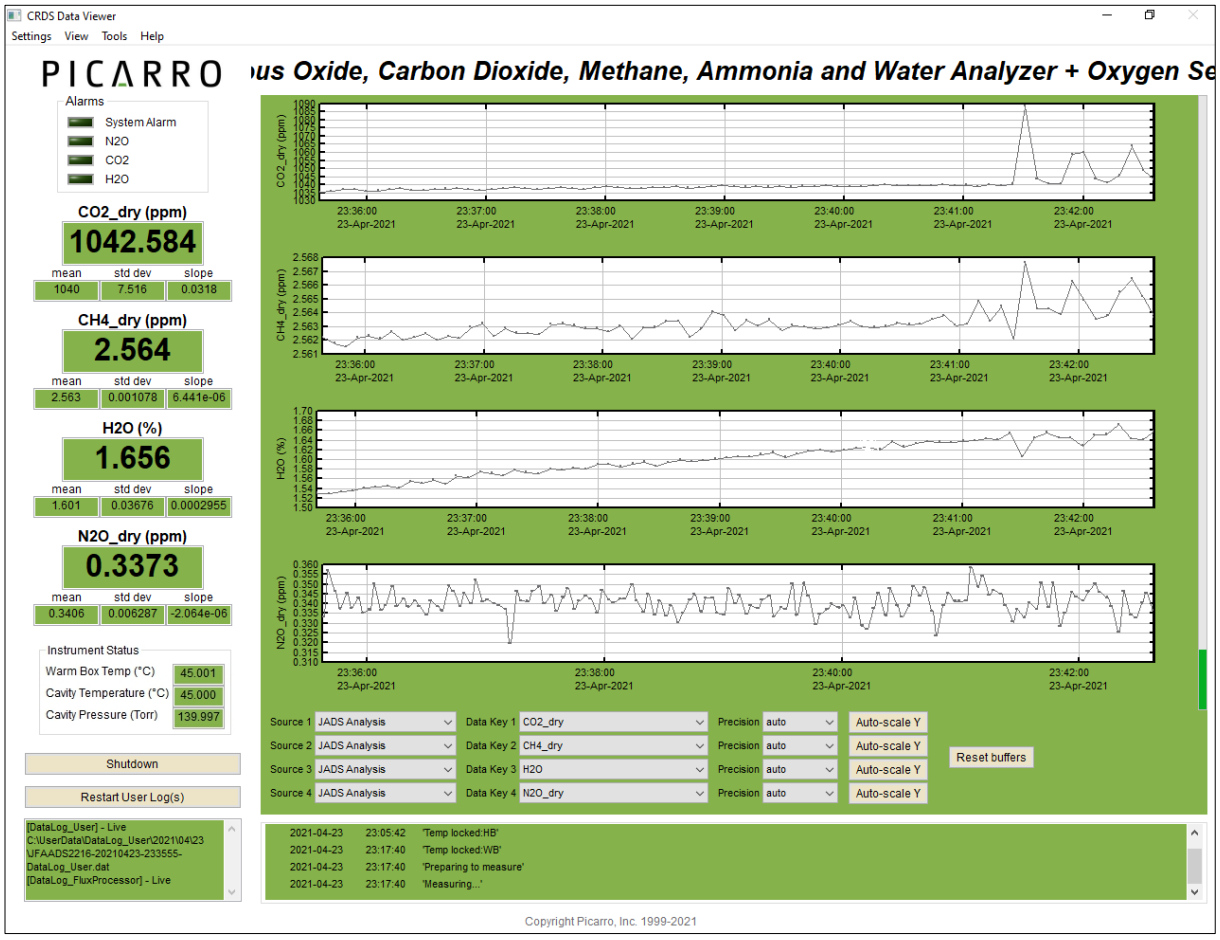


Figure 14: GUI/Data Viewer Screen

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.

CAUTION

If you have trouble turning off the analyzer software, do not use the Windows Task Manager to kill the process(es). Instead, double-click on the "Stop Instrument" icon in the Diagnostics folder on your desktop and select the default option to stop the software with the drivers running. See Figure 15 below.

Flow Clean, Dry Gas (When Using an A2000 Pump)

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).

Flow Clean, Dry Gas (When Using an A0702 Pump):

1. For a G2308 or G2508 using an A0702 closed system pump and sample chamber, disconnect the sample line at the analyzer inlet, and connect the dry gas source to the inlet. The gas will flow through the analyzer, pump, and sample chamber, then out to atmosphere or a contained exhaust (if used). If the user wishes to not have dry gas go through the sample chamber, it can be disconnected.

Shutdown

2. Click on the **Shutdown** button located on the left side of the Data Viewer window.
3. A window will pop-up (Figure 15) prompting the user to confirm the shutdown. Once confirmed, the analyzer software and hardware will turn off. (Note: If three options are given on an older instrument, choose the **For Shipment** option.)
4. Manually turn off the pump(s) and dry gas (only if system requires it).

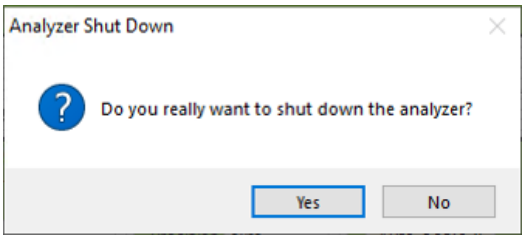


Figure 15: Shutdown Confirmation Pop-Up Dialog

After clicking **Yes** to confirm, the analyzer software, then the computer OS will shut off after a few minutes. *Leave any dry gas or desiccant attached to the inlet during this process*.

5. 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 Desktop Icons and Folders

The following icons and folders related to analyzer operation are populated on the Windows desktop.

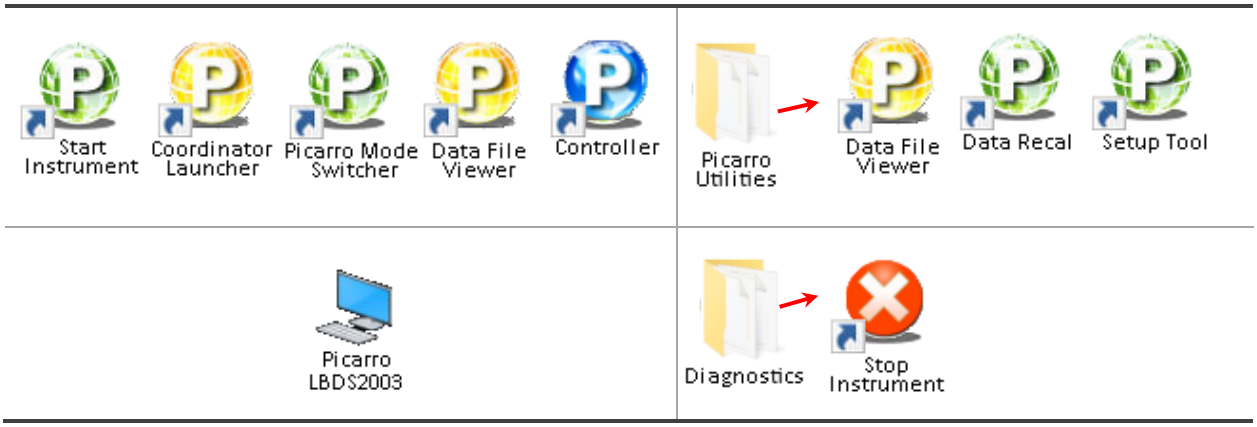


Figure 16: Desktop Icons and Folders

Desktop Icons

- **Start Instrument:** If the instrument software is already running, this restarts the software. If the instrument software has been shut down, this starts the software.
- **Coordinator Launcher (not present on all configurations):** Clicking on this icon opens a window that allows you to choose the proper coordinator to operate peripheral modules on certain analyzers.
- **Picarro Mode Switcher:** When clicked, a window opens (Figure 17) that allows you to switch between various measurement modes. Most analyzer models are configured for one mode and may not include the Mode Switcher. If the analyzer has multiple modes, this allows the user to switch between them easily. See **Table 1** for supported measurement modes by-model.

Figure 17: Picarro Mode Switcher

- **Picarro Controller:** When clicked, opens a useful diagnostic panel allowing the user to see the analyzer's internal temperatures, pressure, and spectroscopy in real time. This program has user-accessible functions but should not be used to change instrument parameters without the direction of Picarro support.
- **My Computer Icon** renamed to the individual analyzer's serial number
- **Data file 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 B – Data File Viewer***.

Picarro Utilities Folder

- **Data Recal:** When clicked, a window opens that allows you to recalibrate your data based on known, certified data.
- **Setup Tool:** When clicked, a window opens that allows you to edit various settings for your analyzer (See ***APPENDIX A – Setup Tool and Communication*** for information.
- **Data file Viewer:** (see above)

Diagnostics Folder

- **Stop Instrument:** When clicked, a window opens that allows you to turn off the analyzer in an emergency event. Upon clicking on this icon, the following window will pop up. Please see ***Section 5.2, Shutdown*** to shut down the analyzer under normal circumstances.

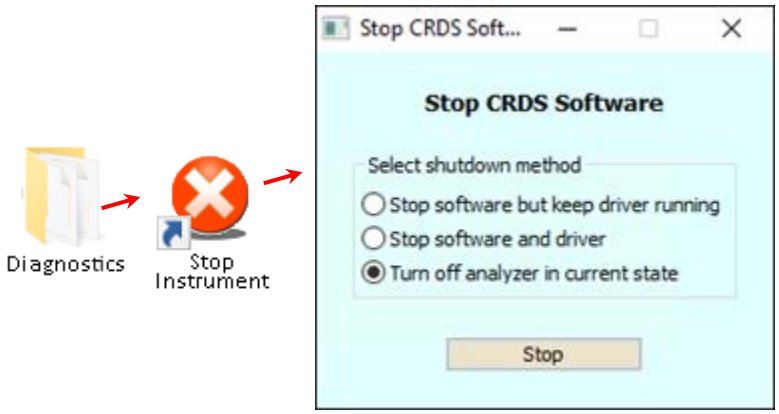


Figure 18: Stop CRDS Software Pop-up

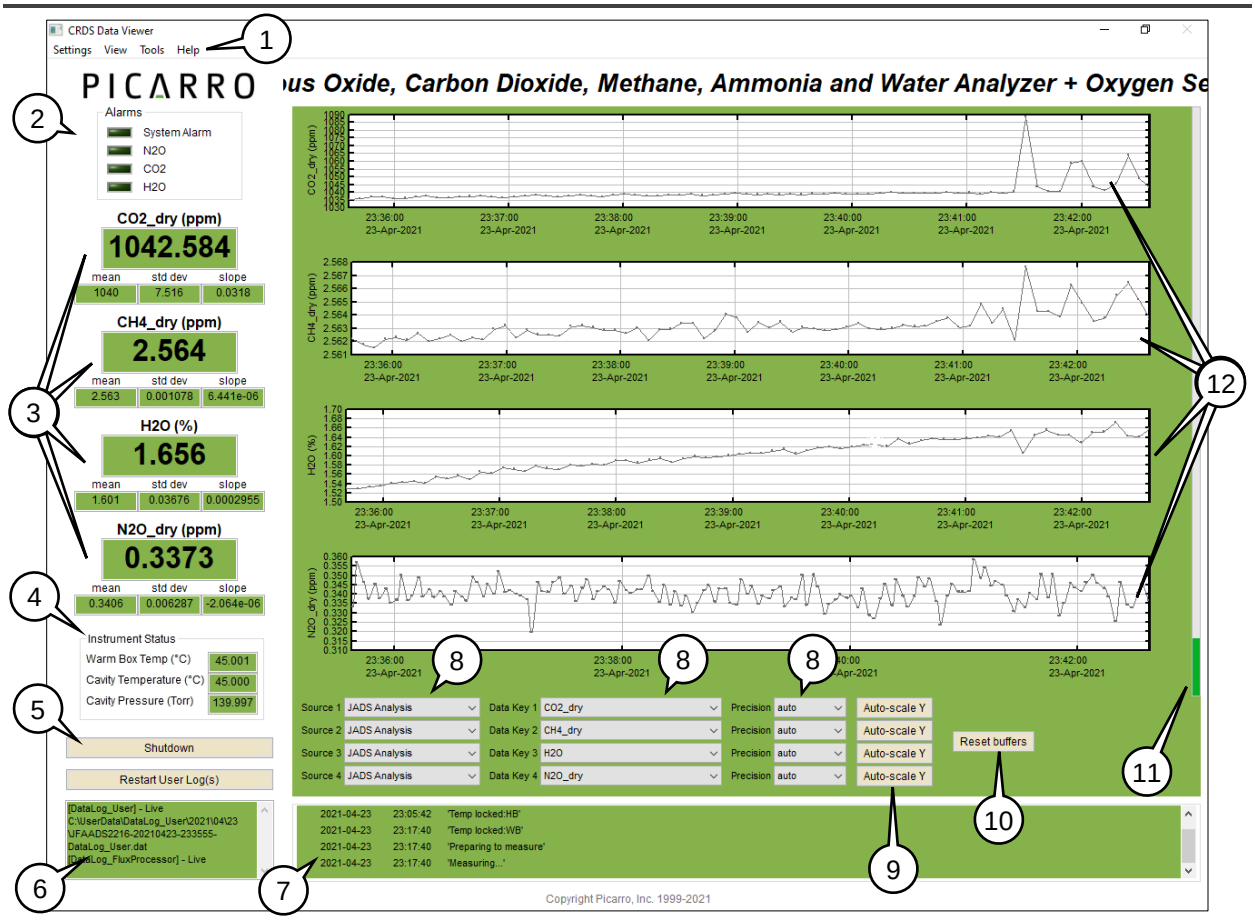
6. List of GUI Functions

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 19 are described in the following sections.



1. Settings, View, Tools, and Help menus
2. Alarm Panel
3. Digital Readouts
4. Instrument Status
5. Shutdown and Restart Log Buttons
6. Data Log; Filename, and 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 Buffer Level Meter
12. Data Windows – Graphical Readouts

Figure 19: Layout of G2103/G2308/G2508/G2509 Analyzer GUI

6.2 Settings, View, Tools and Help Menus

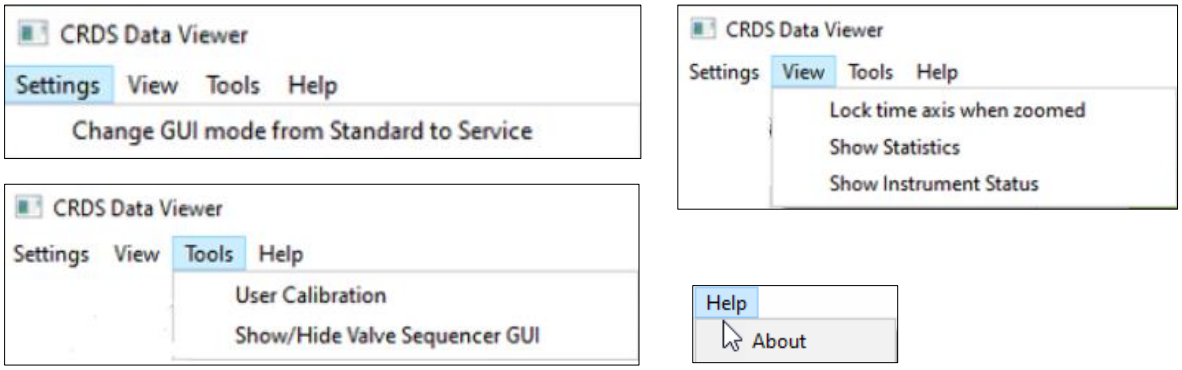


Figure 20: Menu Toolbar Options

Settings Menu

Left clicking on the **Settings** menu pulls down a menu that has one entry: **Change GUI Mode from Standard to Service (or Change GUI mode from Service to Standard if it is already in service mode)**.

This is the access point to a password protected service mode (default password is **picarro**) where additional operational and measurement parameters are available in the data keys. Selecting and clicking on this entry opens the Cavity Ring-Down Spectrometer Controller.

View Menu

This menu item has three entries:

1. **Lock time axis when zoomed/Unlock time axis:** When locked, forces all graphs to display the same time scale during zoom.
2. **Show/Hide Statistics:** Toggles the measurement statistics display, see the section ***Digital Readouts*** below.
3. **Show/Hide Instrument Status:** Toggles the instruments status display. See the section ***Instrument Status***, below.

Tools Menu

This menu item has three entries:

1. **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. Picarro recommends using the Data Recalibration tool instead of this manual User Calibration when possible, as the Recal tool retains a traceable record of recalibration events.

2. **Show/Hide Sequencer GUI:** Toggles the display of the external valve sequencer window (user may need to hit **alt-tab** to bring it to the front).

Help Menu

About: Displays the version number 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 **CO2 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.

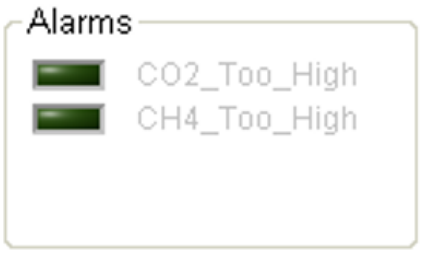


Figure 21: Alarm Panel

To view the alarm set point, click on the **Alarm Icon** and a dialog box (Figure 22) will appear indicating the alarm setting and allow the user to enable it or change the setpoint.

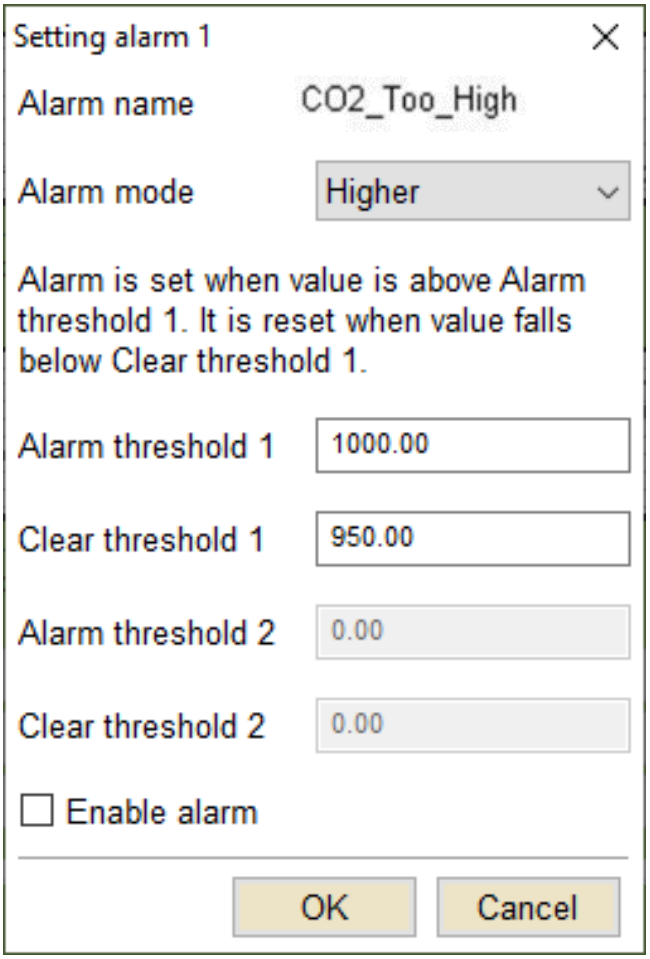


Figure 22: Alarm Settings Dialog Box

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 consistent with 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 (Figure 23). Changing the Data Key changes the Digital Readout as well as the Data Window view. If the **Show Statistics** entry is enabled in the **View** menu, the mean, standard deviation, and slope of the data in the graph 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.

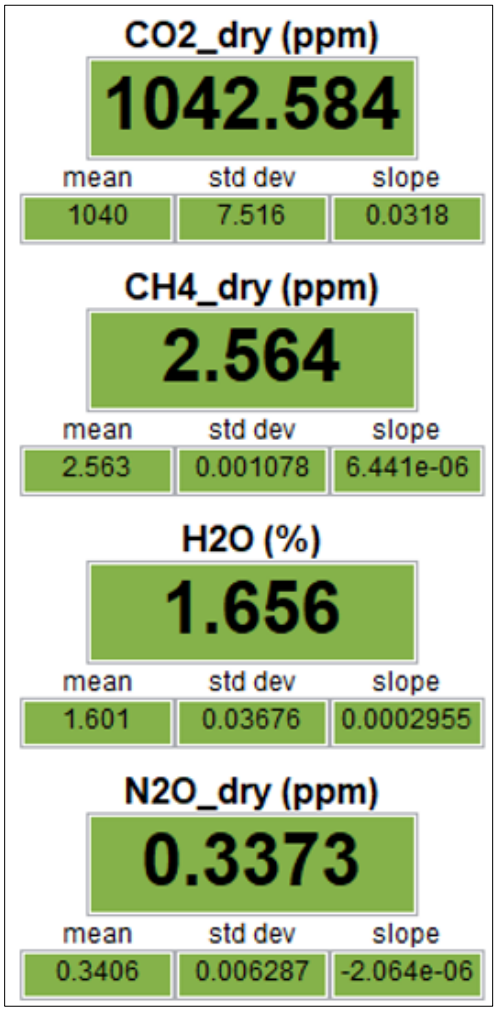


Figure 23: Digital Readouts Panel

6.5 Instrument Status

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

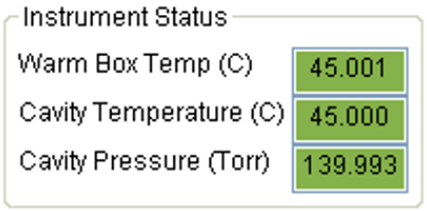


Figure 24: Instrument Status Panel

6.6 Shutdown and Stop User Log(s) Buttons

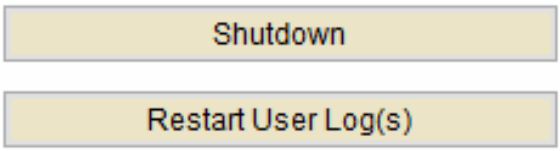


Figure 25: Shutdown/Stop User Log

Shutdown Button:

Shuts down the analyzer. See ***Section 5.2, Shutdown*** for more information.

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\04\24”) will be generated at midnight, as will month and year folders at the appropriate times.

Figure 26: 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.

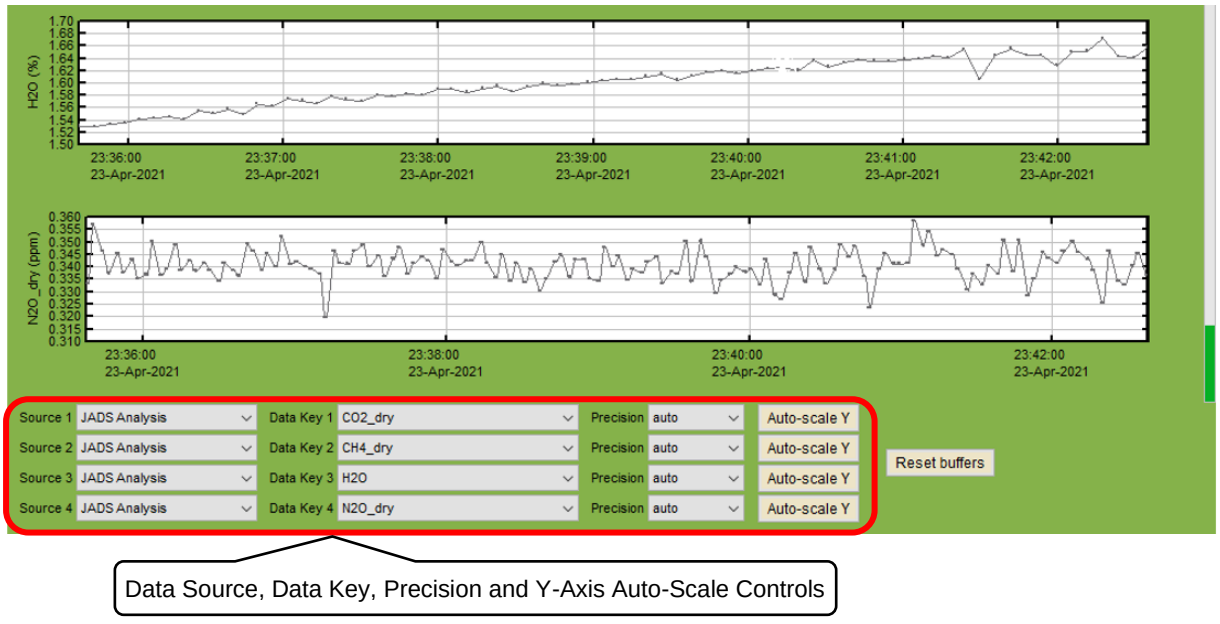


Figure 27: Data Window Panel

6.8 Data Source and Data Key Pull Down Menus

Data Source and Data Key menus (Figure 28) enable selection of the data stream that is viewed in the data window.

- Gas concentrations if 'instrument Analysis' (where instrument 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**.

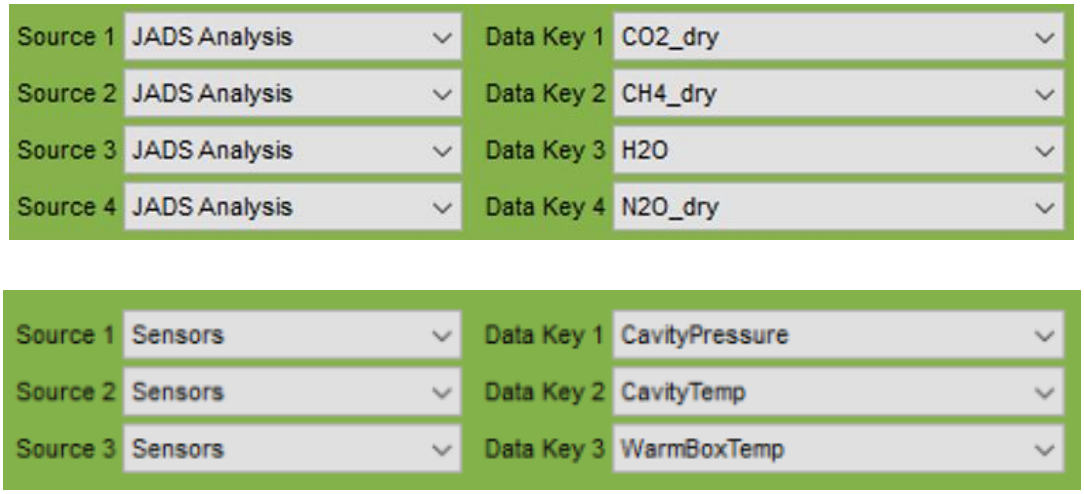


Figure 28: Data Source and Data Key Pull Down Menus

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.

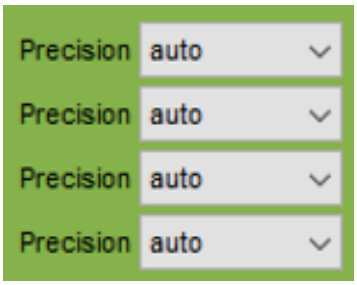


Figure 29: Precision Pull-down Pane

6.10 Status Log Window

This window displays instrument status messages, in the following form: **MM/DD/YYYY, 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.

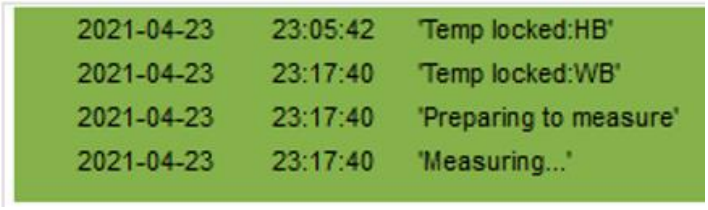


Figure 30: Analyzer Status Log

6.11 Data Buffer Level Meter

The meter to the right of the Data Window (Figure 31) indicates how much of the internal memory of the GUI is used to retain historical data collected with the instrument. There is an internal limit of a finite number of points. Once that number of data points is collected, the buffer is full, and old data is removed from the buffer as new data is collected. *This buffer affects only the data displayed in the data window, not the data stored in any files.* This buffer is empty upon instrument startup and can also be emptied by pressing the reset data buffer button in the lower-right-hand corner of the GUI.

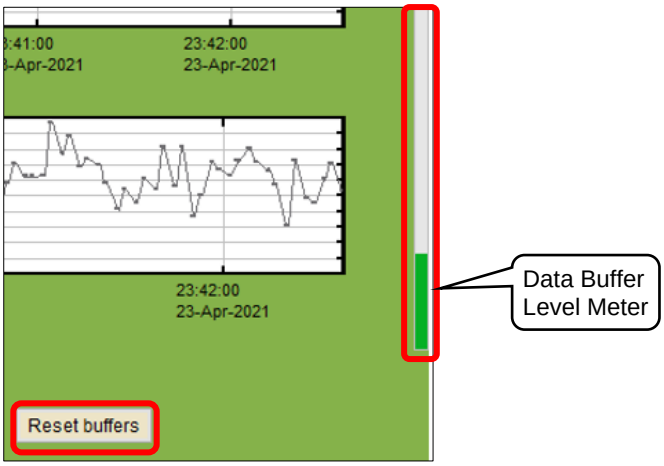


Figure 31: Data Buffer Level Meter and Reset Buffers Button

6.12 Reset Buffers 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.*

6.13 Graph Zooming

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 32). When the box is drawn, release the left button and the boxed area will automatically scale to fill the data window.

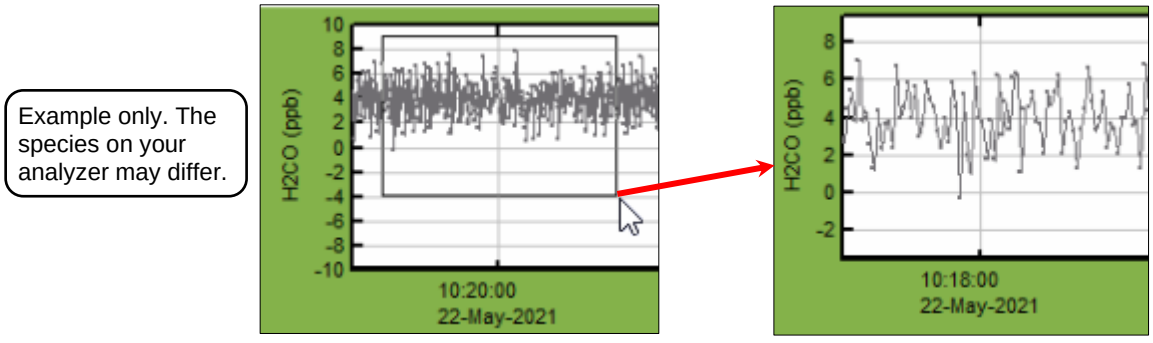


Figure 32: Data Graph Zoom Function

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

To lock or unlock the time axis of each graph during zooming, select that menu item in the **View** menu.

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

To Zoom the X and Y axes: hover over a plot, hold down the control button and move the cursor up/down or left/right using the right mouse button. This feature can be very helpful when using the **Lock time axis when zoomed** option, as the scaling of the Y axis on a second plot doesn't always match the desired scaling to observe certain types of data.

If so, the user may hold down the control button while hovering over on a second plot, click and hold the right mouse button while moving the mouse forward, continue holding the control button, release the mouse button and pull the mouse backwards on the desk, click again the right mouse button and then repeat the forward-moving mouse movement multiple times to zoom in significantly. Interleaving this approach with the use of the control-left mouse button command makes it easy to keep centering the plot as the user zooms in.

These pan and zoom features are often useful when time axes are locked, and the user wishes to align the Y axis in multiple plots.

7. Ammonia-Specific Considerations

G2103 G2508 G2509

7.1 Sample Gas Handling for Ammonia Measurements

Adsorption and Surface Materials

Sample gas handling for ammonia measurements requires specific considerations due to the high tendency of ammonia to adsorb to surfaces, and for ammonium salts to form in filters through aerosol deposition. The high 'stickiness' of the ammonia molecule is caused by the formation of hydrogen bonds with water molecules adsorbed onto surfaces of sampling lines. On the one hand, adsorption can lead to a loss of ammonia to the inner walls of the inlet tubing. On the other hand, revolatilization of ammonia can also lead to strong memory effects.

The degree of adsorption depends significantly on the type of surface material. In both the G2103 ammonia analyzer and the G2509 multi species gas analyzer, SilcoNert coated, and Teflon parts are used to reduce adsorption. For accurate ammonia measurements, it is crucial to also avoid stainless steel and metal surfaces for any gas handling parts that are attached to the inlet of the analyzer. Instead, Picarro recommends using PTFE (Teflon) or PFA tubing, and SilcoNert 2000 and PTFE coated materials, and to keep the length of the sample line tubing as short as possible. The latter is especially important for monitoring atmospheric background levels of ammonia with the G2103. If the application requires longer sample tubes (>10 m) and/or if the analyzer is exposed to high ammonia concentrations, then heating the tubing might be an option to reduce adsorption effects.

Picarro has not tested ammonia measurement accuracy using the A0702 recirculation pump.

Flow Rate and Adsorption

Another critical parameter is the flow rate: A higher flow rate reduces adsorption effects and increases the response time of the analyzer. For the G2103 ammonia analyzer, the flow rate is increased to 1.5 L/min compared to the 240 mL/min for the standard concentration analyzers (e.g., G2308 and G2508). The G2509 analyzer operates at a flow rate of about 1.3 L/min. For some setups with long tubing attached to the inlet of the analyzer, it can be beneficial to increase the flow towards the analyzer with an additional assist pump, and to tee off to the analyzer immediately upstream of this pump.

7.2 Sample Filtration

Internal PFA Filter Replacement Frequency

The G2103 and G2509 ammonia analyzers have two built-in, sub-micron Teflon filters that remove particulates from the gas sample stream. The first filter is user-replaceable, and it can be purchased via the Picarro webstore. To purchase, visit store.picarro.com and enter S1021 in the Keyword Search pane. If viewing this manual in PDF format, click on this direct link: Picarro Store – S1021 Particulate Filter.

External PFA Filter

For ammonia-specific work, an additional external S1021 filter should always be affixed to the inlet of the analyzer and replaced after two weeks of use. The filter can be purchased in a pack of 10 (roughly a 6 month supply), with part number S3174.

The use of this external filter is critical for reducing the buildup of ammonium salts in the Teflon membranes, as ammonia can be revolatilized by ambient moisture, leading to phantom ammonia readings in ammonia-free gas streams. The use of a third external filter reduces the complexity of the replacement process, so that customers do not need to shut down and open up the Picarro instrument to change the inlet particulate filter. As noted above, the internal inlet particulate filter should still be replaced yearly.

NOTE

We highly recommend discussing the best practices for ammonia measurements with a Picarro application scientist to ensure the highest level of data quality for your continuous ammonia measurement needs. To do so, please reach out to support@picarro.com.

7.3 Managing Multiple Sample Sources

Monitoring ammonia concentrations at different sample inlets requires the use of a manifold. The Picarro A0311-S 16-Port Distribution Manifold (Silco) for 'sticky' gases was designed to reduce memory effects: All surfaces are coated with SilcoNert, and a flow-through valve body ensures a continuous flow through all sampling lines, i.e., one gas line is routed through the valve into the analyzer and the remaining 15 gas lines are routed towards a vacuum pump attached to the manifold (Figure 33).

For detailed information on connecting to multiple sample sources, Refer to ***APPENDIX D – External Valve Sequencer***.

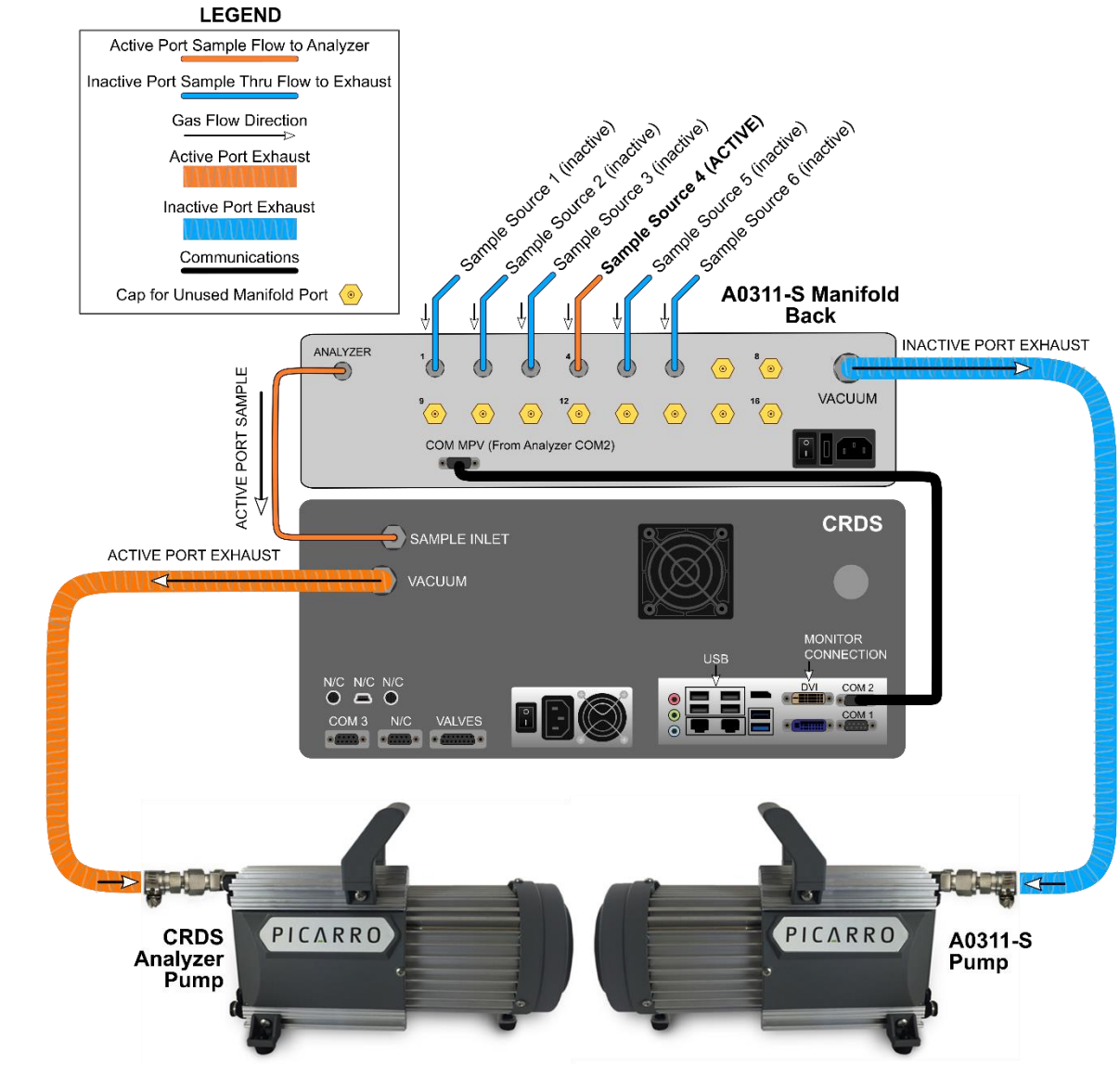


Figure 33: Multiple Sample Handling Configuration using A0311-S

8. File Management

The Analyzer generates various ASCII-format text output files that are updated after each batch of concentration measurements is complete. The data files are stored in UserData folders and Archive folder. The UserData files and folders are user customizable, meanwhile the Archive always stores all the data and serves as an internal backup.

8.1 User Data Folder

The User Data folder is located at:

C:\UserData\DataLog_User - with files arranged by year\month\day\hour.

The User Data 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 **Setup Tool**, the user can select and customize the data columns, file length, total storage size and folder structure for the user data logs. Setup Tool is described in more depth in ***APPENDIX A – Setup Tool and Communication*.**

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

8.2 Data File Names

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

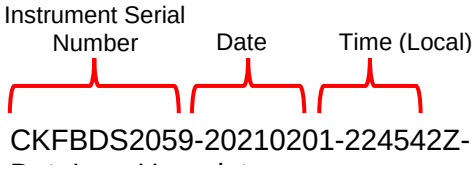


Figure 34: Example Data File Name

- **CKFBDS2059** is the analyzer serial number
- **20210201** is the date, 02/01/2021, in format *yyyymmdd* (to allow chronological sorting of data files).
- **224542** is the time the file was started in Local Time, 22:45:42, formatted as *hhmmss* using a 24-hour clock.

8.3 Data Archive

The archive directory is:

C:\Picarro\G2000\Log\Archive

and has subdirectories:

DataLog_*Mailbox, DataLog_Private* and *DataLog_EventLogs* with files arranged by year\month\day\hour.

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:

C:\Picarro*G2000\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.

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, 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. In your Picarro GUI, navigate to:

Tools → User Calibration → (password: picarro) →

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

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, and not exceeding 10 psig. Picarro recommends e.g., the Q1-14B-590 or Q1-14B-580 regulator from Airgas/Scott, which can be purchased as part of the A0921, A0923, or A0925 gas kits from the Picarro Web Store. Enter http://store.picarro.com/ in your web browser, then once at the store homepage, enter one of the above gas kit part numbers in the Keyword Search field.
- 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. Disconnect the tubing from the instrument inlet.
2. Turn off the main cylinder valve on the current cylinder.
3. 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.
4. Disconnect the pressure regulator from the tank.
5. Connect the pressure regulator assembly to the next gas tank,
6. Flush the regulator with the new gas, following the instructions mentioned in the previous section.
7. 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. Some of these points can be used for recalibration, while the remaining points can be used as quality control calibrants. In an ideal situation, three concentration certified standards should be analyzed on the system to generate CRDS-reported values for concentration. Standards spanning and encompassing the intended sample analysis should then be used to build a standard calibration curve. Parameters of this curve will then be used to correct the instrument readings so that they match standard values. The other standards will be simultaneously used for quality control, to verify other recalibrated values against their certified values.

NOTE

The following steps illustrate the Data Recal procedure for 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 or isotope 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 can be found in the **Picarro Utilities** folder on the desktop. The Data Recal software utility can be launched by double-clicking on the **Data Recal** icon in the folder. Shown in Figure 35 below is a screenshot of the window that will open.

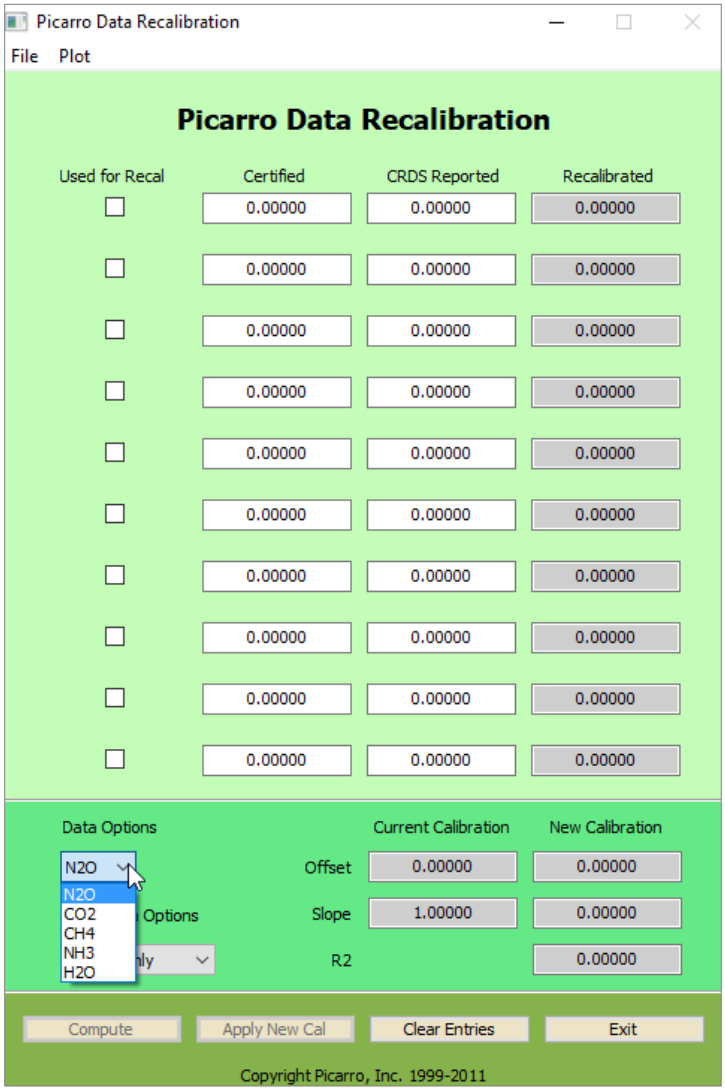


Figure 35: Data Recal Software Utility GUI

The Data Recal Software Utility consists of three sections:

1. **Numerical Input** and **Selection** sections (Figure 36):

   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.

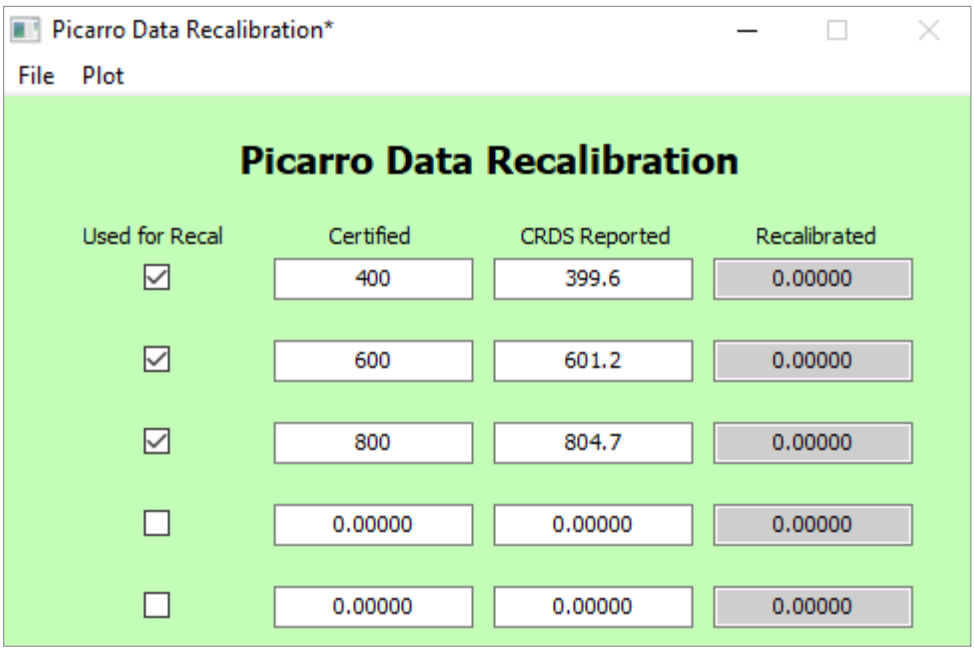


Figure 36: Recalibration Section of Data Recal Software Utility GUI

2. **Calibration Output** Section (Figure 37):

   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** is 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).

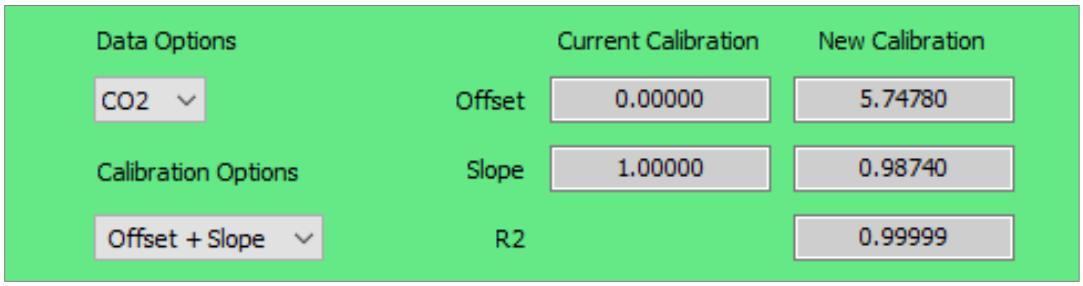


Figure 37: Calibration Output Section of Data Recal Software Utility GUI

3. **Action Selection** Section (Figure 38):

   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 36), 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 36), indicating the new change.

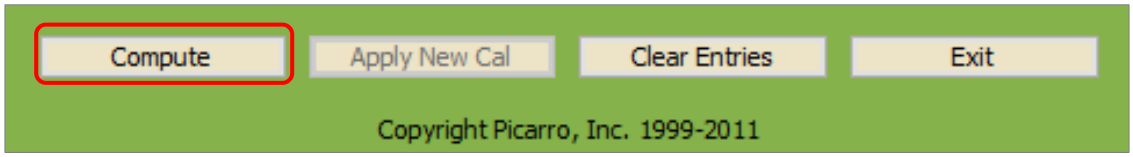


Figure 38: Action Selection Section of Data Recal Software Utility GUI

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 39 below.

Figure 39: Data Recalibration – Plot Linear Fitting

The plot that the utility will generate is shown in Figure 40; this plot will display two graphs. The top graph presents measurements for the recalibrated standards (calibration and QC), as well as a line fit through those points. The bottom graph shows the residuals, which shows how far each measurement is from the best-fit line.

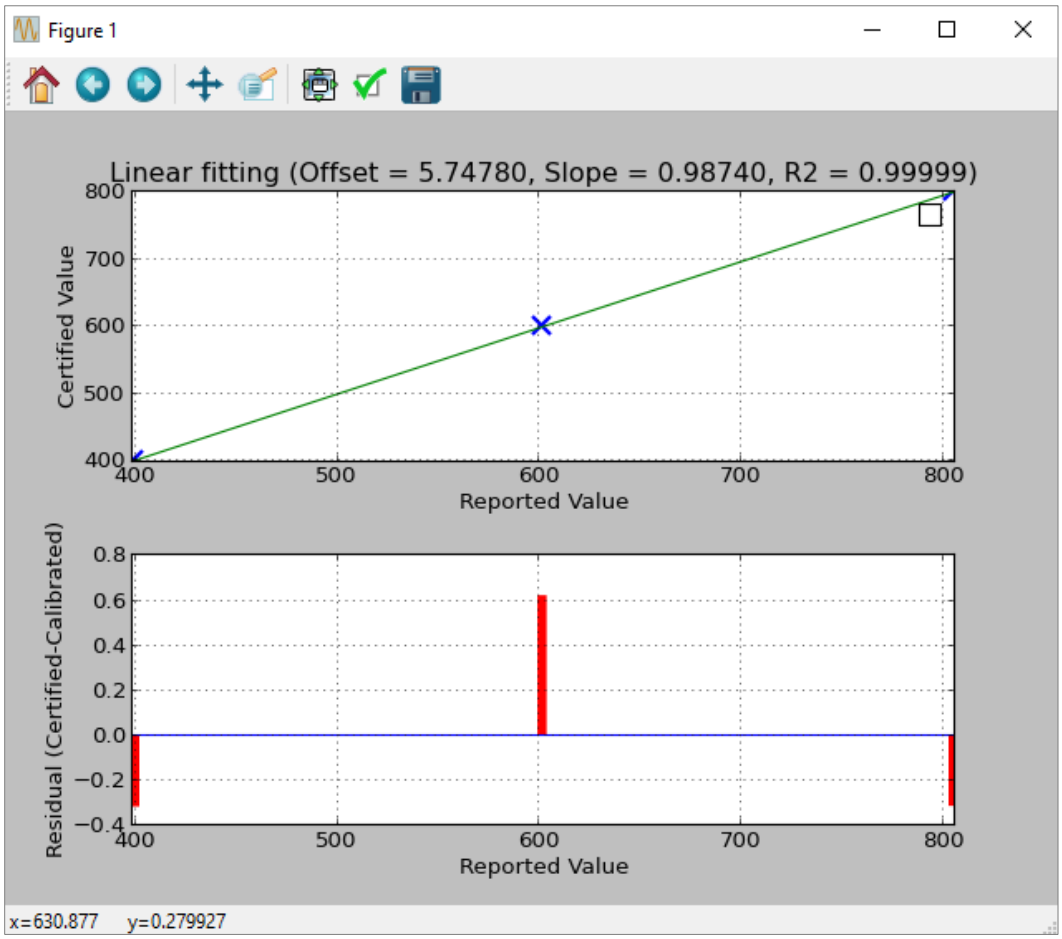


Figure 40: Slope of Data Recalibration

If the user decides to accept the new calibration values based on this plot, they may click on the **Apply New Cal** button (Figure 41).

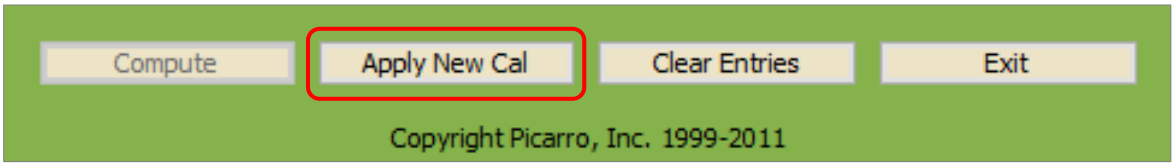


Figure 41: Apply New Calibration Slope and Intercept

The user will then be prompted to enter a Calibration Password (Figure 42). The default Calibration Password is **picarro**, all lower case.

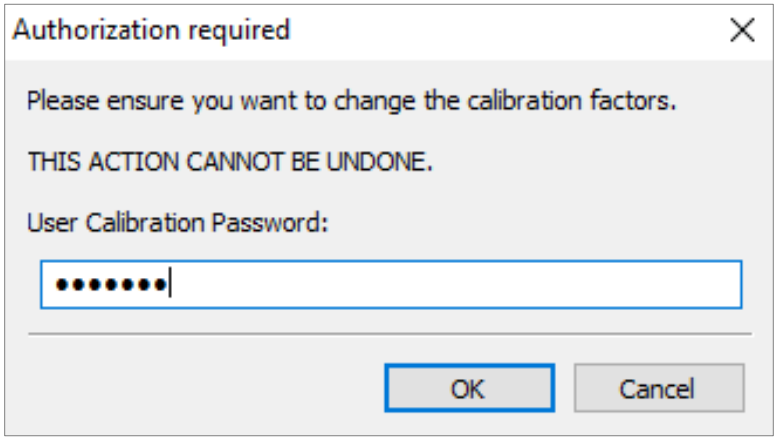


Figure 42: User Authorization Dialog

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.

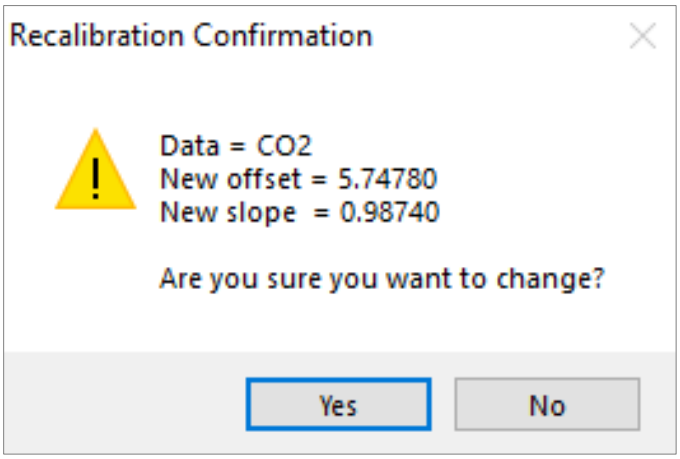


Figure 43: Calibration Confirmation Pop-up

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 44 below). Saving these files enables the user to track the instrument recalibration history.

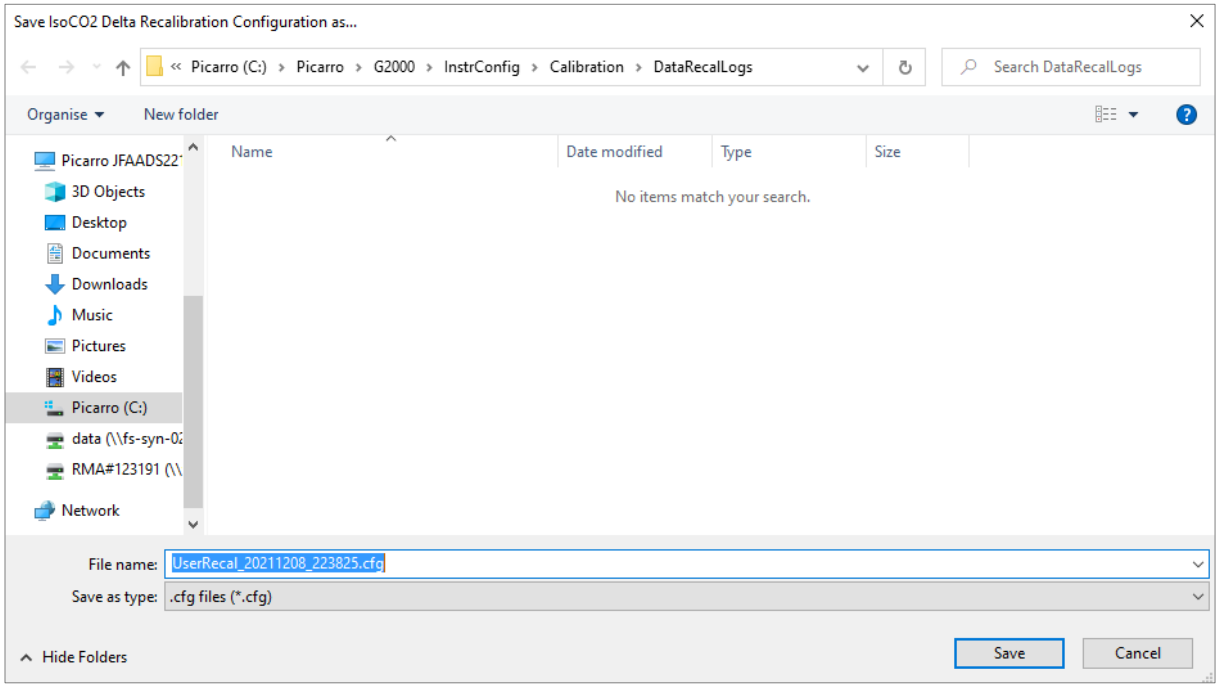


Figure 44: Data Recalibration Save-As File Dialog

The recalibration file for this example would contain the information as shown in Figure 45 below.

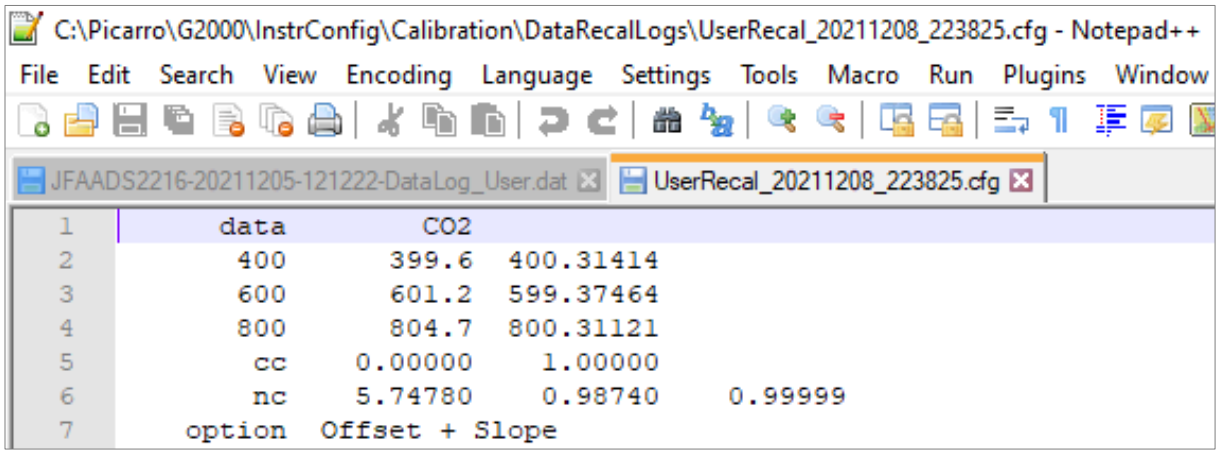


Figure 45: Data Recal Log File Example

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 46). This window contains a warning that continuing to exit will cause the new calibration data to be lost:

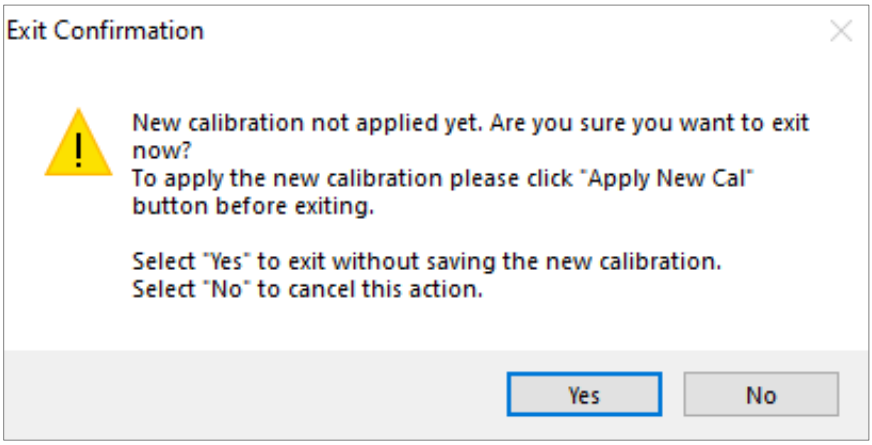


Figure 46: Recalibration Exit Confirmation Pop-up

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.

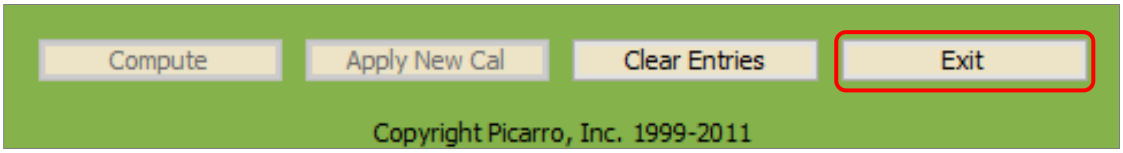


Figure 47: Exit Data Recalibration Utility

NOTE

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

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

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

c. **The "Offset + Slope" calibration option is selected. This error occurs because the entered values will lead to an erroneous zero-slope value.**

Loading a Previous/Stored Calibration

Saved calibration configurations can also be reloaded by clicking **File** in the upper left corner of the window (Figure 48) and selecting **Load Recalibration File**.

Figure 48: Data Recalibration Load File

From the load file dialogue, the user may select and open the file they wish to load (Figure 49).

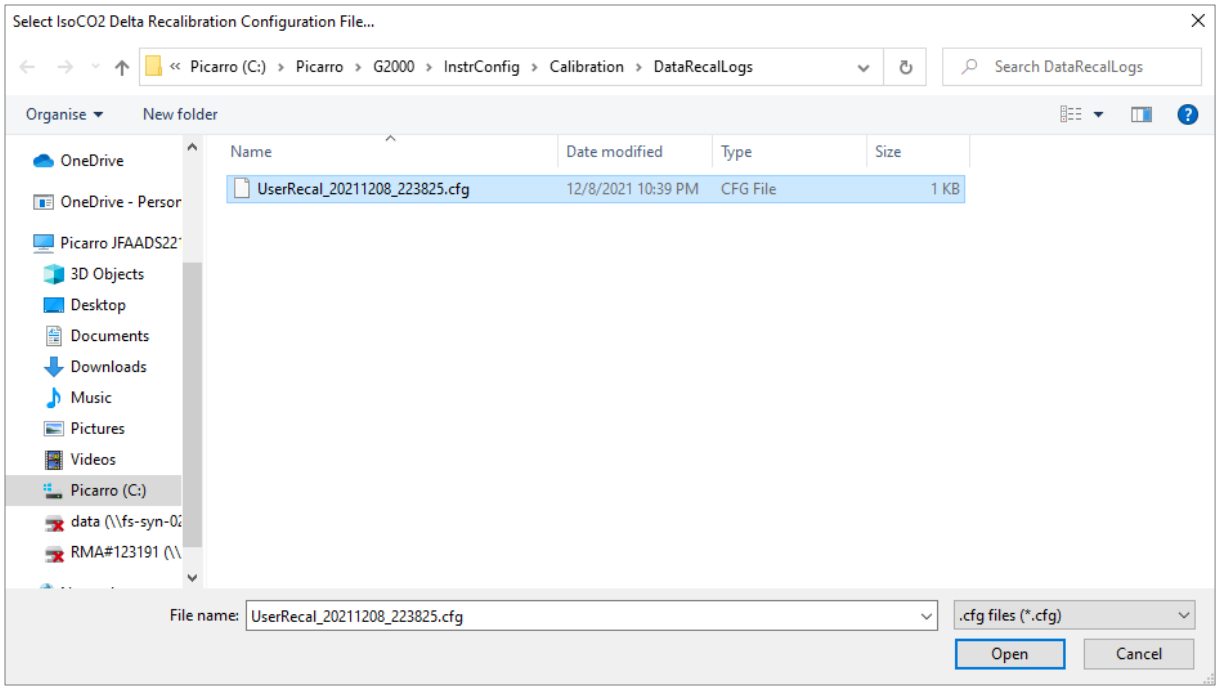


Figure 49: Data Recalibration Load File Dialog

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 59) 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 50 below, this calculation would be accomplished point-by-point by calculating the corrected data "**y**" using the analyzer's data "**x**" so that:

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

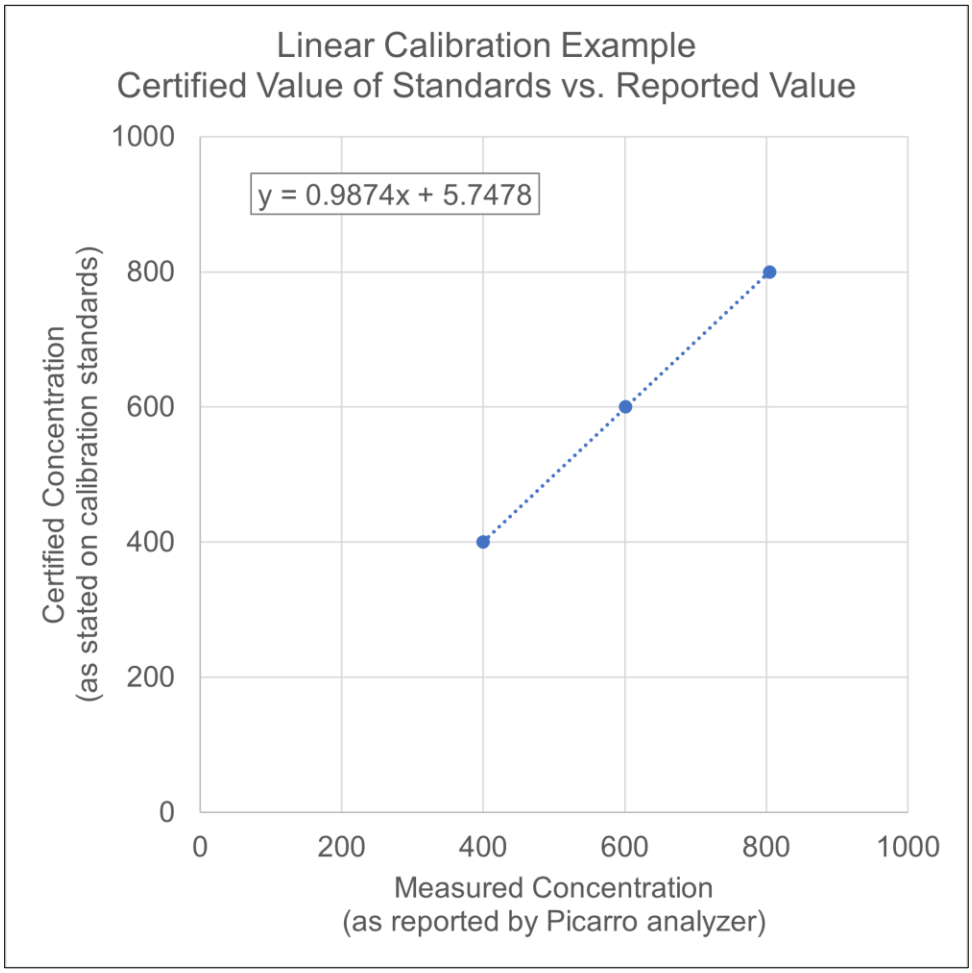


Figure 50: Linear Calibration Example

Calibration values are input into the analyzer by selecting **Tools → User Calibration** from the main Picarro GUI, 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

9.7 Surrogate Gas Validation G2103

Picarro's CRDS technology guarantees unmatched long-term stability because of a very precise cavity temperature and pressure control, and the ability to generate a clean stable frequency. Overall, this greatly reduces the need for analyzer calibration. For the G2103 analyzer, we recommend verifying the performance of the analyzer on a yearly basis. Calibrating or verifying the calibration of ammonia measurements is generally challenging due to the reactive nature of ammonia (e.g., it is difficult to keep ammonia standards stable for more than a few months). The Picarro G2103 ammonia analyzer was designed with this challenge in mind: The accuracy and linearity of the analyzer can be validated using a surrogate gas, in this case CO_2. Carbon dioxide is a non-reactive, commercially available gas that has an absorption spectrum adjacent to ammonia. Therefore, the performance of the analyzer can be validated by measuring air standards with varying carbon dioxide concentrations instead of measuring ammonia standards. The surrogate gas validation approach ensures an easy and straightforward validation of the ammonia signals on the G2103.

Zero-point validation of ammonia measurements is also challenging because high-grade zero air standards usually contain several ppb of ammonia. Picarro recommends purifying the zero air further using Phosphoric Acid Impregnated Activated Charcoal (PAIAC).

NOTE

More details on best practices for the surrogate gas validation and the zero-point validation are given in our technical guide titled: *Rapid Analyzer Validation Using a Traceable Surrogate Gas Approach.* Following is the link to the document:
https://www.picarro.com/Surrogate-Gas-Validation

Also, a supplemental surrogate gas validation Excel worksheet can be used in conjunction with the above technical guide. Following is the link to the worksheet:
https://www.picarro.com/Surrogate-Gas-Validation-Worksheet

The link will open the worksheet in your web browser, but the file can be saved to your PC for opening in Excel for use.

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 front panel power switch should apply power. The green power LED is illuminated when it detects the correct power levels.

1. Check that the AC power cord is attached and plugged into a working outlet.
2. 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 User Interface Program Does Not Start

Context: The computer may be configured to start the instrument and the associated user interface program automatically after it completes its boot-up sequence, or the program may be launched using the **Start instrument** icon on the desktop.

Communications problems with the analyzer may occur if the analyzer fails to initialize correctly on power up. Should the analyzer initialization process not complete correctly, shut down the instrument by shutting down the Windows operating system on the control computer:

NOTE

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

1. Using the Start menu, select the red **Shut Down** button and select **Shut Down** in the drop-down box under “What do you want the computer to do?” Wait for the shutdown to complete normally and for the computer and analyzer to turn off completely.
2. After a few seconds, restart the computer by momentarily depressing the power button.

10.3 Sample Pressure not Controlled to Appropriate Value for Concentration Measurements

Context: Under normal operation, the cavity pressure is automatically locked to the correct value by means of electronically controlled inlet and outlet valves. The message **Pressure Locked** on the front panel display and the user interface indicates that the cavity pressure is at the appropriate value. 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 spec. If removing plumbing from upstream of the instrument inlet doesn't work, the inlet particulate filter may need to be replaced. See ***Section 11.1, User-Replaceable Hardware***.
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.

10.4 User Interface Program "Freezes"/Won't Update Graphs as Data are Collected

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

1. Re-setting the computer and the instrument requires that the computer be shut down and restarted. If the computer responds to the mouse, a normal Windows shutdown may be carried out. Use the Start menu, select the red **Shut down** button and select **Shut down** in the drop-down box under "What do you want the computer to do?" Wait for the shutdown to complete normally and for the computer and analyzer to turn off completely. After a few seconds, restart the computer by momentarily depressing the power button.
2. If the computer does not respond to the mouse, hold down the power switch on the front panel for a few seconds until the computer and the instrument turn off. After another few seconds, restart the analyzer by momentarily depressing the power button.

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.

11.1 User-Replaceable Hardware

Particulate Filter

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

- 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

CPU Fan

The analyzer CPU fan is user-replaceable. Use the following link to order replacements and to find the instructional video and supporting maintenance document.

- CPU Fan: For MI970 Motherboards:

  S0060 CPU Fan – If viewing this manual as a paper hard copy, enter the following URL in your browser:

  http://store.picarro.com/For-Analyzer/Parts/CPU-Fan.html

A2000 Pump Rebuild Kit

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

11.2 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 **Shutdown** button located on the left side of the Data Viewer window.
2. A window will pop-up (Figure 51) prompting the user to confirm the shutdown. Once confirmed, the analyzer software and hardware will turn off.

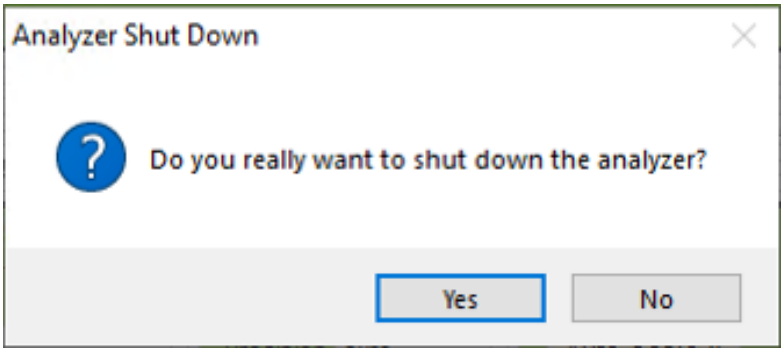


Figure 51: Shutdown Confirmation Pop-Up Dialog

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 Tool and Communication

A.1 Setup Tool

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

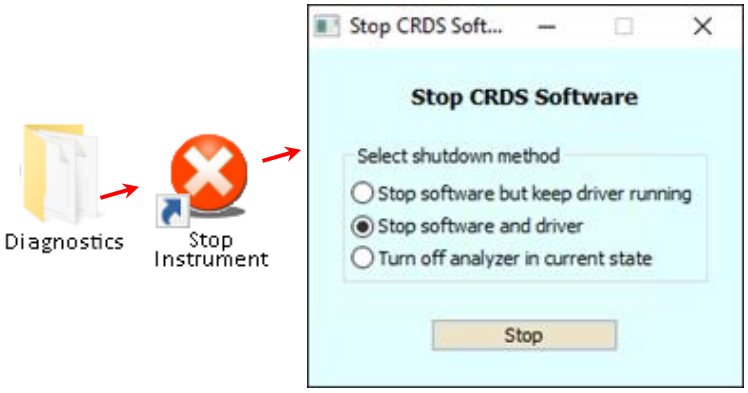
Seven tabs of the Setup Tool Window are explained in the next pages in brief. A more in-depth description of the material is provided in the subsequent section. If you have any questions about the Setup Tool, please contact Picarro or refer to Picarro Community for further details.

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

NOTE

Before running the Setup Tool, the instrument software and drivers must be stopped.

From the desktop, open the *Diagnostics* folder, double-click on the *Stop Instrument* icon. The *Stop CRDS Software* window appears. Select the radio button "*Stop software and driver*," then click the *Stop* button.



Data Logger Tab

Configuring Data File Saving Details with Data Logger

The **Data Logger** tab (Figure 52) allows the user to configure various data file saving details, including which data elements are written to data files.

- **Data Columns:** Controls which data elements are written to data files.
- **Hours of Each Log File:** Controls the size of each data document.

- **Enable Mailbox Archiving:** Enables archiving of data in the mailbox folder – C:\Picarro\G2000\Log\Archive\DataLog_Mailbox
- **Archived Directory Structure:** Specifies part of naming convention for data documents.
- **Total User Log Storage Size (GB):** Specifies the size of storage allowed for User Data (Recent Data).
- **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 **Apply** to put changes into effect and then **Exit** to close the window.

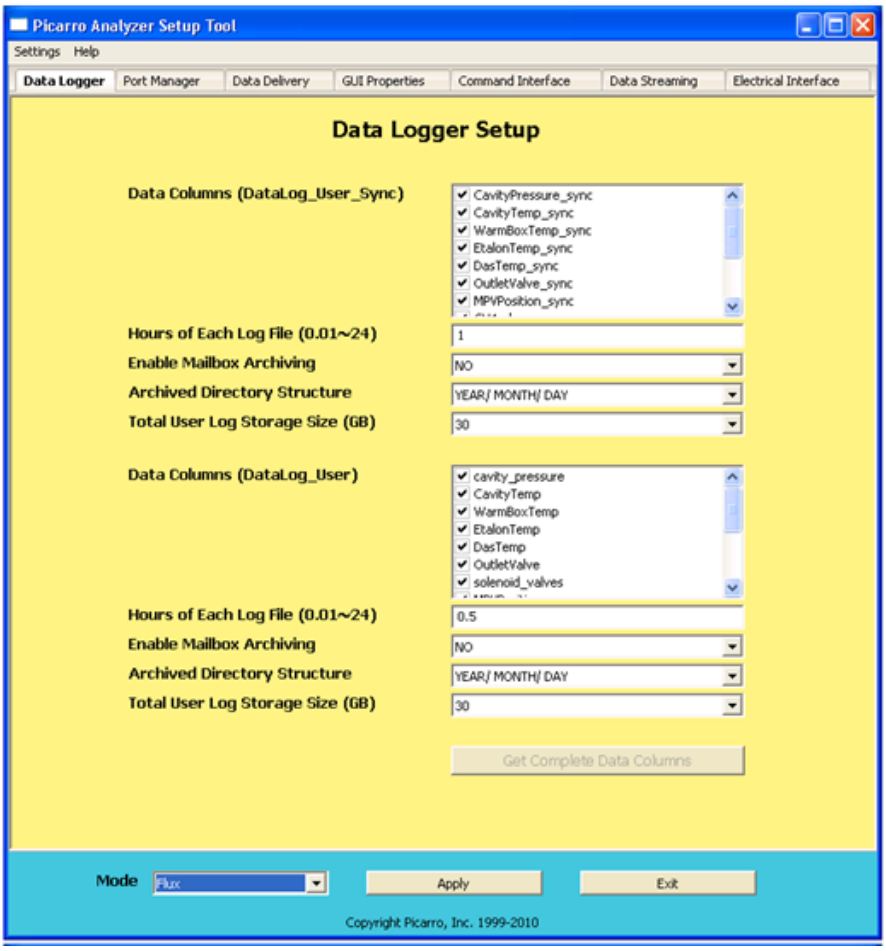


Figure 52: Data Logger Setup Window

Port Manager Tab

Managing Ports for Digital Data Output/Input and Serial Communication with Port Manager

The **Port Manager** tab (Figure 53) 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 D – External Valve Sequencer***.
- **Command Interface:** (COM1/COM2/TCP/Off).

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

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

To learn more about Serial Communication, see ***Remote Data Access*** in ***APPENDIX A – Setup Tool and Communication***.

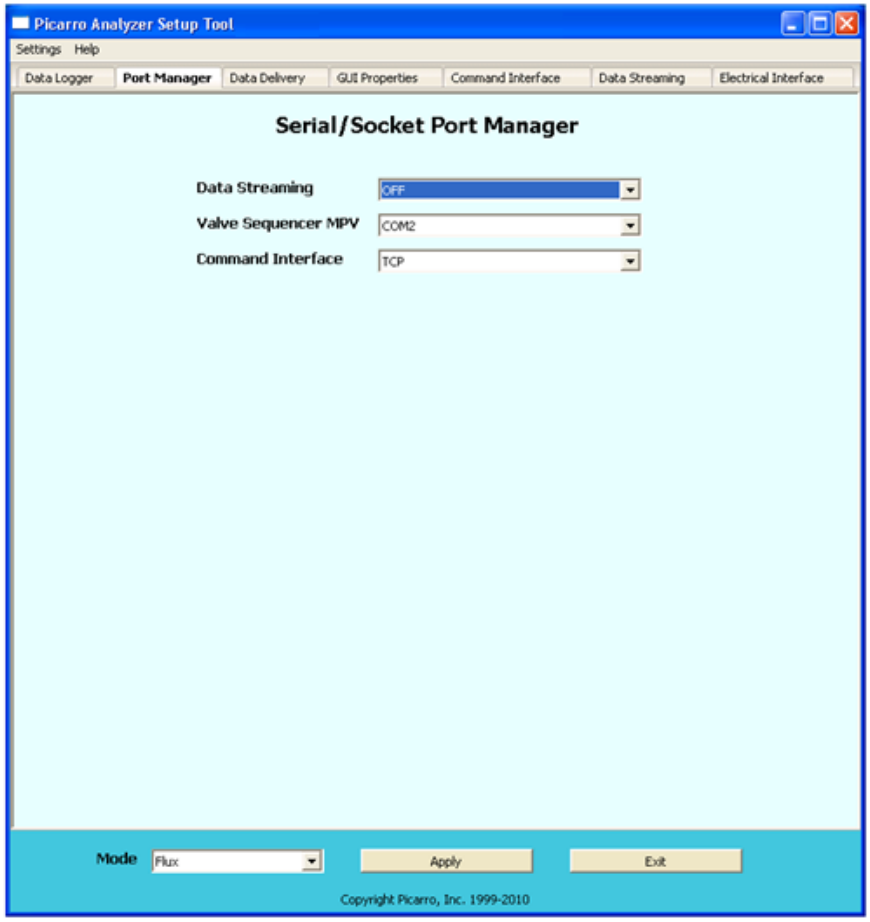


Figure 53: Serial/Socket Port Manager Window

Data Delivery Tab

The **Data Delivery** tab (Figure 54) allows the user to schedule remote data delivery (email).

- **Delivery Start Time:** Time of the day when data will be sent.
- **SSL:** Depending on the sender's email server, the sender can activate the Secure Sockets Layer (SSL).
- **Use Authentication:** Turning this on will require the receiver to provide a password and a username to access data. Set up the password and Username from this window.
- **From:** Sender's email
- **To:** Receiver's email.
- **Subject:** subject line of the email.
- **Data Directory:** Location of the data you want email.

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

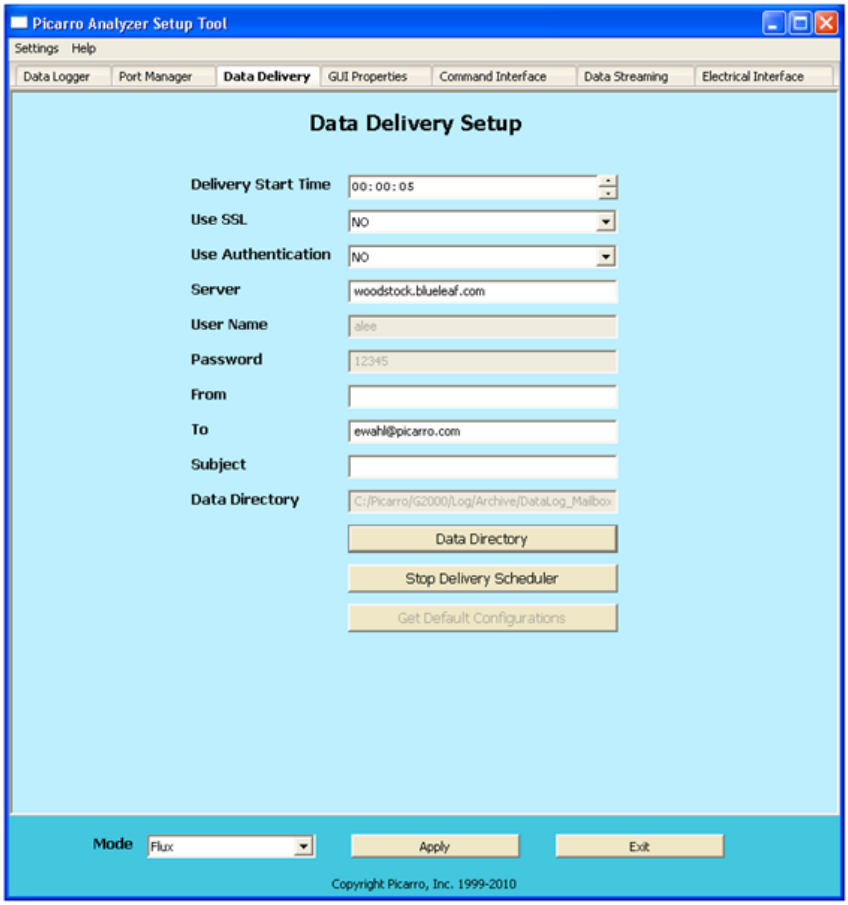


Figure 54: Data Delivery Settings Tab

GUI Properties

The **GUI PROPERTIES** tab (Figure 55) allows you to set the number of graphs displayed and to enable the control of Valve Sequencer from the main GUI.

Number of Graphs: Set the desired number of line graphs to be visible on the main GUI.

Enable Control of Valve Sequencer: To make the Valve Sequencer menu item visible under the **Tools** menu of the main GUI:

3. Click on **Settings** of the **Setup Tool** window, and then **Switch to Service** mode.
4. Choose **Yes** next to **Enable Control Valve Sequencer** drop down menu on the **GUI Properties** tab.
5. Click **Apply** to put changes into effect and then **Exit** to close the window.

You should now be able to access the **Show/Hide Valve Sequencer GUI** menu from the main GUI under the **Tools** menu**.**

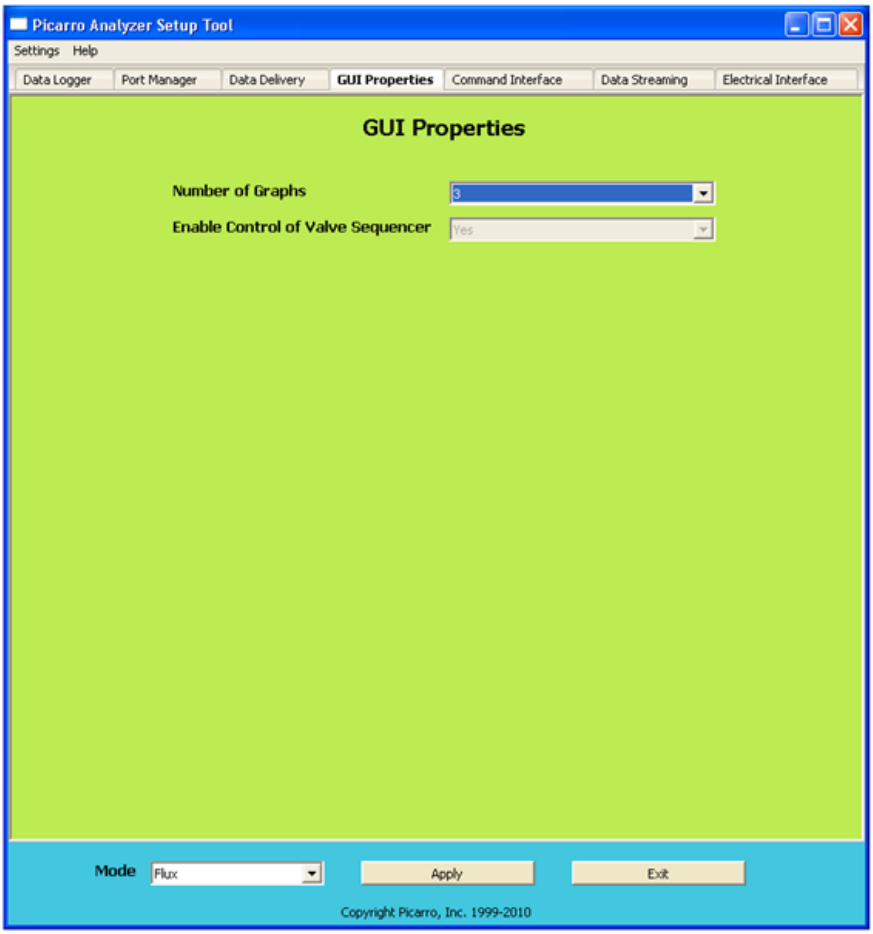


Figure 55: GUI Properties Settings Tab

Command Interface – Specifying Digital Data Output

The **COMMAND INTERFACE** tab allows you to specify the data elements that are sent via COM port/TCP (specified in the **PORT MANAGER** tab). Two types of data can be specified here:

Output Data Source:

- 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 **Apply** to put changes into effect and then **Exit** to close the window.

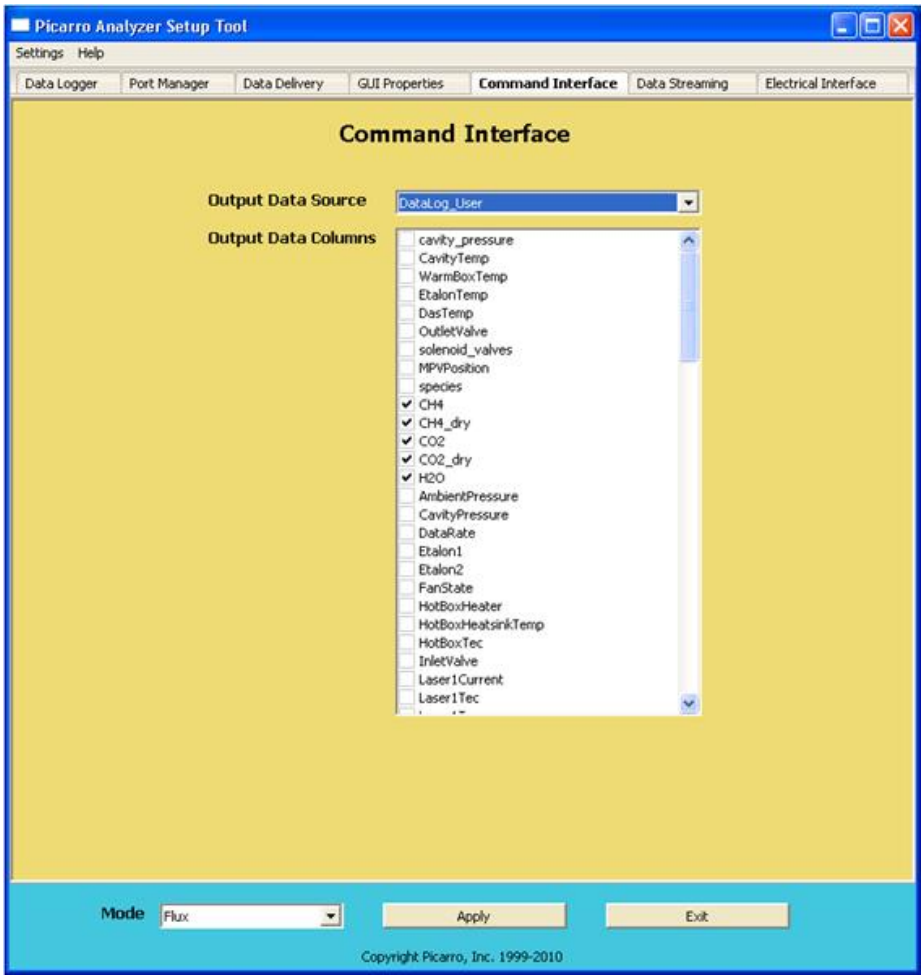


Figure 56: Command Interface Settings Tab

Data Streaming – Specifying Digital Data Output

The **DATA STREAMING** tab allows you to specify the data elements that you want to send via COM port (specified from the **PORT MANAGER** tab). 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 **Apply** to put changes into effect and then **Exit** to close the window.

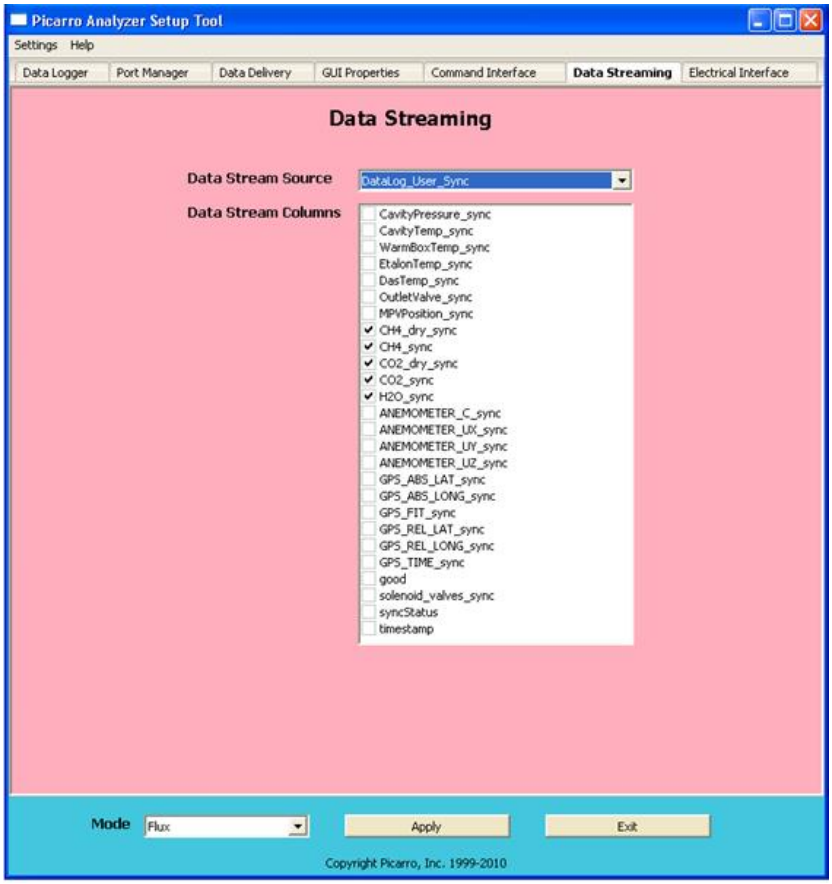


Figure 57: Data Streaming Settings Window

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** tab (Figure 58) allows you to customize each analog output channel.

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

NOTE

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

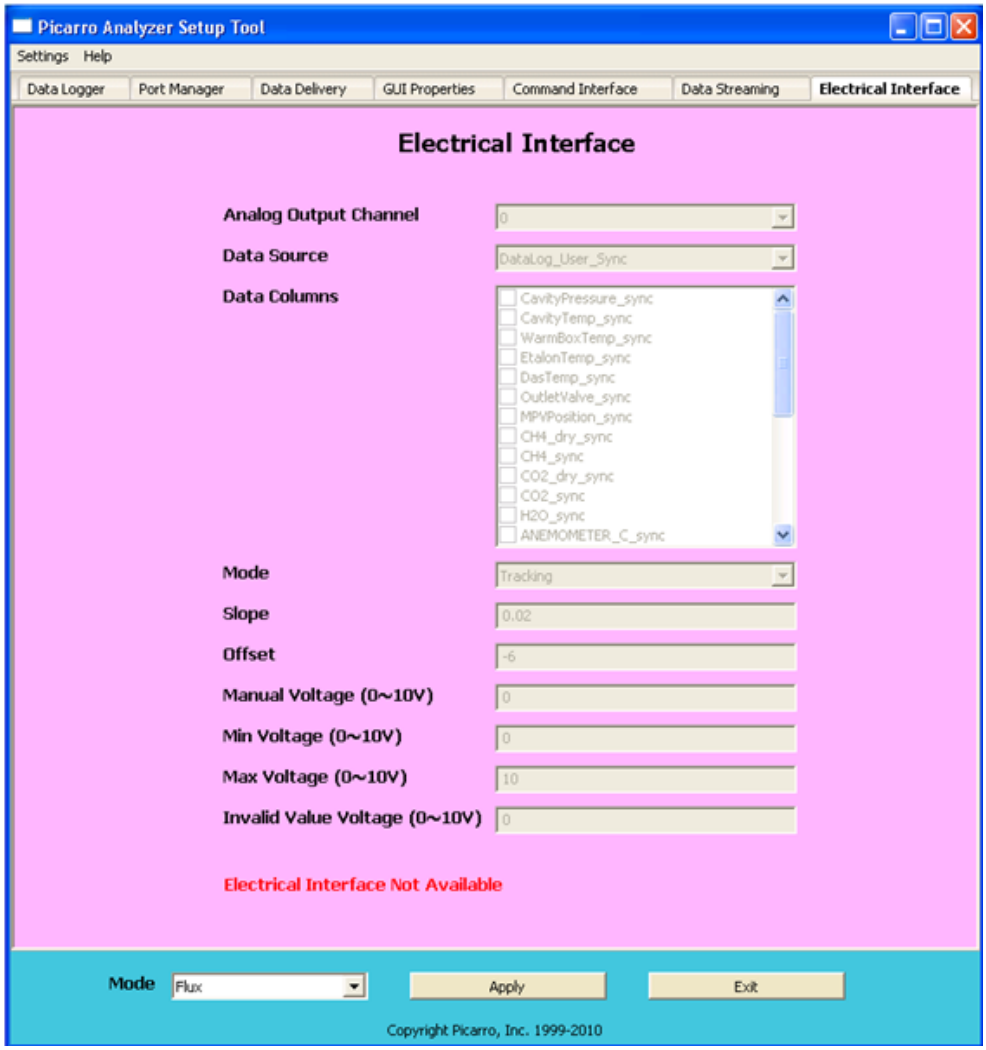


Figure 58: Electrical Interface Settings Window

A.2 Remote Data Access

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 *C:\Picarro\G2000\HostExe\RemoteAccess.exe* program. This program can be set up to run periodically using the Windows task scheduler at a user-configurable frequency. If a dial-up connection to the Internet is employed, it is used only on demand to minimize the connection time.

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

The initialization file is:

C:\Picarro\G2000\AppConfig\Config\UtilitiesRemoteAccess\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 – Data File Viewer

B.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 users to select any folder containing instrument data from a given day.

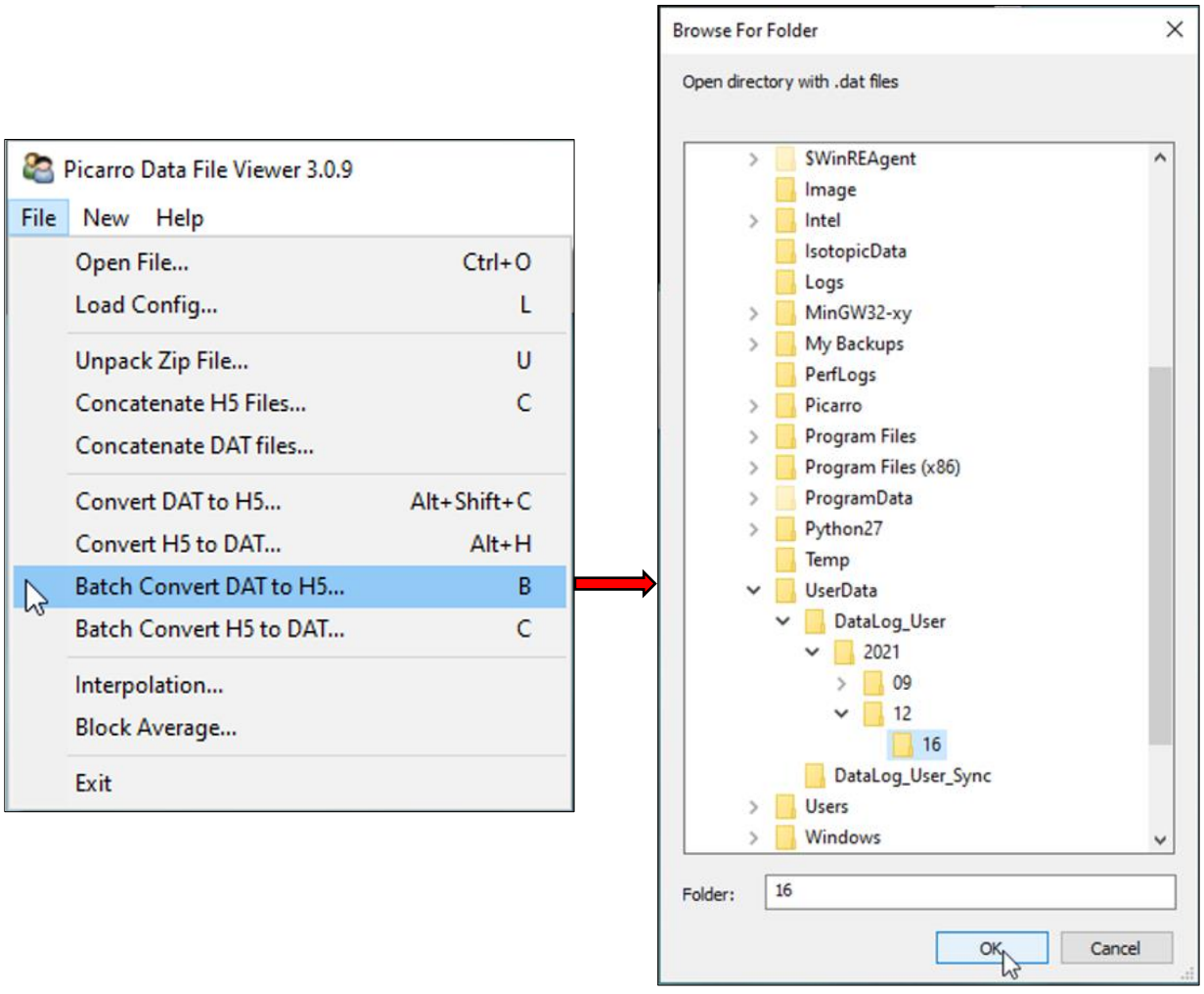


Figure 59: Batch Convert DAT to H5 – Navigation

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 very long 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 60).

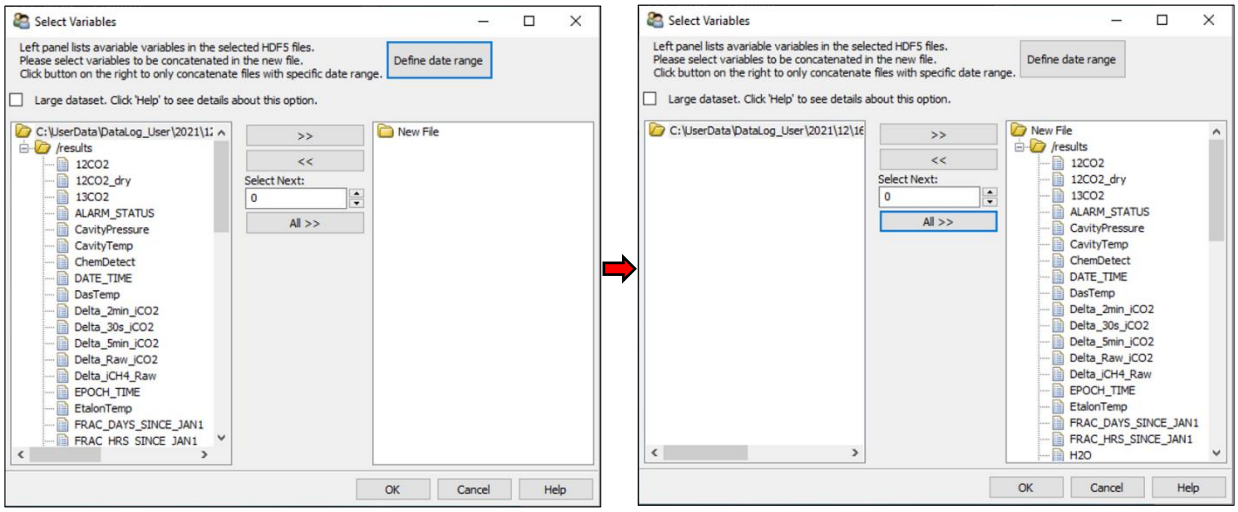


Figure 60: Selecting Variables for Concatenation

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

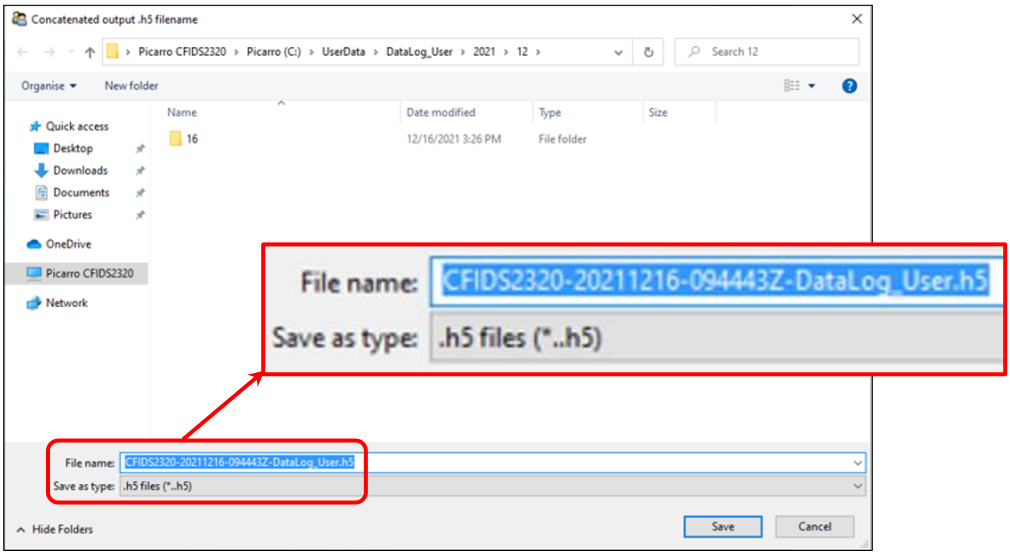


Figure 61: Concatenated Output .h5 Filename

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.

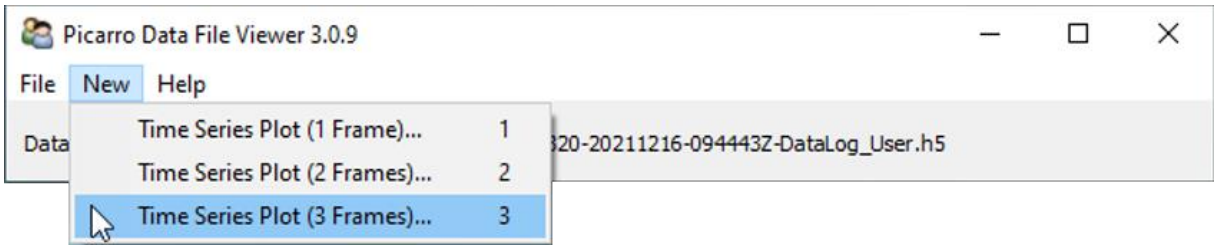


Figure 62: Time Series Selection Options

7. In the new window that appears, 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.

B.2 Data File Viewer Overview

The Picarro Data File Viewer software is located on the desktop of the Picarro instrument. The software allows the user to graph and to conduct statistical analysis of the raw data. Additional functions include Allan Variance plot and quadratic or polynomial fittings. The Picarro Data File Viewer includes two main menus: File and New (Figure 63).

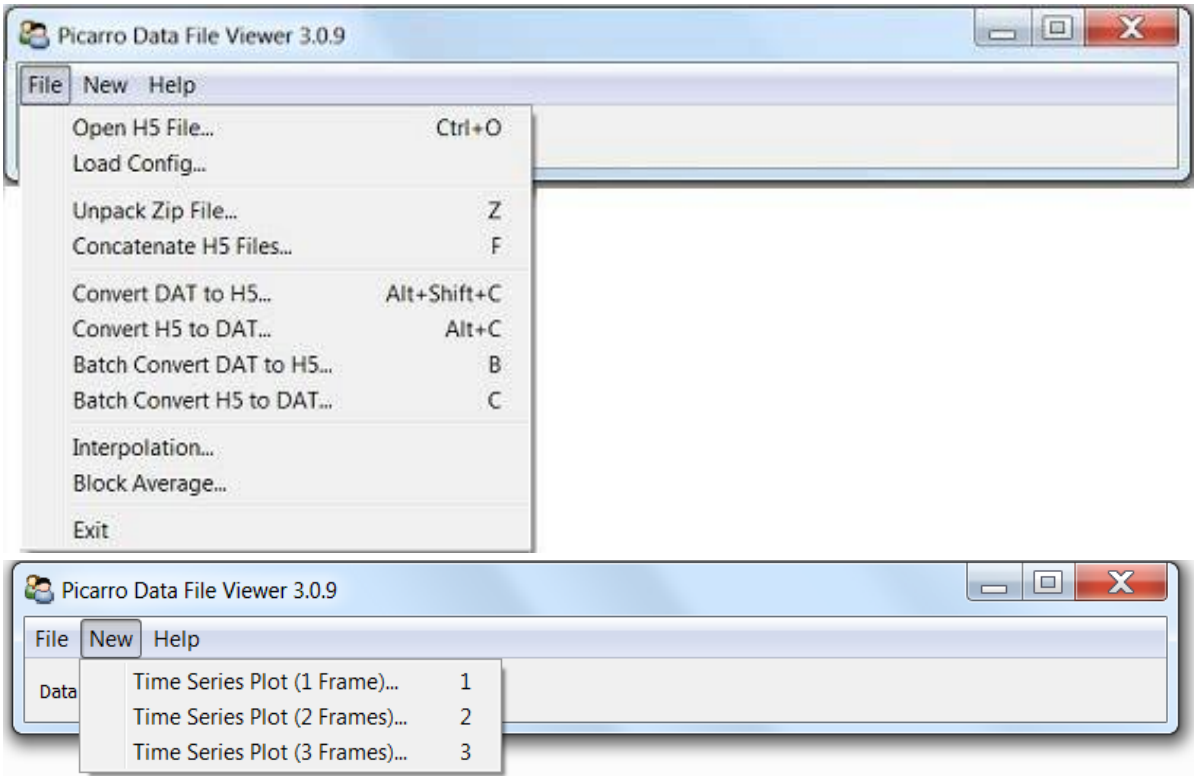


Figure 63: Picarro Data File Viewer – File and New Menus

B.3 File Menu

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

Open H5

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

Load Config

File > Load Config: Loads a configuration file (ini format) to restore parameters of a workplace. Refer to **Save Configuration** on Page 101 for more information.

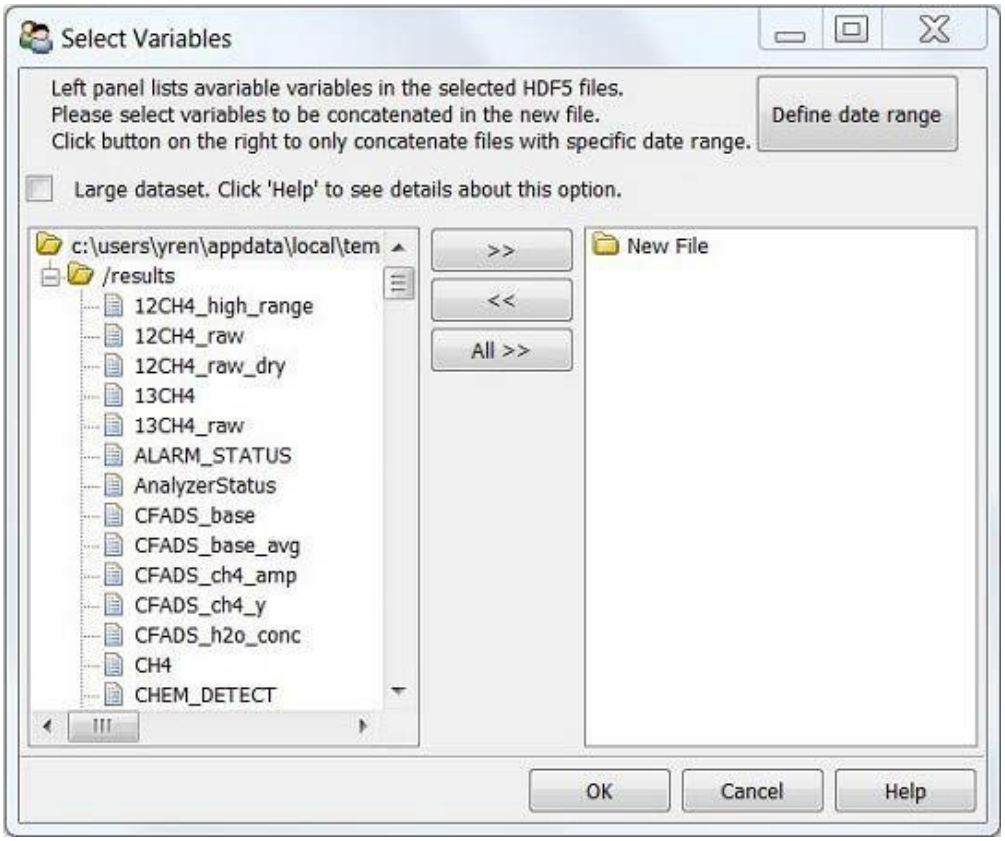
Unpack Zip File

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 64), 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 64: Select Variables Form

Define Date Range

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

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

Select File > Concatenate H5 Files, then click **Define Date Range** to specify the desired date range as shown in Figure 65.

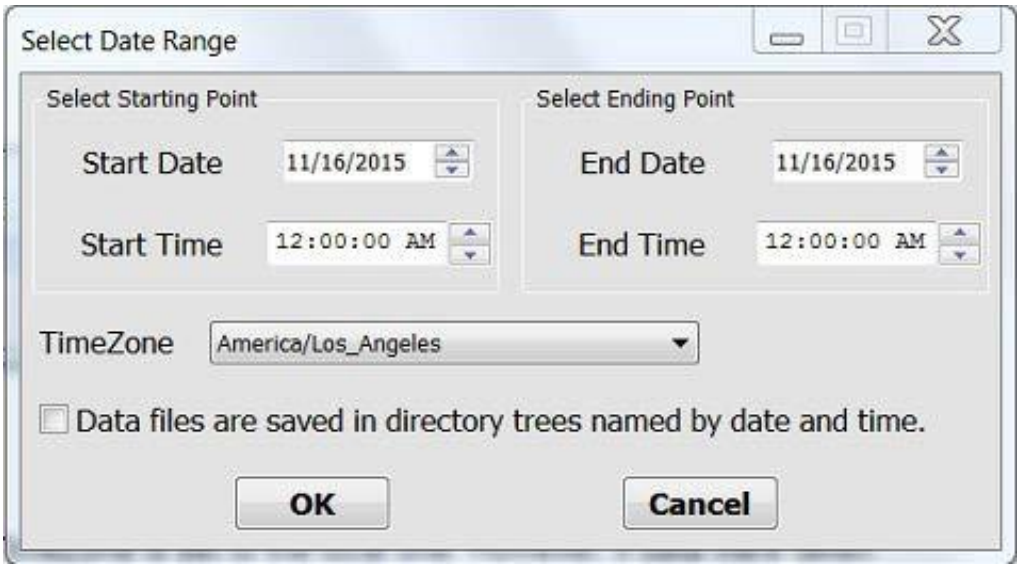


Figure 65: Define Date Range Dialog

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

Picarro software saves data in a directory tree that is named by the creation year, month, and day as shown in Figure 66. Select this option if the target folder has this file structure. This way, Data File Viewer will only search folders within the desired date range, which can substantially reduce processing time.

Figure 66: 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.

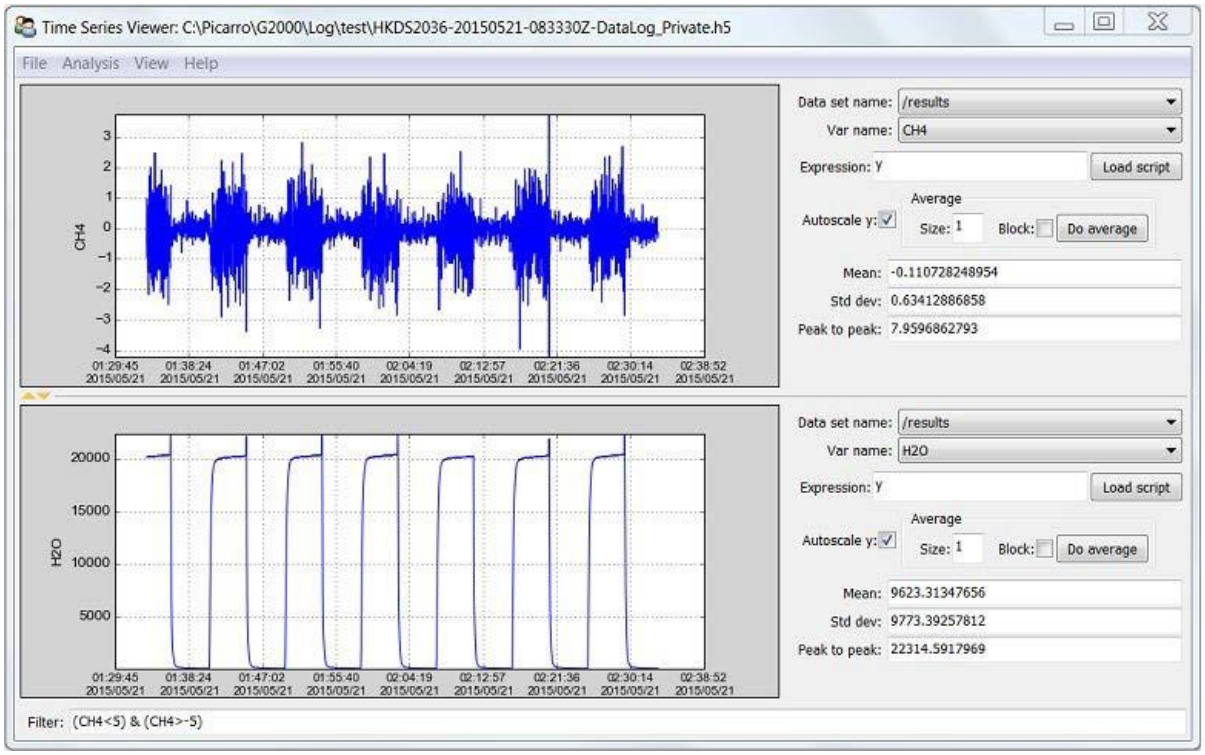
NOTE

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.

B.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 67: Time Series Viewer

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

B.5 Time Series Viewer Menus

The Time Series Viewer form includes the following menus:

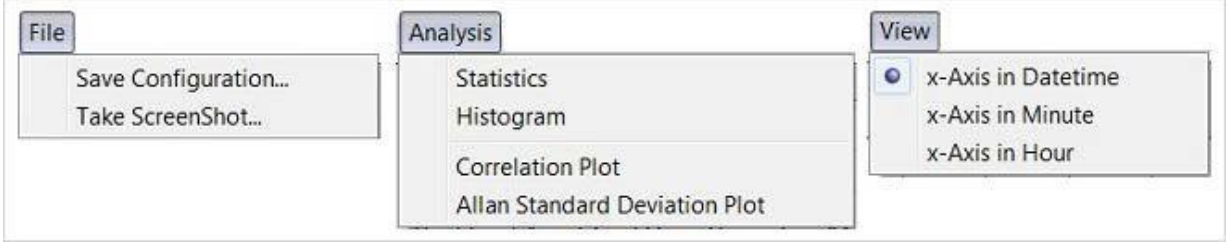


Figure 68: Time Series Viewer Menus

Time Series Viewer File Menu

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

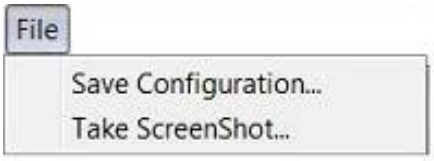


Figure 69: Time Series Viewer – File Menu

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.

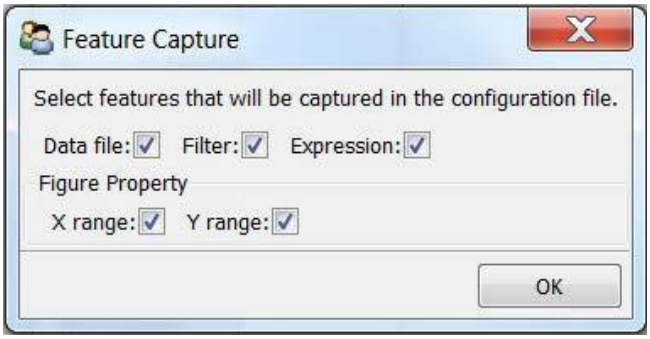


Figure 70: Time Series Viewer – Feature Capture

CAUTION

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

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

- If all features are captured, a saved workplace is reproduced.
- If Data file is not captured, saved parameters will be applied to the data file in memory.
- If Expression is not captured, plots will not be transformed.
- If X (Y) range is not captured, figures will be auto-scaled on the x (y) axis.

Take Screenshot

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

Time Series Viewer Analysis Menu

Use the Analysis menu to calculate statistics, generate a histogram, and to plot correlations and Allan Standard deviations.

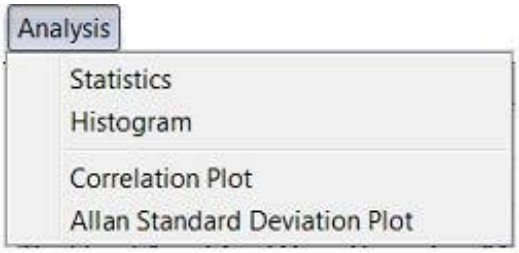


Figure 71: Time Series Viewer – Analysis Menu

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 72 below.

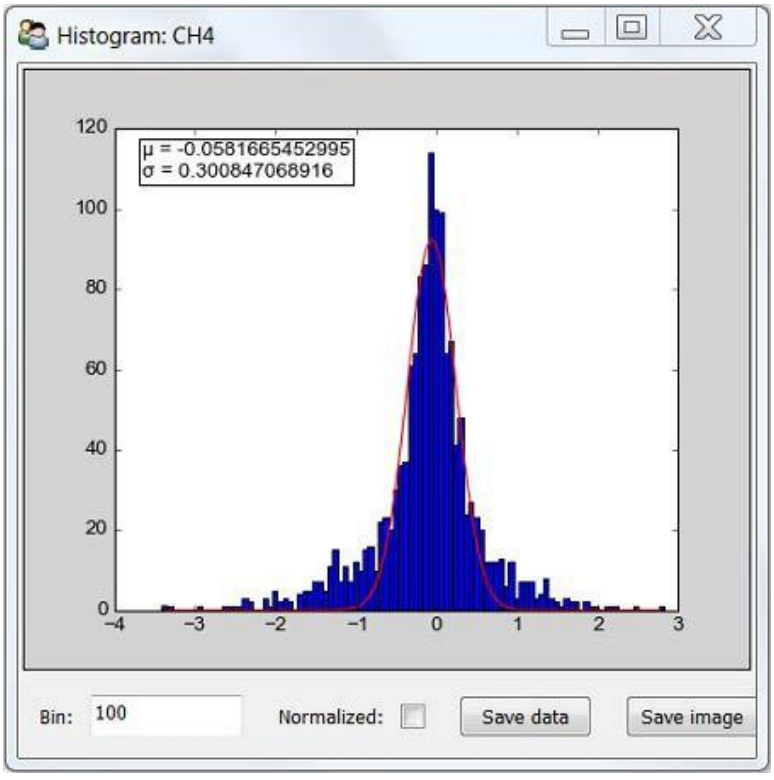


Figure 72: Histogram Window – CH4

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 ***Correlation/XY Plot*** on Page 107 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 73: 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.

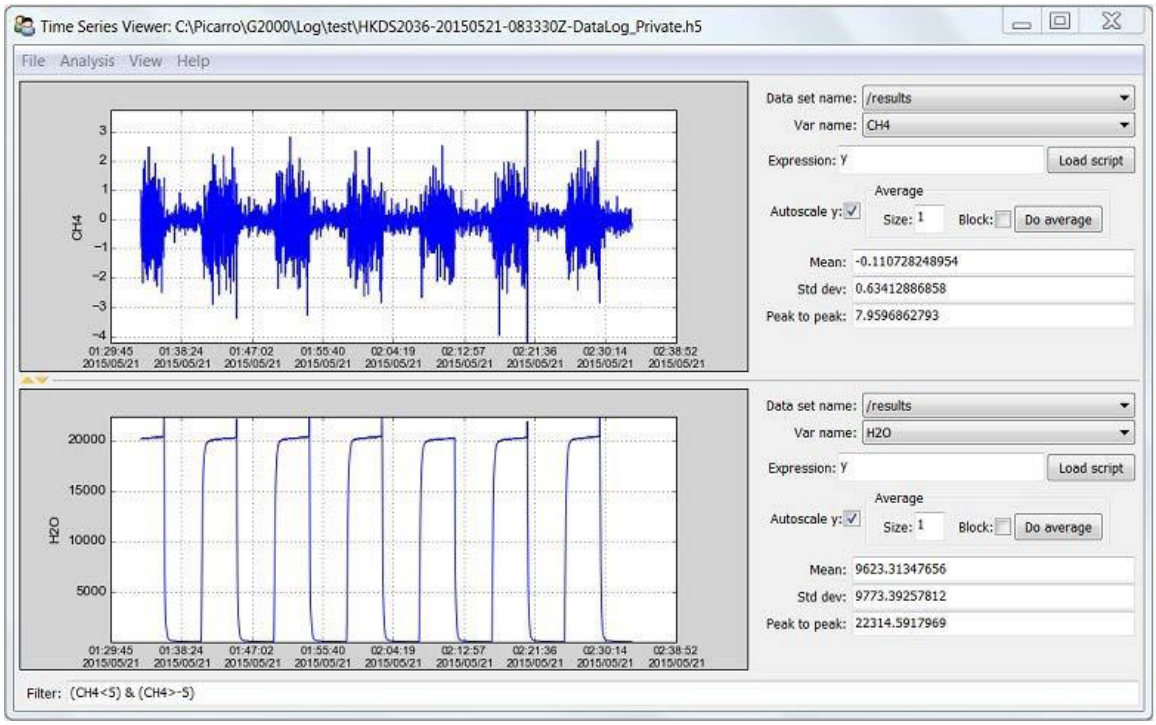
The Time Series Viewer Canvas

The Time Series Viewer canvas (Figure 74 below) is comprised of interactive graphs and a variety of configuration options.

Mouse Options and Graph Transform

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

- Left click and drag: Zooms into the selected area of the plot.
- Left click and drag with the SHIFT key down: Pans the plot.
- Left click and drag with CTRL key down: Zooms out from the plot.
- Left click and drag with ALT key down: Stretches the plot.
- Right-click: Opens an additional menu. Refer to Right-click Menu below in the next section.



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

Figure 74: Time Series Viewer Canvas

Right-click Menu

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

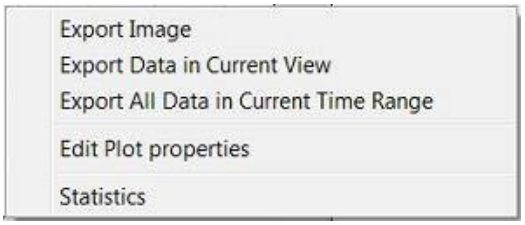


Figure 75: Canvas Right-click Pop-up Menu

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

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

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

Edit Plot properties: Opens the Image **Editor form** (Figure 76 below), where the following options can be specified.

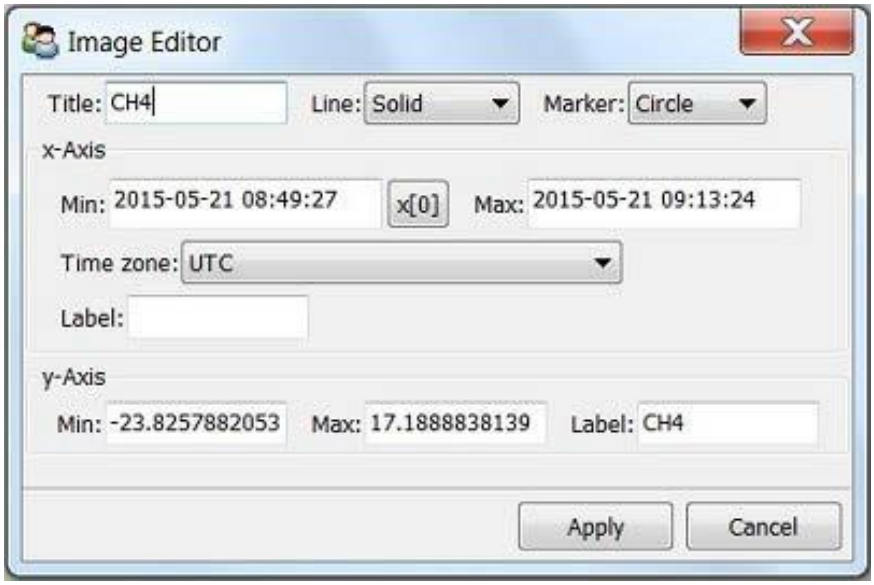


Figure 76: Image Editor Form

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 of 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 77) to select the dataset that will be used for this time series graph. Use the **Var name** drop down to select the column in the dataset to use in the graph.

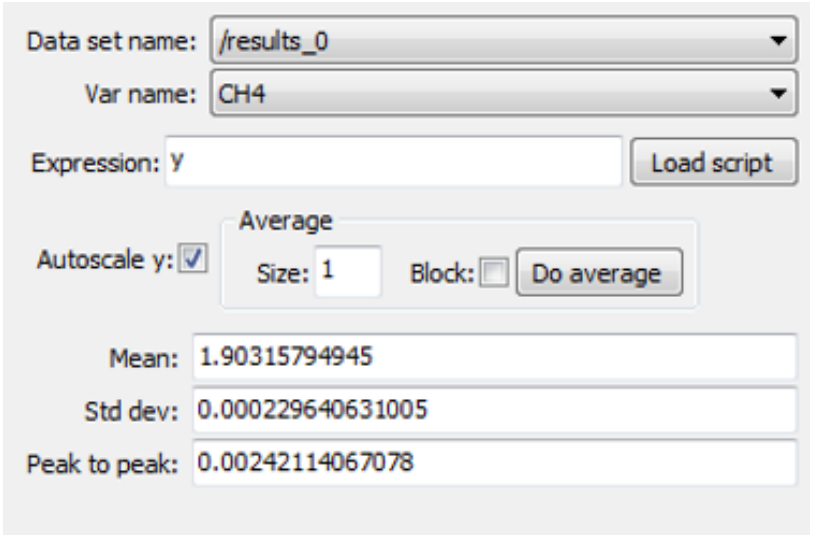


Figure 77: Time Series Viewer Dataset Options

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 77) provide all the statistical information of data in the current view.

Correlation/XY Plot

The Correlation/XY Plot window (Figure 78) includes two menu items: File and Analysis. For details about the File menu, see ***Save Configuration*** on page 101.

REMINDER

The canvas in this plot is interactive. For details about the plot canvas, see *The Time Series Viewer Canvas* on Page 103.

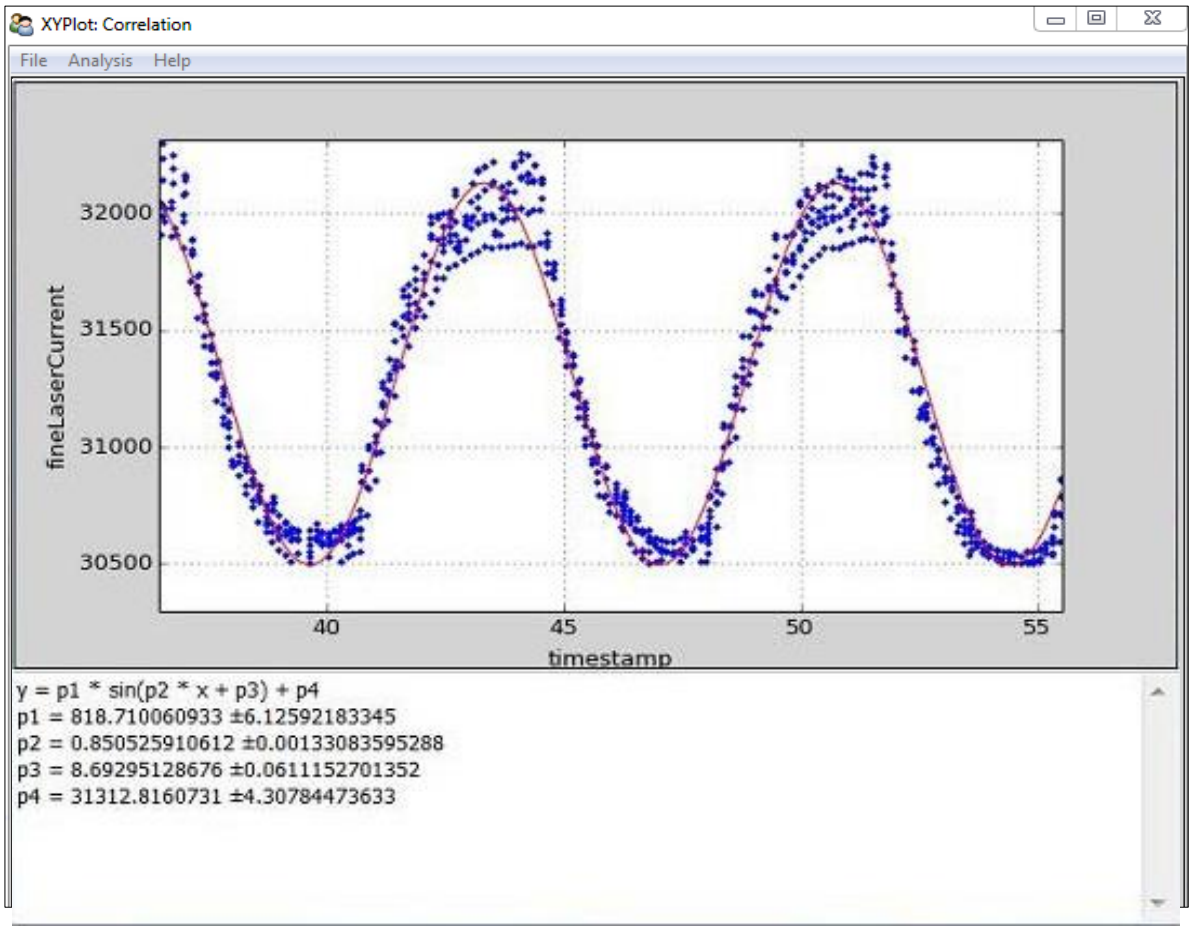


Figure 78: Correlation XY Plot

Analysis Menu

The Analysis Menu (Figure 79) includes three options: **Fitting, Integration**, and **Statistics.**

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

1. **Linear fit:** Specifies to fit to linear function:

   y = c1x + c0

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

   y = c2x2 + c1x + c0

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

   y = Σcnxn

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

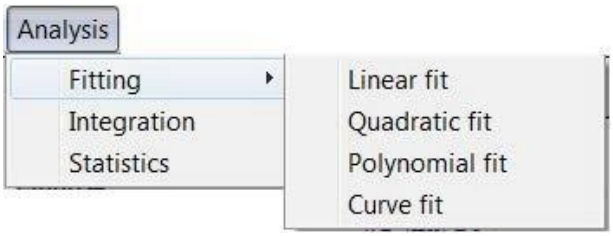


Figure 79: Analysis Menu

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 80).

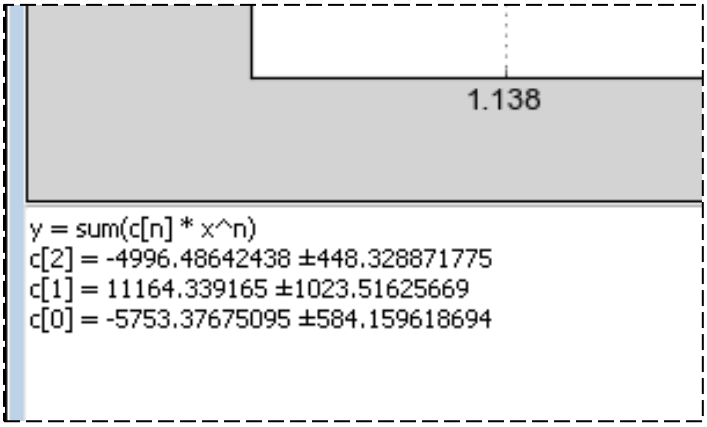


Figure 80: Results of Quadratic Fitting

APPENDIX C – Setting up Contained Pump Exhaust Flow

C.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 81: A2000 Pump Vacuum and Exhaust Ports

C.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

C.3 Directions

5. Remove the noise dampener fitting from the bottom of the pump using a long flathead screwdriver (Figure 82).

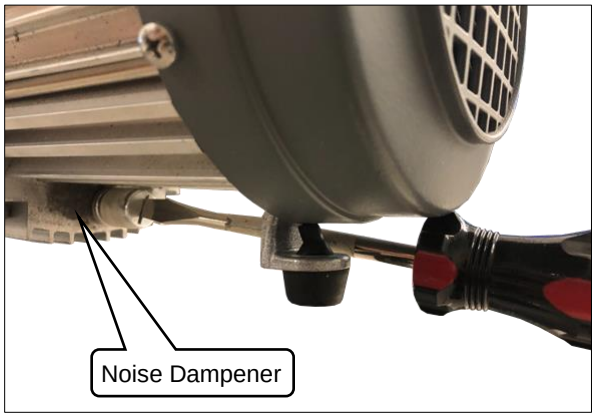


Figure 82: Pump Noise Dampener Removal

6. Slide the adapter gasket PN 22929 onto the adapter fitting PN 22928 (Figure 83), screw it into the pump exhaust port, and then tighten it 1/4 turn using a 9/16” wrench.
7. Remove the Swagelok nut and ferules from the adapter fitting to ensure their orientation is as shown below, then loosely reattach to the adapter.
8. 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

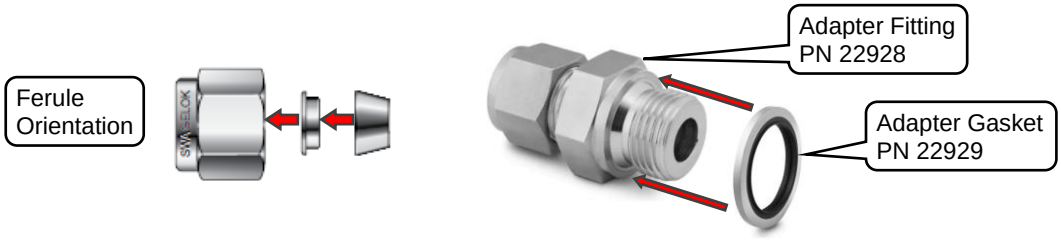


Figure 83: Pump Exhaust Line Adapter Fittings

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

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

APPENDIX D – External Valve Sequencer

D.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 Software*** (described in ***Section D.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

D.2 A0311 16-Port Distribution Manifold

Compatibility

The A0311 (Figure 84) is broadly compatible with all Picarro analyzers with the exception of those with known surface and chemical compatibility issues (such as the G2103, G2108, G2204, G2205, G2114, 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 *A0311 16-Port Distribution Manifold User Manual* (P/N 40-0038).

Figure 84: A0311 – 16-port Distribution Manifold

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

Compatibility

The A0311-S (Figure 85) is broadly compatible with all Picarro analyzers but is optimized for use with sticky and reactive gases in the following platforms, nominally:

- G2103, G2108, G2204, G2205, G2114, 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 *A0311-S 16-Port Sequencer User Manual* (P/N 40-0023).

Figure 85: A0311-S – 16-Port Sequencer – Fast Multiport Gas Sampler

D.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 or A0311-S 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 ***Port Manager Tab*** located in ***Section A.1 Setup Tool*** 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 D.1*). Using unsupported solenoids may result in damage to the power board.

D.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.

D.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.

D.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 **Tools** drop-down menu, select **Show/Hide Valve Sequencer GUI**. The Picarro valve sequencer window will be displayed (Figure 86), but typically sitting behind the main GUI. Hitting alt-tab brings the Valve Sequencer GUI to the front.

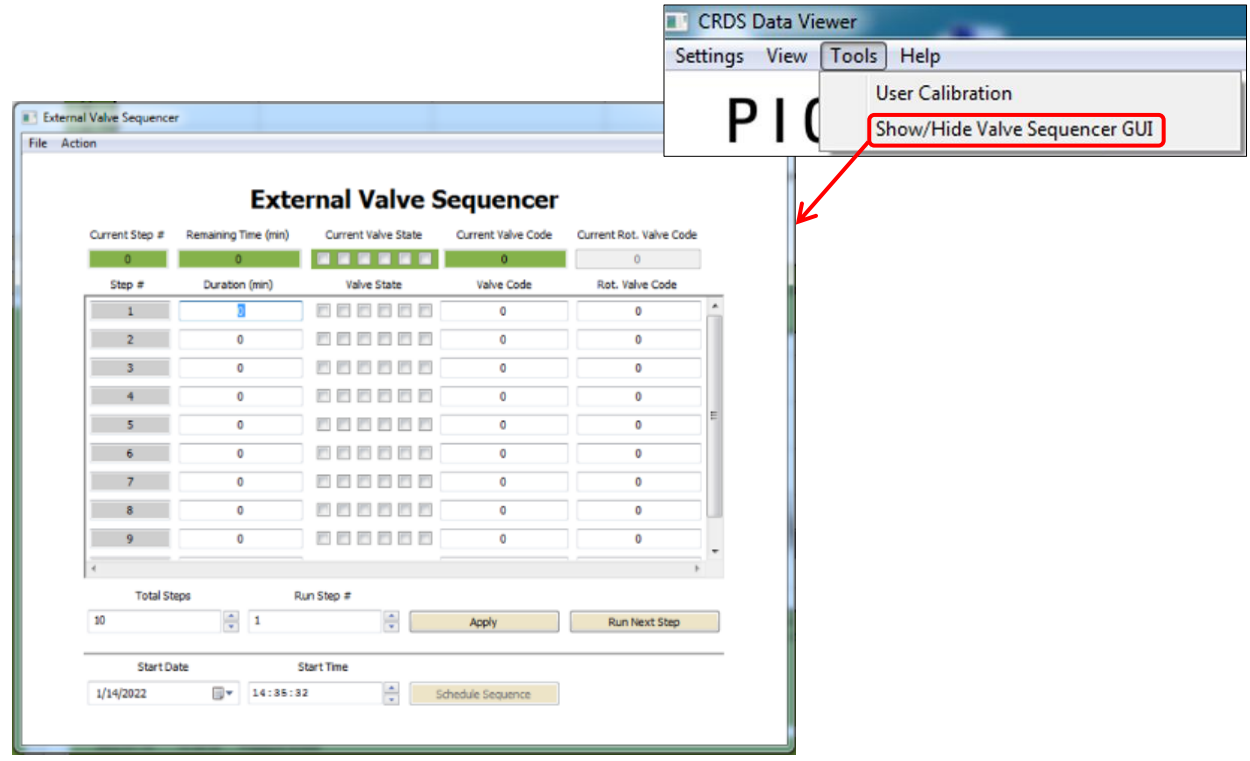


Figure 86: Launching the Valve Sequencer GUI

Valve Sequencer UI Menus

The sequencer GUI provides the dropdown menu choices shown here.

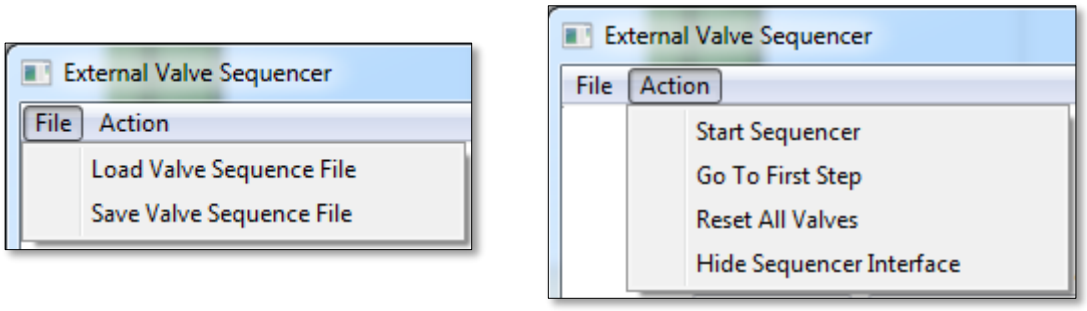


Figure 87: Valve Sequencer UI Dropdown Menus

For the following functional descriptions, Figure 88 shows a full view of an example sequencer UI.

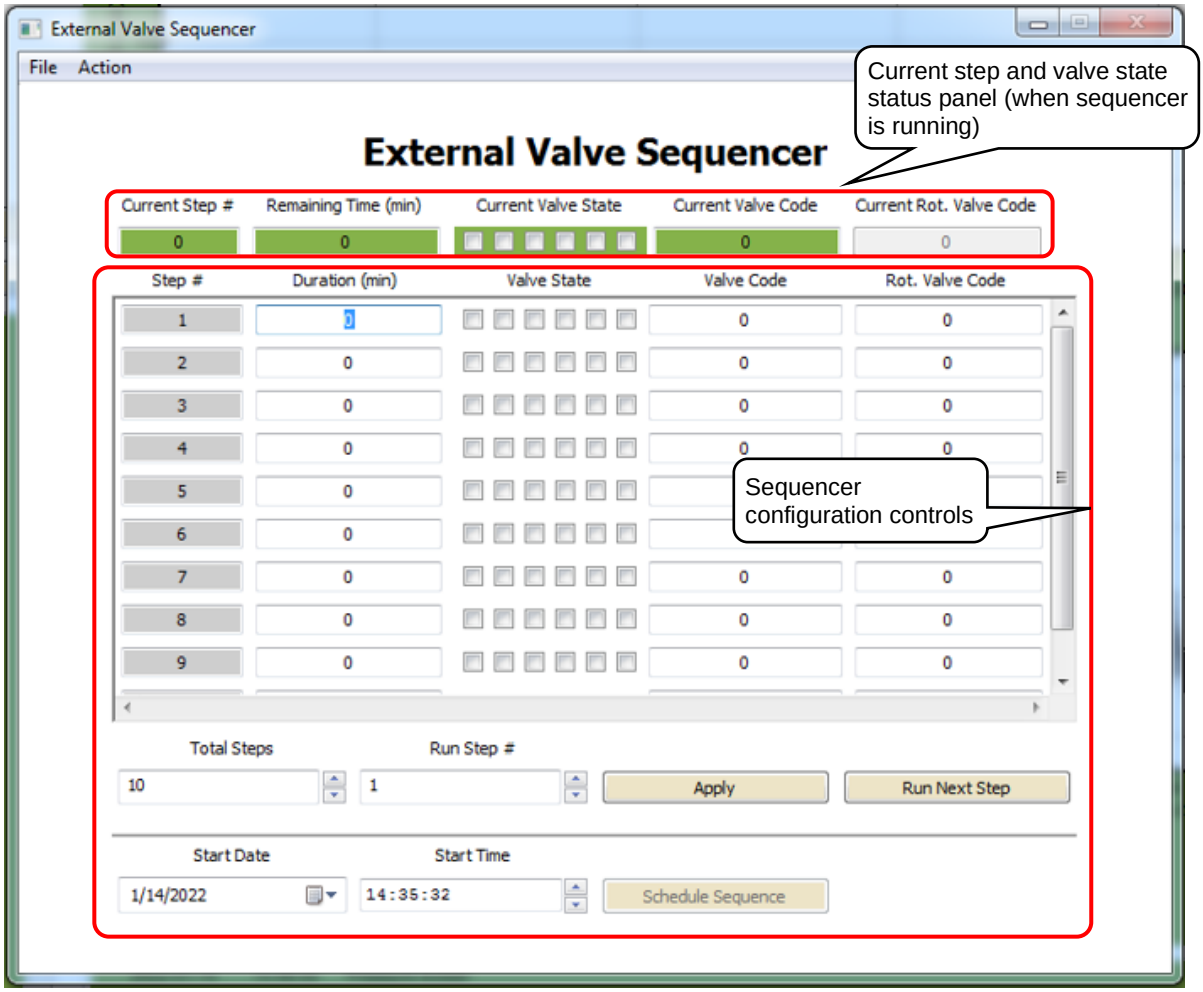


Figure 88: External Valve Sequencer UI

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.

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

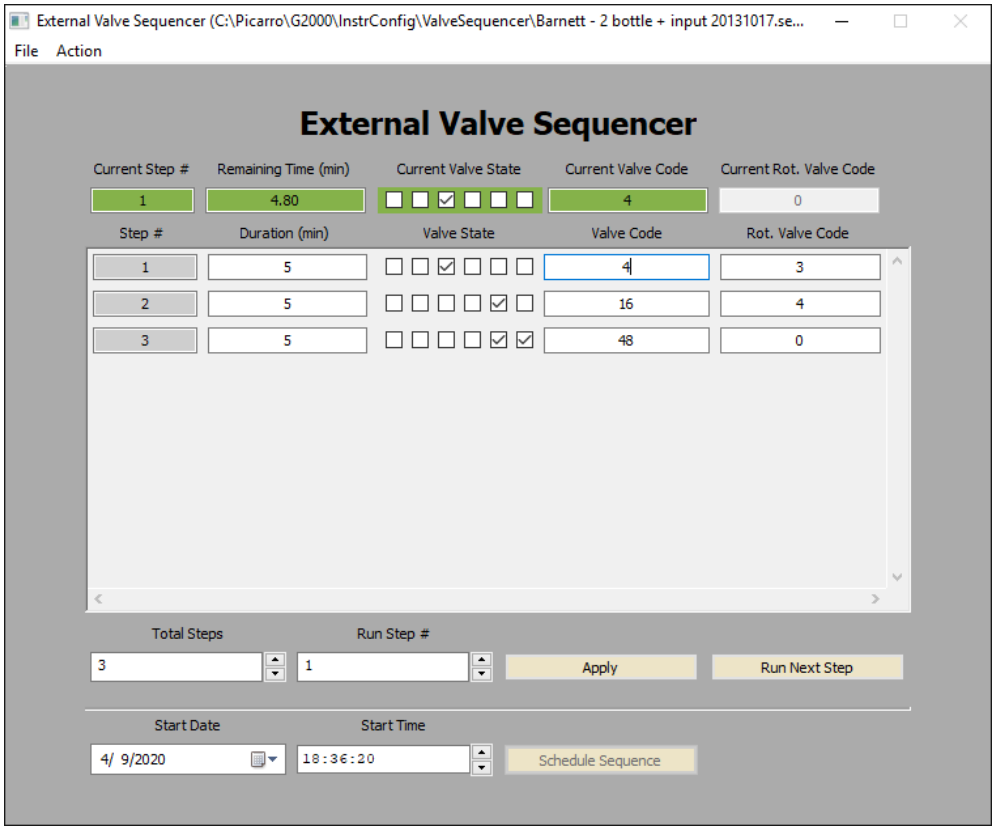
   Valve 4 Powered = $2^{(\text{Valve number}-1)} = 2^{(4-1)} = 8$

   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 89: 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 87). The sequence may be saved with any name the user chooses.

D.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:

C:\Picarro\G2000\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 in the **User Setup** utility, **Data Logger** tab, **Data Columns** window.

If the variable is not available in that window, from the **User Setup > Settings** menu, select the service mode, password **picarro**, and then select the value from the variables that populate into the **Data Columns** window.

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**.

D.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 grayed 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 E – 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

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

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 F – 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.

F.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 91. 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 91.

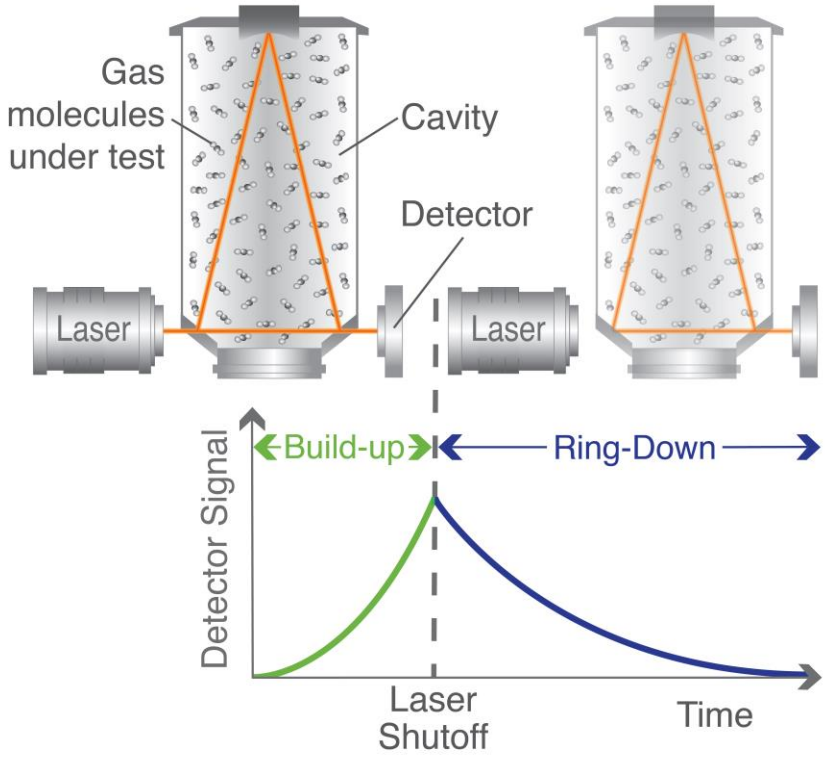


Figure 90: Schematic of Picarro CRDS Analyzer Cavity

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.

F.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 92). 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.

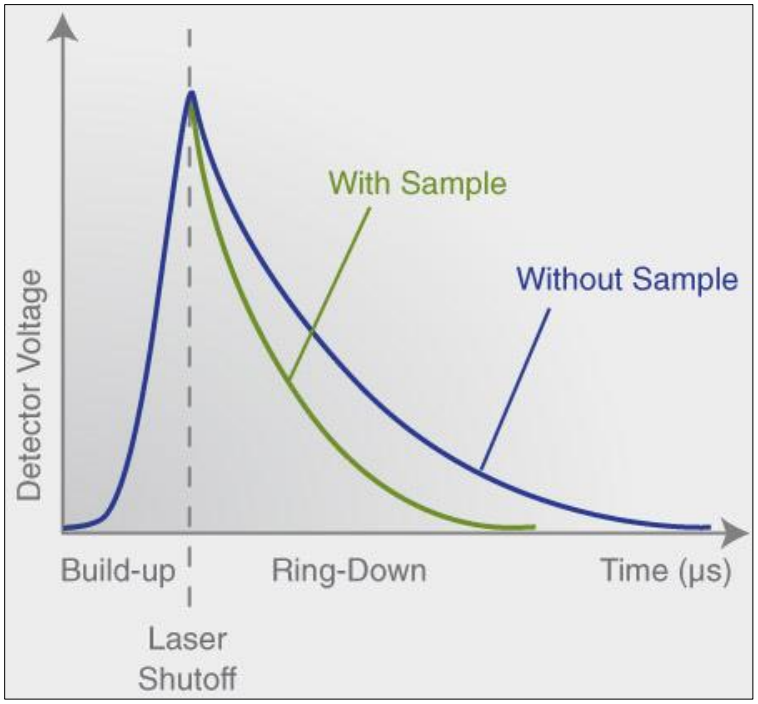


Figure 91: Light Intensity as Function of Time in CRDS System

F.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.

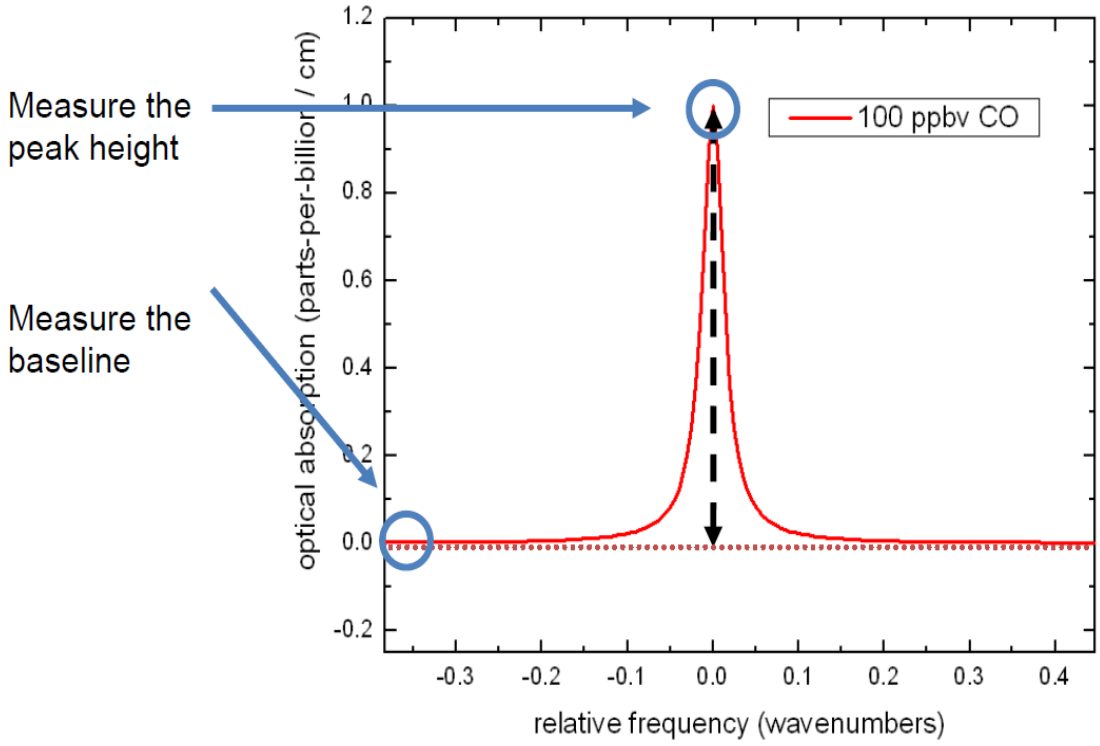


Figure 92: Absorption Spectral Curve

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.

F.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 G – 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.