FPG
DEW POINT
CALIBRATOR

Qrometric
Industrial and scientific metrology

Operation and Maintenance Manual

V1.16

Warranty

Qrometric Limited (QROMETRIC) warrants that its products are manufactured to the highest quality of material and workmanship specifications. QROMETRIC guarantees the reliability of its products for a period of 12 months from the date of initial shipment when operated in normal use and within the specified design limitations. Under this Warranty, QROMETRIC will, at its discretion, repair or replace any component that upon examination by QROMETRIC or its duly authorised representatives proves to be defective during the warranty period provided the system is returned to the factory for inspection and repair shipping prepaid. Improper or unauthorised maintenance, storage, repair, or alteration of any kind by personnel other than QROMETRIC or its duly authorised representatives may void all warranties. Warranty may also be voided for misuse, neglect, accident, corrosion, and improper installation. This Warranty is exclusive and in lieu of any and all other warranties of merchantability, fitness for a particular purpose, or any other warranty, expressed or implied, and all other liabilities and obligations on the part of QROMETRIC. QROMETRIC will not be liable for any other claims or damages, either direct, indirect, or consequential arising out of the use of its products.

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1 Important Information

PLEASE READ <u>ALL</u> SAFETY INSTRUCTIONS CAREFULLY

- **Check all connections carefully before use**
- **Disconnect power supply before opening the instrument housing**
- **In the event of damage, <u>DO NOT</u> use the instrument**
- **The FPG's power connection must be earthed**

Further safety instructions are provided where necessary and clearly indicated by the two symbols shown either side of this statement.

2 Introduction

2.1 Scope of Document

The FPG is a self-contained and portable dew/frost point generator for calibrating dew/frost point instrumentation. This instruction manual applies to all three FPG Models: FPG-60, FPG-80 and FPG-100. It is also available online at www.qrometric.com.

2.2 Terminology and Conventions

There are many different terms and conventions used in the field of operation of the FPG. This manual assumes the following definitions:

- **Humidity** is a generic term relating to the concentration of water in the gas phase (or vapour) in another (matrix) gas. It is sometimes used interchangeably with 'moisture' though this is strictly incorrect, as moisture content typically is the water content of a solid or liquid. Given the conditions, it might be more sensible to refer to 'dryness' but this is rarely used.

- **Dew Point or Frost Point Temperature** is a common measure of humidity. It is sometimes referred to as the dew point or dew/frost point temperature. This manual uses the convention 'dew point' above 0°C and 'frost point' below 0°C – that each is a temperature with a unit '°C' is assumed.

  It should be noted that *below* 0°C the *same* humidity condition can be described in terms of a dew point *or* a frost point temperature, but that the values are different. For a full explanation, please refer to the following guide published by the UK National Physical Laboratory, which also details other humidity metrics, including parts per million (by volume) or PPMv:

  https://www.qrometric.com/wp-content/uploads/2021/12/NPL-Guide-to-the-Measurement-of-Humidity.pdf

  An online calculator can be found at https://www.qrometric.com/calculator/ which can be used to convert between the different humidity parameters, including dew point and frost point temperatures and PPMv, etc.

- **Hygrometer** is a generic term that refers to an instrument that measures humidity. There are many different technologies that are used, including chilled mirror hygrometers (CMH), optical hygrometers, Phosphorous Pentoxide cells, microwave resonator elements and capacitive substrate sensors, including Aluminium Oxide and thin film polymers.F

- **Moisture Analyser** is a generic term that refers to an instrument that measures humidity, though again, strictly speaking it is not moisture that is being measured.

- **Dew Point Sensors** typically use Aluminium Oxide or thin film polymers whose electrical properties change with humidity conditions below 0°Cfp – they usually configured to provide measurements in terms of dew/frost point (temperature).
- **Chilled Mirror Hygrometers (CMH)** are considered one of the best reference instruments for measuring humidity – they are sometimes referred to as 'dew point mirror or meters'.
- **Optical Hygrometers** employ laser spectroscopic techniques to measure humidity – there are a number of different types, including cavity ring-down, tuneable diode, etc.

2.3 Introducing the FPG

The FPG generates precisely controlled dew/frost point conditions that can be used for calibrating dew point sensors, and most types of hygrometers, from ambient dew point conditions to frost point temperatures as low as -100°C.

The FPG uses a temperature-controlled saturator to generate a stable water vapour pressure (and associated dew point) within a closed-loop. An integrated sample pump maintains a continuous flow through the saturator, the 3-port dew point probe manifold and the external sample connection. At equilibrium, the saturator temperature and system pressure provide humidity reference conditions to which hygrometers can be compared and calibrated. The temperature of the saturator defines the humidity of the sample gas, which is measured as dew/frost point temperature.

As long as the loop is properly sealed (see section 6.1.3), the amount of water in the system remains constant, whatever the programmed condition. The dew point temperature condition is defined by the saturator temperature – the water not in the vapour phase is condensed on the saturator. The water in the system is derived from the humidity in the matrix gas with which the system is initially purged (usually ambient air). It is important this is done with the saturator temperature set above its dew point temperature (see section 5.2.3.2).

The FPG is completely self-contained, transportable and requires only mains power to function. Coupled with the rapid set point change and stabilisation time, calibration can easily be performed at the location where the hygrometers are installed.

The FPG must be used and serviced following the instructions and warnings provided in this manual. Any use of the FPG contrary to manufacturer's instructions for use will put operator safety at risk and compromise health and safety in the workplace.

2.4 Remote API

The FPG comes standard with an Application Programming Interface (API) which is a text-based, remote command interface connected through the FPG Ethernet port. FPG data can be captured and set points defined using custom scripts or third-party software, including FPG metrology automated calibration software.

2.5 Options, Accessories and Extras

A range of options, accessories and extras (including calibration) can be purchased for the FPG. Full order code information can be found in section 12, and are described throughout this manual (options, optionally).

3 FPG Instructions

This chapter provides the first steps and most important information needed to start using your FPG. It should only be used as a general overview and not as a substitute for reading the complete manual. To gain a thorough understanding, please read the other chapters, taking careful note of the indicated warnings.

3.1 Unpacking the FPG

The FPG will be delivered to you in a cardboard transportation box or, if ordered, a custom soft padded transport bag or hard transport case. It is recommended to keep the delivery packaging in case of future need for transport for calibration, repair or storage.

Typically included:

1. FPG transportable dew/frost point calibrator
2. Power cable
3. Sample loop connection: FPG-60, 6 mm Swagelok Tube Fitting or FPG-80/FPG-100, ¼" VCR Metal Gasket Face Seal Fitting
4. Adjustable torque screwdriver with 3 mm Hex bit
5. Optional probe adaptors
6. Optional second PRT for independent measurement of saturator temperature
7. Calibration certificate

Before you start operating the FPG, carefully remove all items from the case and visually check for any signs of damage. Check the contents included matches up to the delivery note.

IF YOU FIND ANY ITEMS TO BE MISSING OR DAMAGED, PLEASE CONTACT YOUR SUPPLIER <u>IMMEDIATELY</u>.

Make sure that the power rating on the rear label corresponds to your local power supply specification – an incorrect power rating may cause damage to the FPG.

3.2 Locating the FPG

Before proceeding, ensure that:

1. The unit is placed level, horizontally and is stable on its four rubber feet.
2. The FPG has at least 10 mm clearance underneath and at least 100 mm at the rear and side to allow sufficient air flow.
3. Access to the electrical mains connector at the instrument rear is adequate.

3.3 Mains Supply

The FPG requires a source of mains power. Please ensure the power rating of your supply matches the instrument's specifications. When you have checked this, you should:

- Plug the supplied AC power cord into the rear panel of the FPG.
- Plug the other end of the power cord into a mains AC outlet.
- Turn the power switch to ON (it is located to the left of the AC power connector).

3.4 Closed-Loop Operation

The FPG will only function correctly if operated as a closed-loop system. This means each of the three dew point sensor apertures on the front panel manifold need to be firmly sealed, either with its supplied cap or a probe port with sensor and the rear sample loop circuit must be completed (see section 6.1).

The FPG operates as a closed-loop with gas flow established by an internal pump. The circuit must not be open, otherwise ambient humidity will be drawn into the FPG, and this will condense as ice and could eventually block the internal saturator. Should this happen, the FPG saturator will automatically shut off the pump and saturator temperature control. Please follow the drying out procedure in these circumstances (see sections 5.2.3.2 and 6.3.7).

For basic operation with no external devices connected, the rear panel sample U-loop connection must be in place as shown below:

Depending on the configuration set-up (see section 6.4), the U-loop can be removed to allow connection to other instruments.

The FPG is now ready to turn on.

3.5 Powering on the FPG

Switch on power with the rear panel switch next to the power inlet connection.

Press the ‘ON’ button on the front panel of the FPG.

The display will then power up and the FPG home screen will appear.

If nothing happens, check the power source and that the above steps have been correctly followed.

3.6 Shutting Down the FPG

It is important that the correct shut down procedures are followed to ensure no damage occurs to the instrument. Power should be turned off using the FPG user interface or by pressing the front panel button. **DO NOT pull plug out or switch off at power source while the FPG is running.**

DO NOT switch off at rear, pull plug out or switch off at power source before the FPG has finished shutting down.

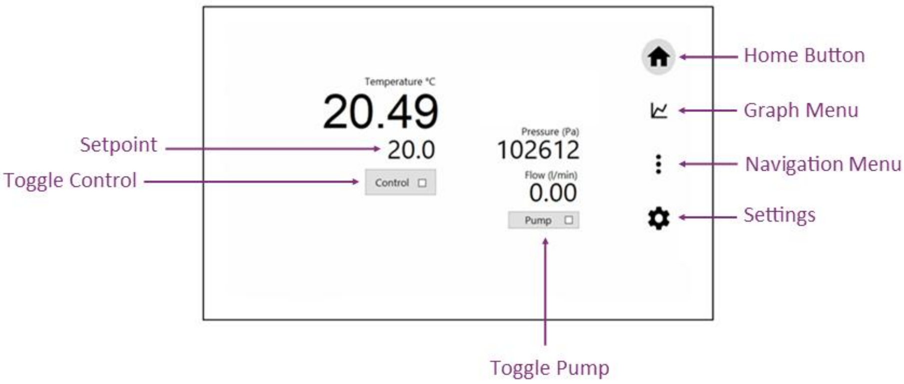
3.7 Transporting the FPG

When the FPG is being prepared for transport, the U-loop **MUST** be reinstalled. **Note that it is VERY IMPORTANT to NOT stand the FPG on its rear handles with the VCR-tube fitting adaptors fitted.** This is because the VCR-tube fitting adaptors protrude out further than the handles. Therefore, the adaptors are exposed to collision, which can result in damage to the internal pipework. **This is NOT covered by warranty.**

3.8 Basic Operation

3.8.1 Home Screen

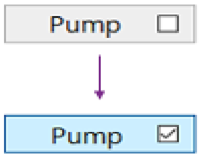
Once powered on the FPG will display the home screen:



The largest number (20.49) is the measured saturator temperature.

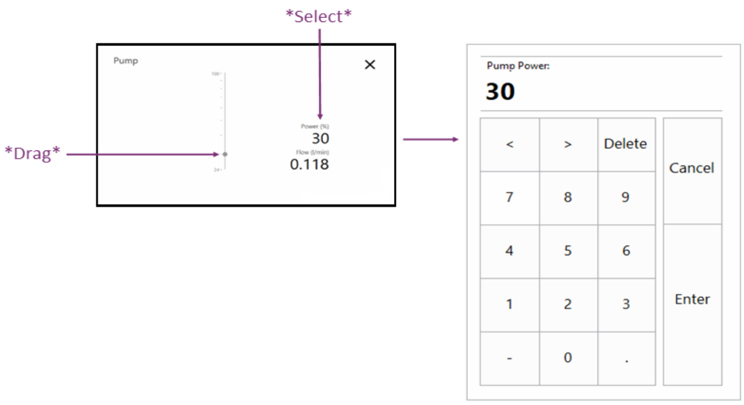
3.8.2 Flow

To establish gas flow through the circuit, turn on the internal pump using the toggle button:



When the pump is on, its button will turn blue and the check box will be ticked.

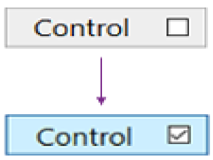
Flow rate through the system can be adjusted by changing the pump power. Press on the number to access the pump power setting. This can be set by pressing the 'Power' value and typing a number into the displayed keypad or dragging the slider.



3.8.3 Saturator Temperature and Control

To set a saturator temperature, click the set point number and enter a value on the screen. Please note that the FPG has no water source, therefore, it will not generate conditions above ambient dew point.

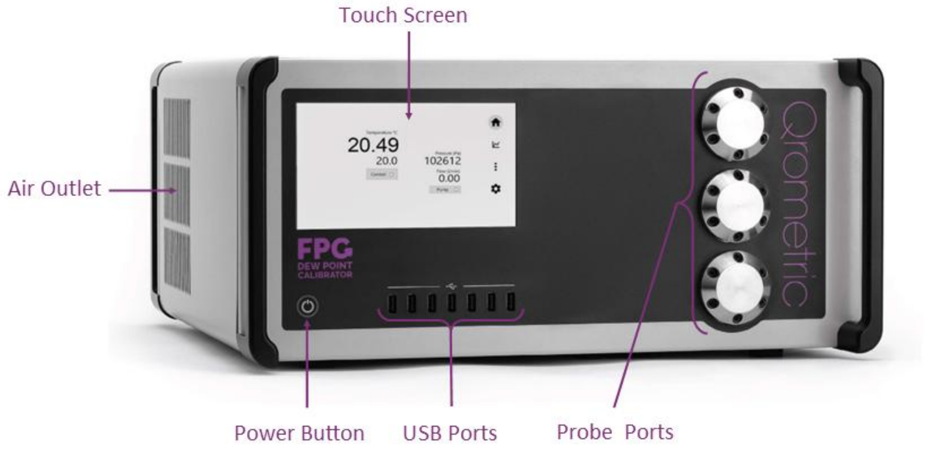
To turn on control of the temperature, click the CONTROL button, which will toggle to ticked and blue when on (as illustrated below):



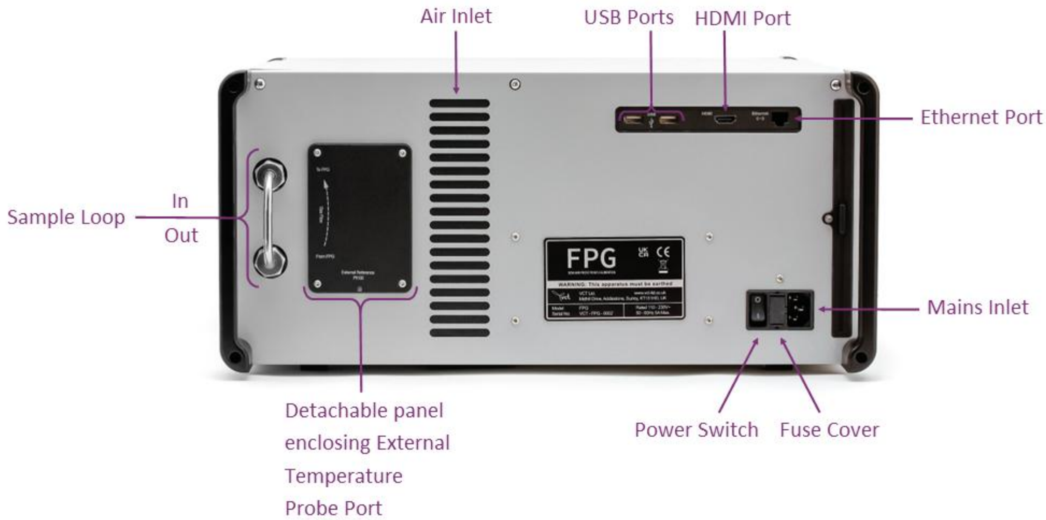
Press ENTER and ensure CONTROL is on as shown by the ticked box.

4 FPG Physical Layout

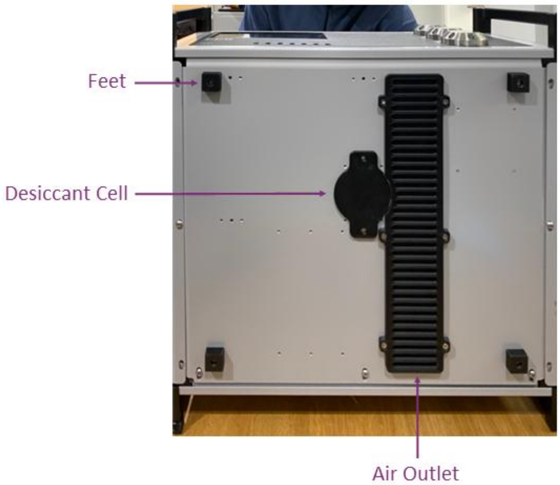
4.1 Front and Side Panels



4.2 Rear Panel



4.3 Underside



4.4 USB Ports

The FPG's front panel includes seven USB ports, which can be used for plugging in an external keyboard and/or mouse. They currently serve no other purpose but are provisioned in case of future feature development.

4.5 Configurable Probe Ports

There are a number of probe adaptors available for most manufacturers' dew point probes.

See section 12 for further details and order information.

4.6 Rear Panel

The rear panel of the FPG comprises:

1. Power inlet and switch
2. External sample loop connections
3. Ethernet network port
4. USB ports ×2
5. HDMI port
6. Detachable panel, beneath which there is located:
    a. External temperature probe port
    b. USB port (service use only)

4.6.1 Sample Gas Connections

The fundamental physics at the heart of the FPG mean it can be used for traceable calibration without the need for a transfer standard hygrometer. However, as is the case in temperature calibration, a reference measurement is often used to improve confidence and reduce uncertainty. For this reason, the FPG includes external sample loop fittings so the user can validate performance at any time by connecting a reference instrument such as a dew point mirror. If no external instrument is connected or if the FPG is being prepped for transit, the provided U-loop pipe should be connected.

The inlet and outlet connections are located on the rear panel of the instrument as shown above. The inlet is the top connection, and the outlet is the bottom connection. Connections are 6 mm Swagelok for the FPG-60 or ¼” VCR for the FPG-80 and FPG-100.

4.6.2 USB Port on Cable

For service use only.

4.6.3 Network Port

The rear panel of the FPG includes an Ethernet network port to allow the user to connect the instrument to a network and allow for remote API access and screen sharing. Details for connecting via the Ethernet network port are outlined in section 9.2.

4.6.4 Power Switch

The main power switch is on the rear panel of the FPG and located to the left of the power plug.

4.6.5 Power Socket

The supplied power cable is to be connected to the power socket on the instrument rear panel. The supported power supply voltage is 100…250 VAC 50/60 Hz. Power requirements can be found on the label on the rear panel of the FPG.

4.6.6 USB Ports

The FPG’s rear panel includes two rear USB ports and seven front USB ports adding the ability to plug in a keyboard and/or mouse if this is preferred to the touchscreen. There is scope for future functional expansion.

4.6.7 HDMI Port

The HDMI port is in place for future functional firmware upgrades to display integrated software.

4.6.8 Air Filters

On the far-right of the rear panel. These can be periodically removed and cleaned with a vacuum cleaner.

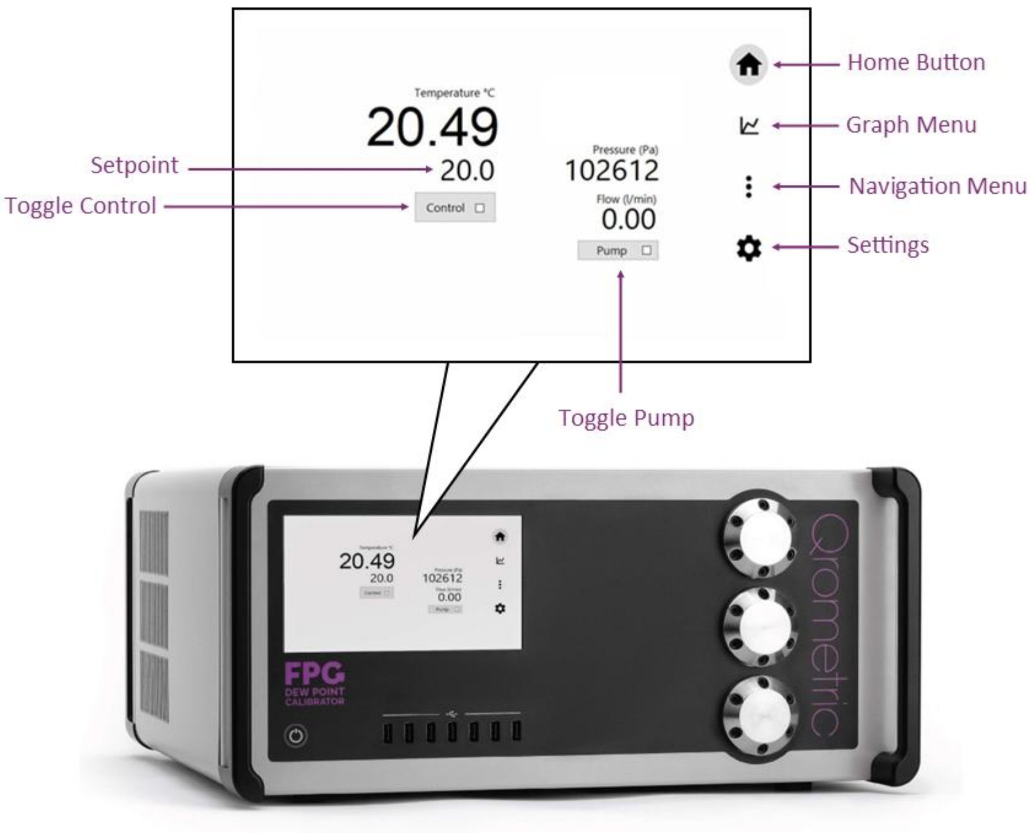
5 FPG User Interface

5.1 Front Panel

The front panel of the FPG consists of:

1. A full colour LCD touchscreen
2. Seven USB ports
3. Power button
4. Three configurable probe ports

Once the Power button has been pressed and the unit has powered up, the display will be activated and operational within a few seconds. To select menus or buttons on the screen, simply touch the desired key on the screen itself. A mouse and keyboard can also be connected via the integrated USB ports. The figure below shows the front panel and a sample display configuration.

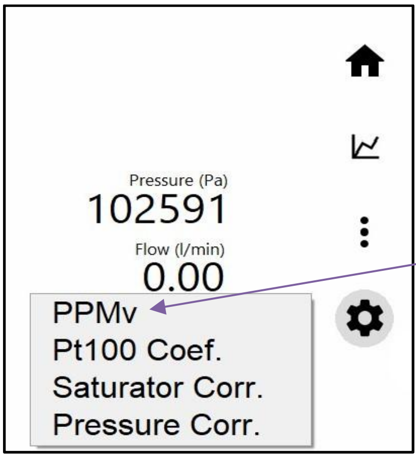


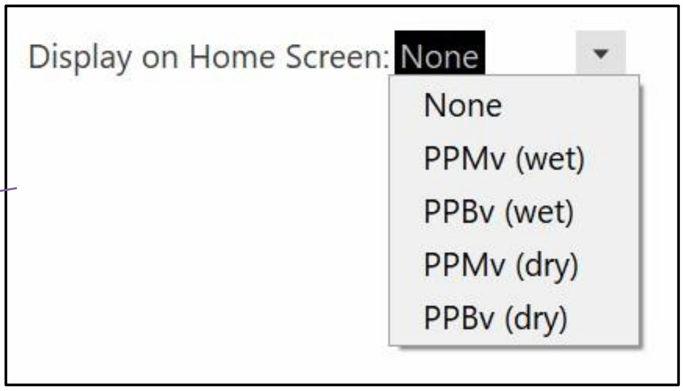
5.2 LCD Touchscreen

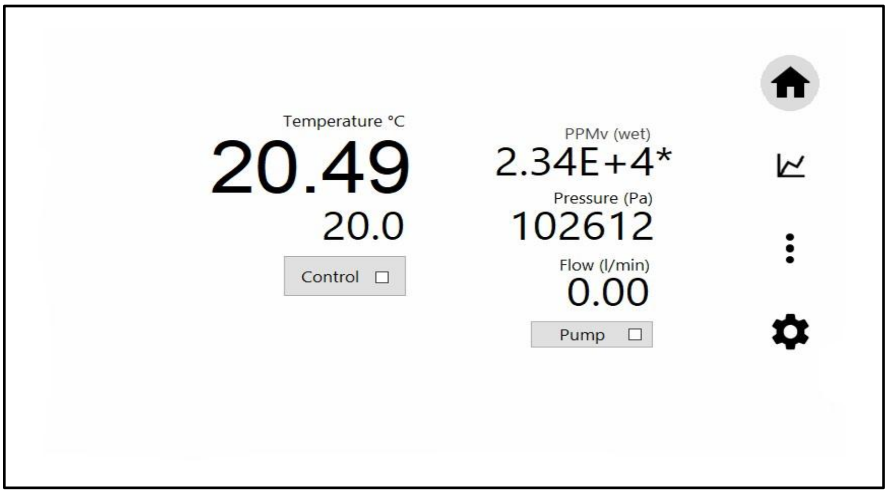
The FPG includes a full colour, LCD touchscreen. This section explains how to navigate the touchscreen's various functions to get the most out of your device. You can select a function from the menu by simply touching the relevant point on the touchscreen with either your finger or a stylus – **please note that <u>SHARP OBJECTS</u> should <u>NOT</u> be used as they can damage the touchscreen**.

5.2.1 Home Screen

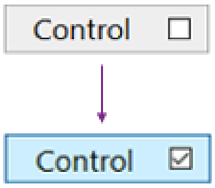
The FPG can measure its internal temperature and pressure, as well as gas flow rate. Measured temperature, pressure and flow is displayed on the home screen which can be customised to also include a calculated PPMv or PPBv of both the wet and dry variation. This is done by selecting Settings -> PPMv and then selecting from the drop-down options as shown below. You can return to the Home Screen at any time by pressing the HOME button represented by a house/home icon or by pressing the ‘X’ where appropriate.



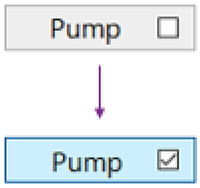




5.2.1.1 Toggle Control and Pump



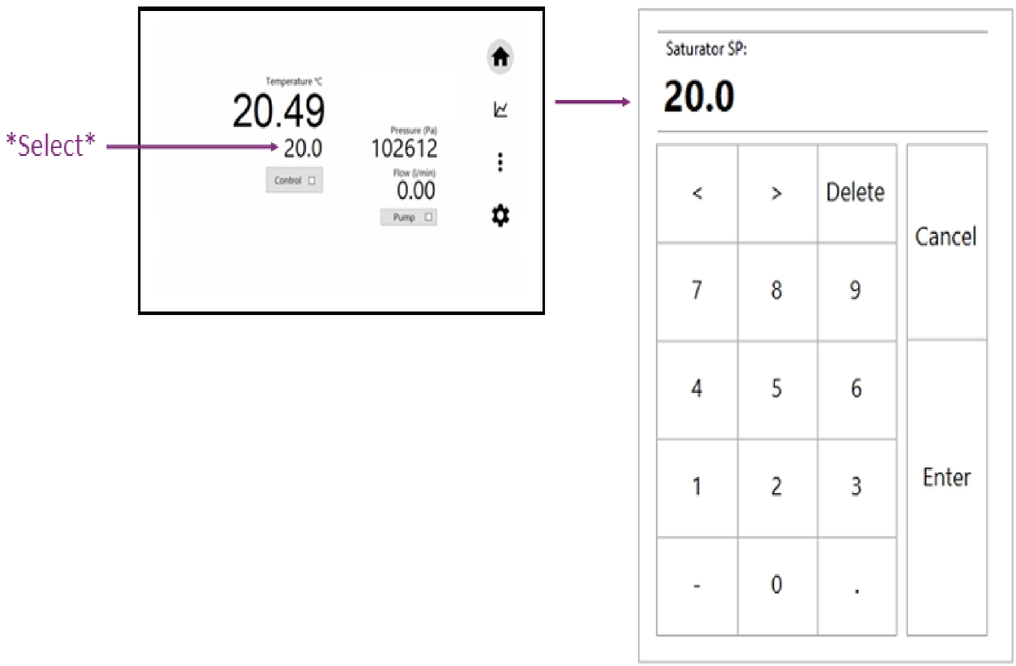
Control can be switched on and off with a simple tap of its box to tell the instrument to actively cool or warm to the set point.



The FPG includes a pump to move air between its chamber and through external instrument. It can be toggled with a simple tap.

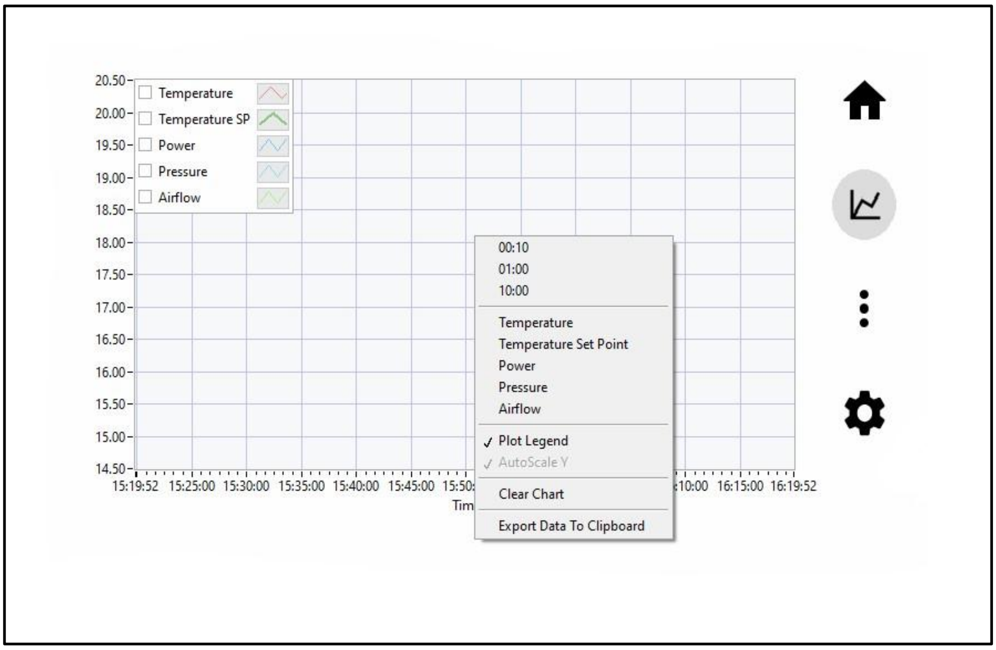
5.2.1.2 Change Set Point

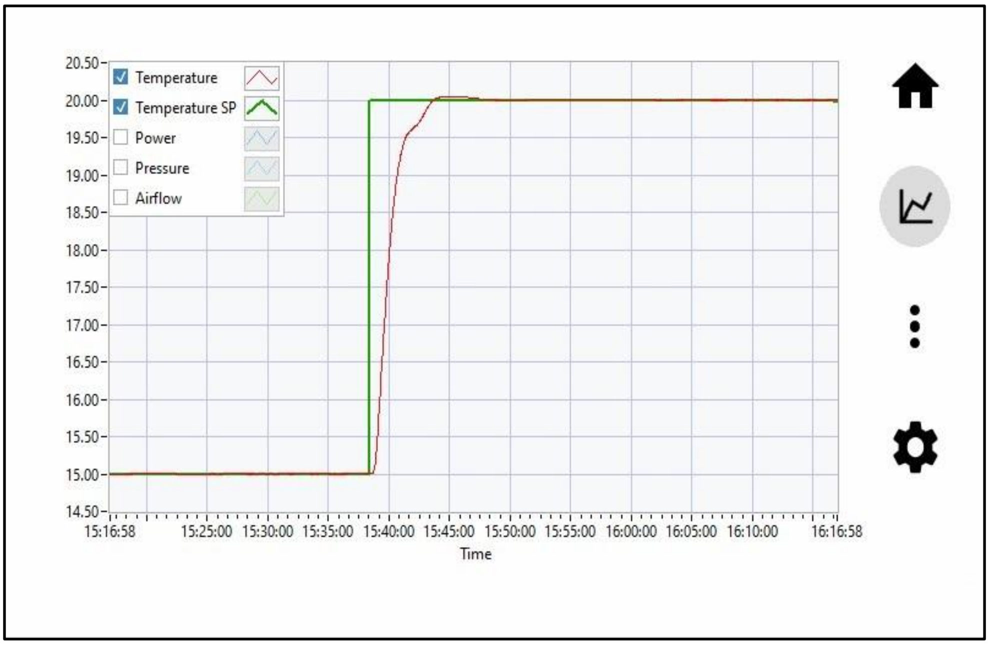
The saturator set point can be adjusted by clicking the set point value to bring up the number pad shown below. The user then keys in the desired value and hits enter. The FPG will then cool or warm to this temperature, provided 'Control' is on.



5.2.2 Graph Menu

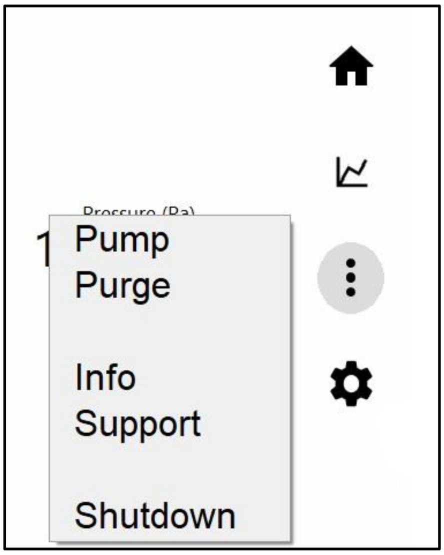
The graph menu sets the FPG to display data graphically. By touching the X or Y axes, parameters can be selected and the time base configured.





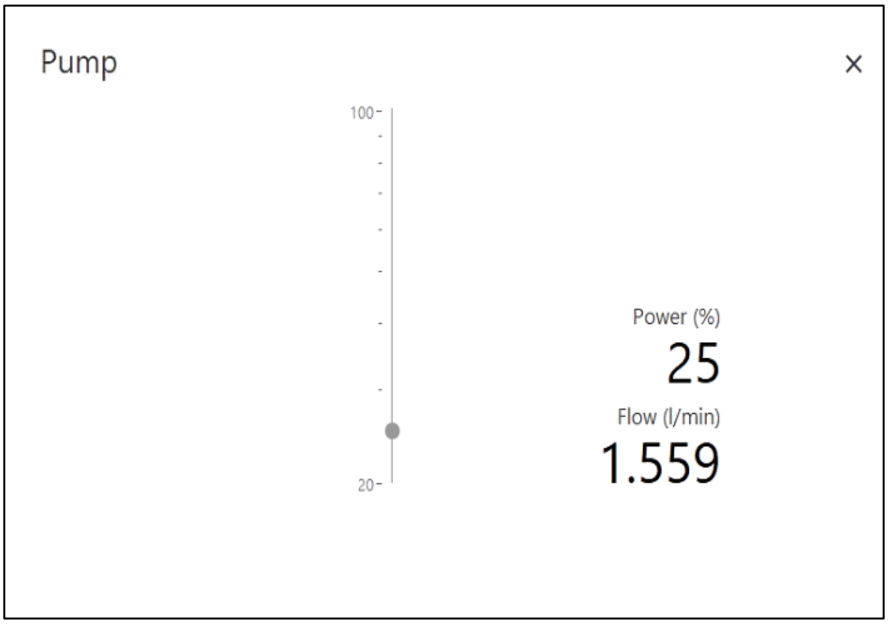
5.2.3 Navigation Menu

The FPG includes a navigation menu represented by three vertical dots. From the navigation menu, the user can access the pump settings, purge menu, access system information (Info), access Support information or Shutdown the unit.



5.2.3.1 Gas Flow Pump

The FPG incorporates a gas pump, whose power can be varied to adjust flow rate through the system.



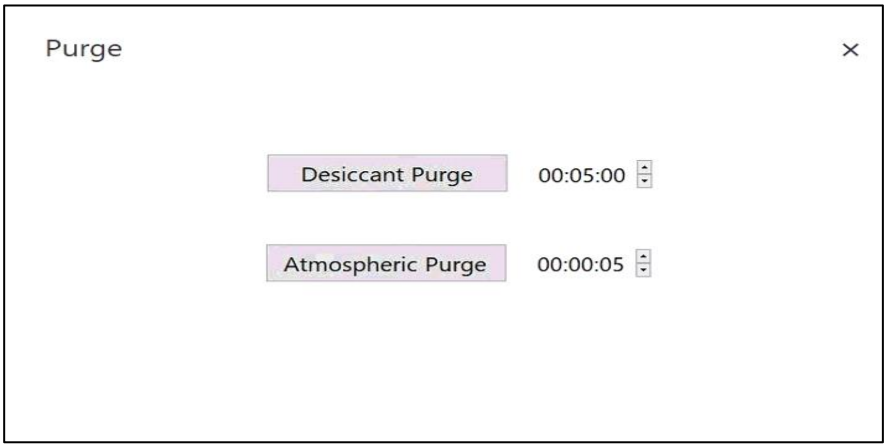
5.2.3.2 Purge

There are various circumstances when the FPG gas circuit needs to be dried out and/or purged with fresh gas. These include:

- contamination in the system (perhaps due to dirty probes in the manifold)
- liquid water in the saturator (when saturator is at ambient temperature) due to ingress of ambient humidity into the system due to leaks
- preparing the FPG for transit.

The atmospheric purge includes a HEPA (99.9% at 0.3 micron) filter and will refill the gas circuit with fresh ambient air. The desiccant circuit will run the gas in the FPG through the desiccant cell and (with new desiccant) will dry down the circuit to about -40°Cfp.

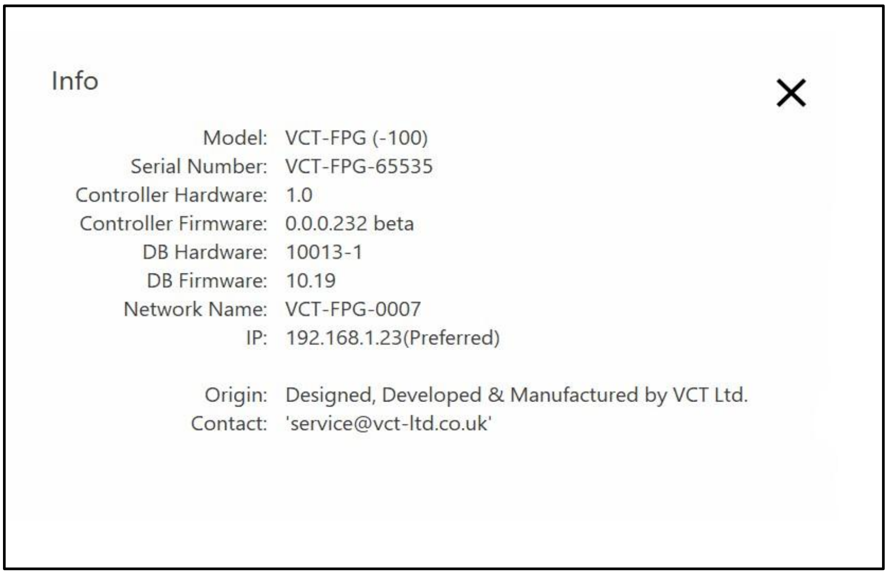
On the ‘Purge’ menu, select the desired purge type, and required duration. On pressing the button, the appropriate solenoid valve will open and the timer will count down. The user must stay on this Menu for the purge to continue; leaving the menu will pause the purge timer.



Please note that the FPG pump needs to be on to drive flow through the FPG desiccant and atmospheric vents, however, there will be a net system pressure drop of circa 50 mbar with the pump on. To equalise pressure with ambient conditions, run a momentary (1S) atmospheric purge with the pump off.

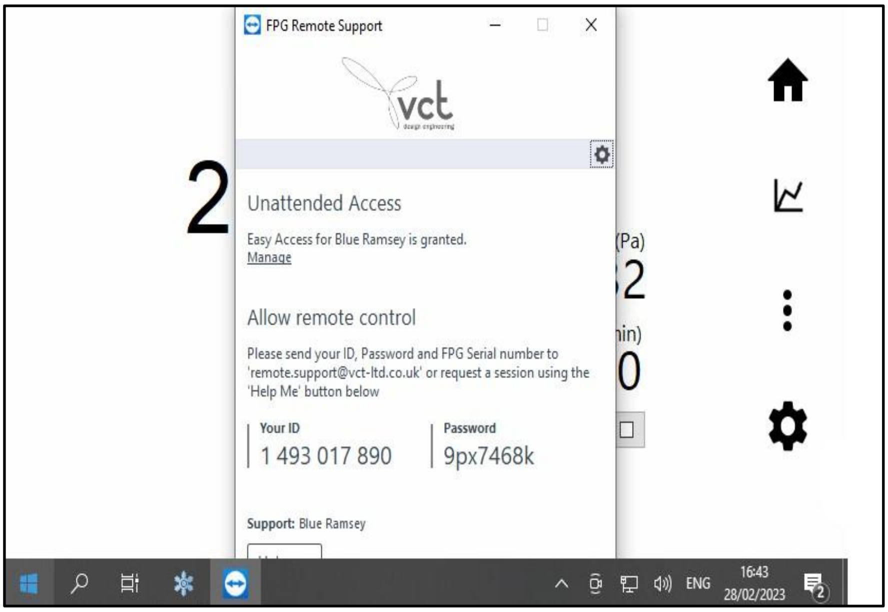
5.2.3.3 Info

System info can be accessed through the navigation menu. You can confirm your FPG model and serial number, both can also be found on the rear of the unit. The instruments current firmware version can be seen here along with the network information, including the currently assigned IP address. Finally, the page includes contact details for the manufacturer; your supplier can provide you with the contact details needed for FPG service and support.



5.2.3.4 Support

Should remote support/diagnostics be required, and an internet connection is available, Qrometric is happy to provide remote support via TeamViewer. Please see section 9.2 for details on connecting the FPG to your network:

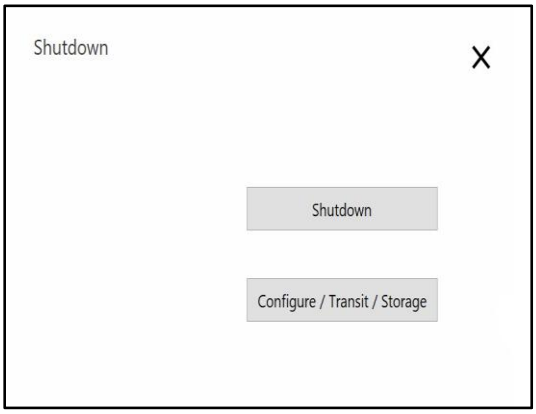


Contact support@qrometric.com if remote support is required.

5.2.3.5 Shut Down

The system should be shut down through the navigation menu, this is the preferable method of shutting down the FPG as it greatly decreases the risk of mechanical damage to internal moving parts. The front power button is also a reliable way of powering down the FPG.

DO NOT power down the FPG by using the rear switch, pulling out the power cable or switching off at the mains as this may damage your instrument.



Shutdown – will before a hardware and software shutdown with immediate effect.

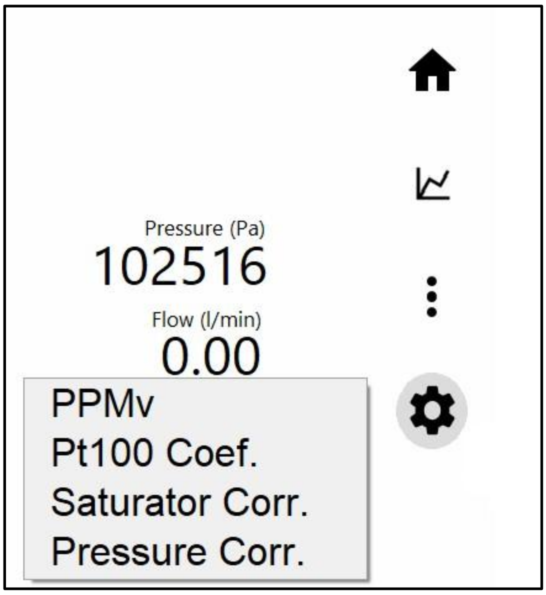
Configure / Transit / Storage – will perform both a hardware and software shutdown after running a 5-minute desiccant purge.

5.2.4 Settings Menu

The FPG settings menu is accessed by selecting the cog icon on the right-hand side. From here, settings can be changed to display PPMv, Pt100 Coefficients and Saturator Corrections can be viewed and adjusted.

5.2.4.1 Parts per Million by Volume (PPMv) / Parts per Billion by Volume (PPBv)

If you require the water vapour ratios PPMv (wet or dry) or PPBv (wet or dry) to be displayed on the FPG home screen, you can choose to display this as shown below. Please note, this is a value calculated from the FPG saturator temperature and pressure measurements.

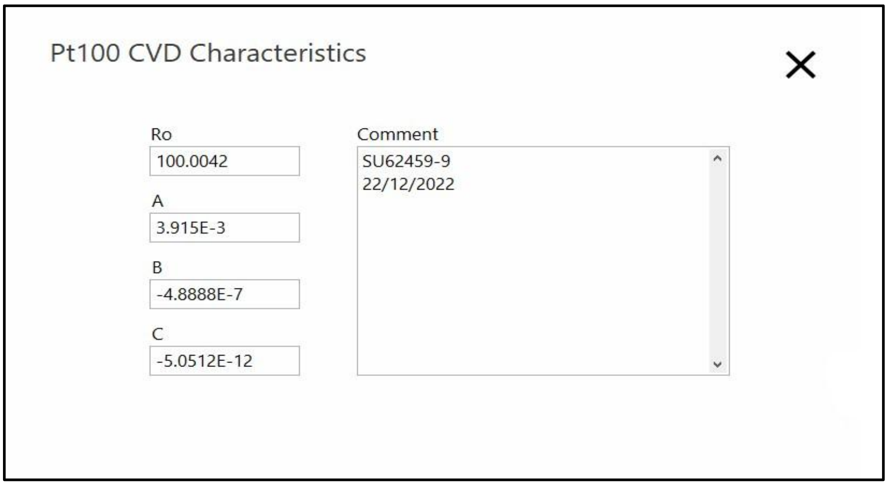


5.2.4.2 Pt100 CVD Characteristics

The saturator temperature control is via a 1/10th DIN PT100. Associated CVD coefficients specific to the Pt100 fitted to the FPG are entered during production.

Changing these coefficients will invalidate the FPG calibration.

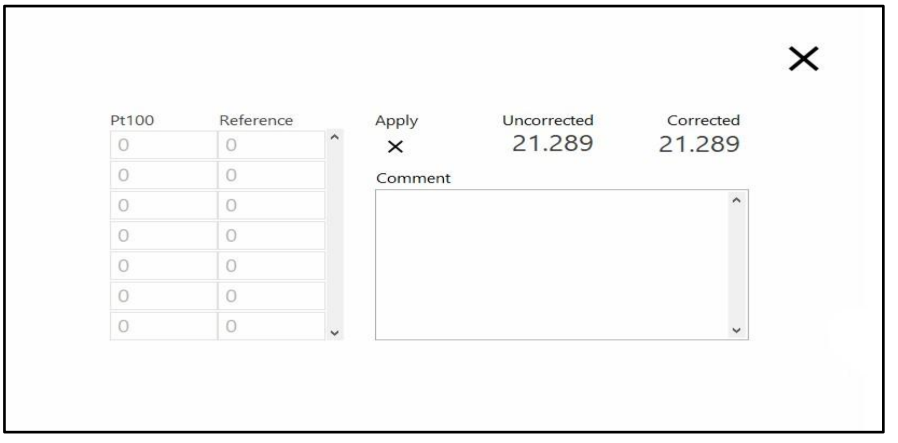
Please note a future firmware release will password protect this section. Qrometric has a record of the factory coefficients should they be inadvertently changed. Please contact support@qrometric.com in this circumstance.



5.2.4.3 Saturator Correction

Corrections to the Saturator Temperature determined from the calibration of FPG can be applied here.

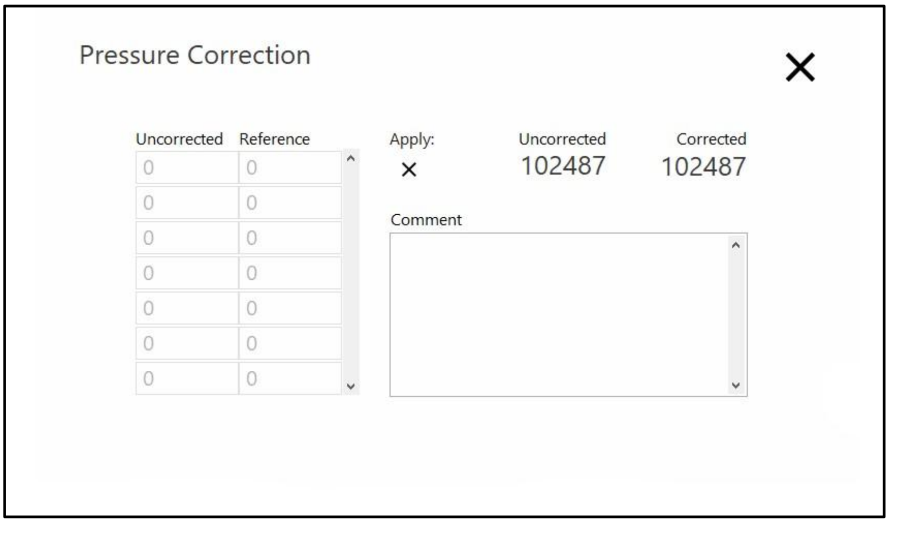
Changing these settings will invalidate the FPG calibration.



It is not recommended to apply corrections but instead record any drift in the calibration over time, to build up historical trend data.

5.2.4.4 Pressure Sensor Calibration

The internal pressure sensor can be calibrated by comparison to a reference measurement between the range 80…120 kPa. The internal pump must be off during calibration. Any calibration corrections can be applied through this screen:



6 Set-Up and Operation: Best Practice

The FPG generates stable dew-frost point conditions which can be used for calibrating humidity instrumentation that measure from ambient conditions down to trace levels. There are various configurations in which it can be used. Each has advantages and disadvantages, so care should be taken in choosing the most suitable set-up.

6.1 Connections to the FPG

For the manifold and rear ports on FPG, VCR gaskets are employed.

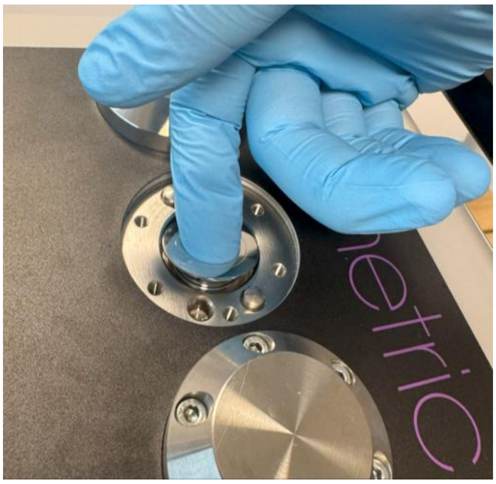
These are single-use consumables that should be replaced every time a connection is remade.

Careful handling of the gaskets and VCR faces should be observed to ensure no finger marks/grease is transferred to them. The wearing of nitrile gloves is recommended.

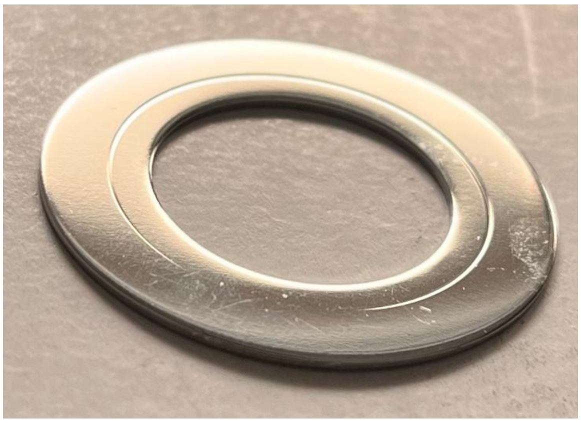
6.1.1 Probe Port Caps and Adaptors

The FPG has three probe ports. It is delivered with each of these closed with a probe port cap (PA0). The caps can be replaced with a probe adaptor with thread and insertion depth compatible with the dew point sensor test instruments to be calibrated.

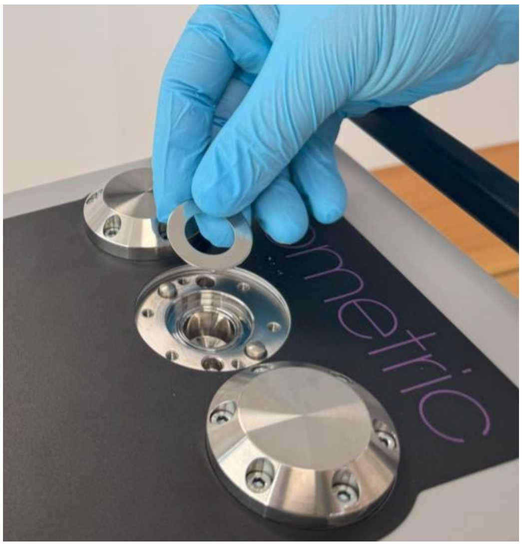
To remove a cap, unscrew each of the 6 mm x 3 mm hex screws and carefully remove the cap. Note the magnetic alignment plug and VCR gasket. Discard the VCR gasket, noting the impression on it that each VCR face has made.

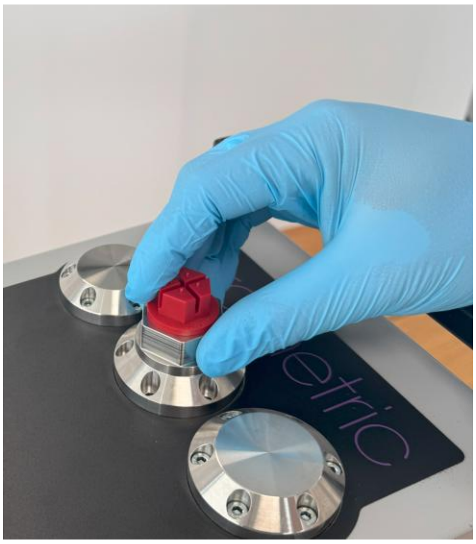


The image below shows what a mis-aligned gasket looks like after removal. The impression on the gasket should be a complete circle to make a proper seal. The following instructions describe how best to achieve that.

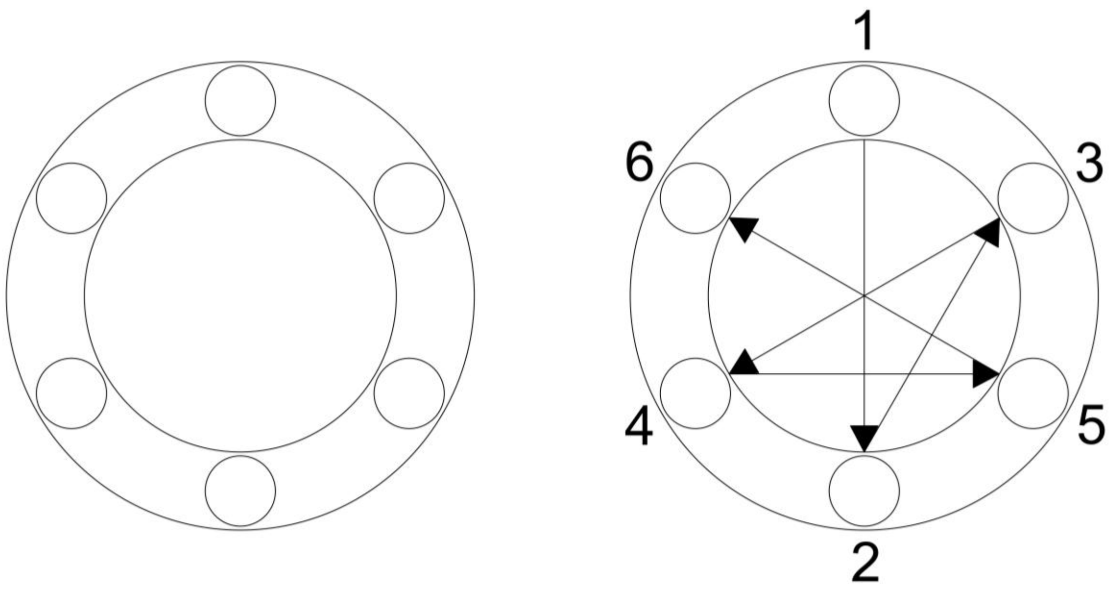


With the FPG standing vertical – and wearing nitrile gloves – place a new VCR adaptor in the manifold port and place the adaptor in position ensuring the alignment pin is positioned as follows:





It is very important to create an even seal on the caps/adaptors. To ensure this, hold the cap/adaptor firmly in position and follow the below bolting patten to ensure uniform contact and seal on the VCR gasket.



The first step is to finger tighten all the bolts, following the sequence as shown above (1 to 6).

Then set your torque driver to 1 Nm and tighten all the bolts using the same sequence.

Then tighten the bolts to 2 Nm and again to 3 Nm, again repeating the same sequence.

For good practice, it is recommended to perform a final check by applying a circular pass of the bolts to make sure that the bolts are at the required torque (1, 3, 5, 2, 4, 6).

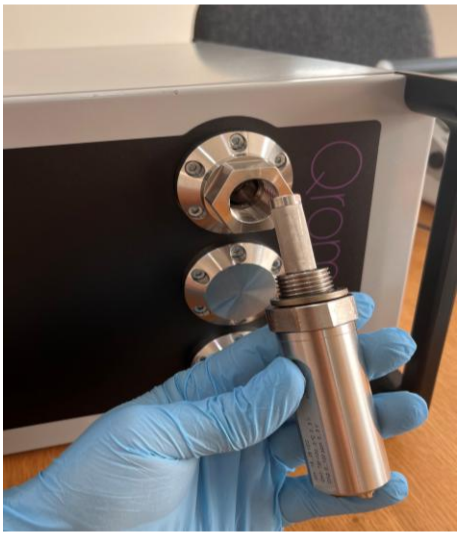
SUMMARY:

- Finger tight star pattern
- 1 Nm star pattern
- 2 Nm star pattern
- 3 Nm star pattern
- 3 Nm final check circular pass

6.1.2 Probe Connections

Once the probe adaptor has been securely installed, the probe can be screwed in:

Note that the integrity of the probe to FPG seal is dependent on the quality and condition of the dew point probe seal and its condition

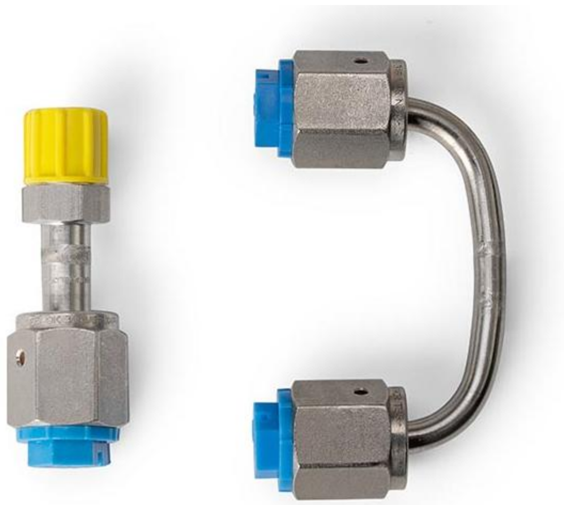


NOTE: To prevent putting stress on the probe adaptor bolts when the probe is being tightened, hold the adaptor in position with a 30 mm spanner on the hex section and tighten the probe accordingly.

6.1.3 Sample Loop Connections

On the rear of the FPG is a sample loop which during normal operation completes the recirculating gas circuit. These ports are ¼” VCR face seal fittings. The loop can be removed and, in its place attached adaptors and associated pipework to install a sampling hygrometer, either to be calibrated itself, or to validate/calibrate the FPG. It is essential that the loop is completed and carefully sealed.

NOTE: THE FPG <u>CANNOT</u> GENERATE A FLOW OF GAS WHICH IS VENTED TO ATMOSPHERE.



To remove the loop, carefully loosen and remove the VCR nuts using a 19 mm spanner. Discard the VCR gasket on each face seal, noting the impression the fitting has made.

The FPG can be supplied (ordered separately) with a pair of VCR to either ¼” or 6 mm Swagelok tube fitting adaptors and two VCR Swagelok NI-4-VCR-2-ZCT-VS side-load gaskets – these are preferable to Retainer or Non-Retained types, which are too easy to misalign.

Side Load VCR Gasket - Swagelok P/N NI-4-VCR-2-ZCT-VS

A good fitting is important for FPG operation, and new gaskets should be used every time a new connection is made.

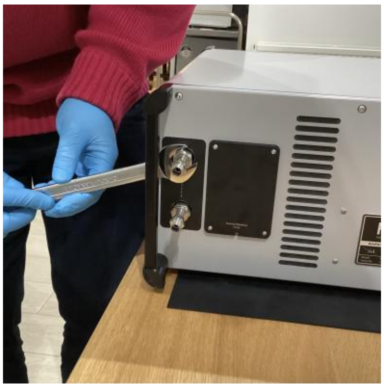
When fitting new gaskets, you must wear new, powder-free nitrile gloves to maintain the cleanliness of the contact surfaces:

New VCR fittings can be attached either directly to VCR fitting on rear of the FPG, or onto the Swagelok face seal VCR fitting itself:

To avoid system leaks, ensure that the gasket is fully pressed down into the right position:

Misaligned Side Load VCR gasket

Check that there is not a gasket on both the male and female VCR fittings:

Best practice when tightening VCR fittings can be found on page 19 of the following link:

https://www.swagelok.com/downloads/webcatalogs/EN/MS-01-24.PDF

Care must be taken in selection of sample tubes to connect the FPG to external instruments to reduce the risk of leaks and measurement errors. For the optimal performance, stainless steel should be used throughout, especially when operating below -50°Cfp. High-quality PTFE tubing, e.g. Polyflon FEP is a reasonable alternative above -50°Cfp.

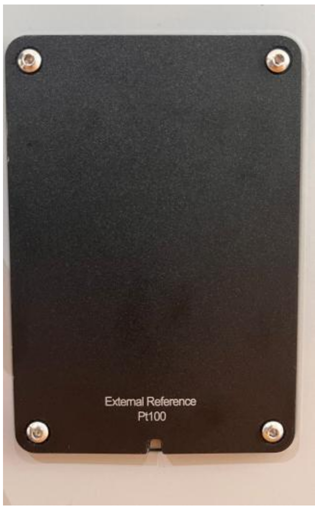
With VCR-tube fitting adaptors attached, DO NOT stand the FPG on its rear bracket. This will damage the internal pipework and is not covered by warranty (see section 3.7 for guidance on transporting the FPG).

6.1.4 External Temperature Probe

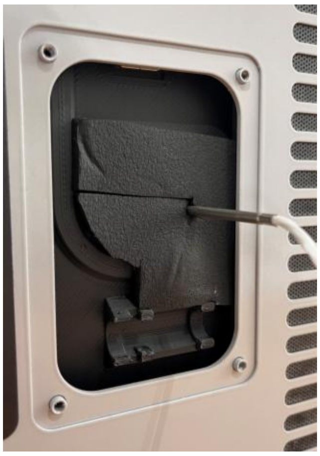
The rear of the FPG has a port on the rear for a 3 mm diameter x 130 mm long external temperature probe so that an independent measurement of saturator temperature can be made, and which itself can be used as a dew point reference value (see section 6.4).

The optional Q-FPG-PRT2 is a 10th DIN Pt100 which is supplied with CVD coefficients and ISO17025 calibration. It is supplied with a 5-pin LEMO connector (FGG.1B.305.CLAD52) with wiring appropriate to plug into an T12 temperature bridge or external temp connection of any MBW chilled mirror hygrometer.

To insert the probe, the saturator temperature must be heated up above ambient dew point temperature. Then remove the rear cover:



Insert probe into aperture as far as it will go:



Reaffix cover with the cable extending below and plug into temperature bridge or external temperature port on reference hygrometer, being sure to enter the probe CVD coefficients into the display instrument or software.

For transportation, the probe, its cable and connector can be stowed behind the rear cover:

To remove the PRT for calibration, make sure the FPG temperature is at 20°C and use a pair of needle nose pliers and grip the metal sheath and pull it out. Do NOT pull the cable to remove.

6.2 Applications and Calibration Scenarios

The FPG's primary intended use is for the calibration of dew point sensors and hygrometers over the range -100…10°C frost/dew point.

The following describes examples of typical FPG applications and some issues to consider. For further advice on any given application, please contact QROMETRIC or your supplier.

6.2.1 Test Instrument Configuration

- Test instruments can be screwed into the front panel manifold into each of three configurable probe ports. Adaptors for different probe types are available.
- Up to three sampling hygrometers can be attached to the rear sample loop in parallel.
- Multiple sampling hygrometers can be attached to the rear sample loop in series.
- An external manifold can be attached to the rear sample loop.

For examples of set-ups, see section 6.4.

6.2.2 Calibration Reference Values

Calibration reference values can be determined in three different ways:

- FPG saturator temperature (control) probe.
- FPG saturator second temperature probe (optional).
- External sampling hygrometer (e.g. chilled mirror hygrometer) (optional).

For a discussion on reference calibration and traceability, see section 7.1.

You can use the FPG as the reference to calibrate several devices attached to the sample loop or use one external loop device as the reference to calibrate others.

Using a transfer standard hygrometer is the preferred approach, however, is not always practical, especially for on-site calibration.

A transfer standard measurement is the most dependable reference sand will highlight if there are any issues, such as leaks, or if there is a long time needed for stabilisation. Bear in mind however, that the reference itself will require time to stabilise, and will add to the system volume and increase time for equilibrium to be reached (see section 6.3.1).

6.3 Set-Up: Considerations

6.3.1 System Qualification

As with any calibration system, it is important the user qualifies its performance to satisfy themselves of its performance. The FPG has undergone extensive testing and as long as the integrity of the external gas circuit is satisfactory, and the system has been dried out and/or purged with ambient air, according to the instructions (see section 6.3.7), the generated dew point condition will correspond to the saturator temperature within the accuracies described in the specification and the system can be used without an external reference with confidence. However, this should be periodically confirmed, either by the user with a reference standard instrument or by sending the FPG for calibration at regular intervals.

6.3.2 Calibration Range

The three models of the FPG have different working ranges: -100°C, -80°C and -60°C up to 10°C. Be aware that over these ranges accuracy changes with ± 0.1°C, ± 0.2°C and ± 0.5°C for -60…0°C, -80…-60°C and -100°C respectively (see section 11).

The highest attainable dew point value is determined by the dew point of the gas initially in the FPG gas circuit when the saturator is not cooling. The gas can be refreshed with new gas by running an atmospheric purge (see below). With fresh gas in the system, the maximum dew point attainable will be then be just below ambient dew point.

6.3.3 Volume of System

With only the back panel sample loop U-loop in place, the internal gas volume of the FPG is about 80ml. It should be noted when using devices attached to the external sample loop, the total volume of the gas circuit depends on the number and internal volume of the connected devices. Increased volume will affect the time taken to reach water vapour pressure equilibrium when set points are changed, especially at low dew-frost point temperatures.

6.3.4 Stabilisation Time

Calibration and measurement in dry gases requires careful consideration of sampling components.

The drier the set point (i.e. the lower the dew point), the longer the system will take to reach equilibrium. The effect of moisture desorption from the internal surfaces of the gas circuit needs to be considered. For faster stabilisation time, the external loop sample tubes should be as short as possible and constructed from stainless steel. For best results, an independent measurement of the generated condition should be included, though this measurement itself will increase the gas circuit volume and the time to reach stability.

Further, it is important to consider the stabilisation time of the instruments under test. Different dew point probes and the type of filter fitted will take different times to come into equilibrium with the FPG manifold condition. With external sampling hygrometers, the desorption/adsorption of water from the internal surface of the connecting pipework needs to come into equilibrium as well as the instruments themselves. Make sure the test instrument measurements have stabilised before moving to a new calibration point.

NOTE: It is best practice to start with the lowest dew-frost point and then increase. This enables the system to reach equilibrium much faster.

6.3.5 Gas Circuit Integrity and Leak Test

It is important to confirm the gas circuit integrity of the FPG with no other instruments attached on first receipt. If there are any leaks, tighten up all fittings according to section 6.1.1 and 6.1.3.

For optimal performance the FPG gas circuit needs to be completely sealed with no leaks.

At very low dew points, if there are fittings or seals – either on the external loop or the manifold – that are compromised, water vapour will ingress into the gas circuit, additional ice will condense in the saturator and eventually the adjacent pipework may become blocked. In the event of such a blockage, the pump will stop and the FPG will indicate it needs to be dried out (see section 5.2.3.2).

When a new system configuration is set up, the easiest and best way to test its integrity (leak tight) is to test and observe the system holding pressure when a below ambient dew point condition is established according to the below procedure.

The expected pressure drop in the system will depend on its total volume, and this depends on what is attached to the FPG. With the minimum system volume, i.e. with only the sample U-loop in place and probe port caps not adaptors, the pressure in the system when changing set point from ambient temperature and pressure to -80°C should drop by approximately 60 hPa. **ONCE STABLE AT THIS CONDITION, THE SYSTEM <u>SHOULD</u> THEN MAINTAIN THIS PRESSURE**. If the pressure does not decrease or starts to increase once the saturator temperature stabilises, there is a leak. If it maintains the lower pressure, then the system can be confirmed as leak tight. If there are leaks, the

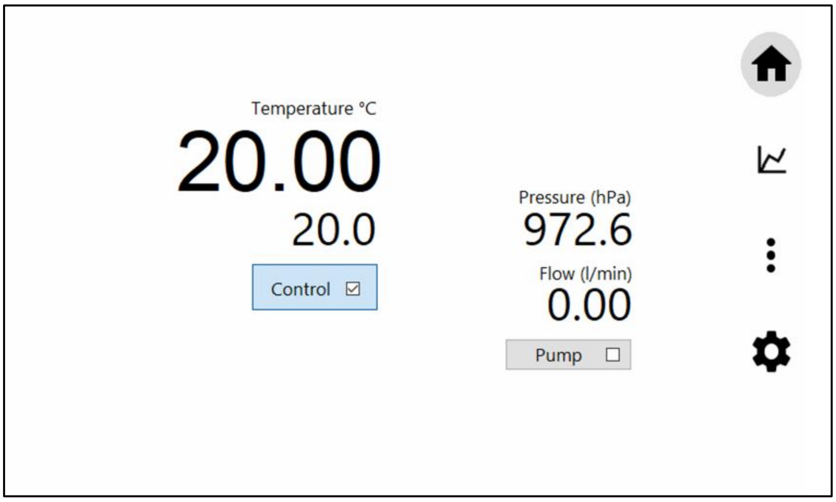
FPG will continue to generate dew point conditions that correspond to the saturator temperature, but there may be an impact on the generated condition.

6.3.5.1 Quick Pressure Integrity Check

NOTE: The following procedure is easiest to follow with the use of an external mouse attached to the FPG.

6.3.5.1.1 Step 1

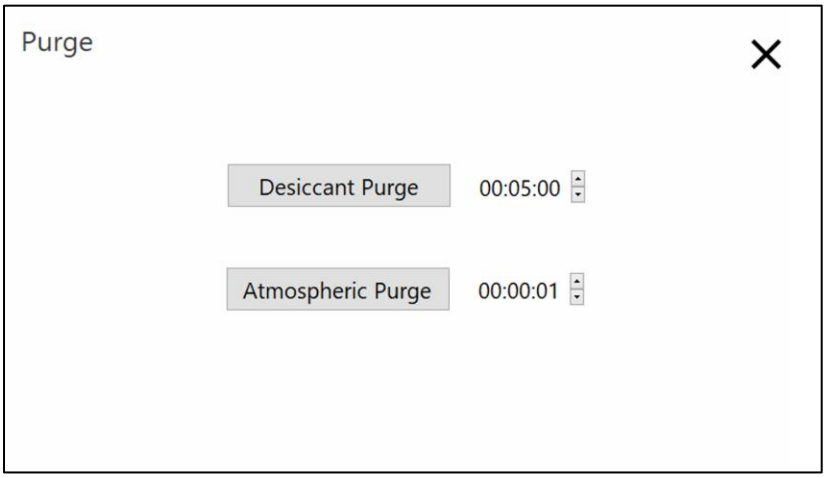
Set the Saturator temperature to 20°C and tick the Control button.



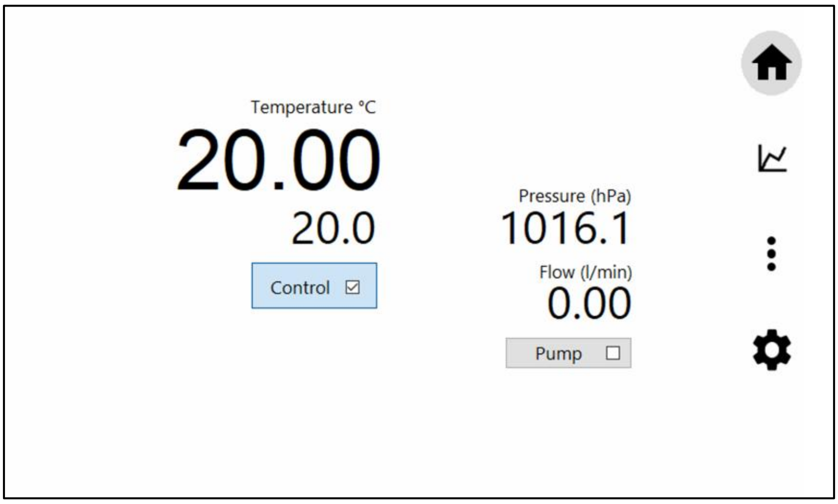
Wait for the temperature to stabilise. Make sure the Pump button is unchecked.

6.3.5.1.2 Step 2

Press the three-dot button and select purge.

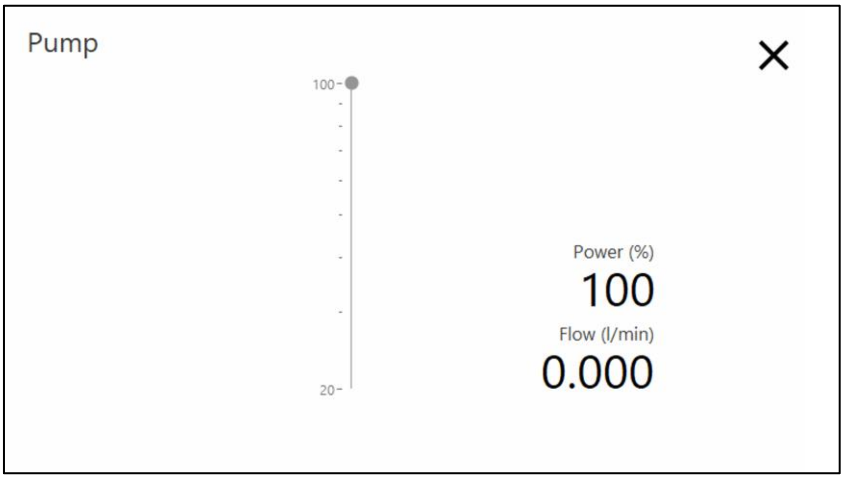


Set the Atmospheric Purge to be for 1 second and press the button. This will equalise the internal system pressure to ambient pressure. Close the window with the X button.



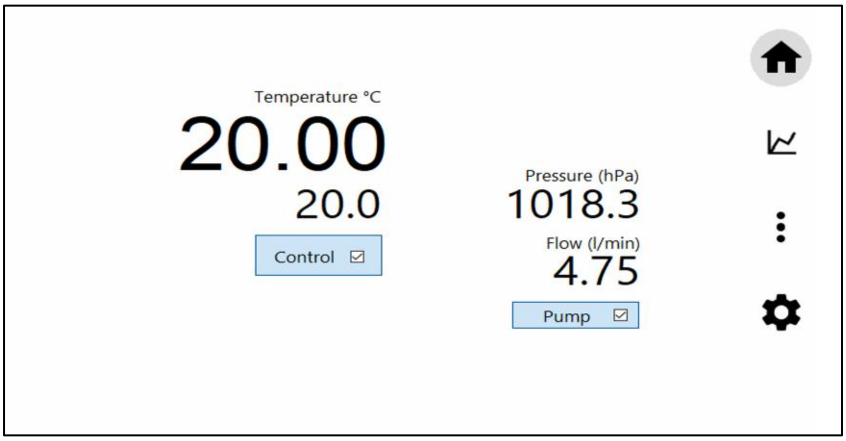
6.3.5.1.3 Step 3

Press the numbers above the Pump button, set 100% pump power and press the X to close the window.



6.3.5.1.4 Step 4

Turn on the pump by pressing the button

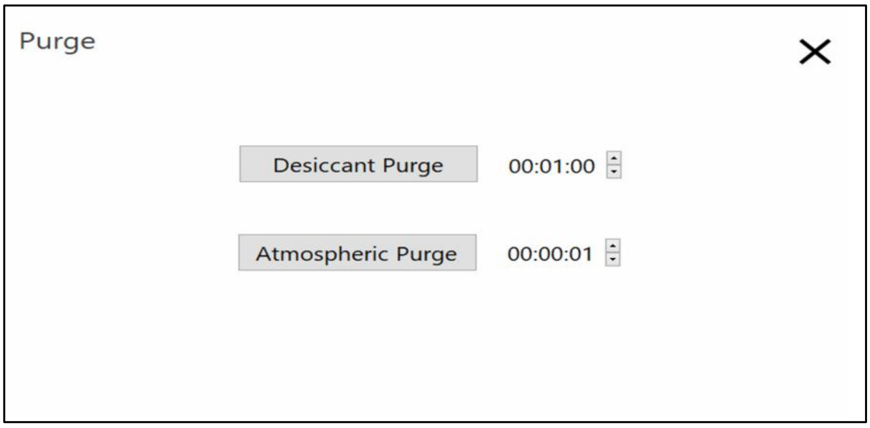


6.3.5.1.5 Step 5

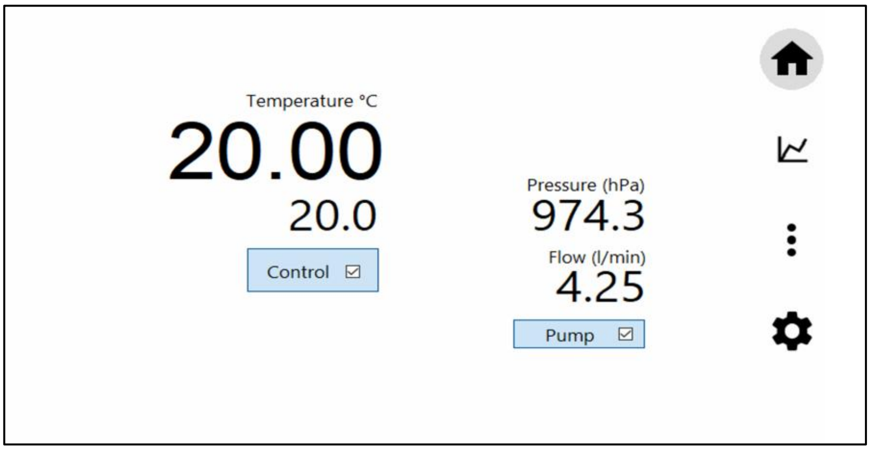
Press the 3 dots and select Purge.

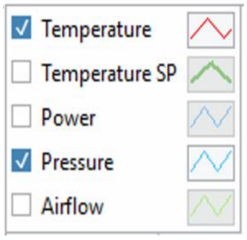
6.3.5.1.6 Step 6

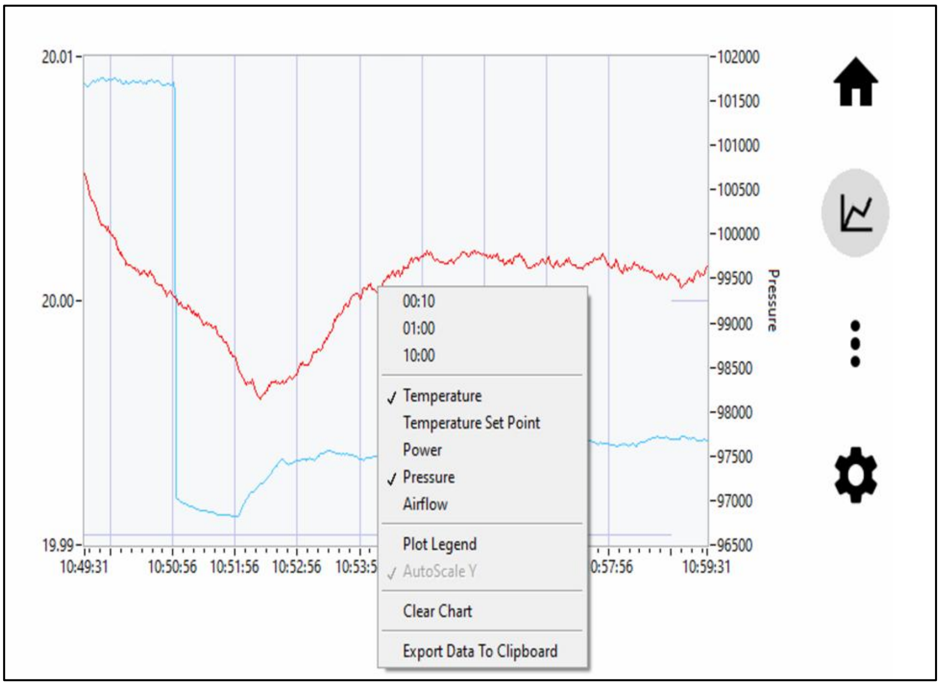
Run the Atmospheric Purge for 10 seconds and close the window with the X.



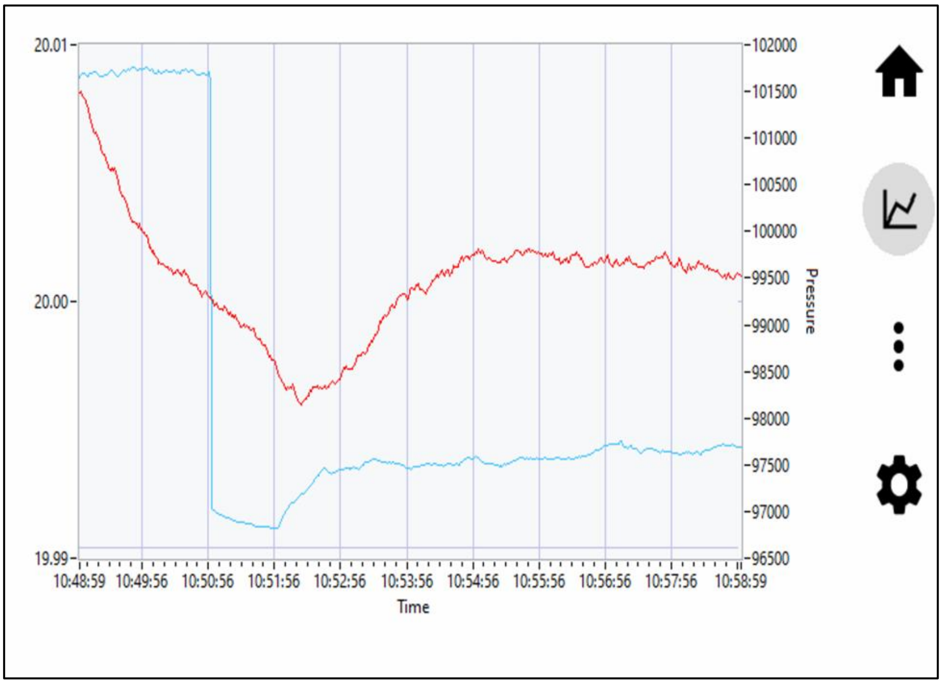
The pressure should drop by ~30..70 hPa and maintain this without rising significantly.



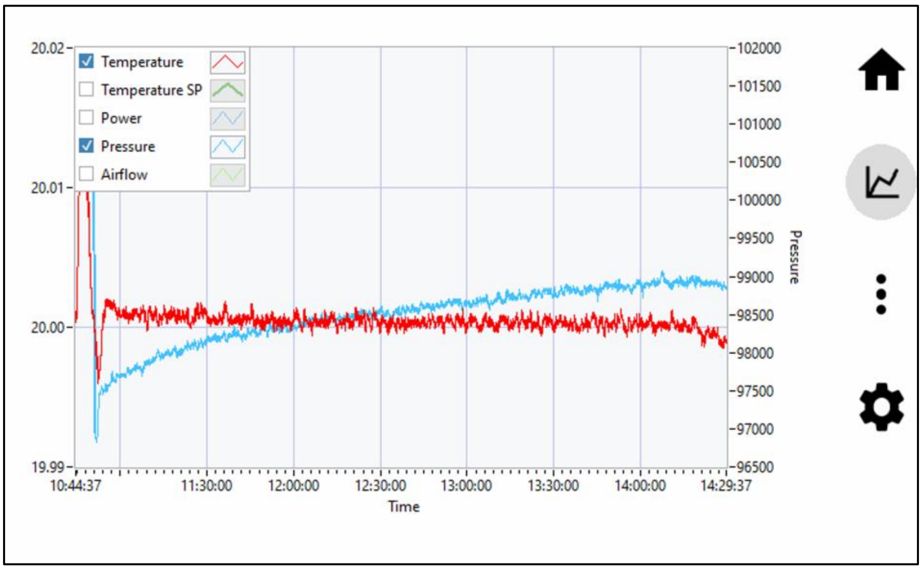




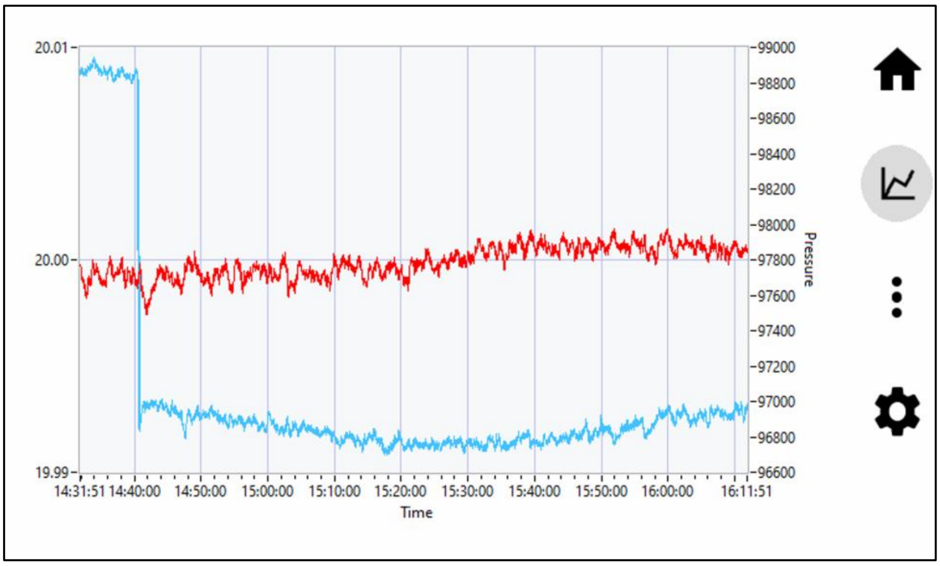
Any significant leak will be immediately obvious as the pressure will trend back to ambient pressure quickly. From the below graph the initial assessment is that there are no *significant* leaks.



Leaving the instrument for longer, may indicate smaller leaks, for example:



In this instance, fittings were tightened and the test repeated, demonstrating an example of a good result:



Note that some variation in pressure will be observed due to ambient temperature fluctuations, so for best results leave the test to run for up to 24 hours. Note that the longest time base it is possible to display on the graph is 23 hours and 59 minutes.

6.3.5.2 Leaks due to attached instrument

Some instruments under test leak, and there is not much that can be done to completely seal the system. In this case an evaluation of the leak rate, and the use of an independent reference measurement is the best course of action to assure a dependable calibration.

As a rule of thumb, a pressure rise of ~10h Pa over the course of an hour is acceptable for calibration down to -80°Cfp. For very low dew-frost point conditions (ultra trace humidity-moisture), it is important to achieve the best possible pressure integrity.

6.3.5.3 Location of leaks

The location of the leak needs to be considered when evaluating any uncertainty in the measured vales. For example, if a dew point probe has poor sealing, there will be an ingress of ambient water vapour near to the measurement sensing element and the local condition will be higher than the rest of the system. This demonstrates weakness of the probe design itself rather than the FPG.

A poor connection on the inlet of an external sampling hygrometer will affect its measured value more than a poor connection on the outlet. In fact, some instruments have lower quality fittings on the outlet gas path, or additional hardware such as sample pumps, which may cause leaks or compromise the generated value in a closed-loop system.

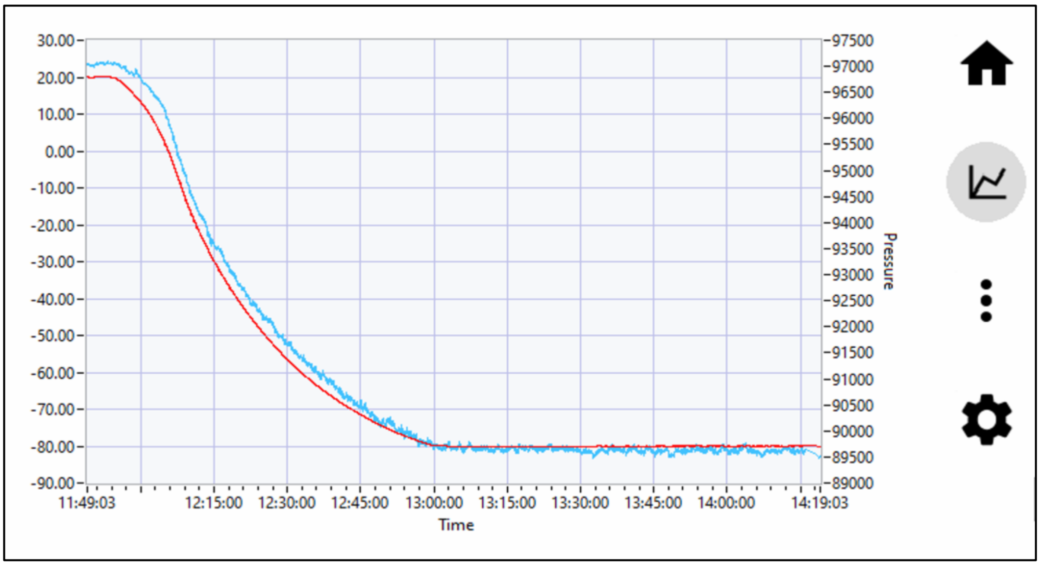
6.3.5.4 Flow dependency leak test

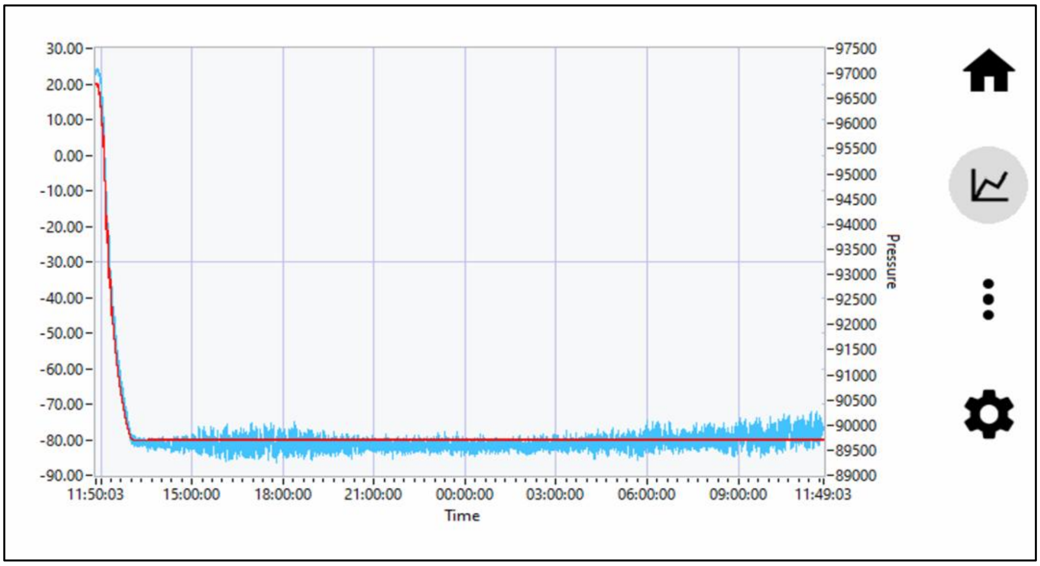
Some dew point probe manufacturers specify that their instruments measure consistently independent of gas flow rate. This can be useful for evaluating any possible leaks local to the probe itself, for example, if the probe seal is not adequate.

Leaks will affect measurements differently at different gas flow rates. For example, higher gas flow will mean the leaks are less apparent. By making several measurements at a fixed FPG saturator set point, with different pump power settings, if the dew point probes measurements are consistent, then the user can be confident of good sealing and pressure integrity.

6.3.5.5 Full pressure integrity test

FPG is carefully tested in production and before shipping, the following full pressure integrity check is performed. This involves running the quick pressure check (see section 6.3.5.1), and in addition, cooling the saturator to its lowest temperature to create the largest possible pressure differential and running the test for 24 hours. The pass/fail criteria are that there is no discernible trend upwards over this period. An example trace is shown below:





On receiving the instrument for the first time, it is strongly recommended to re-run the full pressure integrity test, before any instruments are attached, to satisfy the user the instrument has been received in full working order.

Qrometric request that the result of the test – either a screengrab, or simple photograph of this graph – are emailed to support@qrometric.com.

At the end of the tests, reset the pump power to the required value for operation.

6.3.6 Sample Gas Flow

The FPG's integrated pump generates sample gas flow through the system. Generating flow through *the system* requires a pressure differential, the magnitude of which is related to the FPG pump power. The differences in pressure between the saturator and the test instrument resolve differences in dew/frost point and hence the uncertainty of the calibration. This effect has been evaluated by fitting pressure sensors in various positions around the gas circuit and determining the consequential uncertainty contribution. See section 6.5 for further details.

6.3.7 Drying Out Procedure

BASE HUMIDITY IN GAS CIRCUIT
It is good practice to measure the base humidity in the gas circuit using a hygrometer connected to the external sample loop before and after a measurement run. To do this set the saturator temperature to 20°C. With the saturator at this condition, if the measured dew point is above 15°C, it is likely there has been a leak of ambient humidity into the system when the saturator was cooling, which has condensed onto the saturator. To dry this out, run the desiccant purge until the measured dew point is below ambient dew point conditions, then run an atmospheric purge to refresh the FPG gas circuit.

To dry out the system, run a desiccant purge according to section 5.2.3.2 and follow procedures beginning calibrations according to section 6.5.

6.3.8 Calibration above ambient dew point

In normal use, having followed set up procedures according to section 6.5, the maximum dew point that can be controlled is just below the dew point of the ambient air used to purge the system. This is because there is no water source in the FPG, it uses the water molecules from the ambient air. As soon as the saturator temperature is above the ambient dew point, all the water molecules trapped in the system have been evaporated.

With careful use and an external reference measurement, the FPG *can* be used to calibrate at dew points above the ambient dew point. This is done by purging the system with ambient air with the saturator at a temperature ***below*** the ambient dew point and deliberately trapping extra water molecules in the system by condensing them on the saturator, and then slowly warming up the saturator to the desired value.

Trial and error is required to trap an appropriate amount of water. The time to purge with ambient air and the temperature at which to cool the saturator depends on ambient conditions.

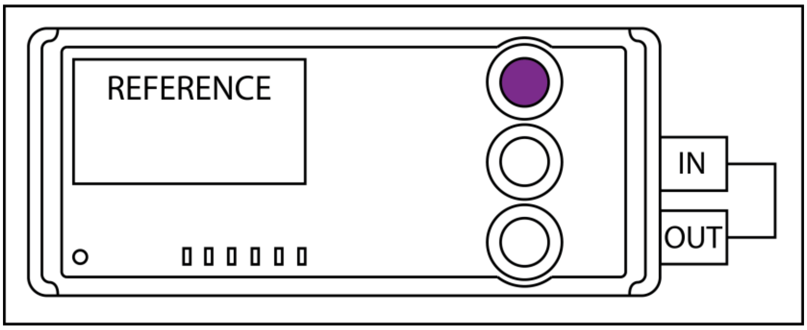
DO NOT USE THE SATURATOR TEMPERATURE AS A REFERENCE IN THIS CIRCUMSTANCE. This should only be attempted with a separate reference device to measure the condition in the FPG gas circuit.

NOTE: a limit will be reached when there is too much water collected on the saturator, and it will collect as liquid water in the system pipework. At this point, the saturator temperature will not correspond to dew point in the FPG gas circuit. The only way to proceed is to start again having dried out the FPG according to section 5.2.3.2.

No guarantees are made of the performance at above ambient temperature dew points.

6.4 Example Set-Ups

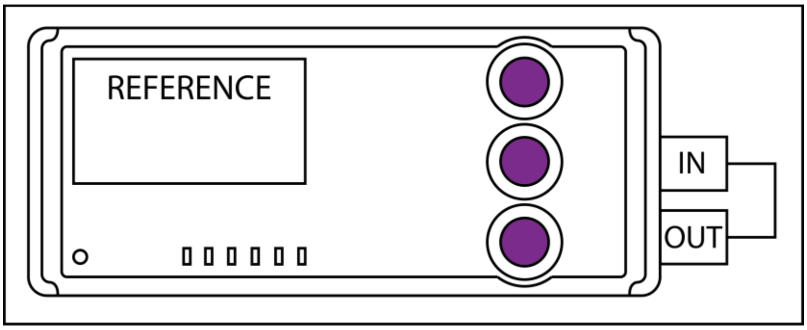
6.4.1 FPG Stand-Alone: 1 x Dew Point Sensor in Manifold (FPG as Reference)



- **Advantages:** No external sample loop volume = fast stabilisation time, low uncertainty, easily transportable, suitable for use on-site.

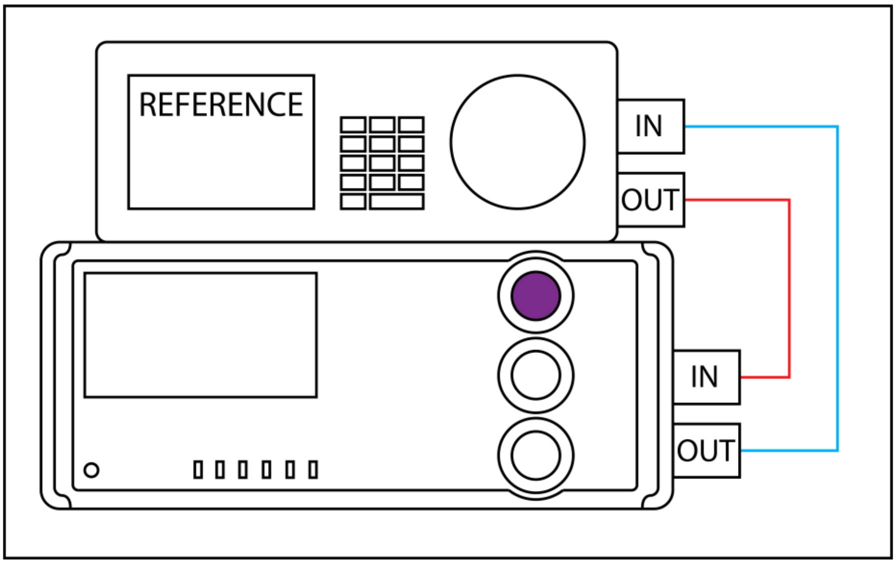
- **Disadvantages:** No independent verification of generated condition.
- **Optional:** Independent verification of saturator temperature using external PRT.

6.4.2 FPG Stand-Alone: 3 x Dew Point Sensor in Manifold (FPG as Reference)



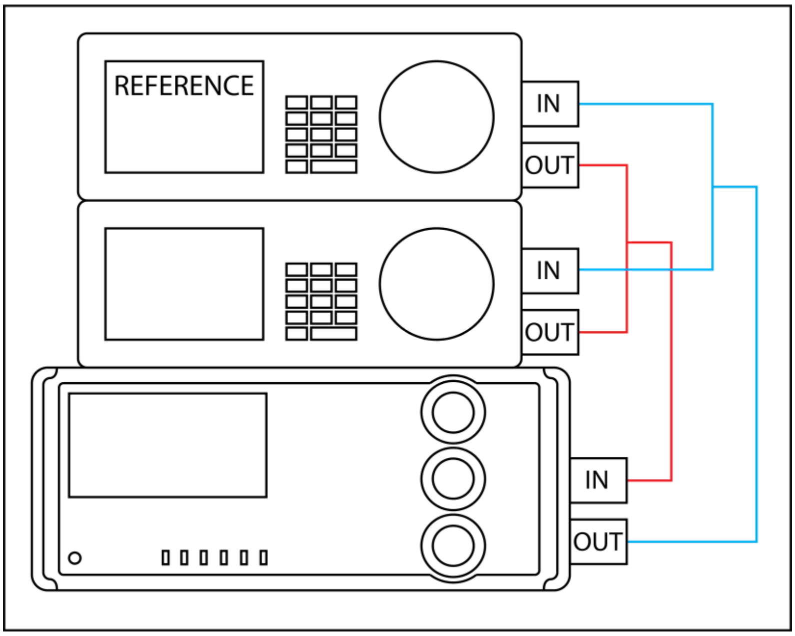
- **Advantages:** No external sample loop volume = fast stabilisation time, low uncertainty, easily transportable, suitable for use on-site.
- **Disadvantages:** No independent verification of generated condition.
- **Optional:** Independent verification of saturator temperature using external PRT.

6.4.3 FPG: 1 x Dew Point Sensor in Manifold (External Reference on Sample Loop)



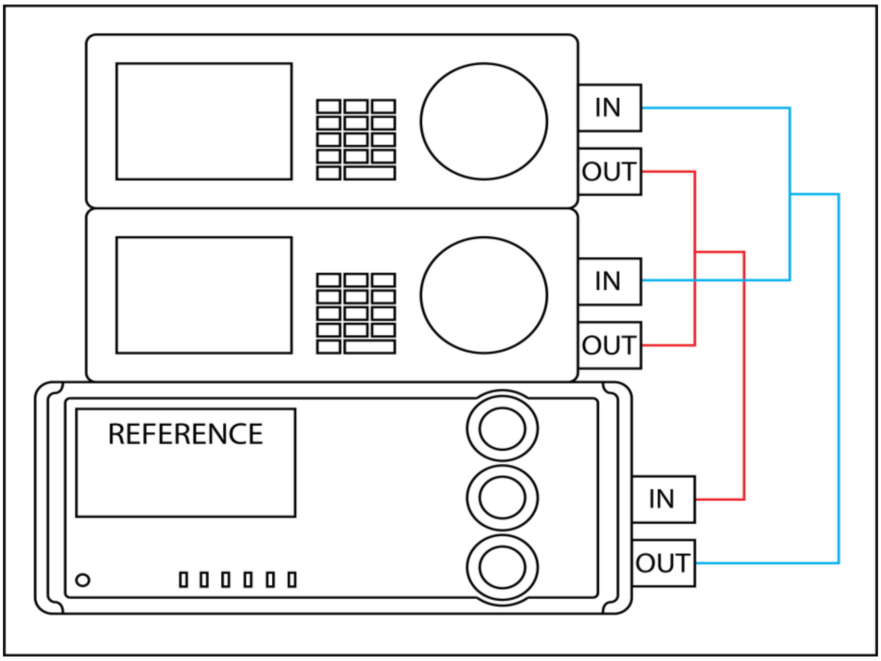
- **Advantages:** Relatively small sample loop volume, reasonable stabilisation time, low uncertainty, independent verification of dew point, no need to calibrate FPG.
- **Disadvantages:** More difficult to transport.
- **Optional:** Independent verification of saturator temperature using external PRT.
- **Considerations:** The difference in the pressure between saturator and sampling hygrometer (and its effect on dew point), though minimal, should be evaluated (see section 6.5).

6.4.4 FPG: No Sensors in Manifold, 2 x Hygrometers in Parallel on Sample Loop (One as Reference to the Other)



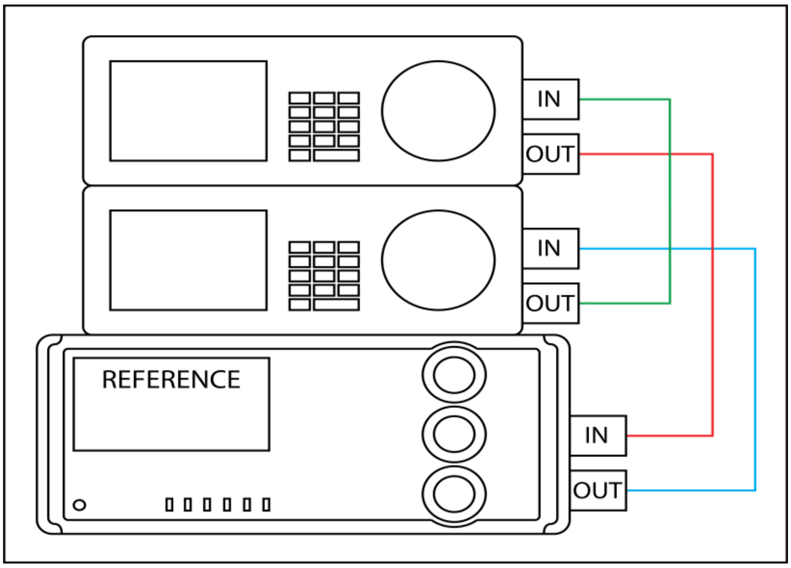
- **Advantages:** Low uncertainty, independent verification of dew point, no need to calibrate the FPG.
- **Disadvantages:** Higher pump power to drive larger flow means potential difference between generated and measured value (see section 6.5). Larger system volume means longer stabilisation time.
- **Optional:** Independent verification of saturator temperature using external PRT.
- **Considerations:** Differences between generated and measured values don't matter when one hygrometer is used as a reference to the other, and the pressures will be the same if pipework is kept at similar lengths.

6.4.5 FPG: No Sensors in Manifold, Two Sampling Hygrometers in Parallel on Sample Loop (FPG as Reference)



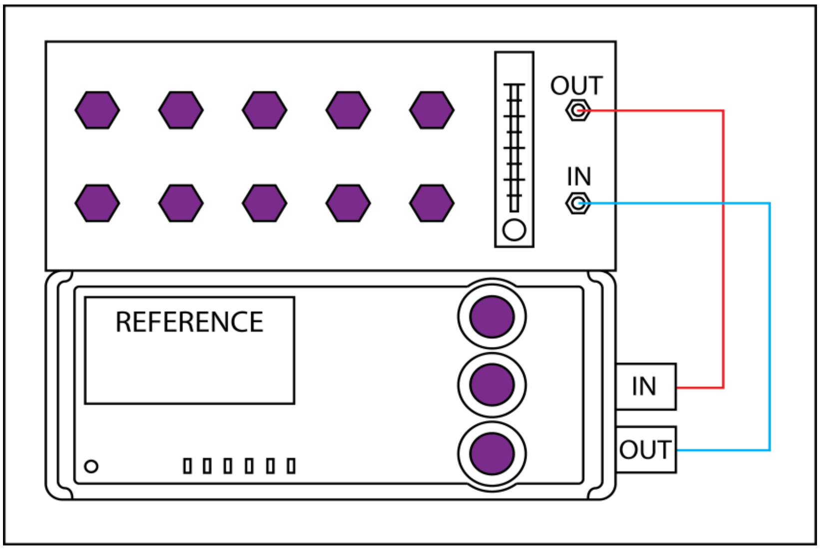
- **Advantages:** Multiple external hygrometers simultaneously.
- **Disadvantages:** Higher pump power to drive larger flow means potential difference between generated and measured value needs to be evaluated. Larger system volume means longer stabilisation time.
- **Optional:** Independent verification of saturator temperature using external PRT.
- **Considerations:** Difference in generated dew point due to pressure difference can be calculated out if pressure sensors are calibrated or factored into uncertainty calculations (see section 6.5).

6.4.6 FPG: No Sensors in Manifold, Two or More Sampling Hygrometers in Series on Sample Loop (FPG as Reference)



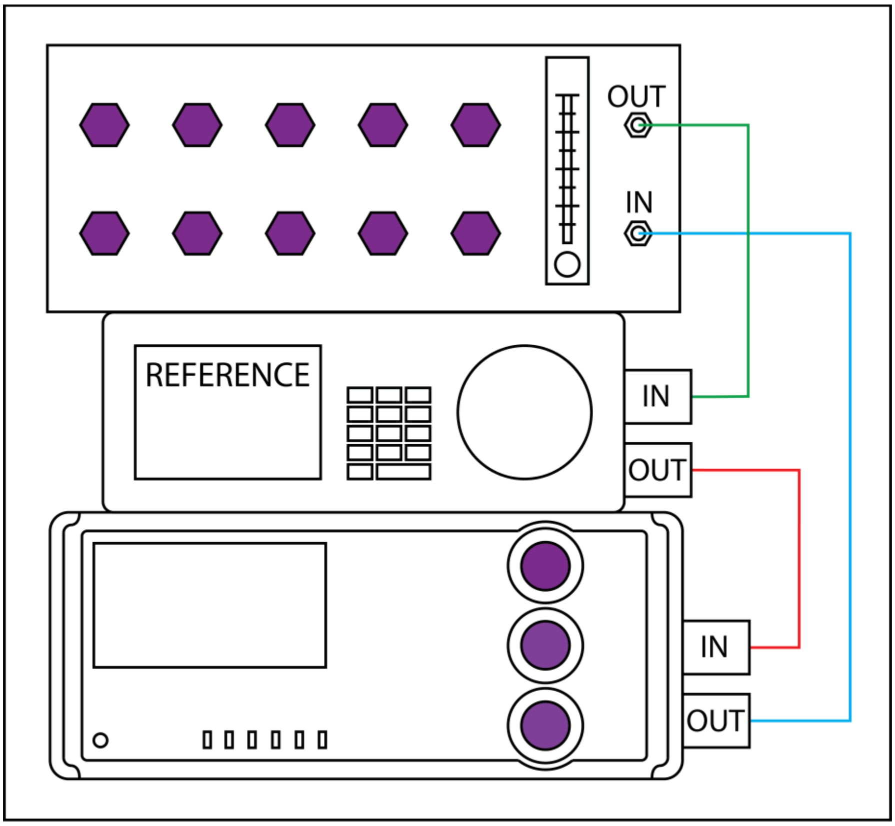
- **Advantages:** Multiple external hygrometers simultaneously. Series means pump power/flow rate can be kept relatively low.
- **Disadvantages:** Pressure differences in the system need to be evaluated. Much larger system volume means much longer stabilisation time.
- **Optional:** Independent verification of saturator temperature using external PRT.
- **Considerations:** Difference in generated dew point due to pressure difference can be calculated out if pressure sensors are calibrated or factored into uncertainty calculations (see section 6.5).

6.4.7 FPG: 3 x Dew Point Sensors in Manifold, External Manifold Fully Populated (FPG as Reference)



- **Advantages:** Multiple external hygrometers simultaneously. Series means pump power/flow rate can be kept relatively low.
- **Disadvantages:** Pressure drops across the system need to be evaluated. Much larger system volume means much longer stabilisation time. Any leaks in the any ports will impact the conditions experienced by probes downstream in the loop. No independent verification of generated condition.
- **Optional:** Independent verification of saturator temperature using external PRT.
- **Considerations:** Difference in generated dew point due to pressure difference can be calculated out if pressure sensors are calibrated or factored into uncertainty calculations (see section 6.5).

6.4.8 FPG – 3 x Dew Point Sensors in Manifold, External Manifold with up to 10 Dew Point Sensors (plus Additional [Reference] Hygrometer in Series)



- **Advantages:** Multiple external hygrometers simultaneously. Series means pump power/flow rate can be kept relatively low.
- **Disadvantages:** Pressure drops across the system need to be evaluated. Much larger system volume means much longer stabilisation time. Any leaks in the any ports will impact the conditions experienced by probes downstream in the loop.
- **Optional:** Independent verification of saturator temperature using external PRT.
- **Considerations:** Difference in generated dew point due to pressure difference can be calculated out if pressure sensors are calibrated or factored into uncertainty calculations (see section 6.6).

6.5 Example Calibration Procedure

6.5.1 Stand-Alone FPG Without External Reference

1. Set-up test instruments according to above.
2. Start with the FPG saturator temperature set to 20°C.
3. Run Desiccant Purge for 10 minutes.
4. Run Atmospheric Purge for 1 minute.
5. Set lowest value of saturator temperature and allow to stabilise.

6. Set profile in ascending steps.
7. Start and log data using MBW GeckoR2.
8. At end of run, set the FPG saturator temperature to 20°C.

6.5.2 FPG with External Reference

1. Set-up test instruments according to above.
2. Start with the FPG saturator temperature set to 20°C.
3. Measure dew point in system.
4. Run Desiccant Purge if system dew point is higher than ambient dew point conditions.
5. Run Atmospheric Purge for 1 minute.
6. Set lowest value of saturator temperature and allow to stabilise.
7. Set profile in ascending set points.
8. Start and log data using MBW GeckoR2.
9. At end of run, warm up FPG saturator temperature to 20°C.
10. Measure dew point in system.

If the dew point of the system at the end of the run (step 10) is higher than at the beginning (step 3) then there has been a leak and an ingress of ambient humidity into the system.

6.6 Uncertainty Framework

Table 1: FPG Uncertainty Framework for the Generated Condition at -60°C

FPG Uncertainty at -60 °C Uncertainty Contributions	Type	Value	Units	Sensitivity	Distribution	Divisor	Std. Un.
Temperature Effects							
FPG SatT control PRT calibration uncertainty	B	0.040	°C	1.00	Normal 2s	2.00	0.020
FPG SatT control PRT drift	B	0.005	°C	1.00	Rectangular √3	1.73	0.003
FPG SatT control PRT stem conduction	B	0.005	°C	1.00	Rectangular √3	1.73	0.003
FPG SatT control PRT self-heating and residual heat fluxes	B	0.005	°C	1.00	Rectangular √3	1.73	0.003
FPG SatT control uncorrected deviations	B	0.005	°C	1.00	Rectangular √3	1.73	0.003
FPG Display Resolution	B	0.0005	°C	1.00	Rectangular √3	1.73	0.000
FPG SatT Repeatability	A	0.004	°C	1.00	Normal 1s	1.00	0.004
Temperature Effects combined uncertainty							**0.0212**
Saturator Contributions:							
Saturation efficiency	B	0.0001	°C	1.00	Rectangular √3	1.73	0.000
Saturator contamination	A	0.001	°C	1.00	Normal 1s	1.00	0.001
Temperature gradient between saturator surface and PRT	A	0.01	°C	1.00	Normal 1s	1.00	0.010
Saturator Temperature homogeneity	A	0.01	°C	1.00	Normal 1s	1.00	0.010
Saturator Temperature stability	A	0.001	°C	1.00	Normal 1s	1.00	0.001
Saturator Contributions combined uncertainty							**0.0142**
Pressure Effects							
FPG internal pressure sensor calibration uncertainty	B	70	Pa	0.00006	Normal 1s	1.00	0.004
FPG internal pressure sensor drift	B	300	Pa	0.00006	Rectangular √3	1.73	0.010
FPG pressure resolution	B	0.5	Pa	0.0001	Rectangular √3	1.73	0.000
FPG internal pressure sensor repeatability	A	300	Pa	0.00006	Rectangular √3	1.73	0.010
Stability	B	150	Pa	0.00006	Normal 1s	1.00	0.009
Pressure differences between Saturator and Manifold	A	460	Pa	0.00008	Normal 1s	1.00	0.035
Pressure Effects combined uncertainty							**0.0394**
Flow Effects							
Flow dependency related to Pressure differentials	A	390	Pa	0.00008	Normal 1s	1.00	0.030
Flow Effects combined uncertainty							**0.0299**
Other Uncertainties							
Internal sorption/desorption/leaks effects	B	0.5	Pa	0.0001	Rectangular √3	1.73	0.00003
Flow Effects combined uncertainty							**0.0000**
FPG combined uncertainty							**0.06**
FPG expanded uncertainty						95% confidence	**0.11**

Table 2: Uncertainty Framework for Calibrating an FPG Using an External Mirror at -60°C

FPG Uncertainty Framework - with an external reference at -60°C Uncertainty Contributions	Type	Value	Units	Sensitivity	Distribution	Divisor	Std. Un.
Reference Mirror							
Calibration Uncertainty	A	0.20	°C	1.00	Normal 2s	2.00	0.100
Drift	B	0.02	°C	1.00	Rectangular √3	1.73	0.012
Contamination	B	0.01	°C	1.00	Rectangular √3	1.73	0.004
Temp Gradients across mirror	B	0.01	°C	1.00	Rectangular √3	1.73	0.006
Resolution	B	0.0005	°C	1.00	Rectangular √3	1.73	0.000
Repeatability	B	0.05	°C	1.00	Normal 1s	1.00	0.050
Stability	B	0.01	°C	1.00	Rectangular √3	1.73	0.006
Mirror combined uncertainty							**0.11**
Mirror expanded uncertainty						95% confidence	**0.23**
FPG							
FPG Display Resolution	B	0.0005	°C	1.00	Rectangular √3	1.73	0.000
FPG SatT Repeatability	A	0.004	°C	1.00	Normal 1s	1.00	0.004
Saturator contamination	A	0.001	°C	1.00	Normal 1s	1.00	0.001
Saturator Temperature stability	A	0.001	°C	1.00	Normal 1s	1.00	0.001
Pressure differences between Saturator and Mirror	A	460	Pa	0.00008	Normal 1s	1.00	0.035
Flow dependency	A	390	Pa	0.00000	Normal 1s	1.00	0.000
Internal leaks and desorption effects	B	0.5	Pa	0.0001	Rectangular √3	1.73	0.000
FPG combined uncertainty							**0.04**
FPG expanded uncertainty						95% confidence	**0.07**
OVERALL Expanded Uncertainty						95% confidence	**0.30**

Table 3: Uncertainty Framework for Calibrating an External Mirror Against a Second External Mirror at -75°C

FPG Uncertainty Framework - calibrating by comparison one mirror to another in parallel at -75°C							
Uncertainty Contributions	Type	Value	Units	Sensitivity	Distribution	Divisor	Std. Un.
Ref Mirror							
Calibration Uncertainty	A	0.05	°C	1.00	Normal 2s	2.00	0.025
Drift	B	0.02	°C	1.00	Rectangular √3	1.73	0.012
Contamination	B	0.01	°C	1.00	Rectangular √3	1.73	0.004
Temp Gradients across mirror	B	0.01	°C	1.00	Rectangular √3	1.73	0.006
Resolution	B	0.0005	°C	1.00	Rectangular √3	1.73	0.000
Repeatability	B	0.05	°C	1.00	Normal 1s	1.00	0.050
Stability	B	0.01	°C	1.00	Rectangular √3	1.73	0.006
Mirror combined uncertainty							**0.0578**
Mirror expanded uncertainty						**95% confidence**	**0.1156**
IUT Mirror							
Resolution	B	0.0005	°C	1.00	Rectangular √3	1.73	0.000
Stability	B	0.01	°C	1.00	Rectangular √3	1.73	0.006
Pressure differences between mirrors	B		Pa		Rectangular √3	1.73	0.000
Internal leaks and desorption effects	B	0.5	Pa	0.0001	Rectangular √3	1.73	0.000
IUT combined uncertainty							**0.0058**
IUT expanded uncertainty						**95% confidence**	**0.0116**
OVERALL Expanded Uncertainty						**95% confidence**	**0.13**

Uncertainty frameworks for various FPG configurations have been built and each contribution quantified.

As dew/frost point is pressure dependent, differences in pressure between the saturator and the instrument under test will result in differences in the dew/frost points. To evaluate the magnitude of this effect and the consequential uncertainty contribution, calibrated pressure sensors were fitted to the front manifold, rear panel and external loop. Pressure differences were measured, and the effect converted to a dew point within the uncertainty budget using the sensitivity conversion. In saturator-based humidity generation systems, the effect of surface contamination can be to modify the partial water vapour pressure at the saturator surface, and therefore within the sample loop. Possible contaminants include salts or hydrocarbons, either present in the sample gas, or transferred from contaminated instruments under test. Saturator contamination effects are the subject of a separate study by Bell, Stevens et al. (1992 Meas. Sci. Technol. 3 943). Based on a 4-wire PRT technology, standard contributions for PRT drift, stem conduction, self-heating and repeatability to the uncertainty budget are shown.

If the user wishes to calibrate a probe within the FPG manifold, **Table 1** shows the estimated uncertainty on the condition being generated within the manifold ports.

The FPG itself is calibrated by comparison to a reference dew point mirror and the uncertainty contributions for this procedure can be seen in **Table 2**. As is commonly the case, the reference itself provides a larger contribution than the under test FPG (see section 6.4). The FPG can also be used to calibrate one external instrument against another with the uncertainty framework for this shown in **Table 3**.

6.7 Switching Off the FPG

It is important that the correct shut down procedures are followed to ensure no damage occurs to the instrument. The FPG should be shut down through the settings menu or via the POWER button on the front panel. **DO NOT pull plug out or switch off at power source while the FPG is running or shutting down.**

DO NOT switch off at rear, remove the power connection or switch off at power source before the FPG has finished shutting down.

Damage may result and failures due to this are NOT covered by the FPQ warranty.

7 Calibration & Maintenance

7.1 Calibration

A factory calibration by comparison with a chilled mirror hygrometer is carried out on all new instruments along with a certificate documenting this.

The standard procedure for calibrating the FPG is detailed on the calibration certificate. A pump power of 30% is used.

The saturator PRT (Pt-100) integrated into your FPG is calibrated specifically to your instrument with its CVD coefficients applied. Changing the saturator PRT used will require these coefficients to be changed, which loses the calibration history.

Your FPG can be periodically calibrated at an accredited laboratory providing you with traceability and documented history of your FPG's long-term performance.

The user is also encouraged to carry out measurement cross checks periodically to ensure confidence in their measurements.

It is possible to adjust the FPG's saturator temperature coefficients and apply corrections to the saturator. This is not recommended. The factory calibration is based on coefficients determined during production. Please contact support@qrometric.com should original values be required.

See section 5.2.4.2 for more details.

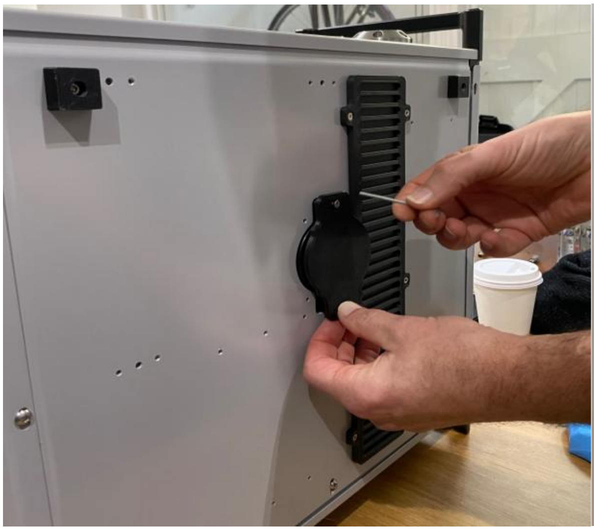
7.2 Desiccant Cell

To replace the desiccant, please follow the procedures set out below.

First, locate the desiccant cell cover on the underside of the FPG (see images below).

Serial Numbers 001…015

Using a 2 mm Allen key, remove the two bolts holding the cover down:




Now the cover is removed, you can pull the desiccant cell out from its slot:

To remove the lid of the desiccant cell, use a thin narrow flat head screwdriver, push in the black locating tabs whilst pulling the lid at the same time.

Serial Number 015…100


Rotate the desiccant cover and withdraw the desiccant cell.

Then remove the layer of cotton that keeps the desiccant in place and pour them out. When refilling the desiccant cell use the line as a guide to fill up to.

Before putting the desiccant cell back into its slot on the underside of the FPG, make sure that the lid is securely in place and is pressed up against the cotton.

7.3 Contamination

Contaminants within the saturator, sample tubes and connections can cause errors in dew-frost point generation and calibration. To prevent dust and other contaminants entering the system, ensure the gas inlets and outlets on both the FPG and attached instrument are closed when not in use and that the sample U-loop is attached.

There is further possibility that contamination is introduced into the system by dirty probes or hygrometers. This may manifest in a mirror fouling on an external dew point mirror which would result in a steadily increasing measurement, that would be reset by mirror cleaning.

To purge the system with fresh gas, follow the instructions in section 5.2.3.2.

In extreme cases of contamination, the desiccant can be replaced by granular activated carbon (GAC) and a long purge using the desiccant purge circuit performed.

In very extreme cases of contamination, contact Qrometric or your supplier for further advice in this regard.

7.4 Exterior Cleaning

7.4.1 Front Panel

The front panel of the FPG can be wiped clean with mild cleaning fluid on a cloth. The LCD screen can be cleaned with glass cleaner and a cloth to remove fingerprints and other marks. Cleaning is best performed with the instrument powered down as marks on the screen often become more visible.

7.4.2 Rear Panel

The rear panel of the FPG does not generally require cleaning. The fan grills, however, should have any dust or debris removed to ensure adequate air flow is maintained. Vacuum cleaning is recommended.

7.4.3 Side, Bottom and Top Panels

Panels including grills should be periodically cleared of dust and debris, as described above. Otherwise, the user can use mild chemicals and a cloth to remove any unwanted stains and marks from the sides and top of the FPG.

8 Installation

8.1 Facility Requirements

8.1.1 Environmental

The FPG is a laboratory grade instrument and works best when external conditions are stable and within a particular range. If possible, it is best to operate your FPG under the following conditions:

- Operating Temperature 15 to 30 °C
- Operating Humidity 20 to 75 %rh non-condensing

8.1.2 Power Source

The universal power supply cable required by the FPG is included in your order as standard. Your facility must be able to supply the FPG with 100…250 VAC at 50/60 Hz.

The power supply MUST be earthed.

8.1.3 Instrument Cooling

Ensure the FPG has at least 10 mm clearance underneath and at least 100 mm at the rear and side to allow sufficient air flow and that there is nothing obvious blocking the fan grills such as dust and debris.

8.2 Preparation for Use

Prior to use, ensure the FPG is safely and securely bench mounted before connecting any of its external cables or tubing.

Before proceeding with, ensure that:

1. The unit is placed level, horizontally and is stable on its four rubber feet.
2. The FPG has at least 10 mm clearance underneath and at least 100 mm at the rear and side to allow sufficient air flow.
3. Access to the electrical mains connector at the instrument rear is adequate.

The FPG itself is W450 mm x D300 mm x H180 mm and an area of at least W480 mm x D330 mm x H200 mm is available to allow sufficient air flow and access to the instrument.

8.3 Preparation for Transit

Care should be taken when prepping the FPG for transit:

1. Set the temperature to 20°C and allow to stabilise.
2. Once at ambient remove no caps and sample loop and run atmospheric purge for five minutes to remove any condensation from the saturator.
3. With sample loop in place, run a 5-minute desiccant purge to ensure the unit is shipped dry.
4. Follow the shut down procedure described above.

Other considerations:

1. Ensure sample loop is connected to prevent excess water vapour or contamination entering the gas pathway.
2. Be careful that the external PRT wire is not bending at a sharp angle anywhere along the cable.

If the FPG needs to be shipped, ensure it is in its original packaging. The soft case is suitable for hand carry only. For air or road shipping, a sturdy cardboard box should be used with at least 100 mm of packing material. A hard transit case is also available for purchase with your FPG.

With VCR-tube fitting adaptors attached, DO NOT stand the FPG on its rear bracket. This will damage the internal pipework and is NOT covered by warranty (see section 3.7).

9 Remote Communication

9.1 Communication with the FPG

The FPG can be remotely controlled, and its information-data accessed using a series of API commands which allows integration with third-party logging and calibration software or user created software using a series of commands which can be found below.

Off-site connections are possible from external networks using manufacturer installed remote access software, or by using a Direct connection to a PC.

9.2 Setting up a connection

The FPG must be connected via the Ethernet port at the rear of the unit. The assigned Local IP address is displayed by selecting the Info page of the drop-down Navigation menu, as outlined in section 5.2.3.3.

9.2.1 LAN Connection

When connecting over a Local network, there are two main methods for connecting to the FPG. This can be done by either:

1. Directly plugging the FPG in, using a RJ45 patch (standard straight through) network cable, to an available RJ45 socket connected to the Local Network.
2. Connecting the FPG to a Wi-Fi converter or Adapter using RJ45 patch cable. To connect, plug the patch cable to the FPG and the adapter, and then configure the adapter Wi-Fi settings for your network. Most Wi-Fi adaptors are compatible with the FPG, though their configuration is beyond the scope of this user manual.

Your controlling device (most likely a PC) ***must*** be on the same Local Area Network (LAN) as your FPG.

By default, the FPG network adaptor is configured to automatically obtain an IP address from the network router via DHCP. If it is unable to determine an IP address via DCHP, it will automatically assign itself a fixed IP address.

The FPG's IP address is displayed in the Info page within the Navigation Menu, as detailed in section 5.2.3.3.

9.2.2 Direct Connection to PC

In situations where there are no available LAN connections or adapters, is possible to directly connect a PC to the FPG using RJ45 patch (standard straight through) network cable. Simply plug the patch cable directly into the desired PC and FPG, and read the displayed IP address on the Info page within the Navigation Menu, as detailed in section 5.2.3.3. The IP displayed during a direct connection usually starts with 169.254.?.? . For assistance in this regard, please contact support@qrometric.com.

9.3 API Commands

API Commands are sent and received to the FPG IP address via port 6341.

This section explains API commands with examples as well as including a full list of possible commands. Anything that can be accessed or performed using the touchscreen can also be sent as a command and vice versa. They can be executed via either a numeric, short or long form, for example,

`19`

`SPR`

`Saturator Power`

all execute the same command.

Multiple commands can be executed at once using commas to separate, for example,

`24,26,27`

will return a string x,y,z, where x,y,z are the responses for their respective commands, 24,26,27.

9.3.1 Read Only Commands

Commands that simply request information, queries, only read data from the FPG and will not write to it. They are identified by an R in the table below.

9.3.1.1 Digital Response: 1 or 0

If simply checking a status (such as whether Control is on/off) a response of 1 or 0 will be returned.

For example,

`STC`

asks for the status of the Saturator Temperature Control. Returning a value of `1` means that Control is set to on while `0` means it is off.

The following table is useful as a quick guide:

Returned Value	Meaning
1	Yes or On
0	No or Off

9.3.1.2 Numerical Responses

Formats of numerical responses will vary, full detail can be found in the command table. The FPG will never send the units of a given value so the user must assume units based on their request and the table to follow.

For example,

`STP`

requests the saturator temperature and may return a value of `-15.348`. The user must then make the educated assumption that the units are °C or use the API reference table.

9.3.1.3 Text Responses

Some queries will return a string of text. This may include letters, numbers and symbols.

For example,

`CHV`

might return a string of letters, numbers and symbols such as `PA14TK1n`, this is the controller hardware version.

9.3.2 Read/Write Commands

Some read commands can become write commands provided that a variable is provided.

For example,

`STS`

will return the saturator temperature setpoint. It can be changed into a write command by simply adding the desired new value:

`STS=20.0`

which will change the setpoint to 20.0°C.

9.3.3 Write Commands

Currently, there is only one command that is write only. It is shown below:

`SHD`

It is used to simply shut down the FPG so, understandably, has no read functionality.

9.3.4 Full Command List

Numeric	Short Form	Long Form	Read/Write	Comment
01	ID	Identity	R	Returns: Model, Serial Number, Manufacturer
02	GEN	General	R	Returns: Saturator Temperature, Saturator Control, Saturator Set-point, Pressure, Air Flow, Errors and Warnings
03	INF	Information	R	Returns: Model, Serial Number, Device Network Name, Driverboard Serial Number, Errors and Warnings

Numeric	Short Form	Long Form	Read/Write	Type	Format	Example	Units
11	STP	Saturator Temperature	R	DBL	%.3f	-15.348	°C
13	STC	Saturator Temperature Control	R/W	INT		1 (0/1)	
14	STS	Saturator Temperature Setpoint	R/W	DBL	%.2f	-20.00 (-100 to 20)	°C
19	SPR	Saturator Power	R	DBL	%.2f	-45.92	%
21	PPR	Pump Power	R/W	DBL	%.0f	25 (20 – 100)	%
22	PCT	Pump Control	R/W	INT		1 (1/0)	
24	AFL	Air Flow	R	DBL	%.2f	1.35	l/min
26	PRS	Pressure	R	DBL	%.0f	93791	Pa
27	PTP	Pressure Temperature	R	DBL	%.2f	25.38	°C
31	DTS	Date and Time Stamp	R	String	Y-m-d H:M:S	2021-10-18 11:10:30	
32	DCC	Desiccant Cell Condition	R	INT		1 (0/1, 1=OK)	
35	TPU	Temperature Units	R	String	2 chr		°C
41	DHV	Driver board Hardware version	R	String		5.1	
42	DFV	Driver board Firmware version	R	String		8.4	
43	CHV	Controller Hardware version	R	String		PA14TK1n	
44	CFV	Controller Firmware version	R	String		1.0.0.75	
45	DSN	Driver board Serial Number	R	String		0003	
46	DNN	Device Network Name	R	String		FPG-0003	
47	MDL	Model	R	String		FPG(-100)	
48	IDN	Serial Number	R	String		0003	
90	ERR	Errors & Warnings	R	String	Err1;Err2;Err3		
101	SHD	Shut Down	W				
112	ABT	About	R	String			
	?	Help	R	String			

9.4 Third-Party Control Software

9.4.1 Calibry

QROMETRIC has worked with Whitestone Technology to create a full integration with their testing and calibration laboratory management software, Calibry. Full automated calibration procedures using the FPG, including automated uncertainty calculation and certificate generation, are easily performed. The use of Calibry and the FPG is documented in a separate user manual available on request from support@qrometric.com.

The full Calibry suite is cloud based and available as a 'software-as-a-service' subscription.

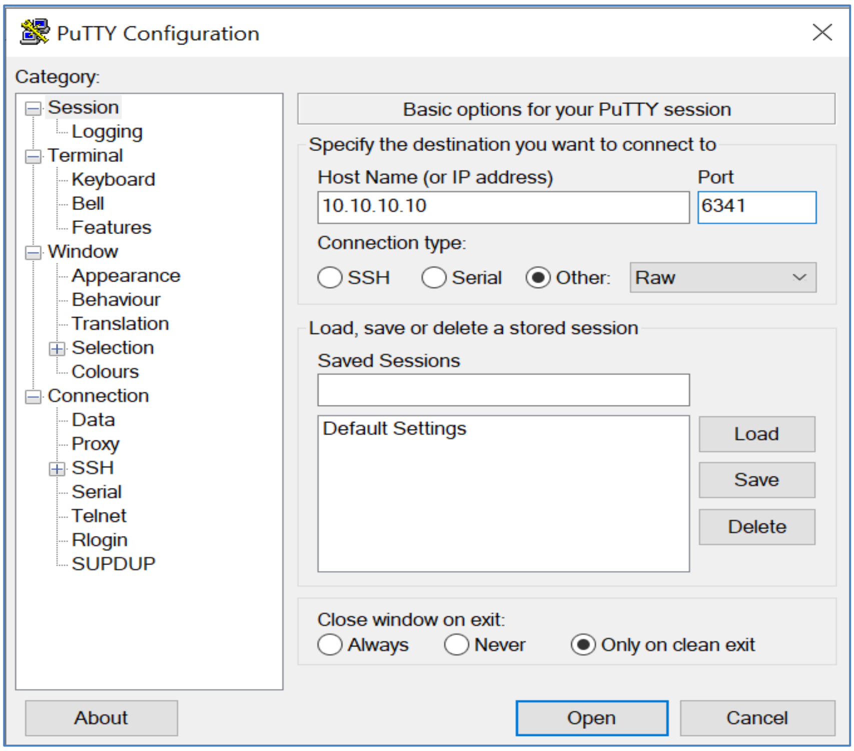
There is a stand-alone version, which just works with the FPG, with preconfigured calibration procedures, known as Calibry Lab-in-a-Box.

For further details please contact info@qrometic.com.

9.4.2 Command Line Interfaces – PuTTY

Command line interfaces such as PuTTY can also be used to send text-based commands to the FPG. Enter the FPG's IP address, found under 'Info' and enter Port 6341. Click 'Open' and PuTTY's command line interface will then open. Connection needs to be of type Raw.

Download PuTTY: latest release (0.78) (greenend.org.uk)



9.4.3 TeamViewer

If the LAN connection is on the Internet, the FPG interface can be accessed remotely via TeamViewer (separate license required) to remotely control the FPG. The TeamViewer ID and password are displayed in the 'Support' section of the interface (see section 5.2.3.4), TeamViewer can also be used on an internal LAN via the local IP address.

9.4.4 MBW GeckoR2

FPG works with MBW GeckoR2 software which can be downloaded from:

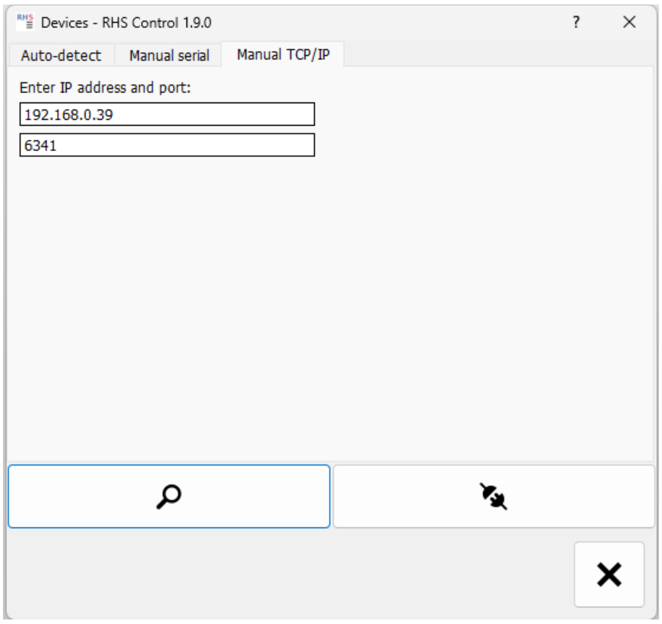
https://www.process-insights.com/download/GeckoR2_Release_0-9-7-3198_2022-03-23.zip

Though it is not a supported product, there is a special configuration file required to enable the FPG communication which is available on request from support@qrometric.com

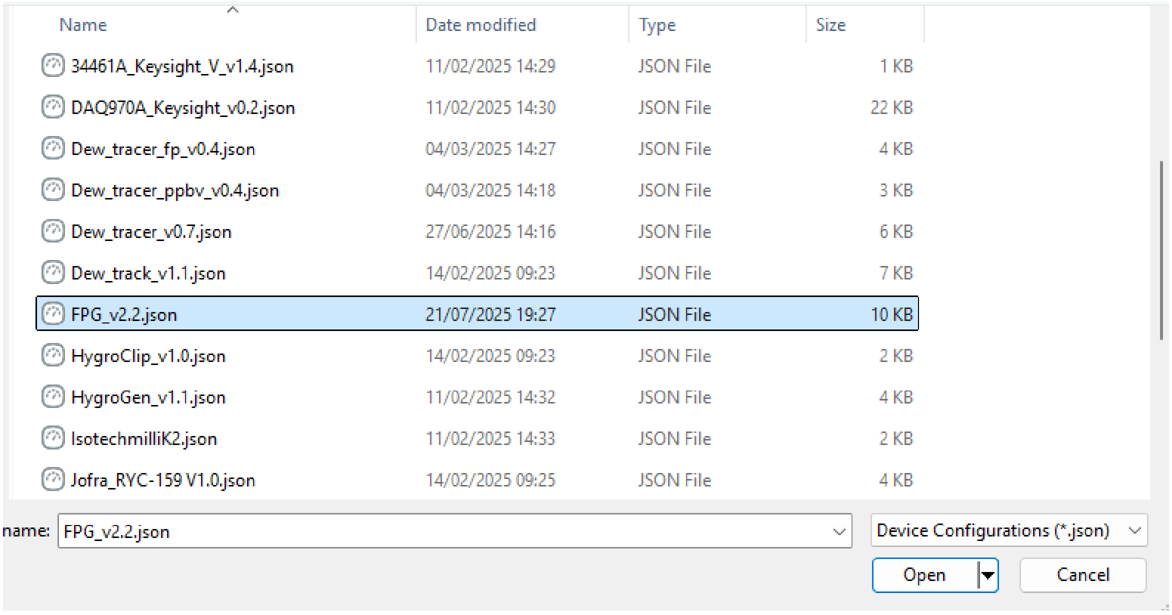
9.4.5 RH Systems Control

FPG works with RH Systems Control software and is available on request from support@qrometric.com. The full user manual for this software of this is beyond the scope of this document, however the following is a quick start guide for using the FPG with RHS Control.

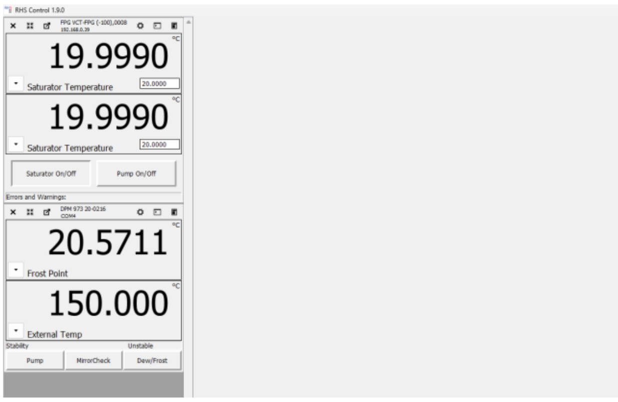
1. Connect the FPG via ethernet to your network, along with the desired PC (or direct connection to a laptop/computer) as outlined in Section 9.1. Note the displayed IP address.
2. Start up the RHS Control executable file on the desired PC. The following window will appear, select the Manual TCP/IP section.



3. Type in the FPG IP and use the port address: 6341. Then press connect button
4. A dialogue box will open for selecting the configuration file. Select the file named like "FPG_v2.2.json", usually located in the "Qrometric" subfolder.

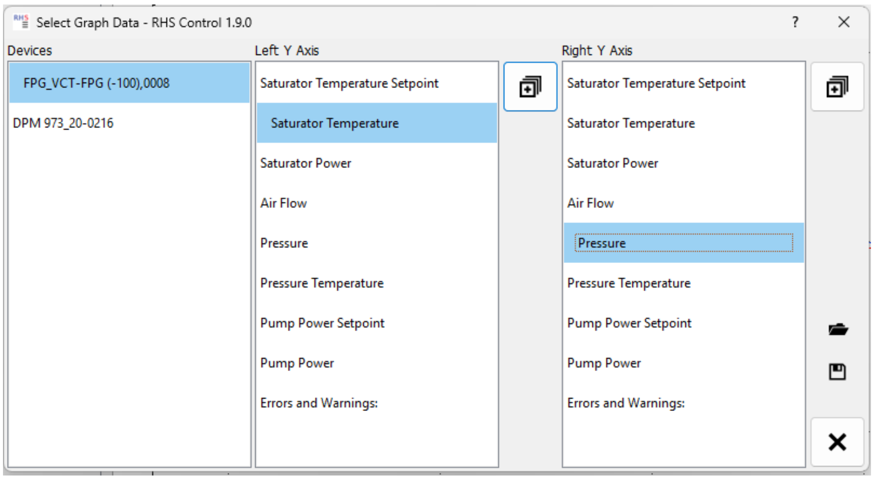


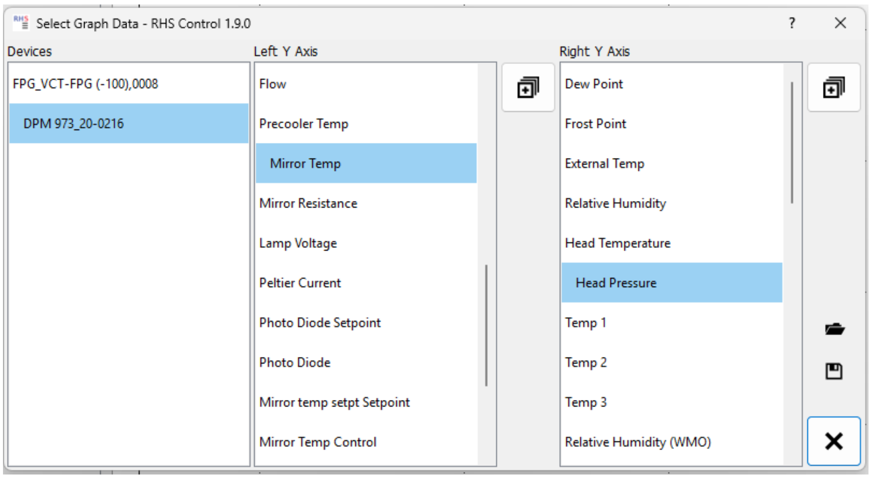
5. If needed, connect another device via RS232 to USB or TCP/IP, then press again.
6. Once this is completed, live data should be displayed on the left-hand side of the window, as shown below:



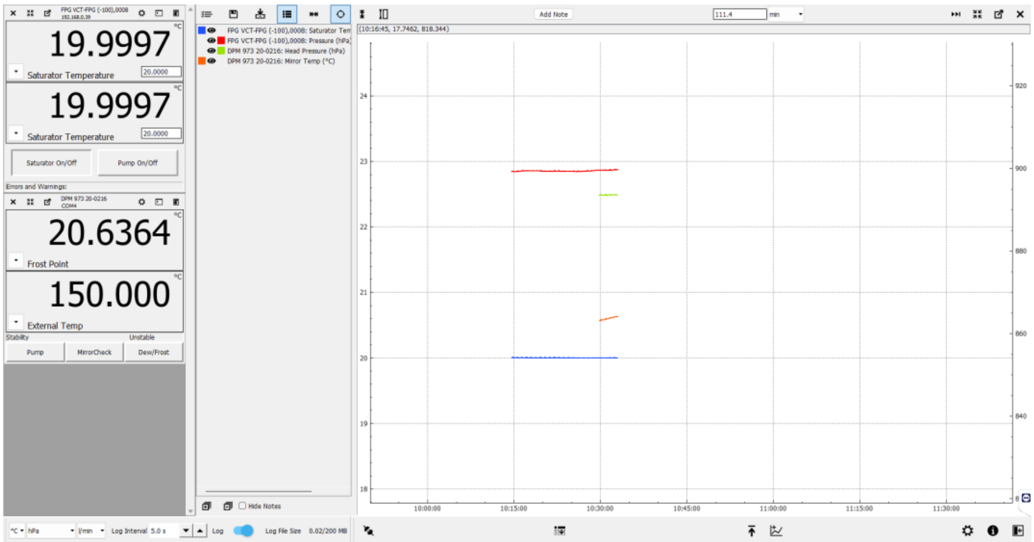
7. To plot the live data over time, click the “Add Graph” button at the bottom right-hand side of the window, as shown below:

8. A dialogue box will open, allowing you to select what variables to plot, in this example we plot the Saturator temperature against a measured mirror temperature from a CMH, along with their measured pressures





9. The graph now displays the live data as it changes over time



10 Messages & FAQ

Message	Notes:
Ambient Temperature High	A High Ambient Temperature message is triggered by a combination of two temperature sensors in the FPG. One is on the case inlet vent and the other is inside the FPG. If either of these reads over 28°C the message appears. The internal FPG case temperature is normally 2°C or 3°C above the inlet temperature. So, if the room temperature is obviously less than 28°C, it indicates there could be some re-circulation either from the FPG itself, or from adjacent equipment. This could be due to obstructed inlet vents, or not quite enough space around the FPG. Ideally, if this message the vents/recirculation should be checked. If you notice the FPG is unable to reach or maintain low saturator temperatures, then either the internal sample gas flow can be reduced (reducing the pump power) or the ambient temperature decreased if possible.
Temperature Stabilising	Temperature stabilising is displayed when the FPG saturator set point has been changed to a new value by the user or external software programming. This means that the dew-frost point in the gas loop may be different to the saturator temperature, and the user should evaluate the generated condition with a reference instrument connected to the back panel or instruments under test connected to the FPG.

FAQ	Response
How do FPG devices calculate frost points?	The FPG does not calculate, it generates frost point based on the temperature control of the internal condensing humidity saturator at the measured pressure. At equilibrium, in the FPG saturator, water condenses and sublimates at an equal rate, similar to the way a condensation hygrometer (chilled mirror) measures dew-frost point. This is the fundamental principle of a primary realisation of humidity used by National Metrology Institutes. Primary realisations typically use a single pass saturator whereas the FPG utilises a closed loop system but works on the same principle. As the gas passes through the saturator, water vapour pressure equilibrates to the saturator temperature.
Does the FPG correct for pressure?	No, there are no pressure corrections applied. The FPG generates the frost point equal to the saturator temperature at the indicated pressure on the FPG display. If there is a pressure difference between the FPG saturator and the Instrument Under Test (IUT) there will be an effect on the IUT's measured dew-frost point that the FPG will not be accounting for. This pressure difference is incorporated into the uncertainty budget, and it is also possible to calculate the effect of the pressure difference on the frost point and correct for it.

We (QROMETRIC) reserve the right to change design or technical data without notice.

11 FPG Specifications

MODEL	Range	Accuracy[1]	FP-DP Stability[2]	SatTemp Stability[3]
FPG-60	-60…10°C	± 0.1°C	± 0.01°C	± 0.01°C
FPG-80	-80…10°C	± 0.2…0.1°C	± 0.01°C	± 0.01°C
FPG-100	-100…10°C	± 0.5…0.1°C	± 0.01°C	± 0.01°C
System Flow	2…4.5 LPM			
System Pressure	800…1200 hPa	0.1%		

1 – Accuracy of generated frost-dew point condition within the system
2 – Stability of the generated frost-dew point condition at equilibrium, in laboratory conditions ± 2°C, as measured with a reference chilled mirror hygrometer on the sample loop over a 10-minute interval, standard deviation ≤ 0.01
3 – Stability of Saturator Temperature at equilibrium, in laboratory conditions ± 2°C, as measured with an external PRT in the rear port over a 10-minute interval, standard deviation ≤ 0.01

Generator type	Dew-frost point, condensation saturator, closed-loop flow
Flow system	Internal pump
Purge function	Filtered atmospheric, Desiccant/Granular activated carbon
Response times	100 minutes, ambient to -100 °C saturator temperature
SatTemp stabilisation time	20 minutes, 20 °C set point change
SatTemp repeatability	± 0.03°C
SatTemp control stability	± 0.01°C
Reproducibility FP-DP	± 0.05°C
Long term stability	± 0.05°C
Displayed parameters	Saturator temperature (°C), Pressure (hPa), Calculated mole fraction
DP Probe adapters	316 Stainless steel, Nitrile O-rings, 3x FPG-PA0 included
DP Probe fittings	User interchangeable probe adapters: G ½”, 5/8” & 3/4” UNF, NPT 1/2", M14 x 1.25 mm pitch
Sample loop connections	FPG-60: 6 mm Swagelok® Tube Fitting FPG-80/FPG-100: ¼” Swagelok® VCR Metal Gasket Face Seal Fitting
User interface	7” LCD Touchscreen
External monitor interface	HDMI
Interface	USB, API via Ethernet
Power	100…230 VAC 50/60 Hz, 5 A Max
Case material	Aluminium, powder coated
Environmental Conditions	Operating environment 15…30 °C, 20…75 %rh Storage environment 0…50 °C, < 95 %rh non-condensing

	Dimensions W x D x H (mm)	Weight
FPG - 60/80/100	450 x 300 x 180	23 kg
FPG - In Box (with soft bag)	580 x 580 x 300	28 kg
FPG - In transport case	670 x 670 x 400	38 kg

12 Ordering Information

Order Code	FPG Models	
Q-FPG-60	FPG Transportable dew-frost point calibrator, -60…10°C Factory cal.: -60, -40, -20, +1, +10 °C FP/DP	
Q-FPG-80	FPG Transportable dew-frost point calibrator, -80…10°C Factory cal.: -80, -65, -40, -20, +1, +10 °C FP/DP	
Q-FPG-100	FPG Transportable dew-frost point calibrator, -100…10°C Factory cal.: -90, -80, -65, -40, -20, +1, +10 °C FP/DP	
	Dew point probe adapters * (others available on request)	Recommended probe length range (including thread)
FPG-PA0	Probe port cap	NA
FPG-MPLUG	Machined PVDF Plug with FKM O-ring to close manifold port	NA
FPG-PA1	G 1/2" thread (standard)	25 to 50 mm
FPG-PA2	5/8" UNF thread	25 to 50 mm
FPG-PA3	3/4" UNF thread	45 to 70 mm
FPG-PA4	NPT 1/2" thread	20 to 40 mm
FPG-PA5	M14 x 1.25mm pitch thread	55 to 80 mm
FPG-PA6	G 1/2" thread (long)	50 to 70 mm
FPG-PA#-P	Adapter plug for specific PA# adapters (see above)	
	Calibration	
Q-FPG-PRT2	Saturator second PRT, includes Lemo and ISO17025 calibration	
FPG-ISO-CAL-UP	ISO17025 accredited FPG calibration upgrade Calibration points as per factory calibration	
FPG-ISO-CAL	ISO17025 accredited FPG calibration Calibration points as per factory calibration	
FPG-FS-TCAL	Factory service and ISO17025 accredited calibration, 6 points (includes 12-month warranty extension)	
	Transport, spares and additional options	
Q-FPG-TB	Transport bag, soft padded	
Q-FPG-TC	Transport case, suitable for air freight	
Q-SS-4-WVCR-6-6M0	Rear panel VCR to 6 mm Swagelok adaptor	
Q-SS-4-WVCR-6-400	Rear panel VCR to 1/4" Swagelok adaptor	
Q-FPG-DC	FPG desiccant-GAC cell	
Q-NI-4-VCR-2-ZCT-VS	Rear VCR Gasket (pack of 30)	
Q-NI-4-VCR-2-ZC-VS	Rear VCR Gasket (single)	
Q-SS-12-VCR-2-VS	Front Manifold Gasket for PA ~Probe cap and adapters.	
FPG-PP	Purge option, valve control, back panel 6mm fittings	
	FPG Software	
QroMet-FPGM	FPG Metrology automated calibration software on local PC	
QroMet-FPGM-HO	FPG Metrology hosted option with customer portal (add-on) per year	
QroMet-FPGM-SM	FPG Metrology Software Maintenance (updates and support) after Year 1 - per year.	
Q-CaLIB-C	Bespoke calibration certificate design	

* Each probe adaptor includes 1 x front manifold VCR gasket.
Warranty: 12 months, return to Qrometric
FPG standard supply scope: FPG, 3x PA-0, torque driver, USB memory stick including user manual, factory calibration certificate, power cable.