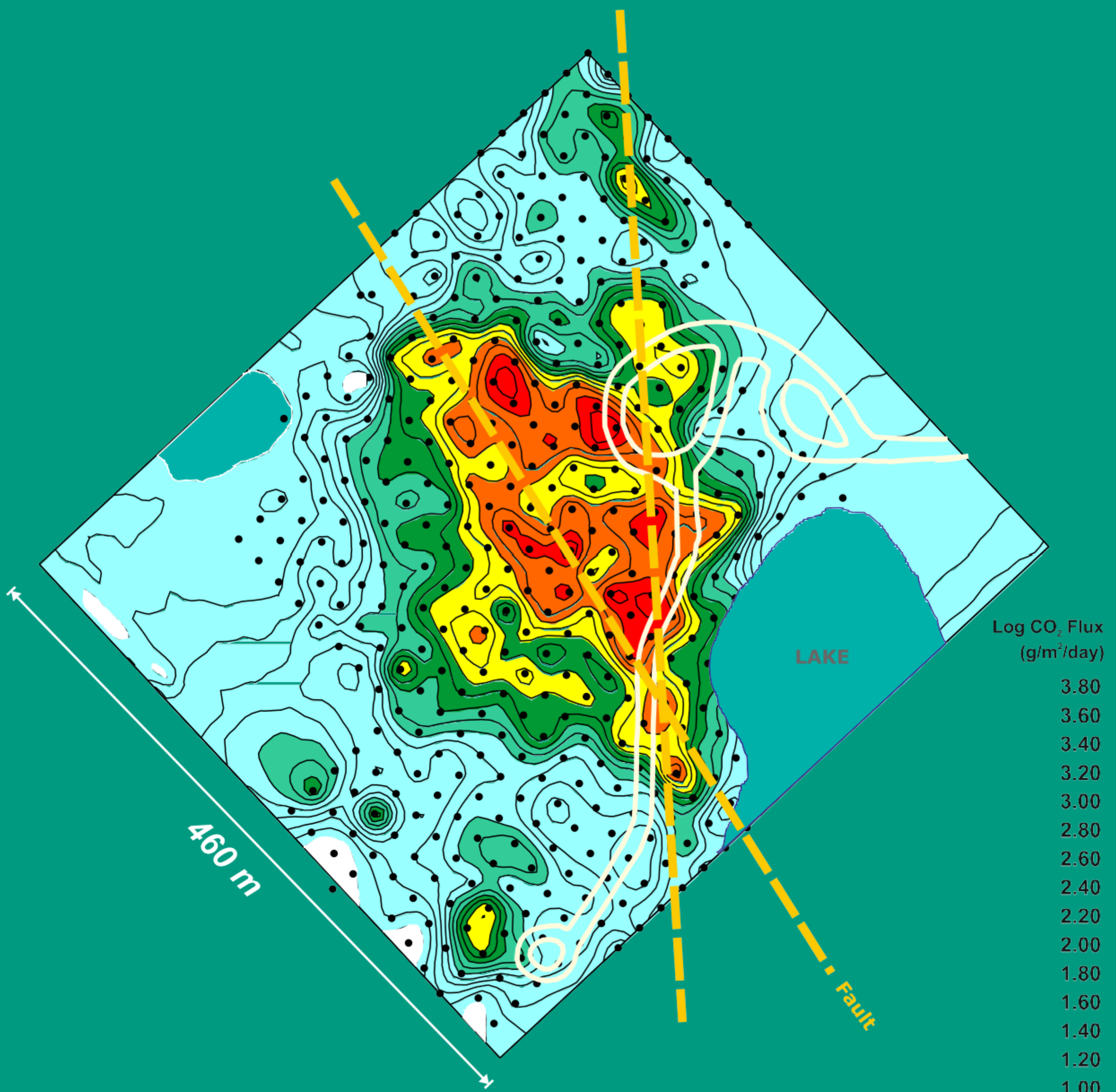
Portable diffuse flux meter

Handbook

Release 9.1
January 2019



Warranty information

Each West Systems instrument is warranted by West Systems Srl to be free from defects in material and workmanship under normal operating conditions; however, West Systems's sole obligation under this warranty shall be to repair or replace any part of the instrument which West Systems 's examination discloses to have been defective in material or workmanship without charge and only under the following conditions, which are:

1. The defects are called to the attention of West Systems in writing within one year after the shipping date of the instrument.

2. The instrument has not been maintained, repaired or altered by anyone who was not approved by West Systems.

3. The instrument was used in the normal, proper, and ordinary manner and has not been abused, altered, misused, neglected, involved in an accident or damaged by act of God or other casualty.

4. The purchaser, whether it is a distributor or direct customer of West Systems or a distributor's customer, packs and ships or delivers the instrument to West Systems (at West Systems 's main office in Pontedera (PI) Italy, within 30 days after West Systems has received written notice of the defect. Unless other arrangements have been made in writing, transportation to West Systems is at customer expense.

5. No-charge repair parts may be sent at West Systems 's sole discretion to the purchase for installation by purchaser.

6. West Systems 's liability is limited to repair or replace any part of the instrument without charge if West Systems 's examination disclosed that part to have been defective in material or workmanship.

7. Before returning an instrument for repair, the Customer must obtain a Return Goods Authorization (RGA), writing to support@westsystems.com and providing information about part number, serial number and description of the issue. Instructions on packaging and shipping will be e-mailed back to the Customer. The company-issued RGA number must be displayed on the return package.

The laws of some locations may not allow the exclusion or limitation on implied warranties or on incidental or consequential damages, so the limitations here in may not apply directly. This warranty gives you specific legal rights, and you may already have other rights which vary from location to location. All warranties that apply, whether included by this contract or by law, are limited to the time period of this warranty which is a twelve-month period commencing from the date the instrument is shipped to the customer.

Responsibility

West shall not be held responsible for any damage to the equipment or for any physical injury or death resulting in whole or in part from the inappropriate use, installation or storage of the equipment, which is the result of not complying with the instructions and warnings, and/or with the standards and regulations in force.

READ THESE INSTRUCTIONS CAREFULLY BEFORE THE FIRST USAGE.

IMPORTANT INFORMATION FOR CORRECT DISPOSAL OF THE PRODUCT IN ACCORDANCE WITH EC DIRECTIVE 2002/96/EC.

At the end of its working life, the product must not be disposed of as urban waste. It must be taken to a special local authority differentiated waste collection centre or to a dealer providing this service. Disposing of a household appliance separately avoids possible negative consequences for the environment and health deriving from inappropriate disposal and enables the constituent materials to be recovered to obtain significant savings in energy and resources. As a reminder of the need to dispose of household appliances separately, the product is marked with a crossed-out wheeled dustbin.

CE The West Systems fluxmeter complies with the requirement of EU directives. For conformity information, contact West Systems at support@westsystems.com.

If your equipment requires maintenance in Italy

Before shipping the instrument back to Italy, remember:

- When you ask your shipping agent to send the instrument to Italy check that on the Air Waybill the Airport of destination is Pisa. Any other airport of destination creates a lot of problems in delivering the items (delay, costs, custom problems, etc).
- Check that the Company your shipping agent chooses lands in Galileo Galilei Airport in Pisa. If not, ask your shipping agent to change the Company or send the items by DHL or UPS or FedEx
- Mark each item with a serial number, if not already present, and write this number on the document (proforma or original invoice or item list) where you list the parts you are sending back to Italy.
- Specify a correct value of the parts you are sending back in the documents mentioned above. Pay attention to these rules because Custom law in Italy is very complicated and probably different from your Country.

If you follow these suggestions everything will be easier for you and for us.

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1. Introduction

1.1 Safety information

Carbon dioxide is a **toxic gas**. Carbon dioxide is colourless, odourless, tasteless and is heavier than air. Air concentration higher than 5000 ppm can cause dizziness, shortness of breath, rapid pulse. Higher concentrations of carbon dioxide can be **lethal**; the short-term exposure limit (STEL) recommended by NIOSH is 30,000 ppm (3%).

Hydrogen Sulfide is a poisonous gas: air concentration higher than a few ppm can be **lethal**; the short-term exposure limit (STEL) recommended by NIOSH is 10 ppm.

Diffuse carbon dioxide fluxes are normally related to anomalous carbon dioxide air concentration. The user must verify the safety conditions before entering dangerous areas using specific and approved instrumentation.

The flux meter described in this manual is designed to measure diffuse emission of soil gases and CANNOT be used for different purposes, especially if related with safety.

The instrument and the electronic accessories are NOT designed to work in explosion risk areas.

2. Preliminary operations

Read carefully the instructions and the recommendations of the following chapter before proceeding.

2.1 Content of the package

The package content may vary depending on the selected configuration.
When you first open the package, check the items with the packing list which is attached to the shipping.

2.2 Batteries

The standard package contains 4 batteries:

- N.2 NiMH 14.4 V, 4.5 Ah battery. One is shipped inside the fluxmeter. One is packed as spare.
- Accumulation chamber battery.
- Smartphone battery. The smartphone is shipped in its original box which contains the battery charger.

Charge all the batteries before continuing.

In order to preserve the battery life:

- Charge the batteries after each utilization of the fluxmeter. Do not store the batteries if not fully charged.
- In case of long periods of inactivity: perform a full charge of the batteries at least every 3 months.

2.3 Filters and tubes

Connect the chamber to the fluxmeter using the provided black/blue twin tubes. In some cases the colour of the twin tubes can be white/blue.
The tube connected to the chamber filter (by convention black or white) must be always connected to the inlet port, as shown in the figure of paragraph 5.6.

Before powering on the fluxmeter, check that the pneumatic connections are correct. An uncorrect or insufficient fitration could cause a damage to the gas analysers due to dirt entering in the measuring cells.

- The tubes inside the fluxmeter are made of clear plastic. Check visually the presence of traces of dirt inside the tube. If so, replace them.
- Check that the filter inside the fluxmeter is installed, as first element of the circuit at the inlet of the case.
- Check that the filter on the chamber is placed and clean. Replace it in case it show traces of dirt. The filter has a direction, indicated on the label, that must be respected.
- Check that the pair of tubes that connects the chamber to the fluxmeter is not swapped.

2.4 Backpack

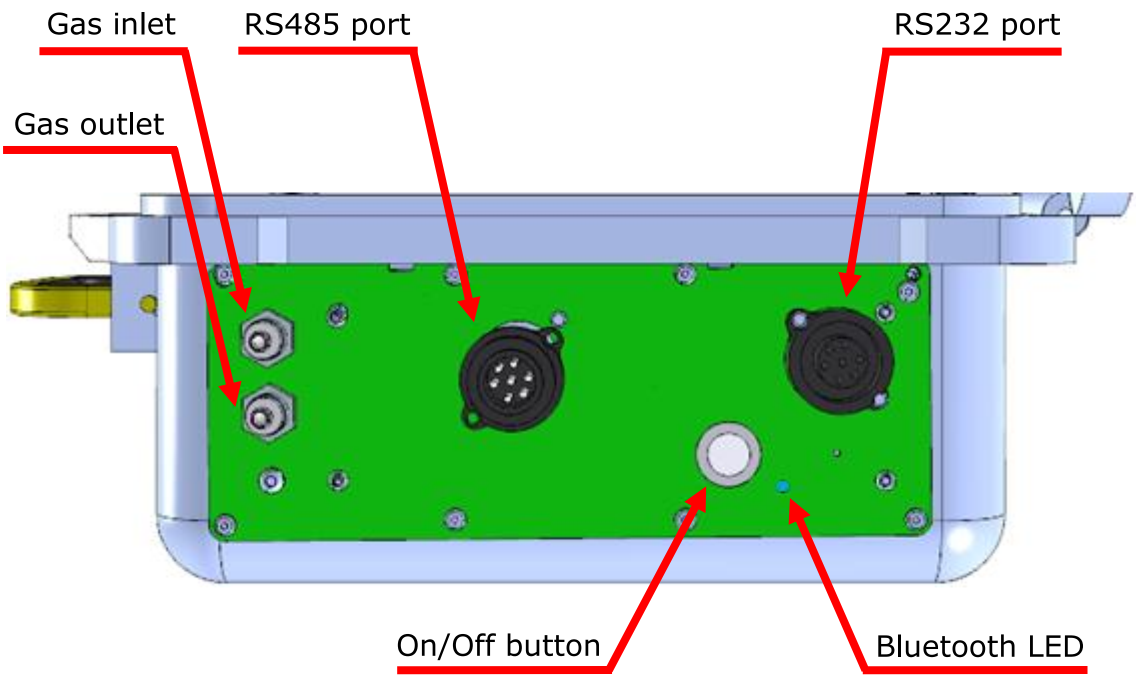
Assemble the fluxmeter on the backback and secure it using the provided knob on the internal side of backpack.

2.5 Powering On

Press and hold for about 2 seconds the On/Off button on the external connection panel.

The On/Off button is equipped with a LED with the following meaning:
- Solid red: powering on. Hold it until it turns green to switch on he fluxmeter.
- Solid green: the fluxmeter is on.
- Flashing red/green: low battery charge. Replace the battery.

In order to preserve battery-life, the instrument will turn off automatically after one hour if not under the control of FluxManager software.



Once powered, the fluxmeter runs the initialization process which takes about 20 seconds. During the initialization the fluxmeter executes a scan of all the connected sensors. If you add or remove a sensor from the instrument, you need to restart the fluxmeter in order for the sensor list to be refreshed. When the initialization is completed, the fluxmeter is ready for connection.

The Bluetooth LED has the following meaning:
- Flashing at 20 Hz frequency: the fluxmeter is during the initialization.
- Flashing at 2 Hz frequency: the Bluetooth is in advertising mode, meaning that is visible by the smartphone and is ready for connection.

- Solid blue: the Bluetooth is connected. During this phase it is not visible by other devices.

The pump is managed by the instrument and it won't turn on until a measurement is started by FluxManager software.

2.6 Warm up

If your instrument is equipped with a LI-COR LI-830/LI-850 carbon dioxide analyzer: the sensor is temperature-stabilized in order to reduce the interferences due to the gas sample temperature.
If the temperature of the sensor is less than 50°C, the signal can suffer of a thermal drift causing an underestimate or overestimate of the CO_2 flux.
The FluxManager software will check the sensor temperature and, in case the value is below 50°C, it will ask the user if he wish to continue. The user can continue being aware of the previous considerations.
Normally the sensor, after a cold startup, requires about 15-20 minutes to reach the 50°C temperature.
We advice to switch on the instrument as first operation as you arrive to the sampling site.
If your instrument is equipped with a WS-TOX-H2S hydrogen sulfide analyzer: we recommend a 15-20 minutes warm-up with the pump on, to give time to the sensor to adapt to the pressure variation induced by the pump.

2.7 Accumulation chamber

Turn on the chamber using the switch on the accumulation chamber handle. This activates the internal Bluetooth making the device discoverable by the FluxManager app.

2.8 Powering Off

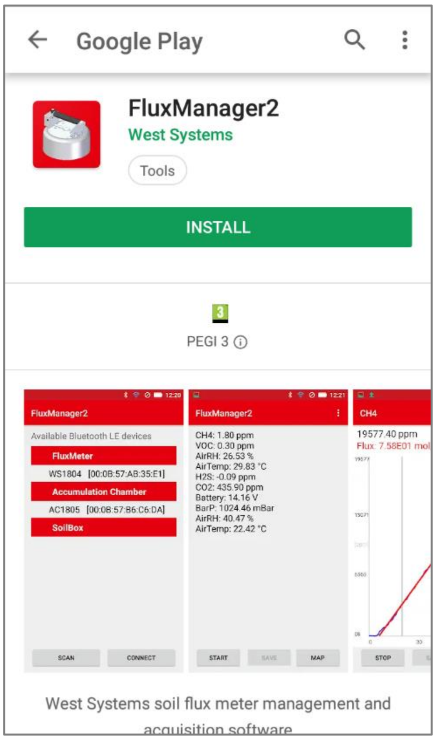
Press the On/Off button on the connection panel.
The LED on the button will become RED immediately, hold the button until the LED is off.

3. FluxManager software

3.1 Installation

West Systems provides the portable fluxmeter with an Android based mobile device (smartphone / tablet / handheld computer). The Android device is necessary as interface to the portable fluxmeter to manage the measurement, display and store the data.
The app is compatible with all devices running Android version 5.1 or higher.

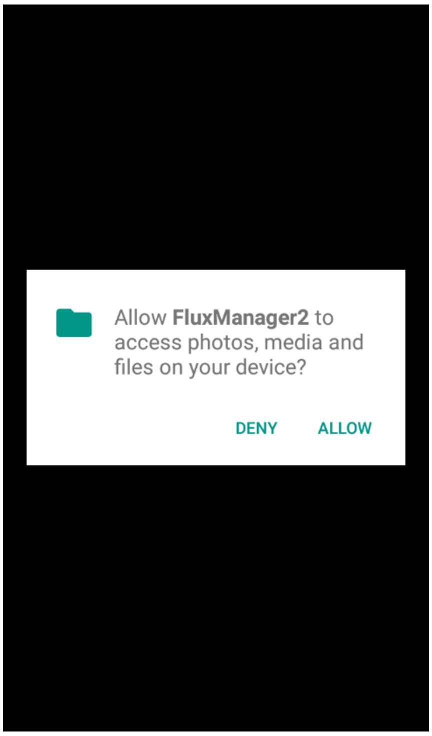
The app FluxManager (as well as Calibra) are freely available on Google Play Store. The mobile device comes from West Systems with the app pre-installed. In case you acquired the mobile device separately, install the app by opening Google Play Store from the device and looking for "Fluxmanager2".

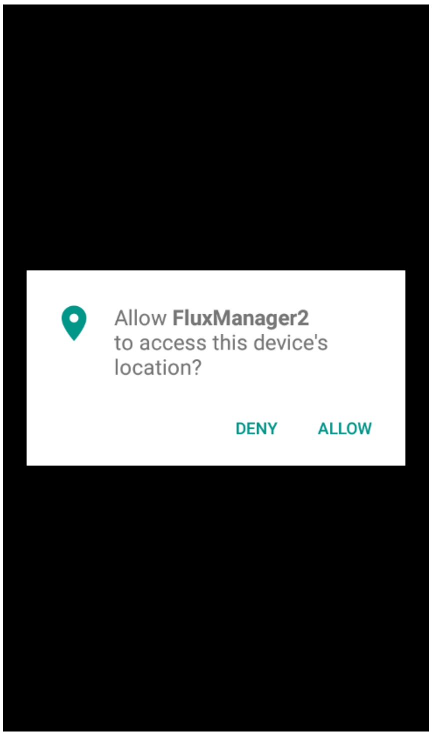


Click *INSTALL* to install the app; click *OPEN* when the installation is completed. The first time the app is launched (after the installation or after the app data has been cleared, for example to free up space), it will prompt the user to get the following permissions:

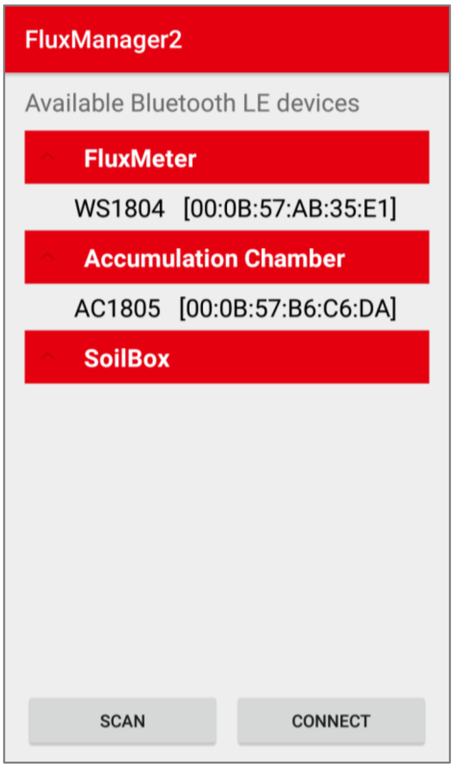
1. Access to device files. This is necessary to save the measurement files.
2. Access to device location. This is necessary to get the GPS position of the measurements.

Depending on the Android version, it may be necessary to launch the app a second time to grant the second permission.

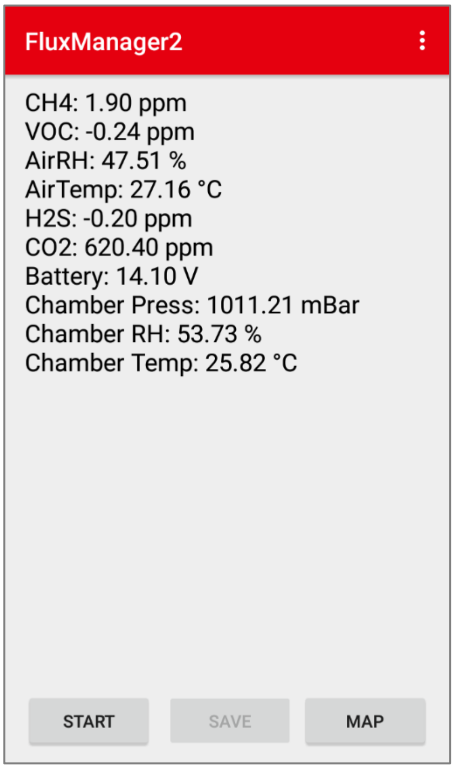

Allow FluxManager2 to access photos, media and files on your device?
DENY
ALLOW


Allow FluxManager2 to access this device's location?
DENY
ALLOW

3.2 Bluetooth connection



There is no need to pair the Bluetooth devices before launching the FluxManager app.
As you launch the app, FluxManager2 automatically scans for available Bluetooth devices in range, for 5 seconds.
As soon as one or more portable fluxmeters, accumulation chambers or soilboxes are recognized, they are added to the list, showing the serial number of the instrument and the MAC address.
Note: a device will be detected only if in advertising mode (Bluetooth LED blinking once every 2 seconds).
The accumulation chamber and the soilbox are immediately in advertising mode as soon as they are switched on. The portable fluxmeter runs an initialization which takes about 20 seconds. During the initialization, the LED blinks at a greater frequency, twice per second. When the initialization is completed, the fluxmeter is in advertising.
In case a Bluetooth device doesn't appear on the list once the scan operation is completed, you can repeat it by pressing the *Scan* button.
On the contrary, if all the expected instruments are on the list, the user can proceed with pressing the *Connect* button. It is not necessary to wait for the scan operation to complete before proceeding to connection.



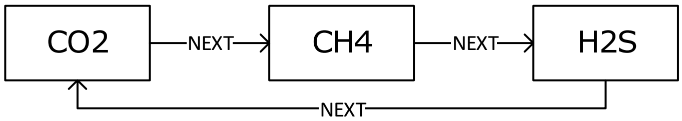
When the user press the *CONNECT* button, the app tries to connect to one device of each category, if available. If more that one fluxmeters are in the range, hence recognized by the app, the user will be prompted to select which one to connect to. The same applies to chambers and soilboxes. In any case the app will try to connect to more that one fluxmeter at the same time.
Once the connection is established, the Bluetooth device stop advertising (so they will not be visible to any Blueooth device). The LED passes from the blinking to steady-on.
The app shows the sensors detected on each Bluetooth device. In this phase the sensors are shown all together.
The real-time reading is shown for each sensor and updated once per second. The system is now ready for starting a flux measurement.
The Battery information indicates the voltage of the 14.4 Volts NiMH battery which supplies the fluxmeter, placed inside the case.

3.3 Measurement

Press the *START* button to start the measurement.
The graphical visualization takes place of sensor list.
At this point only one sensor at a time is displayed.

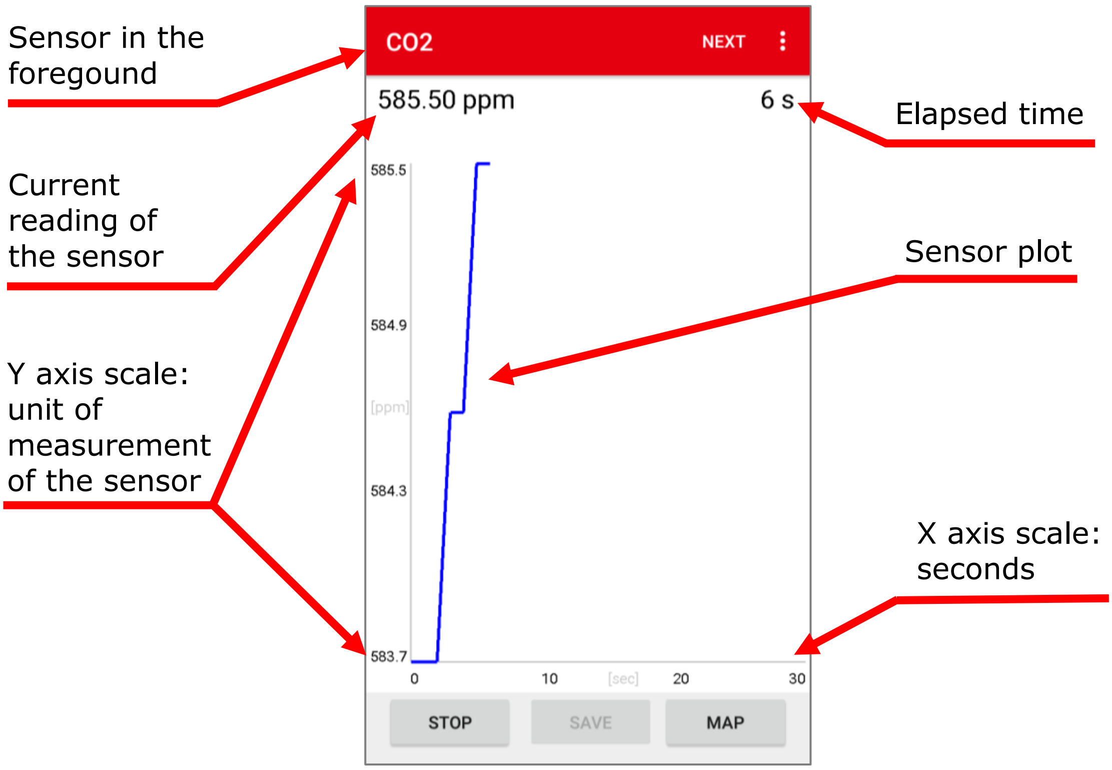
Switching sensor
In case there are more than one sensor with track enabled, only the one in foreground is shown. Press the *NEXT* button to switch between the sensors.

Example:

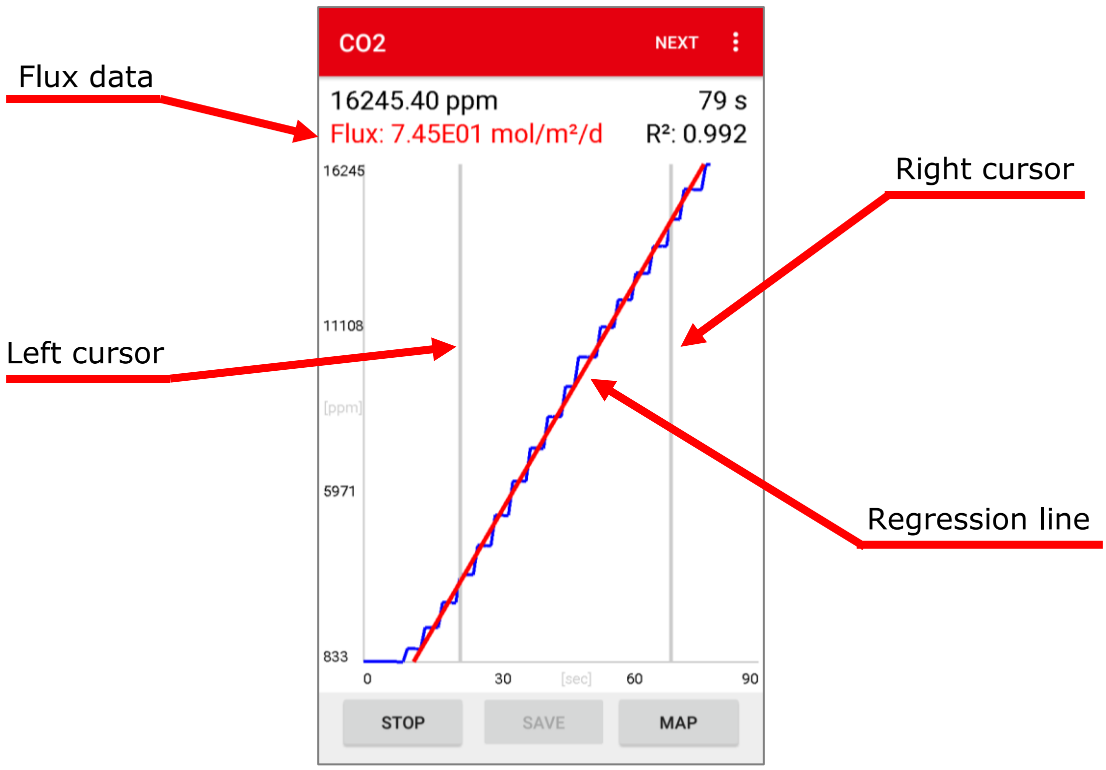


Alternatively you can use the up/down volume buttons of the Android device to browse through the sensors.
The recording remains active for all the sensors regardless of whether or not the sensor is in fogeround or background, or has the track disabled.

Initially only current reading and the elapsed time are displayed.



Touching the display on the plot will cause the positioning of the left cursor. Touching the plot a second time will cause the positioning of the right cursor. Once both cursors are placed, the flux data is visualized in the top panel. It contains the values of the flux (or the slope, depending on the chosen flux unit) and the R^2 regression quality coefficient.
At the same time the regression line is drawn, in red, over the plot.



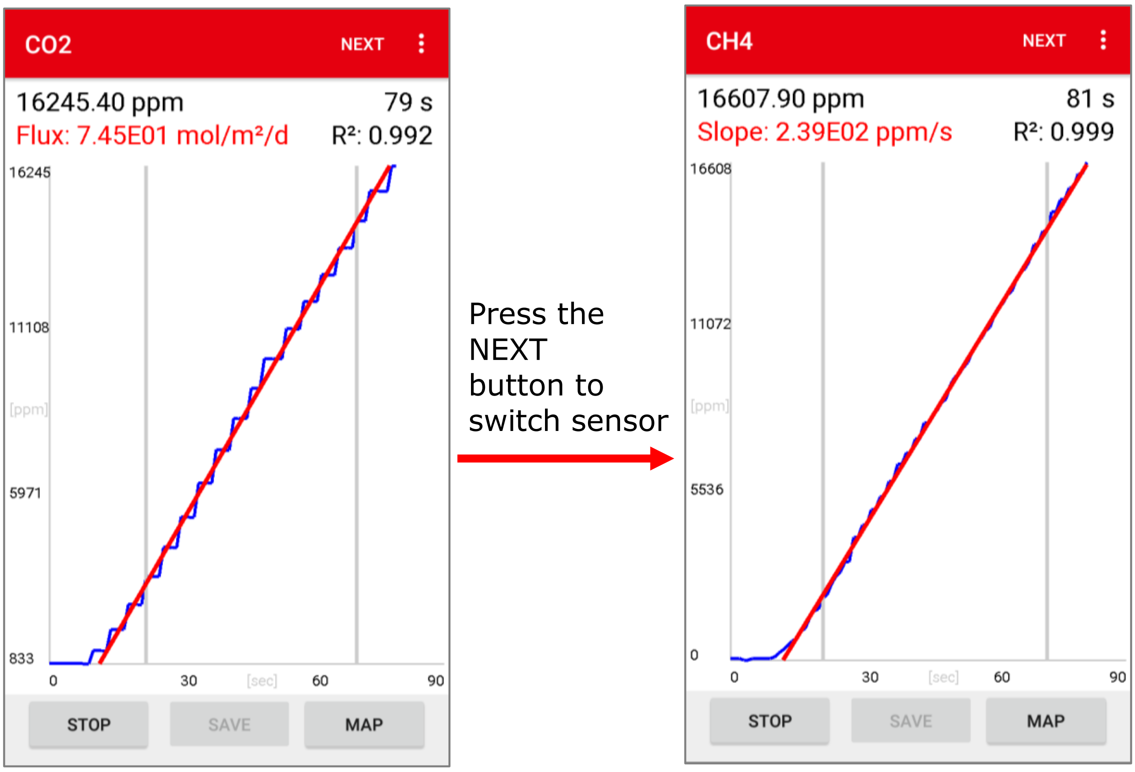
Note: the regression is computed on the points included within the left and right cursors. All the other points are ignored by the calculation.

The selection of the flux curve interval where to compute the flux is critical and a wrong selection can cause an error on the estimation of the flux. In the following pages some examples of the correct interval selection are shown.

To change the interval move the left and right cursors to the desired position. To move the cursors you have to touch the screen close to the limit you want to move and drag it to the correct position. The software will move the limit that is closer to the point you touch on the screen.

Once having selected the interval FluxManager will compute the regression and the results will be shown as text and as best fit line.

Each flux curve (e.g. CH_4, H_2S, CO_2) has a distinct regression interval, then after the computation of the regression of one flux curve you have to select, using the *NEXT* button, the other gas flux curve and select the appriopriate regression interval.

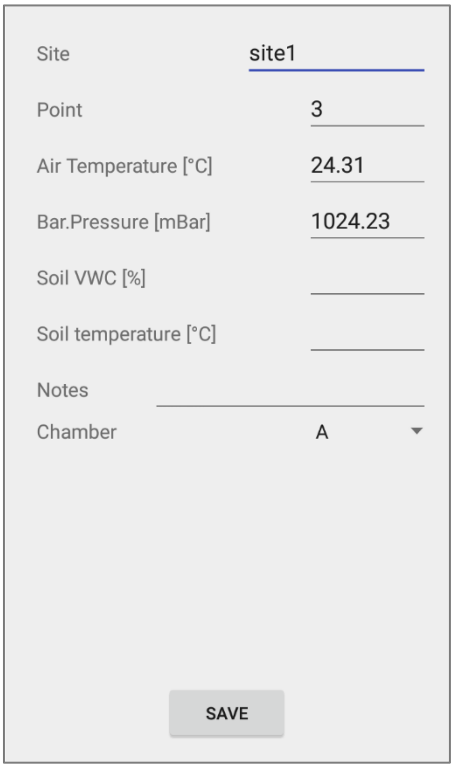


3.4 Saving a measurement

Normally a flux measurement requires from 90 up to 480 seconds. The sampling time of a single flux measurement is chosen by the operator on the run.
The time usually depends on the extent of the soil flux. A weak flux will result in a low R^2 parameter, forcing the user to go on with the measurement hence increasing the sampling time.
Once the sampling is completed, press the *Stop* button to end the acquisition. The chamber and the pump will continue to run for a number of seconds, usually 30 seconds but it can be overwritten by the user (see cleaning time in the parameters section).
Note: the H2S and VOC sensors are particularly influenced by pressure variation. Both turning on and off the pump causes a strong pressure variation which needs time for the mentioned sensors adapt. For this reason, if the H2S or VOC sensors are present, once the pump is turned on, it never stops running, even after the cleaning time.

Note: if you press the *Start* button again without saving, the following screen appears: Press *Continue* to discard the measurement and go on with a new one. Otherwise press *Save* to go directly to the saving window.

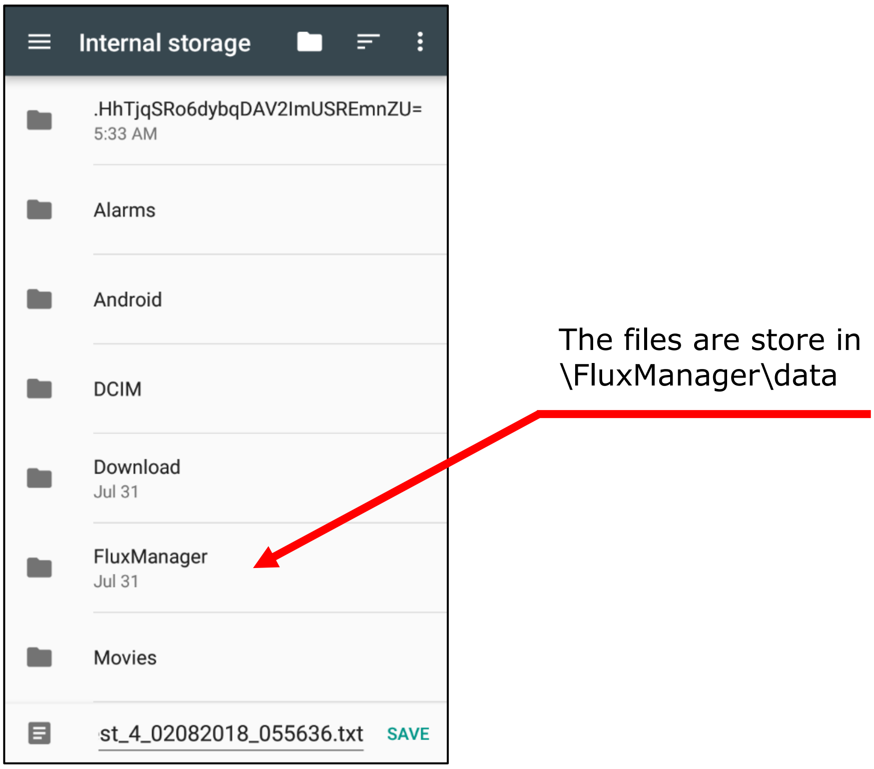
Once the measure is stopped, you can press the *Save* button to save the measurement.
An information summary form appears:



Site: Please enter in this field the name of the sampling site. This is meant to be a descriptive name which helps identifying a set of data.
Once the name of the site is inserted the first time, the application will automatically fill the field with the last used site name.
Note: the name of the site is used to display the recorded points on the map. Only the points related to the most recent site name will be displayed. Hence changing the name of the site in the middle of a campaign will result in the map not showing all the campaign files.
Point: is a numerical index that allows the uset to identify every point in your map. This field is automatically increased by the app every time a file is saved.
Air temperature [°C]: if the accumulation chamber is connected, the field is automatically filled with the value recorded by the thermo-hygrometer placed inside the chamber (average value of the 1 Hz sampling during the measurement). If this value is not available, or if the user prefers to use its own thermometer, he can replace the value. The final value to then written inside the output file. The value alos is used in the ppm/sec-moles conversion.

Barometric pressure [mBar]: if the accumulation chamber is connected, the field is automatically filled with the value recorded by the barometer placed inside the chamber (average value of the 1 Hz sampling during the measurement). If this value is not available, or if the user prefers to use its own barometer, he can replace the value. The final value to then written inside the output file. The value is also used in the ppm/sec-moles conversion.
Soil Volumetric Water Content [%]: if a TDR probe is connected, the field is automatically filled with the value recorded by the probe (average value of the 1 Hz sampling during the measurement). If this value is not available, or if the user prefers to use its own sensor, he can replace the value. The final value to then written inside the output file.
Soil temperature [°C]: if a soil PT100 probe is connected, the field is automatically filled with the value recorded by the probe (average value of the 1 Hz sampling during the measurement). If this value is not available, or if the user prefers to use its own sensor, he can replace the value. The final value to then written inside the output file.
Notes: User sampling note. Feel free to insert any note here, which might help the postprocessing work (example: "strong wind" or "point near well P7".
Chamber: Select the accumulation chamber you are using. Tagging the file with the correct accumulation chamber type is fundamental as the flux is proportional to the volume/area ratio of the chamber (see chapter 3 for details), and different types of chamber have different shapes. Choosing an incorrect chamber leads to an incorrect calculation of the flux from the [ppm/sec] raw data.
If the accumulation chamber is connected, the field is automatically filled with the corresponding type.

Press the *Save* button to save the file. Once the save button is pressed, a text file is generated on the Android device internal memory, in the folder \FluxManager\data.



The file name has the following format:
[SITE NAME]_[POINT]_[DATE]_[TIME].txt
The date is in the format YYYYMMDD
The time is in the format HHMMSS
For example: site1_3_20180101_183500.txt

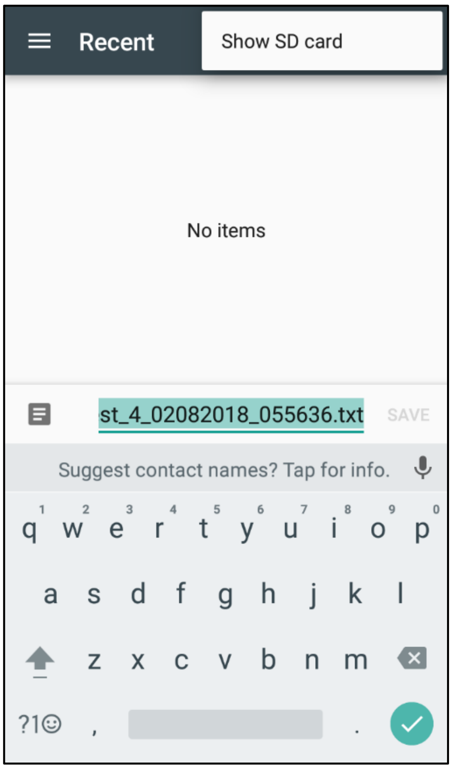
Backup copy
As soon as the user press the Save button, the file is saved in the folder \FluxManager\data, as previously specified.

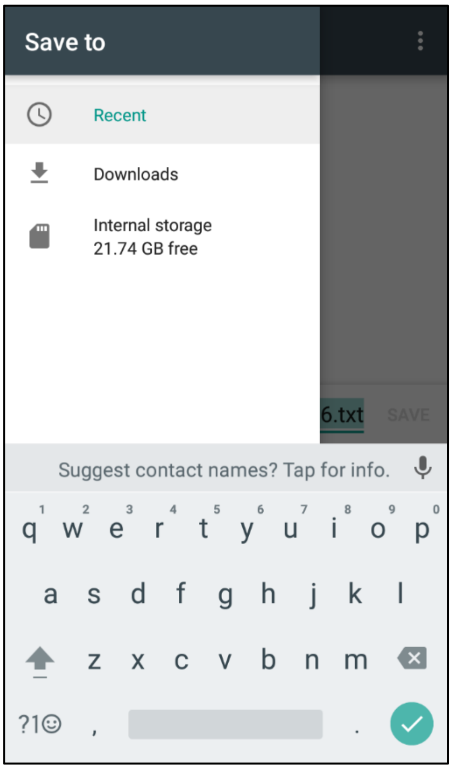
At this point a second window appears, to allow the user to save a backup copy of the file. The purpose of this function is to provide more security to the data, placing the file on different drive or in remote locations.

The most common locations where to save the backup copy are:

3. **SD card**. In this case the data is still lost in case of loss or theft of the smartphone, but is safe in case of damage of the smartphone flash memory or in case of accidental deletion of the files.
   Note: the Android device is not supplied with SD card, it must be inserted by the user.
4. **Google Drive**. Drive is the cloud service provided by Google free of cost for the first 15 GB. This option offerst the maximum security against data loss since the data is is copied on Google servers.
   Note: you need a Google account registered in the smartphone and an Internet connection (e.g. wifi or mobile data).

In order to save the backup copy on the SD card, you may need to enable it by pressing on the Show SD card button on the top right corner.





The backup copy has to be created by the user manually, because the FluxManager app is not allowed by the Android operating system to write silently on paths other than the internal memory of the device.
If you are not interested to create a second copy of the file, press back and you'll be redirected to the sampling window where you can start the following measurement.

3.5 Transfer data to a PC

In order to transfer the files to a PC for editing them with FluxRevision software, connect the Android device using an USB cable.
When the cable is plugged, you should be able to select on the device the MTP mode.

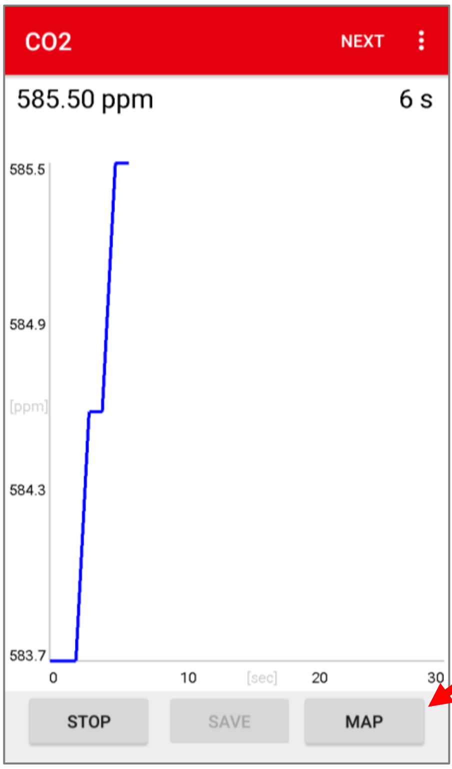
Once the smartphone is connected, open the file explorer on the PC and navigate inside the Android device internal memory. You can find the files in the folder: /FluxManager/data.

Note: depending on the Android version, you might need to restart the Android device to make all the recorded files visible through the MTP mode.

SD card
In case the data has been saved also to the SD card, it's possible to extract the SD card from the smartphone and insert into a SD card reader connected to the PC. The files are then available on the PC through external storage.

Google Drive
In case the data has been saved also on Google Drive, it's possible to just download them on the PC from the Google servers without connecting the smartphone to the PC.

3.6 Map



Press the MAP button to enable the visualization of the map.

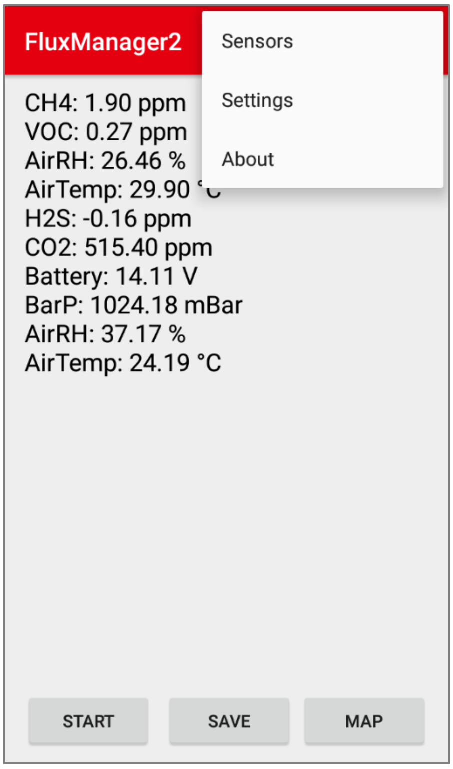
The map is downloaded in real time from the Google Map servers. For this reason the visualization is active only if the Android device has an Internet connection available.
Moreover, the Google Play Services component must be updated on the Android device, in order for the to operate properly.

Measurement points.
Only the points belonging to the current site are displayed
Tapping on a point, the related sampling information are displayed

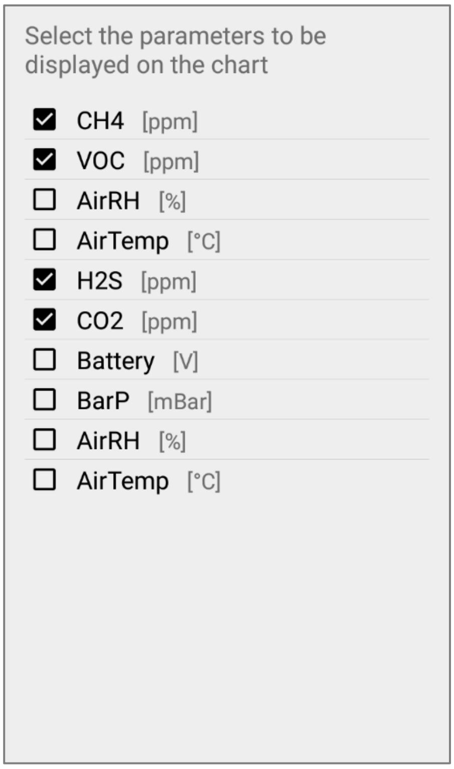
Current position

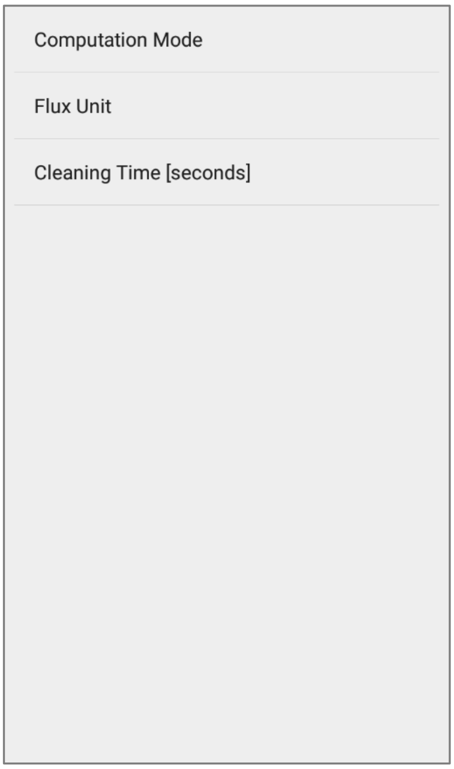
3.7 Preferences

Pressing the menu icon on the top right corner, the main menu appears.



By pressing the menu ***Sensors***, it is possible to enable or disable the chart for each sensor.
This setting affects only the on-field visualization: the sensor with chart disabled are sampled and recorded in the same way as the others (one reading per second). The entire recording is then stored in the output file.
During the measurement, the graph of the sensors with track enabled is visible on the display. Pressing the button *NEXT* or the Up/Down volume buttons, the chart switches to the next sensor whose track is enabled.



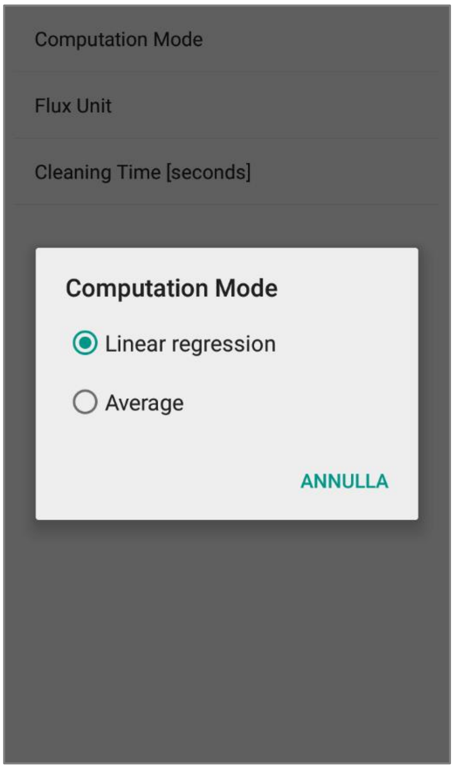


By pressing the menu ***Settings***, the application settings can be visualized and edited:

5. Computation Mode
6. Flux Unit
7. Cleaning Time

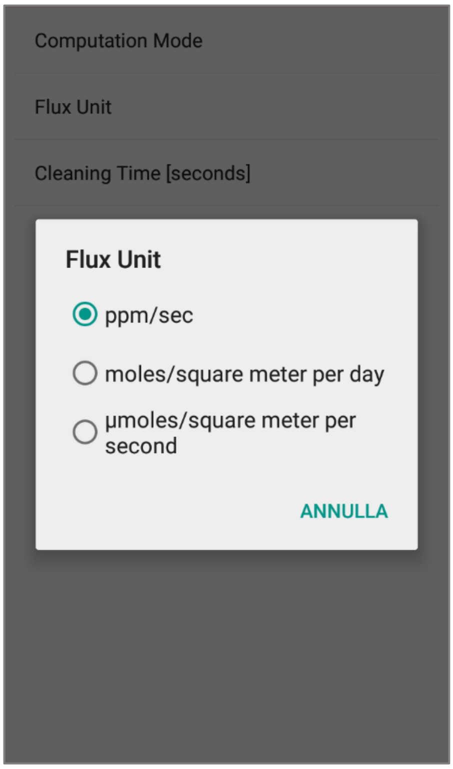
The Computation mode can be configured as following:

8. Linear regression. This is the standard setting when measuring diffuse degassing.
   By placing the left and right cursors on the chart, the app shows the value of the linear regression within the selected interval, and the related R^2 coefficient. The regression line is also drawn on the chart.
9. Average. This setting can be used when measuring gas concentrations or other parameters; in general when the accumulation chamber is not involved.
   By placing the left and right cursors on the chart, the app computes the average value within the selected interval, and the related standard deviation. The average line is also drawn on the chart.

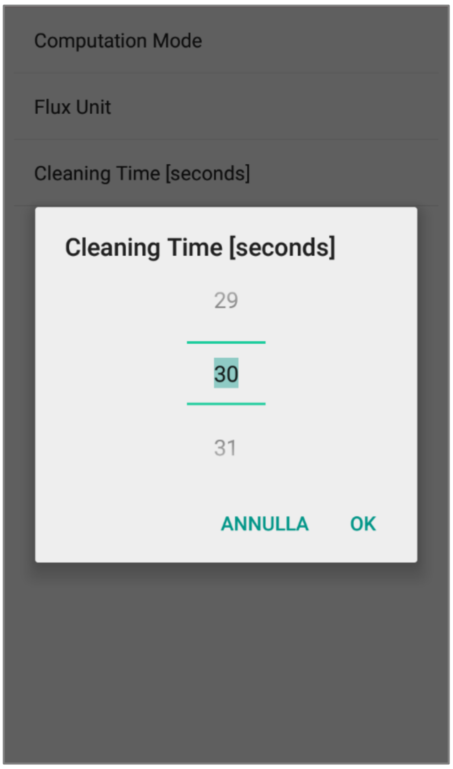


The flux unit can be configured as following:

10. ppm/second
11. moles/m^2/day
12. µmoles/m^2/second

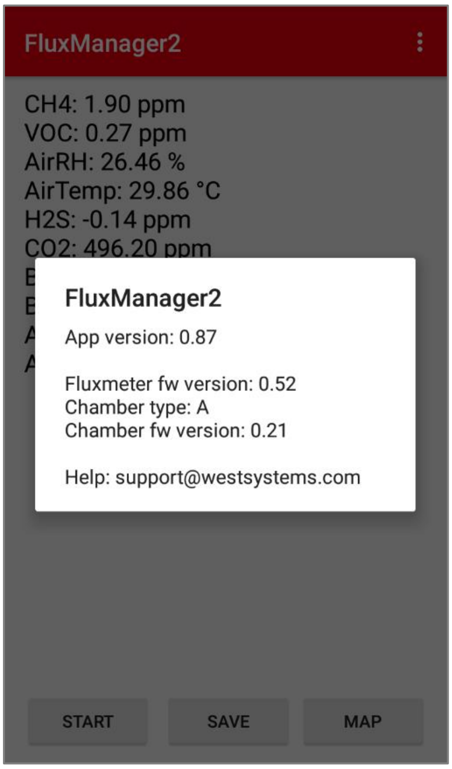


Choose the unit you're more familiar with.
As explained in the following chapter, the ppm/sec represents the "raw data".
Choosing either *moles/m^2/day* or *moles/m^2/second*, the ppm/sec data is converted into flux using the dimensions of the chamber and the environmental parameters.



The cleaning time is the time immediately after the user stops a measurement, during which the pump and the chamber fan remain ON, in order to clean the fluxmeter tubes and sensors' cell with atmospheric air.
During the cleaning time the chamber must be raised from the soil. Usually 20-30 seconds are enough for cleaning the line, but it depends on the concentrations involved and the sensors response time.
The user can use the cleaning time to save the measurement and move to the next sampling point. The cleaning time is not mandatory and the user can start a new measurement before the cleaning time is passed (in this case the pump and the fan are not switched off between the two measurements).
Note: as explained in the previous paragraph, if the H_2S or VOC sensors are present, only the fan is switched off at the end of the cleaning time, while the pumps keeps running.

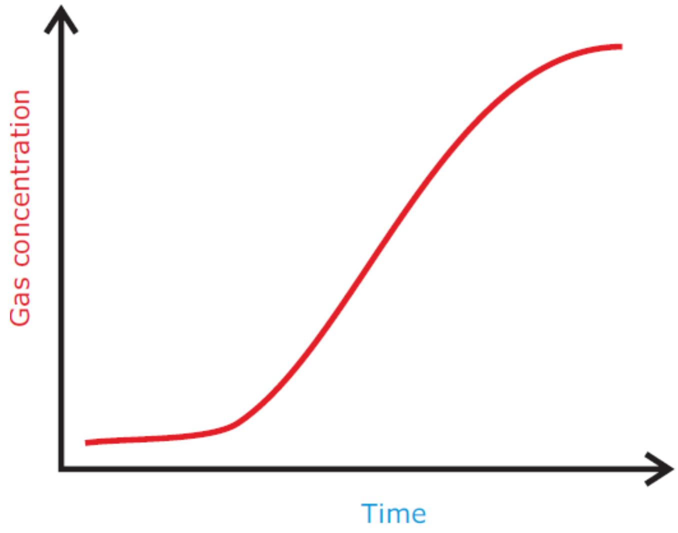
The menu About show the firmware and software version of the connected devices. Please provide this information when requesting support.



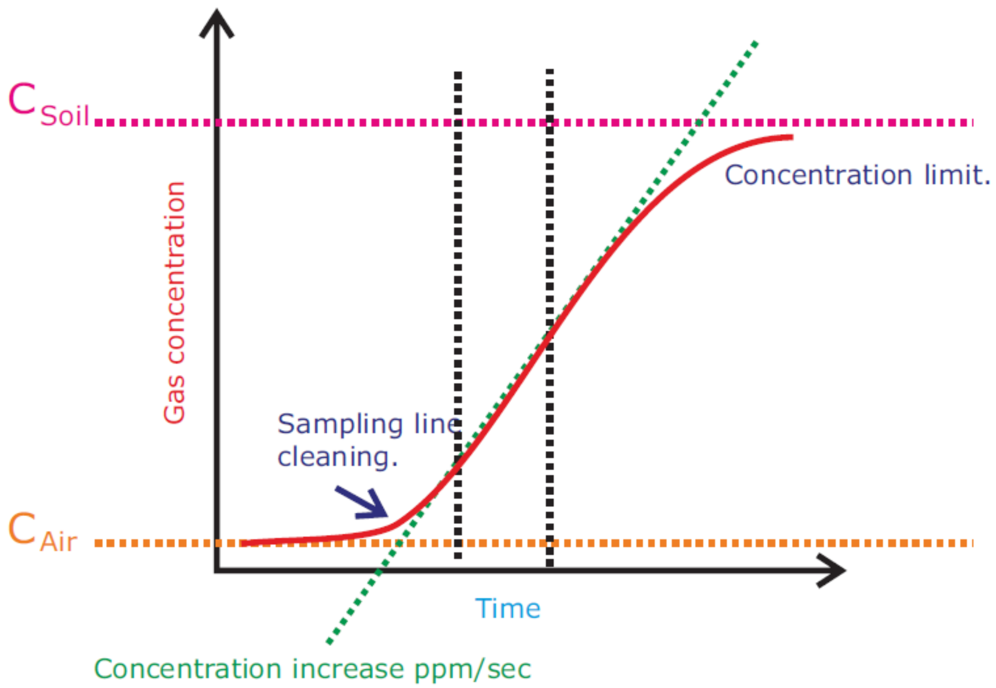
4. Measuring flux

4.1 Theory of operation

In this chapter how to measure the flux and how to interpret the results will be explained. Please refer to chapter 3 to learn about the use of the instrument and the FluxManager software. To better understand the this chapter a basic theory is explained.
The theorical flux curve is shown in the figure below: The plot represent the variation of the concentration of the target gas versus time.

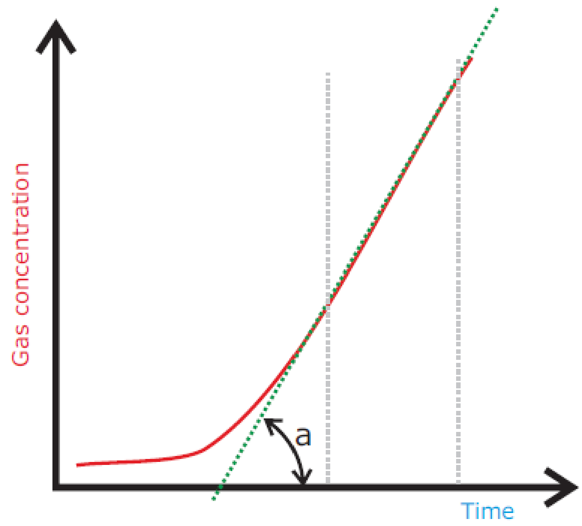


In the next figure some characteristic areas of the plot are identified



C_{Air} is the target gas air concentration, 350 ppm in the case of carbon dioxide, few ppm in the case of other gases. C_{Soil} is the target gas concentration in the

soil. A very long recording period is necessary to reach the limit C_{Soil} concentration.
In the first part of the flux curve a "sampling line cleaning" area is highlighted: in this area the gas pumped from the accumulation chamber is replacing the gas into the pump, the tubes and the cell detector cell (dead volumes). The cleaning efficiency depends on the dead volumes and on the pumping flow.
When the target gas concentration become close to the soil concentration the flux curve slope decreases. Normally the flux curve recording time in not enough to highlight this effect. The carbon dioxide concentration in the anomalous soils is normally more than 5%.
The two vertical lines delimit the interval where to compute the flux.



To have a good evaluation of the flux the correct interval of the flux curve has to be selected.

Never compute the flux on an interval shorter than than 30 seconds.

A linear best fit of the flux curve in the interval is computed, in order to evaluate the coefficient a, using the following formula.

A is the angular coefficient of the linear fit, and is computed as

$$a = \frac{\sum x \cdot y - \frac{\sum x \cdot \sum y}{n}}{\sum x^2 - \frac{\left(\sum x\right)^2}{n}}$$

Where ***x*** is the time, in second and ***y*** is the concentration expressed in ppm. Each summative function is intended for each point in the flux curve that is within the selected interval.
The number ***n*** is the number of points used for the flux evaluation.
a has the ppm/sec dimension and is the slope of the the linear regression of the flux curve, and is assumed as the the slope of the flux curve in the selected interval.

ErrQ or R^2 is the linear regression quality factor, and is computed as:

$$ErrQ = \frac{\left(\sum_{x\cdot y} - \frac{\sum_x \cdot \sum_y}{n}\right)^2}{\left[\sum_{x^2} - \frac{(\sum_x)^2}{n}\right]\left[\sum_{y^2} - \frac{(\sum_y)^2}{n}\right]}$$

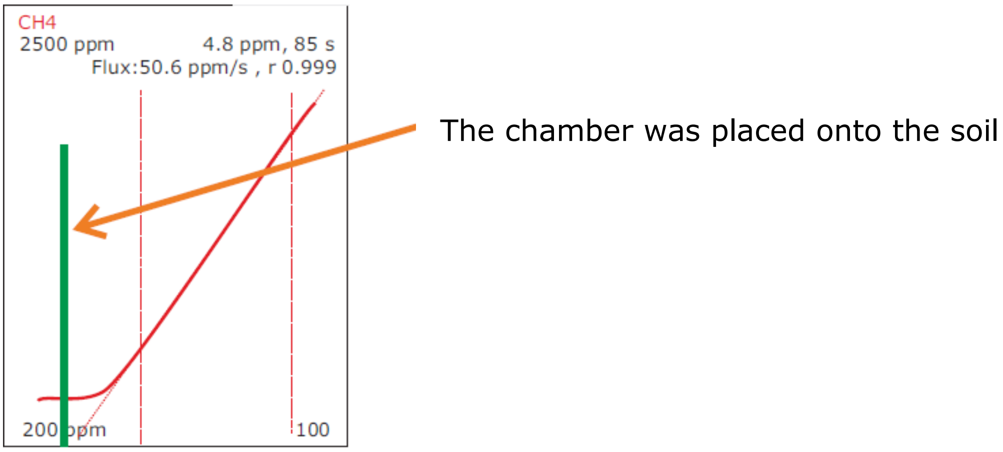
The value of ErrQ can vary in the range from 0 up to 1.
Values of ErrQ close to zero (ErrQ < 0.5) means that the regression is not good and that the linear curve computed does not fit the curve.
Values of ErrQ close to one (ErrQ > 0.9) means that the regression is quite good and the linear curve fits the flux curve very well.
Since the points are homogeneously distributed in the time domain the ErrQ quality factor is a univocal indicator of the regression quality. Please note that when the slope of the regression is zero the ErrQ also has to be zero.

Obtained a, the slope of the flux curve expressed in ppm/sec, an additional calculation will be necessary, taking account of the accumulation chamber shape and of the environmental parameters, to transform the slope into a flux evaluation. This matter is described in detail in the chapter 4.

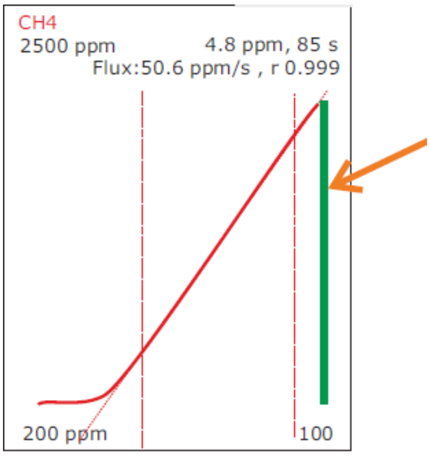
The complete theory of the accumulation chamber method will be not discussed in this handbook and can be found in the papers listed in the Appendix.

4.2 The measurement

Start the measurement on FluxManager as explained in the previous chapter.
Having pressed the *Start* button, the plot of the concentration of the target gas is shown in the display.
Once the measurement is started, the user can place the accumulation chamber in the desired point, checking the perfect sealing of the chamber with the soil.



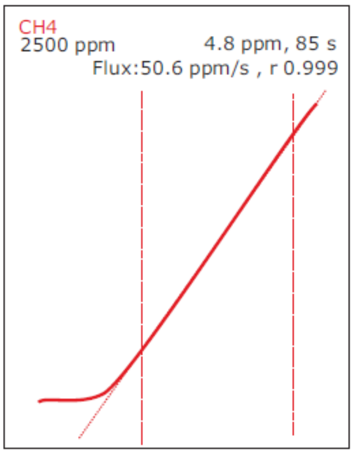
If there is a soil gas emission, a few seconds after placing the chamber on the soil the concentration starts increasing.
Touching the display, the software computes the linear regression within the selected interval.



The chamber was removed from the soil.

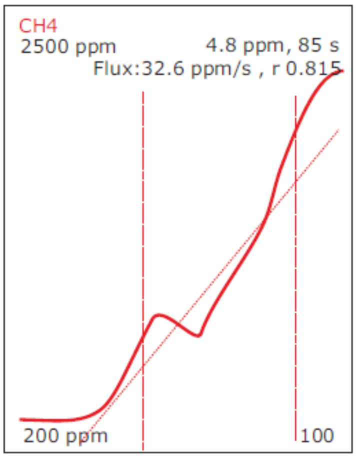
The duration of the flux curve recording is normally in the interval 90-240 seconds. Only when measuring very low flux of hydrogen sulphide or VOC a 300-480 second measurement could be necessary.

The following images show a series of common accumulation shapes.



The "perfect" curve

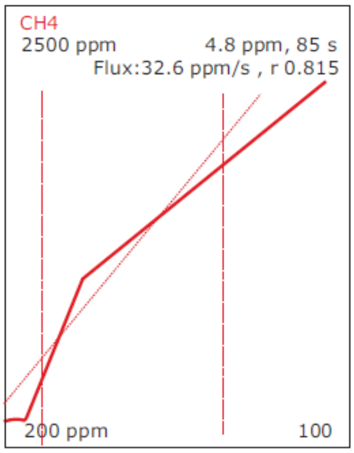
The shape of the curve is quite perfect and the computation of the flux is done with a very good accuracy: R^2 (regression quality factor) very close to 1.



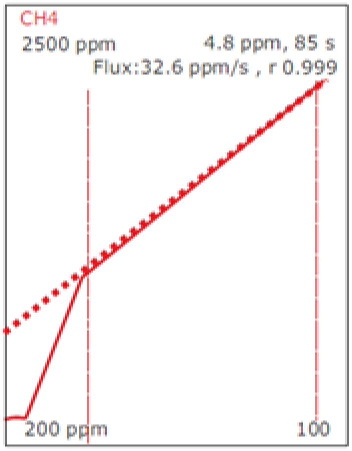
Air contamination

The flux curve is no longer linear; the linear best fit curve do not fit exactly the flux curve as pointed out by the regression quality factor (0.815 in the example). This effect is probably due to atmospheric air contamination.
If you obtain this kind of curve check the sealing of the accumulation chamber with the soil or check that tubes, filters and pump are intact.

Gas stratification

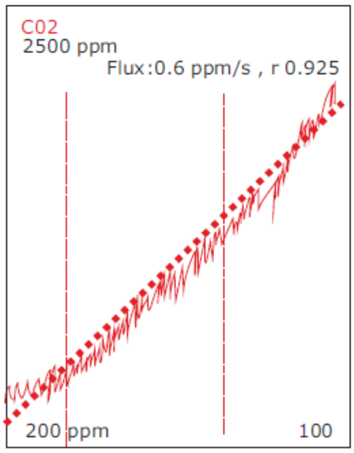


This shape of curve indicates that the concentration of the target in air, close to the soil, is very high. This stratification is quite common in case of very high flux combined with a very stable atmosphere.
In this case clean the gas line making a measure in air, one meter above the soil surface, and afterwards repeat the flux measurement.
You can use the measurement choosing the second part of the curve for regression computation.

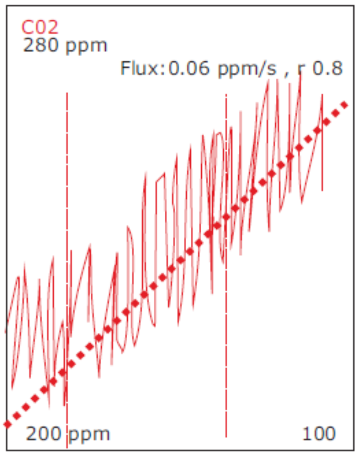


Selecting the second part of the curve the line fits the flux curve very well and the regression quality factor become 0.999

Low fluxes

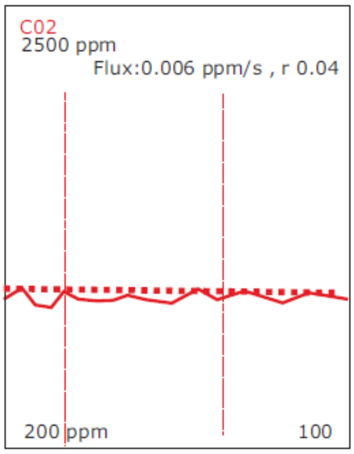


This type of curve is normal when the flux is low and the noise of the detector is comparable with the increase of concentration. This effect is bigger for the methane sensor and is minimum for the carbon dioxide one.



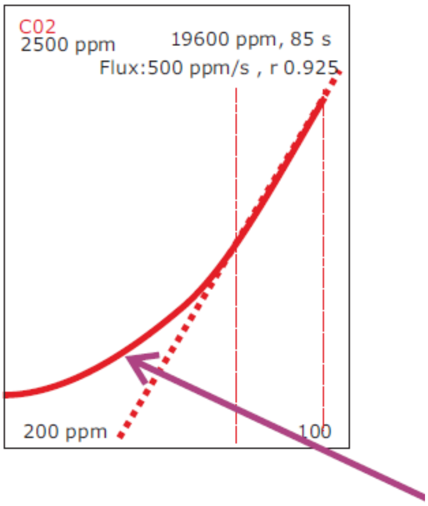
Very low fluxes

Of course the noise increases when the flux is very low.



No flux

The curve is flat and the increase of the gas concentration is very low.
Possible causes:
13. There is no flux
14. The pump is not working
15. The tubes are not connected correctly.



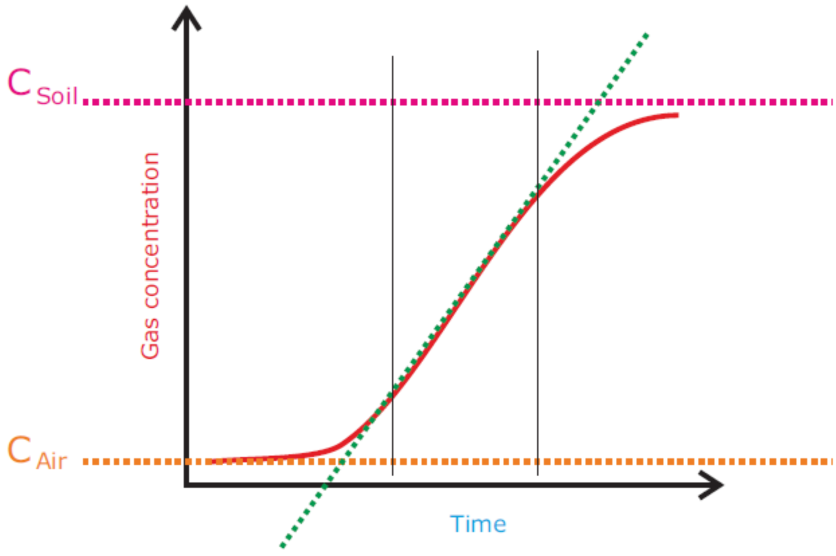
Very high flux

The first part of the curve is not linear. The problem is due to the combined effect of the high flux and the sampling line cleaning. To avoid this increase the flux curve record time until the concentration of gas reachs the full scale value and select the last part of the curve for the flux computation.

The effect is due to the cleaning of the sampling line dead volumes

4.3 Quantifying the flux

As explained in the previous paragraph, the flux is proportional to the concentration increase ratio ppm/sec. The proportionality factor depends on the chamber volume/surface ratio as well as the barometric pressure and the air temperature inside the accumulation chamber.



There are two methods to carry out the field work, in both cases for each measurement you have to record the type of accumulation chamber used, the barometric pressure, and the air temperature.
The variation of few mBar of the pressure and or few degrees of temperature do not affect the evaluation of flux very much, then you can use a mean value for both parameters. Of course that depends on the accuracy you want to reach for the evaluation of flux.
The instrument measures the barometric pressure and the air temperature inside the chamber.

Choosing the flux measurement unit
The first measurements made, 20 years ago, with the accumulation chamber was expressed in cm/sec which is a speed, the speed of carbon dioxide flowing out from the soil. During the last years several units have been used by volcanologist and by geochemistry researchers. The most common unit is grams/m^2 per day, but that requires using different conversion factors for each gas species. Currently we use the unit moles/m^2 per day that has two advantages: a single conversion factor for every gas specie and an easy conversion of the flux in grams/sm per day simply multiplying the result expressed in moles/m^2 per day for the molecular weight of the target gas.

The default unit in the FluxManager is *ppm/sec*, meaning that the conversion to the flux unit is postponed to the post-processing of the data.
Otherwise you can set it to *moles/m^2/day* or *µmoles/m^2/day* to evaluate the flux extent directly in the field.

Method 1: Measuring the slope

Set the Accumulation Chamber factor to 1 in order to have the flux measurement expressed in the slope unit "ppm/sec" and translate it in the desired unit with a post processing.
Using this method you can focus only on the accumulation chamber interfacing with the soil, the flux curve shape and the other aspects of the measurement, putting off choosing the correct accumulation chamber factor.

Method 2: Measuring the flux directly in moles/m^2/day.

To get the results directly in moles/sm/day you have to set the Accumulation Chamber factor to the correct value, taking it from the tables.
For each measurement, if there are variations in the air temperature, or of the barometric pressure, or if you changed the accumulation chamber you have to select the [tools][settings] menu and put the correct accumulation chamber factor in the "A.c.K." field. This operation can be "critical". In any case on the saved files you'll find the results of flux evaluation expressed in both units , the raw ppm/sec and the moles/sm/day computed with the A.c.K. you set.

The accumulation chamber factors

Here following the formula used to compute the A.c.K.:

$$K = \frac{86400 \cdot P}{10^6 \cdot R \cdot T_k} \cdot \frac{V}{A}$$

Where

- **P** is the barometric pressure expressed in mBar (HPa)
- **R** is the gas constant 0.08314510 bar L K^{-1} mol^{-1}
- **T_k** is the air temperature expressed in Kelvin degree
- **V** is the chamber net volume in cubic meters
- **A** is the chamber inlet net area in square meters.

The dimensions of the A.c.K. are

$$K = \frac{moles \cdot meter^{-2} \cdot day^{-1}}{ppm \cdot sec^{-1}}$$

In the table the conversion factors vs temperaure and barometric pressure for the Accumulation Chamber Type A and B are reported.

Example:
You're using the accumulation chamber B, the slope of the flux curve is 2.5 ppm/sec, the barometric pressure is 1008 mBar (HPa) and the air temperature is 22 °C.
From the table B get the value that correspond to the barometric pressure and temperature. In this case I get the value computed for 25°C and 1013 mBar : 0.696. Then the flux is: 2.5 x 0.696= 1.74 moles/m^2 per day.

Accumulation chamber A factors

Volume: 0.00277 m^3
Area: 0.0308 m^2

Barometric pressure [mBar] \ Air temperature [°C]	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40
1033	0.381	0.374	0.367	0.360	0.353	0.347	0.341	0.335	0.329	0.324	0.318	0.313	0.308
1013	0.374	0.367	0.360	0.353	0.347	0.340	0.334	0.329	0.323	0.318	0.312	0.307	0.302
993	0.367	0.359	0.353	0.346	0.340	0.334	0.328	0.322	0.317	0.311	0.306	0.301	0.296
973	0.359	0.352	0.346	0.339	0.333	0.327	0.321	0.316	0.310	0.305	0.300	0.295	0.290
953	0.352	0.345	0.338	0.332	0.326	0.320	0.315	0.309	0.304	0.299	0.294	0.289	0.284
933	0.344	0.338	0.331	0.325	0.319	0.313	0.308	0.303	0.297	0.292	0.288	0.283	0.278
913	0.337	0.331	0.324	0.318	0.312	0.307	0.301	0.296	0.291	0.286	0.281	0.277	0.272
893	0.330	0.323	0.317	0.311	0.306	0.300	0.295	0.290	0.285	0.280	0.275	0.271	0.267
873	0.322	0.316	0.310	0.304	0.299	0.293	0.288	0.283	0.278	0.274	0.269	0.265	0.261
853	0.315	0.309	0.303	0.297	0.292	0.287	0.282	0.277	0.272	0.267	0.263	0.259	0.255
833	0.308	0.302	0.296	0.290	0.285	0.280	0.275	0.270	0.266	0.261	0.257	0.253	0.249
813	0.300	0.294	0.289	0.283	0.278	0.273	0.268	0.264	0.259	0.255	0.251	0.247	0.243
793	0.293	0.287	0.282	0.276	0.271	0.266	0.262	0.257	0.253	0.249	0.244	0.241	0.237
773	0.285	0.280	0.275	0.269	0.264	0.260	0.255	0.251	0.246	0.242	0.238	0.234	0.231
753	0.278	0.273	0.267	0.262	0.258	0.253	0.249	0.244	0.240	0.236	0.232	0.228	0.225
733	0.271	0.265	0.260	0.255	0.251	0.246	0.242	0.238	0.234	0.230	0.226	0.222	0.219
713	0.263	0.258	0.253	0.248	0.244	0.240	0.235	0.231	0.227	0.223	0.220	0.216	0.213
693	0.256	0.251	0.246	0.242	0.237	0.233	0.229	0.225	0.221	0.217	0.214	0.210	0.207
673	0.248	0.244	0.239	0.235	0.230	0.226	0.222	0.218	0.215	0.211	0.207	0.204	0.201
653	0.241	0.236	0.232	0.228	0.223	0.219	0.216	0.212	0.208	0.205	0.201	0.198	0.195
633	0.234	0.229	0.225	0.221	0.217	0.213	0.209	0.205	0.202	0.198	0.195	0.192	0.189
613	0.226	0.222	0.218	0.214	0.210	0.206	0.202	0.199	0.195	0.192	0.189	0.186	0.183
593	0.219	0.215	0.211	0.207	0.203	0.199	0.196	0.192	0.189	0.186	0.183	0.180	0.177
573	0.212	0.207	0.203	0.200	0.196	0.193	0.189	0.186	0.183	0.180	0.177	0.174	0.171
553	0.204	0.200	0.196	0.193	0.189	0.186	0.183	0.179	0.176	0.173	0.170	0.168	0.165
533	0.197	0.193	0.189	0.186	0.182	0.179	0.176	0.173	0.170	0.167	0.164	0.162	0.159
513	0.189	0.186	0.182	0.179	0.176	0.172	0.169	0.166	0.164	0.161	0.158	0.156	0.153
493	0.182	0.178	0.175	0.172	0.169	0.166	0.163	0.160	0.157	0.155	0.152	0.150	0.147

Accumulation chamber B factors

Volume: 0.006186 m^3
Area: 0.0317 m^2

Barometric pressure [mBar] \ Air temperature [°C]	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40
1033	0.827	0.811	0.796	0.781	0.767	0.753	0.740	0.727	0.715	0.703	0.691	0.680	0.669
1013	0.811	0.796	0.781	0.766	0.752	0.739	0.725	0.713	0.701	0.689	0.678	0.667	0.656
993	0.795	0.780	0.765	0.751	0.737	0.724	0.711	0.699	0.687	0.675	0.664	0.653	0.643
973	0.779	0.764	0.750	0.736	0.722	0.709	0.697	0.685	0.673	0.662	0.651	0.640	0.630
953	0.763	0.749	0.734	0.721	0.707	0.695	0.683	0.671	0.659	0.648	0.637	0.627	0.617
933	0.747	0.733	0.719	0.706	0.693	0.680	0.668	0.657	0.645	0.635	0.624	0.614	0.604
913	0.731	0.717	0.704	0.690	0.678	0.666	0.654	0.643	0.632	0.621	0.611	0.601	0.591
893	0.715	0.701	0.688	0.675	0.663	0.651	0.640	0.628	0.618	0.607	0.597	0.588	0.578
873	0.699	0.686	0.673	0.660	0.648	0.636	0.625	0.614	0.604	0.594	0.584	0.574	0.565
853	0.683	0.670	0.657	0.645	0.633	0.622	0.611	0.600	0.590	0.580	0.571	0.561	0.552
833	0.667	0.654	0.642	0.630	0.618	0.607	0.597	0.586	0.576	0.567	0.557	0.548	0.539
813	0.651	0.639	0.626	0.615	0.604	0.593	0.582	0.572	0.562	0.553	0.544	0.535	0.526
793	0.635	0.623	0.611	0.600	0.589	0.578	0.568	0.558	0.549	0.539	0.530	0.522	0.514
773	0.619	0.607	0.596	0.585	0.574	0.564	0.554	0.544	0.535	0.526	0.517	0.509	0.501
753	0.603	0.591	0.580	0.569	0.559	0.549	0.539	0.530	0.521	0.512	0.504	0.496	0.488
733	0.587	0.576	0.565	0.554	0.544	0.534	0.525	0.516	0.507	0.499	0.490	0.482	0.475
713	0.571	0.560	0.549	0.539	0.529	0.520	0.511	0.502	0.493	0.485	0.477	0.469	0.462
693	0.555	0.544	0.534	0.524	0.514	0.505	0.496	0.488	0.479	0.471	0.464	0.456	0.449
673	0.539	0.529	0.519	0.509	0.500	0.491	0.482	0.474	0.466	0.458	0.450	0.443	0.436
653	0.523	0.513	0.503	0.494	0.485	0.476	0.468	0.460	0.452	0.444	0.437	0.430	0.423
633	0.507	0.497	0.488	0.479	0.470	0.461	0.453	0.445	0.438	0.431	0.423	0.417	0.410
613	0.491	0.482	0.472	0.464	0.455	0.447	0.439	0.431	0.424	0.417	0.410	0.403	0.397
593	0.475	0.466	0.457	0.448	0.440	0.432	0.425	0.417	0.410	0.403	0.397	0.390	0.384
573	0.459	0.450	0.442	0.433	0.425	0.418	0.410	0.403	0.396	0.390	0.383	0.377	0.371
553	0.443	0.434	0.426	0.418	0.411	0.403	0.396	0.389	0.383	0.376	0.370	0.364	0.358
533	0.427	0.419	0.411	0.403	0.396	0.389	0.382	0.375	0.369	0.363	0.357	0.351	0.345
513	0.411	0.403	0.395	0.388	0.381	0.374	0.367	0.361	0.355	0.349	0.343	0.338	0.332
493	0.395	0.387	0.380	0.373	0.366	0.359	0.353	0.347	0.341	0.335	0.330	0.324	0.319

Accumulation chamber C factors

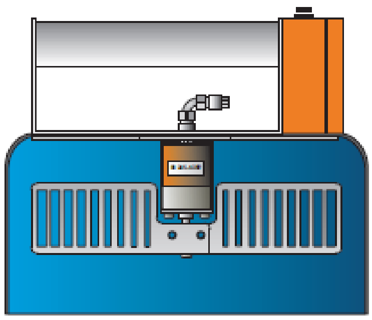
Volume: 0.006878 m^3
Area: 0.0712 m^2

Barometric pressure [mBar] \ Air temperature [°C]	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40
1033	0.410	0.402	0.394	0.387	0.380	0.373	0.366	0.360	0.354	0.348	0.342	0.337	0.331
1013	0.402	0.394	0.386	0.379	0.372	0.366	0.359	0.353	0.347	0.341	0.335	0.330	0.325
993	0.394	0.386	0.379	0.372	0.365	0.358	0.352	0.346	0.340	0.334	0.329	0.323	0.318
973	0.386	0.378	0.371	0.364	0.358	0.351	0.345	0.339	0.333	0.328	0.322	0.317	0.312
953	0.378	0.371	0.364	0.357	0.350	0.344	0.338	0.332	0.326	0.321	0.316	0.310	0.305
933	0.370	0.363	0.356	0.349	0.343	0.337	0.331	0.325	0.319	0.314	0.309	0.304	0.299
913	0.362	0.355	0.348	0.342	0.336	0.329	0.324	0.318	0.313	0.307	0.302	0.297	0.293
893	0.354	0.347	0.341	0.334	0.328	0.322	0.317	0.311	0.306	0.301	0.296	0.291	0.286
873	0.346	0.339	0.333	0.327	0.321	0.315	0.309	0.304	0.299	0.294	0.289	0.284	0.280
853	0.338	0.332	0.325	0.319	0.313	0.308	0.302	0.297	0.292	0.287	0.282	0.278	0.273
833	0.330	0.324	0.318	0.312	0.306	0.301	0.295	0.290	0.285	0.280	0.276	0.271	0.267
813	0.322	0.316	0.310	0.304	0.299	0.293	0.288	0.283	0.278	0.274	0.269	0.265	0.261
793	0.314	0.308	0.303	0.297	0.291	0.286	0.281	0.276	0.272	0.267	0.263	0.258	0.254
773	0.307	0.301	0.295	0.289	0.284	0.279	0.274	0.269	0.265	0.260	0.256	0.252	0.248
753	0.299	0.293	0.287	0.282	0.277	0.272	0.267	0.262	0.258	0.254	0.249	0.245	0.241
733	0.291	0.285	0.280	0.274	0.269	0.265	0.260	0.255	0.251	0.247	0.243	0.239	0.235
713	0.283	0.277	0.272	0.267	0.262	0.257	0.253	0.248	0.244	0.240	0.236	0.232	0.229
693	0.275	0.269	0.264	0.259	0.255	0.250	0.246	0.241	0.237	0.233	0.229	0.226	0.222
673	0.267	0.262	0.257	0.252	0.247	0.243	0.239	0.234	0.230	0.227	0.223	0.219	0.216
653	0.259	0.254	0.249	0.244	0.240	0.236	0.232	0.227	0.224	0.220	0.216	0.213	0.209
633	0.251	0.246	0.241	0.237	0.233	0.228	0.224	0.221	0.217	0.213	0.210	0.206	0.203
613	0.243	0.238	0.234	0.229	0.225	0.221	0.217	0.214	0.210	0.206	0.203	0.200	0.197
593	0.235	0.231	0.226	0.222	0.218	0.214	0.210	0.207	0.203	0.200	0.196	0.193	0.190
573	0.227	0.223	0.219	0.215	0.211	0.207	0.203	0.200	0.196	0.193	0.190	0.187	0.184
553	0.219	0.215	0.211	0.207	0.203	0.200	0.196	0.193	0.189	0.186	0.183	0.180	0.177
533	0.211	0.207	0.203	0.200	0.196	0.192	0.189	0.186	0.183	0.179	0.176	0.174	0.171
513	0.203	0.199	0.196	0.192	0.189	0.185	0.182	0.179	0.176	0.173	0.170	0.167	0.164
493	0.195	0.192	0.188	0.185	0.181	0.178	0.175	0.172	0.169	0.166	0.163	0.161	0.158

5. Components

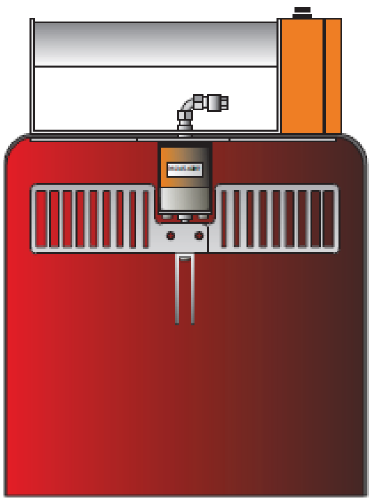
5.1 Accumulation chamber

The accumulation chamber comes in three different dimensions:



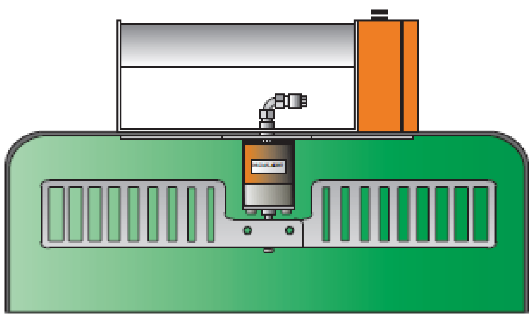
Type A

Net volume:	0.00277 m^3
Base area:	0.0308 m^2
Internal height:	98 mm
Mass:	1.35 Kg (with battery)



Type B

Net volume:	0.006186 m^3
Base area:	0.0317 m^2
Internal height:	198 mm
Mass:	1.55 Kg (with battery)



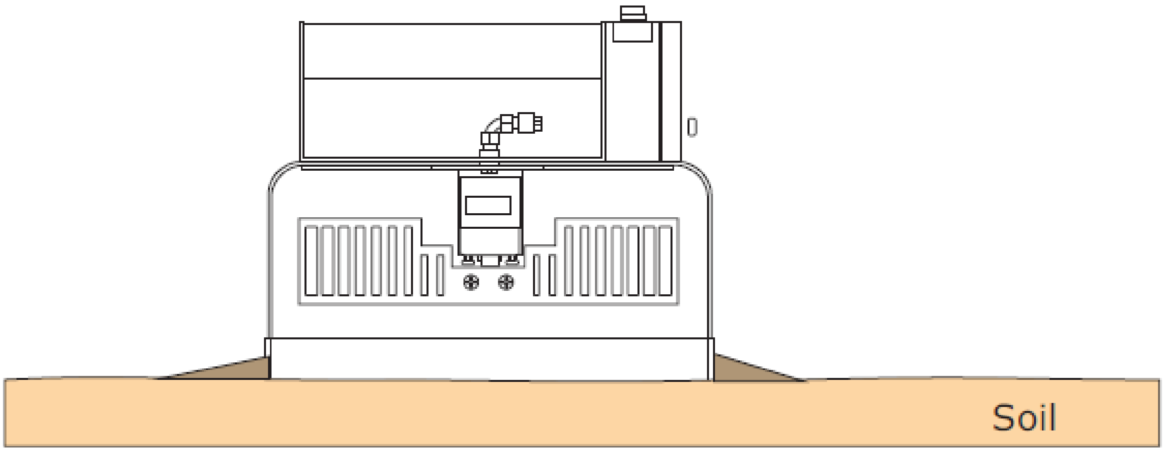
Type C

Net volume:	0.006878 m^3
Base area:	0.0712 m^2
Internal height:	97 mm
Mass:	1.80 Kg (with battery)

The types A and C (height 10 cm) are useful to increase the sensivity of the instrument to very low fluxes by a factor 2. Under normal conditions we advise using the type B (height 20 cm) that can cover a very large range of soil flux with a good sensitivity and linearity.

The accumulation chamber is the main part of your instrument.
The interfacing of the chamber with soil must be performed with great attention.

Once the chamber is placed on soil in the measuring site it has to be verified that the rim is placed correctly on soil in order to avoid atmospheric air to enter the chamber.



If necessary, seal the external rim of the chamber with the soil, as in the figure above, carefully putting some earth around the rim.

The measuring site should be disturbed as litlle as possible. J.D.Rogie et al. have demonstrated that if soil is disturbed, for example levelling the ground or digging a hole in order to place the chamber, the flux condition varies in an unpredictable way and takes a long time to stabilize again

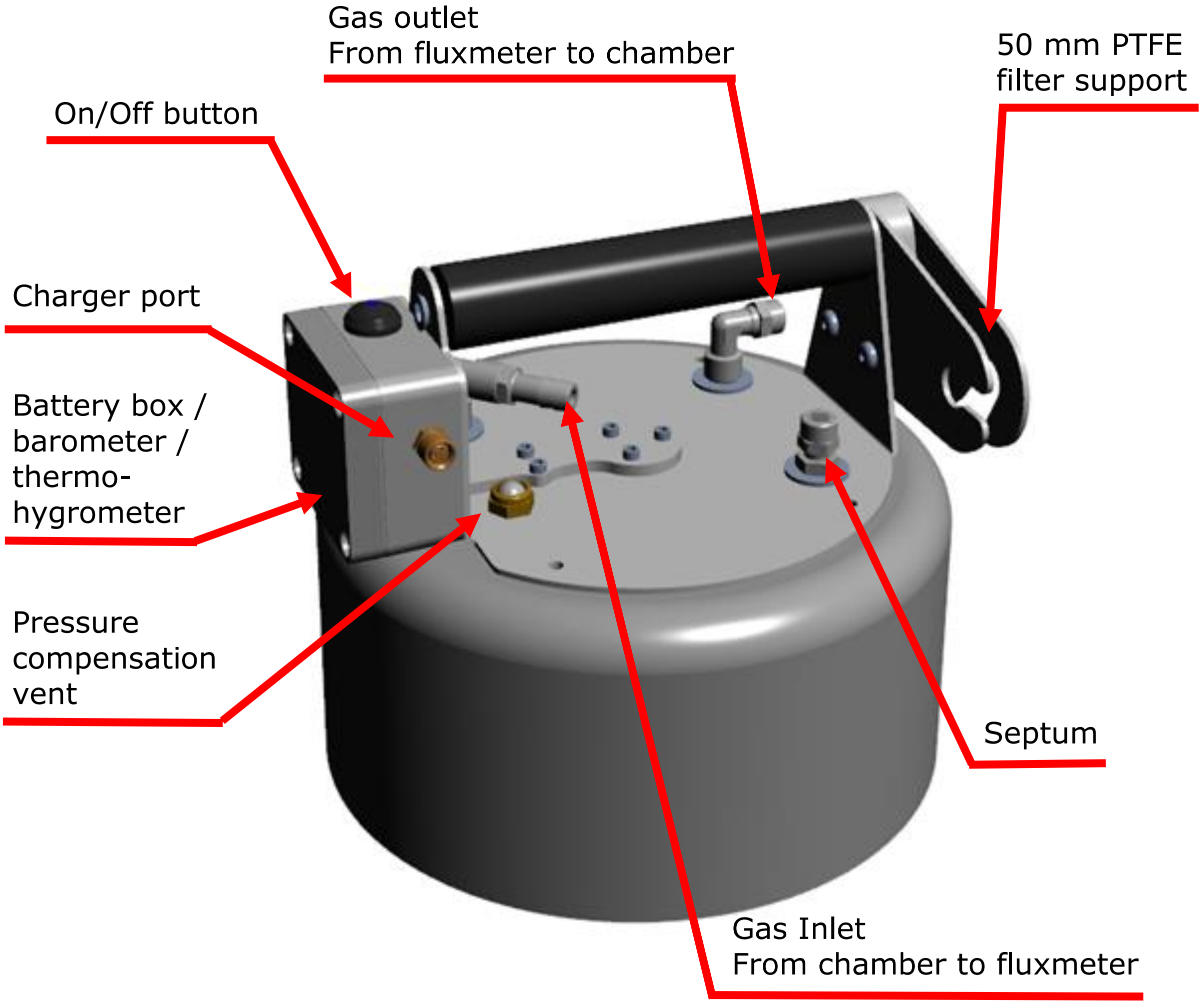
On the contrary, measures performed on the same site, trying to disturb the soil as little as possible, shows a very good precision and repeatibility.

If you plan on sampling underground gas, first perform the flux measurement and then the sampling.

The instrument has good resistance against sulfur gases, but in the case of high concentration of hydrogen sulphide it is better to use a trap in the gas line.
Hydrogen sulphide is very aggressive and therefore we advise reducing to a minimum the instrument (especially the palmtop) and operator exposure to corrosive gases.

Take care of your safety when working in high gas emission areas: do not work alone and use a gas mask or take adequate precautions.

5 Components



Mixing device
The chamber internal fan ensures the homogenization of the gas mixture inside the chamber during the flux measurement.

Manufacturer: McLennan
Model: 1271-12-21
Output speed: 80 rpm
Maximum output torque: 2.5 Ncm

Internal battery
The chamber is powered by an internal rechargeable battery.
Cell type: NiMH
Nominal capacity: 300 mAh
Nominal voltage: 8.4 V
Max. charge voltage: 10.5 V

In case of emergency (for example if you are out in the field with low battery and no possibility to recharge), the internal battery can be replaced by a common 9V alkaline battery:

16. Remove the 4 screws of the battery box with a Phillips head screwdriver.
17. Replace the battery
18. Reinstall the box cover.

Never attempt to charge the chamber when an alkaline battery is inserted.

Battery charger
Connect the provided battery charger to the charger port.
Do not switch on the chamber while charging.

Use only with the provided internal NiMH rechargeable battery.

Do NOT connect the charger if an alkaline battery is inserted.

A full recharge takes about 2 hours. It is recommended to charge the battery after each working day.

The chamber is equipped with a pressure, temperature and relative humidity sensor. The sensor is placed inside the chamber on the ceiling.
The sensor is NOT protected against water or accidental impacts.
Please be careful when placing the chamber on the ground.

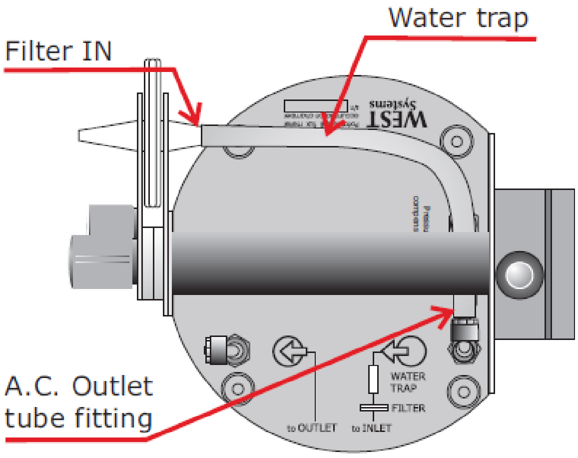
Pressure sensor
The barometric pressure inside the chamber is measured by a digital barometer.

Manufacturer: Freescale
Ordering code: MPL3115A2
Range: 500 to 1100 mBar
Accuracy: ±0.5 mBar

Temperature and relative humidity sensor
The temperature and relative humidty inside the chamber is measured by a digital thermo-hygrometer.

Manufacturer: Sensirion
Ordering code: SHT35
Relative humidity range: 0 to 100%
Relative humidity accuracy: ±1.5 % (range 0-80%)
Temperature range: -40 to 125 °C
Temperature accuracy: ±0.1 °C (range 20-60 °C)

Water Trap
The tube between the filter and the chamber outlet can be used to install a water trap.

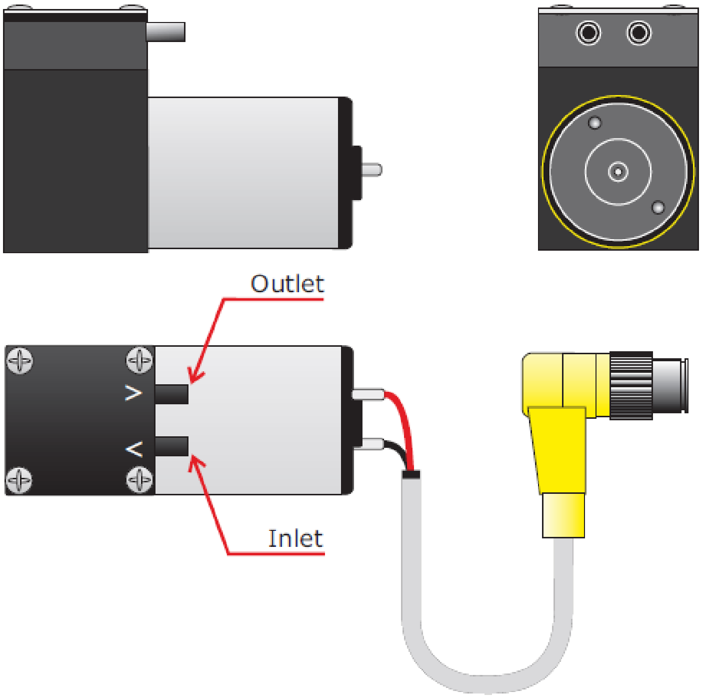


Pressure compensation vent
The vent is used to maintain pressure equilibrium between inside the chamber and the surrounding air outside the chamber, avoiding the pressurization of the chamber that would alter the gas flow from the soil.
Make sure it is not obstructed by dust; clean it if necessary.

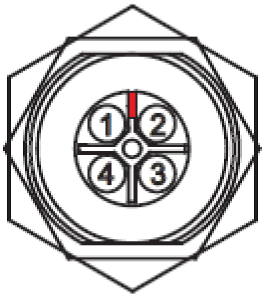
Septum
The septum is used for trace gas sampling. It allows collecting subsamples directly from the chamber gas content. The flux of trace gas species can be manually computed by analysing the subsample.

Manufacturer: Supelco
Ordering code: 27356
Material: PTFE/Silicone
Diameter: 11 mm

5.2 Pump



Power supply female panel connector



PIN 1: VDC, to positive pole of pump
PIN 4: GND, to negative pole of pump

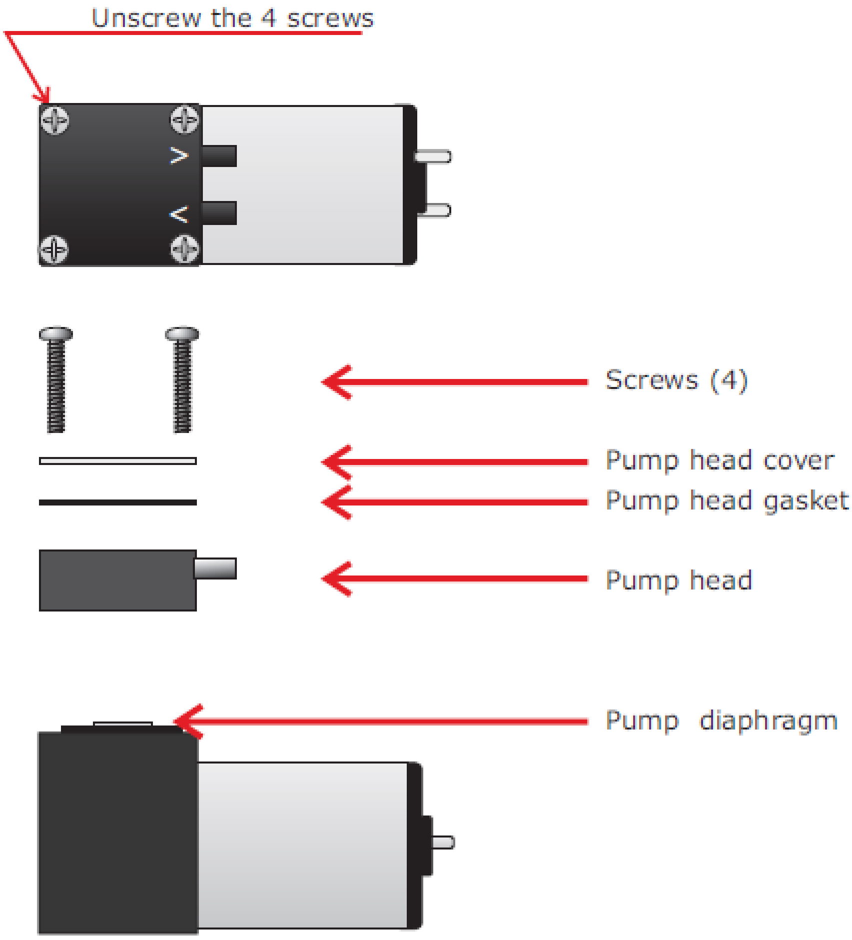
Specifications
Vacuum: 250 mBar absolute
Delivery: 3.1 l/min
Power consumption: 150 mA @ 12 Volts
Manufacturer: KNF
Order model: NMP 830 KNDC
Pneumatic fittings diameter: 4 mm

In order to avoid unwanted variation of pumping flow due to power supply the pump is supplied with a stabilized voltage regulator.

Pump maintenance
The pump efficiency can be affected by deposits of dust or water. In this case it is recommended to clean the pump:

19. Disassemble the pumping head.
20. Clean the diaphragm, the washer, and the valves using a compressed air flow.

21.Reassemble the head.

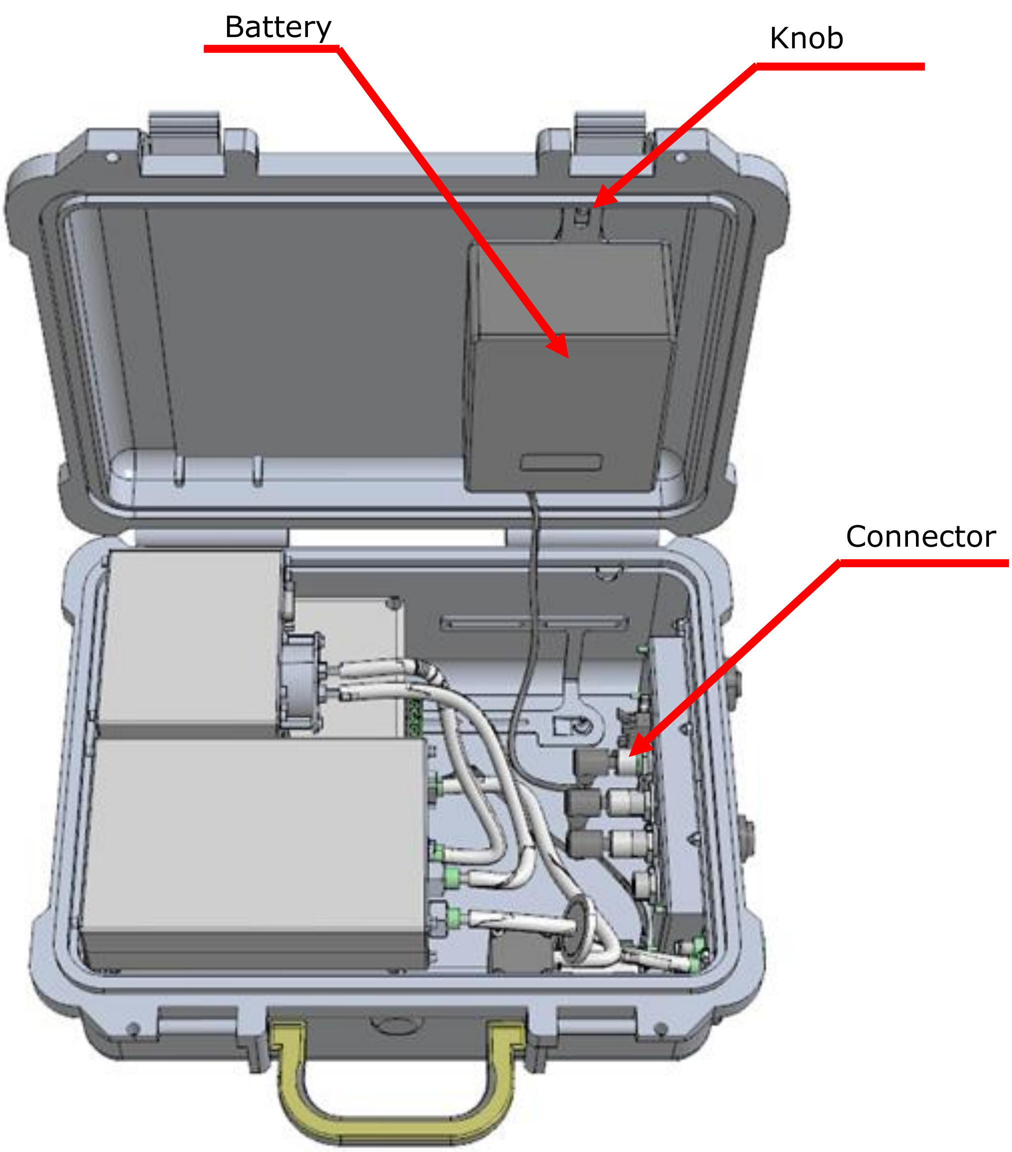


5.3 Fluxmeter battery

Nominal voltage: 14.4 V
Nominal capacity: 4500 mAh
Battery duration: approximately 4 hours.

The system is equipped with two interchangeable battery, to guarantee operation during a whole working day.
To replace the battery, unplug the battery connector from fluxmeter internal panel and remove the knob as indicated in the picture.

Charge the battery after each use.
To charge the battery: unplug the battery connector from the fluxmeter internal panel and connect it to the charger. Please read carefully the instructions in the following paragraph before executing the first charge.



5.4 Fluxmeter battery charger

Model: Mascot 2215
Input voltage: 90-264 VAC, 50/60 Hz
Max output power: 35 W
Trickle charge current: 100mA +/-50mA
Leakage current with mains off: < 1 mA
Charging time for a single battery: ~ 4 hours

Before connecting to the mains, please check that the cord is not damaged. If the cord is damaged, the product must not be used until the cord is replaced. Replacement should be carried out by qualified personnel.

The charger is "switched on" by inserting the mains plug into the mains socket and "switched off" by disconnecting the mains plug from the mains socket. The time from powering this product until its full function starts may exceed 15 seconds.

To avoid overheating make sure there is sufficient room for the circulation of air around the product when in use. Do not cover it up.

When not in use please think about disconnecting the charger from the mains. This will reduce the risk of hazards, reduce the products environmental impact and save electricity costs.

The charger must be kept away from sources of heat and may not be used in the vicinity of flammable anesthetic gases or in other environments with flammable or explosive atmosphere.

Should an operational error or unexpected change in the performance occur during use; disconnect the product from the mains immediately by disconnecting the mains plug from the mains socket and contact the supplier.

This product contains hazardous voltages and there are no user replaceable parts inside the product. Never attempt to remove the cover.

WARNING: No modification of this equipment is allowed. Any repair/service should be carried out by qualified personnel who may get assistance by contacting the manufacturer.

The intended use for this charger is to charge the fluxmeter NiMH battery (P/N AFLBATT00). Do not use it for charging other batteries.

Charge

Disconnect the battery from the fluxmeter and connect it to the charger.

The charger is started by connecting the battery pack to the charger and then connecting the charger to the mains. The LED will be yellow before the fast charge starts and the LED changes to orange. When the batteries are fully charged and the voltage drops because of the -dV signal from the batteries, the charger will go into a top-off charge mode before it goes over to trickle charge mode. During top-off charge the LED will be green with a short intermittent yellow light. When the top-off charge is completed, the charger will go into trickle charge mode and the LED will be green. The charge current is now reduced to a safe level, which allows the charger to stay connected to the NiCd batteries without damaging the batteries. NiMH batteries are not as well suited for trickle charge, and some battery manufacturers recommend that trickle charge does not exceed 24 hours. If in doubt; contact the battery manufacturer for details. If the safety timer runs out before –dV is detected, the charger will go directly to trickle charge mode (no top-off charge) and LED will be continuously green. If the battery voltage is far below normal, the charger will cut the fast charge current and go to trickle charge mode. The LED will then indicate ”error” by flickering green and orange light. If the mains input voltage is turned off, the charger will reset. When the mains input voltage is turned on again a new charge cycle will start. If new batteries are to be connected, the charger must idle for approx 15 sec. to make sure all parameters in the microprocessor have been reset. When the charger has been reset the LED changes to yellow, and a new charge cycle can begin.

LED indications

LED	**MODE**
YELLOW	Battery not connected
YELLOW	Battery initialisation and analysis
ORANGE	Fast charge
GREEN with intermittent YELLOW flash	Top-Off Charge
GREEN	Trickle Charge
Alternating ORANGE-GREEN	ERROR

5.5 Backpack

If you need to free your self from the backpack and the instrument pull the red belt.

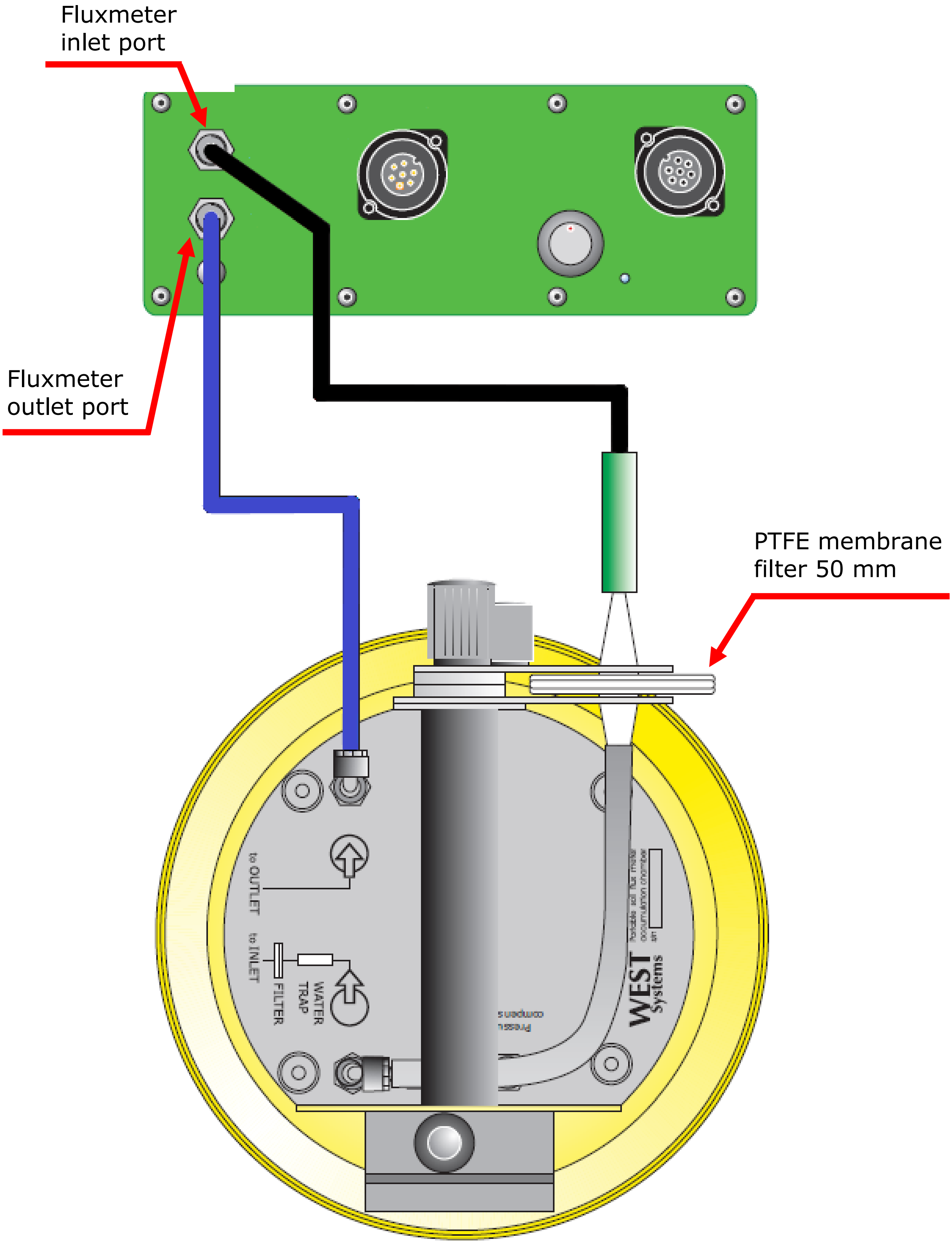
5.6 Tubes

Periodically check the status of the tubes and replace them if necessary.

Fluxmeter internal tube
Internal diameter: 4 mm
External diameter: 6 mm
Minimum bending radius: 15 mm
Material: Polyurethan
Color: clear
Manufacturer: SMC
Order code: RS 686-2680

Chamber twin tube (for connecting the chamber to the fluxmeter)
Internal diameter: 4 mm
External diameter: 6 mm
Material: Polyurethan
Color: Black/Blue or White/Blue
Manufacturer: Legris
Order code: RS 492-8643

The blue tube (return) must be connected to the fluxmeter outlet port. The black (or white) tube (supply) must be connected to the fluxmeter inlet port. On the chamber, the black (or white) tube must be connected to the 50 mm PTFE membrane filter. Make sure not to switch the tubes otherwise the pump will call unfiltered air into the fluxmeter.


Fluxmeter inlet port
Fluxmeter outlet port
PTFE membrane filter 50 mm
to OUTLET
to INLET
FILTER
WATER TRAP
WEST Systems

5.7 Filters

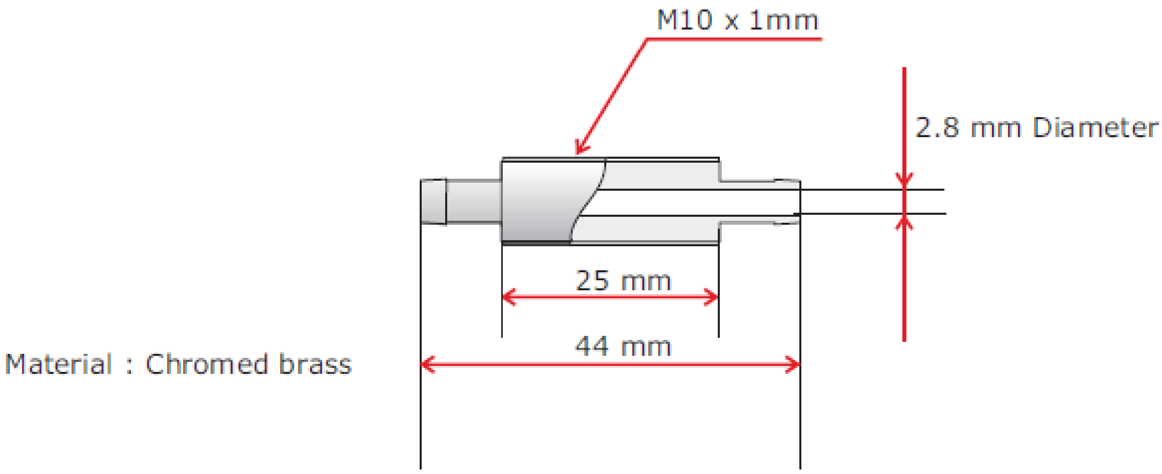
Three types of filters are used to protect the gas sampling line:

22. PTFE membrane filter, diameter 25 mm, pore size 0.2 μm
    Order code: Cole-Parmer EW-02915-20
23. PTFE membrane filter, diameter 50 mm, pore size 0.45 μm
    Order code: Cole-Parmer EW-02915-30
24. PVDF microfibre filter cartridge filter. Filtration efficiency: 93% at 0.01 μm.
    Order code: Balston 9922-05-DQ

The PTFE membrane filters are permeable to gases and water vapour and are impermeable to liquid water and dust particles. The use of the filters protects the gas detectors and the other pneumatic parts. Please check the status of the filters before each sampling campaign.

5.8 Fittings

WEST Systems Tube fitting for 6x4 tubes.

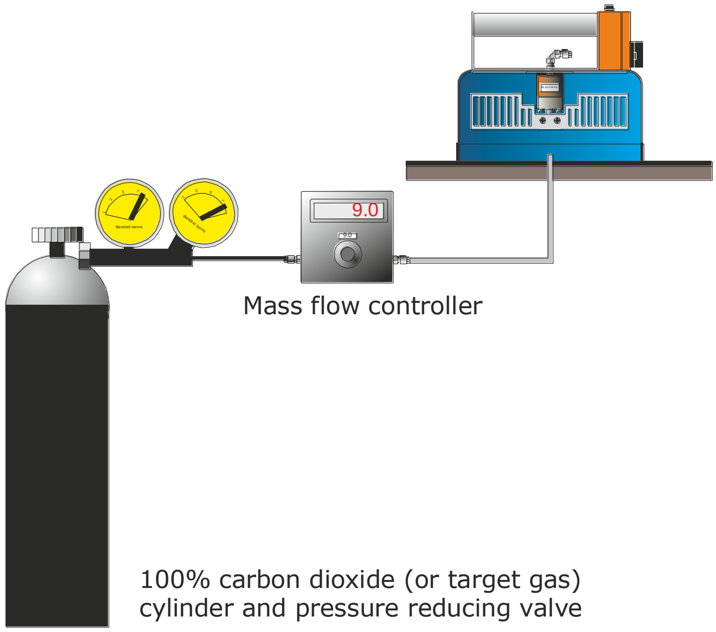


The gas sampling line is assembled with 1/8" gas cylindrical or conical thread fittings. The sealing is guaranteed by Loctite 542 dope.

6. Calibration of the flux meter

The present chapter reports the procedure followed by WEST Systems to check the fluxmeter calibration. The method described refers to carbon dioxide calibration, bu the same procedure is followed for the other gases.

CO2 fluxes from soil are simulated by injecting a known flow of gas into the accumulation chamber. The interface between the accumulation chamber and the calibration table is built to minimize the gas leakage.
The apparatus is schematized in figure.



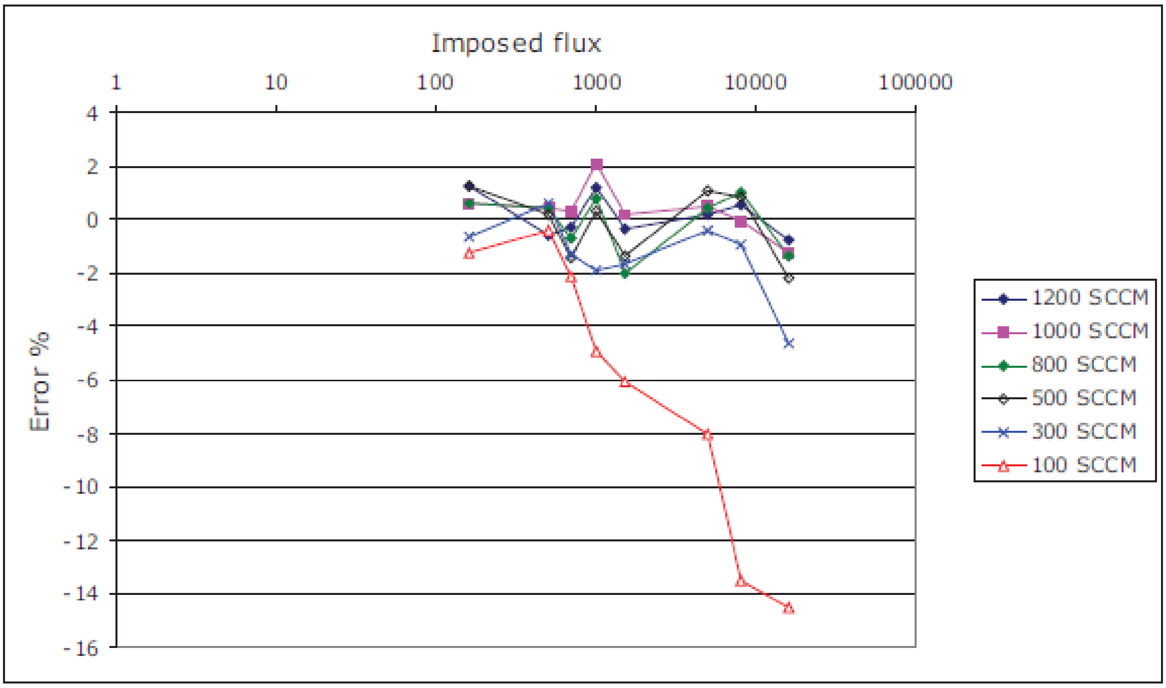
The injected flux is controlled and measured with a precision mass flow controller. This MFC, calibrated for CO2, is electronically stabilized, with accuracy: ± (0.8% of Reading + 0.2% of Full Scale).

6.1 Fluxmeter calibration

For fluxes between 300 and 700 moles/m^2/day, the injected flux is controlled by means of a mechanical flow reducer and measured using a bubble flowmeter (Accuracy 3%) before and after the flux measurement with the accumulation chamber.
Two series of measure were performed for flux of 300 moles/m^2/day to evaluate the coherence between the two different methods of flow measurement.
A thermometer and barometer were utilized to measure the barometric pressure and the air temperature during the experiment in order to select the correct accumulation chamber conversion factor.
A flow meter is utilized to measure the pumping flow during the experiment.
During all the measures a 100% CO2 flow was utilized. The same procudure was utilized to check the instrumental response to methane and hydrogen sulfide.

6.2 The influence of pumping flow

We have carried out some sets of measures utilizing the same injected flux but with different pumping flow from the accumulation chamber to the detector. The pumping flow was changed by means of a mechanical flow reducer and measured with an Alicat Mass flow meter.
We have not noted a significant variation of the measures except when the pumping flow is less than 200 SCCM.

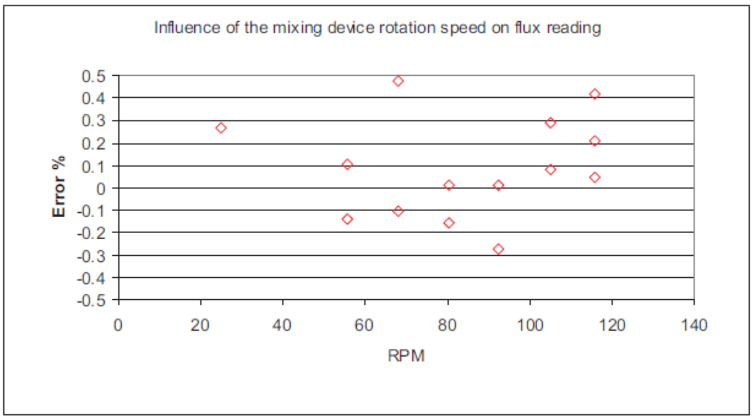


The diagram shows the plot of the measurement error versus the imposed flux of carbon dioxide (expressed in grams per square meter per day) at different pumping flow rates.
In order to avoid unwanted variation of pumping flow due to power supply the pump is supplied at 12 V DC with a stabilized voltage regulator.
The pumping flow, after the power supply stabilization, is 1000 SCCM ± 20%. The efficiency of pump can vary due to dust or moisture in the pump body. Periodic maintenance is necessary.

The mixing device was suspected, by some researcher, to affect the accuracy of the flux measurement. In our experience the precision of the measurements was noteably reduced without a mixing device present. In the two plots below the measurements at various regimes of mixing device rotation are reported.

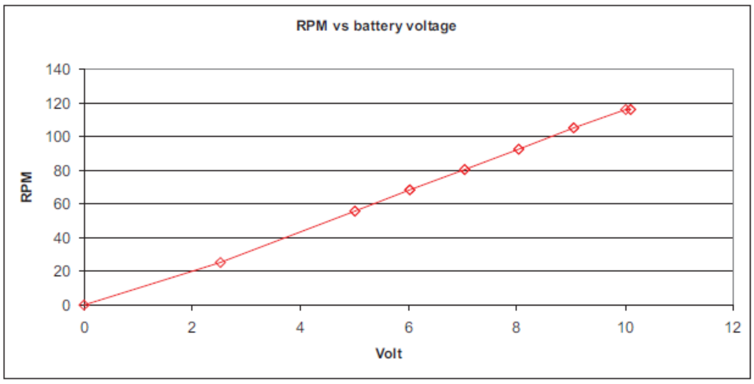
6.3 Influence of the mixing device rotation speed

The following plot shows the measured flux vs the mixing device rotation speed.



Battery status vs RPM.

The following plot shows the mixing device RPM (Rotation per minute) vs power supply voltage. The normal range for the battery voltage is between 9.6 V (new battery) and 6 V (discharged battery).



7. FluxRevision

FluxRevision is the software that allows to quickly elaborate a large number of files created by FluxManager. Note: FluxRevision runs on Microsoft Windows operating systems; the Microsoft .NET framework is required on the machine.

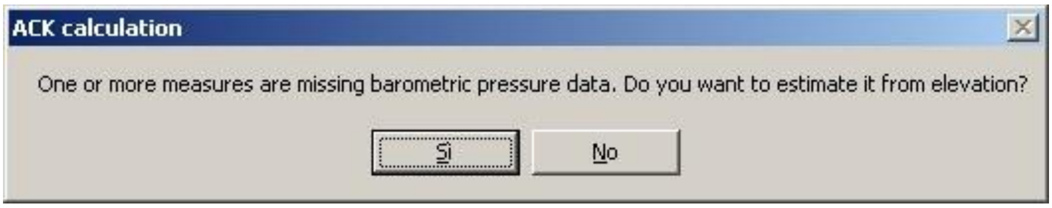
To download the files from the Android device to the PC, follow the instructions reported on chapter 2.

Once you have the files in the PC, start the FluxRevision application. In the first instance you'll be asked to select the folder that contains the FluxManager files. The selected folder will be proposed the next time you start the software. Select the folder and press OK. If there are valid files, the application will start to parse the data.

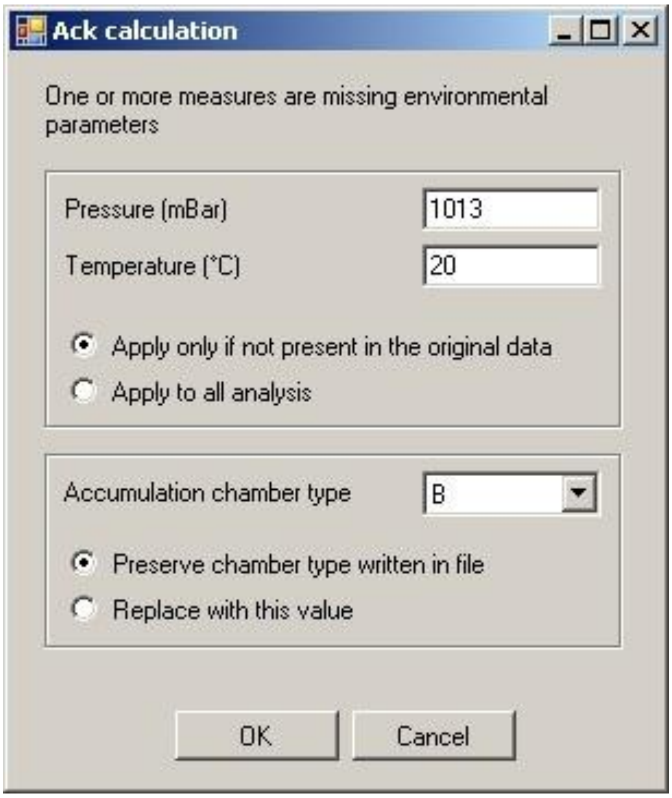
To estimate the flux from the slope of the regression line, the application will need to know the following parameters (see chapter 4 for details):

- Air temperature
- Barometric pressure
- Volume of the accumulation chamber

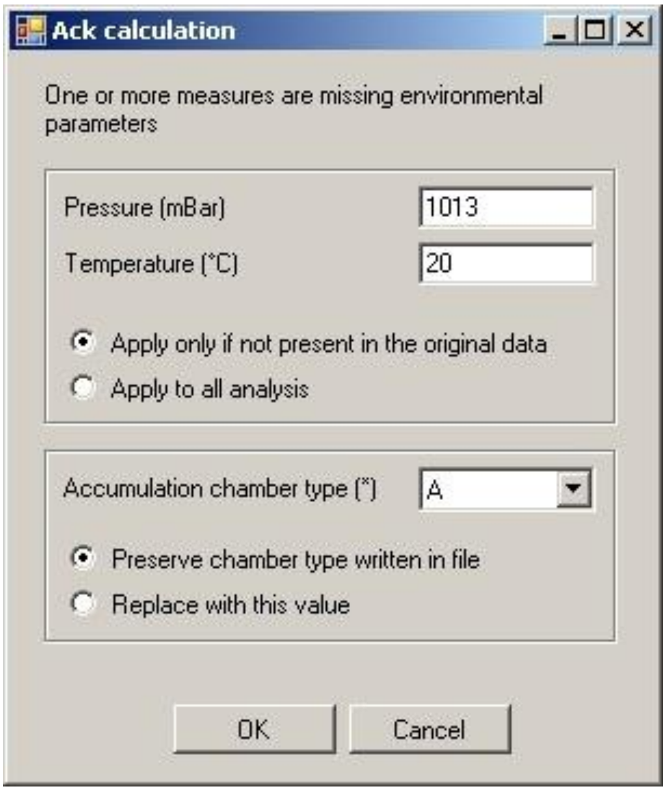
If the barometric pressure is missing (because you don't have a pressure probe inside the fluxmeter and you didn't manually inserted the value in the FluxManager saving window), but the Android device is equipped with a GPS antenna, FluxRevision can estimate the pressure from the elevation (of course this calculation can't be as accurate as having a sensor).



If some files are missing environmental parameters, you'll see the window appear.



The volume of the accumulation chamber is obtained with the type of chamber (e.g. A, B, C) that you inserted in the FluxManager software. Check that the information about the chamber type (A in the illustration) is correct: the displayed type is the one obtained from the files. If the files present more than one chamber types, an asterisk will signal this. For example if you select a folder with some file with accumulation chamber A and some with type B, you will see a window like this:



To set the barometric pressure or the temperature in the measures that are missing this parameter, replace the default values (1013 mBar and 20°C) and press OK. If the "Apply to all analysis" box is checked, the parameters in the measures that already had them will be overwritten.

Once all the files are parsed, you'll see the measures in the list.

Folder: The folder that contains the measure files.

Curve: You can choose the currently displayed gas specie. Changing the specie has the effect to display the ErrQ and the Flux on the list. So the filter and the sorting of the list will refer to the selected specie.

Filter Records: This box allows filtering the measures in the list. The measures excluded from the filter will however be present in the report file.

Never revised: Checking this box, the list will contain only the measures that have never been revised (with no revision date).

ErrQ and **Flux**: Entering a value in these 2 boxes will exclude the measures with Flux or Errq higher or lower than the inserted threshold. Pressing the >= button will invert the sign.

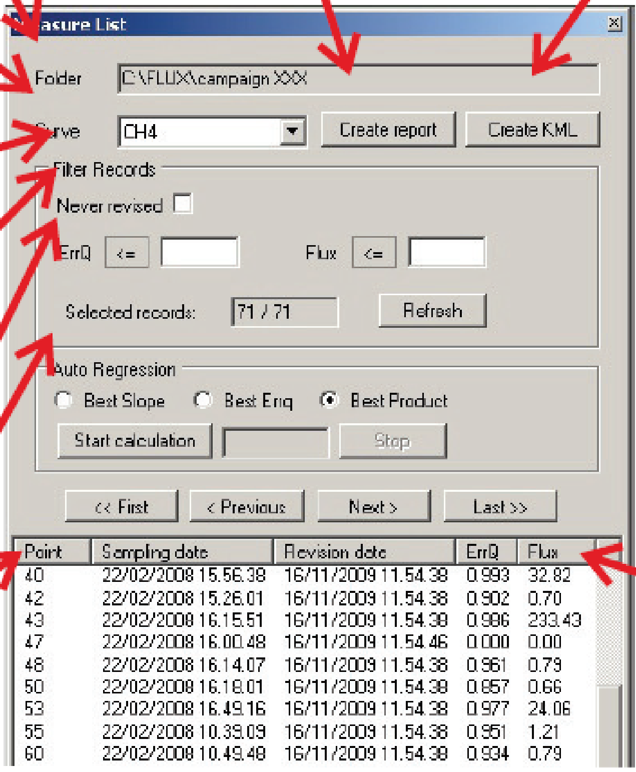
Auto Regression: this will automatically determine the best time interval to calculate the linear regression, according to the following algorithms:

- Best Slope: the interval which determines the highest slope is chosen.
- Best Errq: the interval which determines the highest Errq is chosen.
- Best Product: the algorithm looks for a good compromise between the 2 previous parameters.

First..Last: Navigates the measure list. You can sort the measures by clicking on the column header.

Create report: Allows to create the report file. See the paragraph for details.

Create KML: If the files contain GPS data, will be generated a KML file, just to have a quick representation of the spatial distribution of measure points. The file can be opened with software like Google Earth.

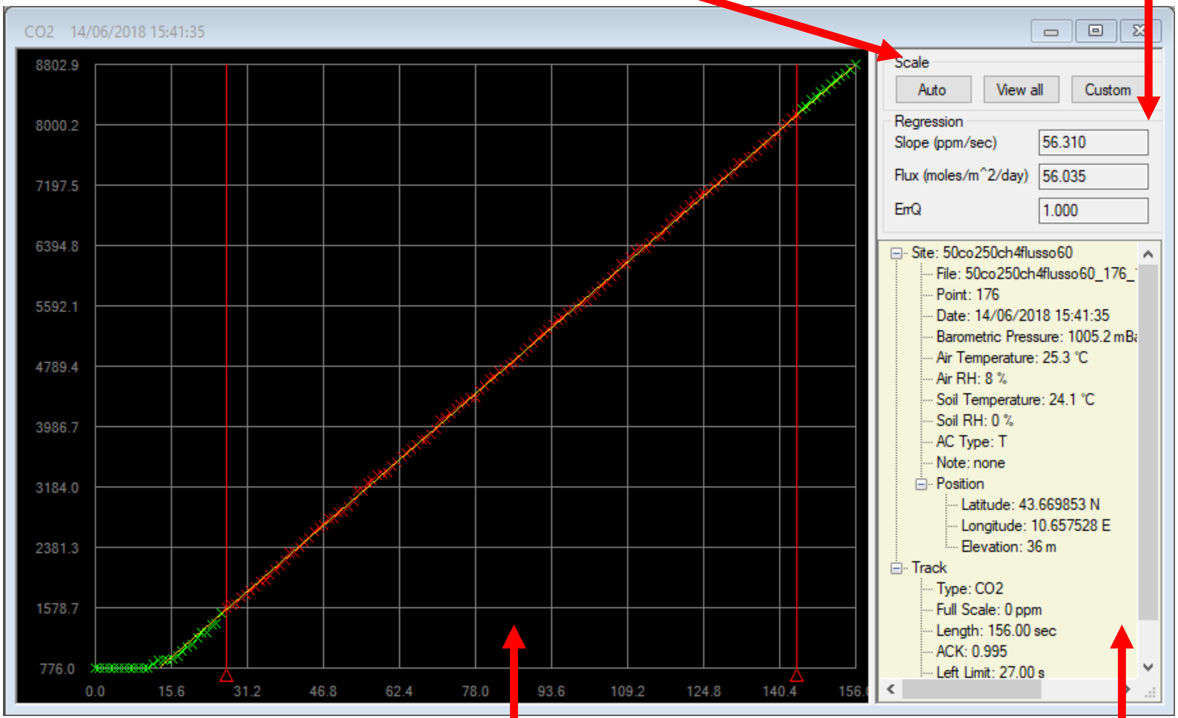


Point: it's the value you inserted in the "Point" field in the FluxManager saving window. By default it's numerical and auto incremental but you can insert also words.
Sampling date: it's the date and the time the measure was performed. Warning: this information is taken from the PDA clock so check it before to start the analysis' sequence.
Revision date: it's the date and time the measure was edited (with FluxRevision) by modifying left and right limits of flux interpolation and then modifying the value of the flux.
ErrQ: it's the value referred to the currently displayed gas specie. For example select Errq <= 0.9 to evaluate if there are curves with a bad linear interpolation.
Flux: it's the value referred to the currently displayed gas specie.

Selecting an item in the list or pressing one of the navigate buttons, the flux curves are displayed. Like in FluxManager, are displayed the graphs of the sensors with TRACK=ON. They are usually the gas sensors.

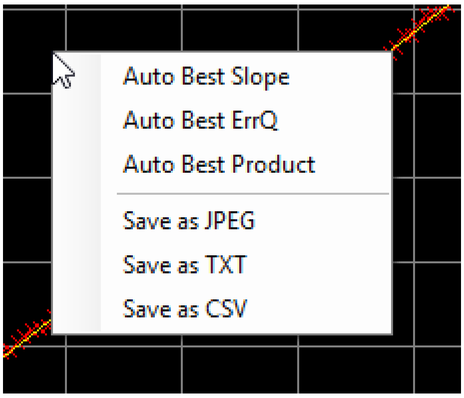
Scaling panel
Auto: resets the image to the automatic scale
View all: sets the axis limits to the minimum and maximum recorded values
Custom: clicking on the button, the mouse pointer becomes a viewfinder and the user can select a portion of the graph to be visualized

Regression panel
The Slope, Flux and ErrQ parameters are initially filled with the result of the regression computed on the field. Moving the regression left and right limit will cause the immediate update of the fields.



Graph
Displays the concentration vs. time plot.
The red points are used to calculate the interpolation line (and so, the flux), the green ones are ignored.
Left click: move the regression limits. The mouse gets the control of the closest limit.
As the button is released, the regression is automatically recomputed and the line redrawn.
Middle click: shows the X and Y value at the point
Right click: the following menu appears:

Information panel
Contains the meta-data of the flux measurement.



Auto Best Slope / **Auto Best ErrQ / Auto Best Product**: see the Auto Regression function in the previous paragraph. In this case the automatic regression is carried out only in the selected file.
Save as JPEG: exports the graph image to a file.
Save as TXT: exports the values of the curve to a text file. The text has two columns: time [seconds] and gas concentration [ppm].
Save as CSV: as in Save as TXT but the output is in CSV (Comma Separated Value) format.

Warning: the files are automatically saved after each operation. By moving the regression limits either manually or automatically, the related file will be updated and the pre-existing interval will be overwritten.
We recommend saving the original FluxManager files in a folder and working with FluxRevision on a copy of the data.

7.1 Report file

The report file is a table where each row corresponds to a measure point. The number of the columns is variable, since the fields indicated in red are repeated for every sensor with TRACK=ON.
In fact, for each sensor the following parameters are printed:

25. LLIMIT and RLIMIT are start and the end of the time interval which the user has set for the linear regression.
26. LCONC and RCONC are the concentrations of the gas at the seconds LLIMIT and RLIMIT respectively
27. SLOPE, FLUX and R2 are the results of the linear regression.

The fields are the following:

- DATE
- TIME
- SITE
- POINT
- LONGITUDE
- LATITUDE
- UTM ZONE
- UTM LONGITUDE
- UTM LATITUDE
- ELEVATION
- POSITION ERROR [m]
- NOTE
- PRESSURE [Hpa]
- AIR TEMPERATURE [°C]
- AIR RELATIVE HUMIDITY [%]

- SOIL TEMPERATURE [°C]
- SOIL RELATIVE HUMIDITY (%)
- ACCUMULATION CHAMBER
- ACK
- SENSOR_ID: LLIMIT [sec]
- SENSOR_ID: RLIMIT [sec]
- SENSOR_ID: LCONC [ppm]
- SENSOR_ID: RCONC [ppm]
- SENSOR_ID: SLOPE [ppm/s]
- SENSOR_ID: FLUX [mol/m2/day]
- SENSOR_ID: R2
- FILENAME

The report file is a text file, the fields are separated by the TAB character, so the file can be easily opened with a spreadsheet editor (e.g. Microsoft Excel).

The LONGITUDE and LATITUDE fields are populated with the original data collected by the smartphone integrated GPS, which uses WGS84 spatial reference system. Since many data elaboration require data with metric-based spatial information, the WGS84 data is converted by FluxRevision in UTM (Universal Transverse Mercator) coordinate system. The UTM ZONE, UTM LONGITUDE and UTM LATITUDE fields are therefore derived from the LONGITUDE and LATITUDE fields.

8. LI-COR Carbon dioxide detector

The information discussed in this chapter applies to the carbon dioxide detector model LI-COR LI-830 or LI-850.
For full specifications and instructions please refer to the LI-COR manual which is attached to this handbook.

8.1 Calibration check

As explained previously in Chapter 4, the flux measurement is proportional to the slope of the concentration curve versus time. The proportionality factor depends on the volume/surface ratio of the accumulation chamber used for the measurement, as well as, the barometric pressure and air temperature at the moment of making the measurement.
The most important aspect to understand is that the flux is proportional to the gradient of concentration over time: ppm/second. This aspect allows us to simplify the control of the response of the gas analyzers.
Each time a measurement campaign is initiated the instrumental response of the gas sensors must be verified and, if necessary, their calibration fine-tuned.

To simplify the explanation, see the following example:

Step 1: Verifying the zero
Inject a flow of nitrogen, or synthetic air, into the instrument. Read the carbon dioxide concentration on the FluxManager app, as explained on chapter 3. Obviously, it is important that the injected mixture does not contain carbon dioxide.
The method for injecting standard gas mixtures is explained in detail in the following pages.

Step 2: Verification of the span
Inject a standard mixture containing approximately 1% (10,000 ppm) of carbon dioxide and check the response of the instrument.
Let's suppose that the check gave the following results:
Injecting a mixture at zero concentration of carbon dioxide the CO2 detector returns a reading of 10 ppm.
Injecting a mixture containing a 10,000 ppm concentration of carbon dioxide the CO2 detector returns a reading of 9,940 ppm.
At a variation of concentration set at 10,000 ppm the instrument has a slightly different response: 9,930 ppm (=9,940-10 ppm). The evaluation error is of about 70 ppm, which in percentage points over the span corresponds to 0.6% less

The error in evaluating the increment in concentration manifests as a systematic error in the evaluation of flux and, therefore, must be corrected by calibrating the instruments when it is too high (> 5%).

When you need to calibrate the detector
The LI-COR is a very stable detector, the pressure compensation and the thermal stabilization features allows the instrument to maintain it calibration for long periods. The calibration is mandatory if you decide to change the optical path or to clean it. In any case we advise calibrating it only if necessary.

8.2 Calibration

What you need to calibrate the detector

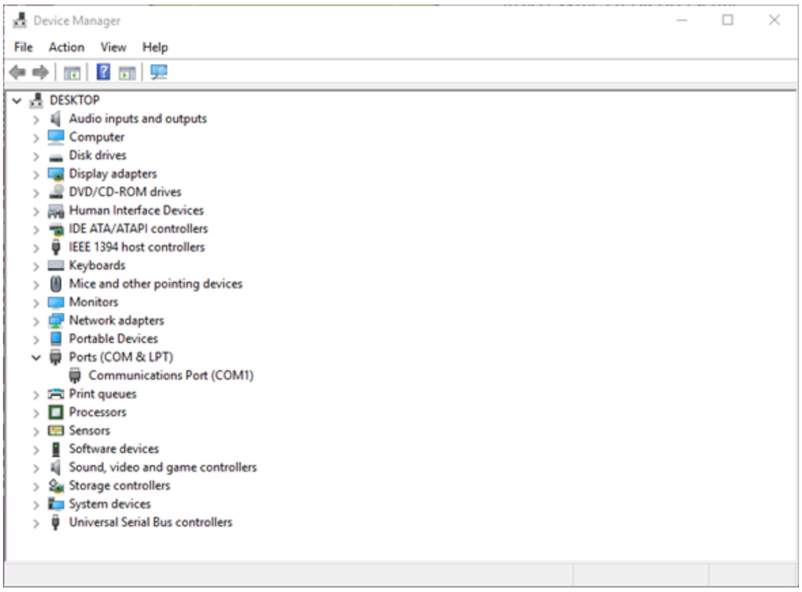
28. A laptop/personal computer running Microsoft Windows operating system;
29. An USB/RS232 adapter;
30. A null modem RS232 cable, connectors DB9 female to DB9 female. The cable is furnished in the detector package;
31. A cylinder of nitrogen or synthetic air, or a SODA LIME trap or a DRAGER PIPE to trap the carbon dioxide.
32. A cylinder of standard mixture of 1% of carbon dioxide in air (or nitrogen); The CO2 concentration has to be minimum the 50% of the full scale value of the detector and maximum the 95% of this value. If the full scale value is 2% by volume of CO2 the concentration of standard must be in the range from 1% up to 1.9% of CO2;
33. A screwdriver to access the DB9 connector.
34. Two gas sampling bags (Tedlar bag or equivalent), for the zero mixture and one for the span mixture. We suggest to label them in order not to switch them.

Calibration

Preliminary operations: install the LI-COR application on the laptop. The application is furnished on a CD together with the detector, or can be downloaded from the LI-COR website.

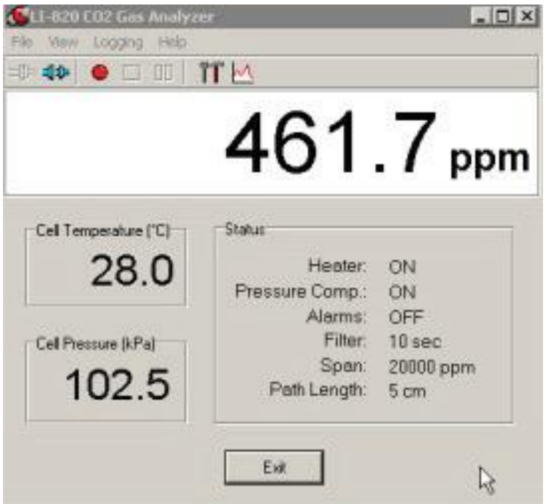
Calibration steps:

1) Switch on the fluxmeter as first operation in order to get the analyzer warming up.
2) Open the FluxManager application and start a measurement in order to get the pump running.
3) Unplug the LI-COR detector from the cable which connects it to the fluxmeter, and plug the RS232 null modem cable in its place.
4) Connect the RS232 serial cable to the USB-RS232 adapter.
5) Connect the USB-RS232 adapter to your laptop. If the laptop is corretly configured with the adapter software drivers, it will create a virtual serial port (e.g. COM10).
   If you are not aware of the name of the port, open *Device Manager* on the the Windows laptop and look for the entry under *Ports (COM & LPT)*. In the following example, the port name is COM1.

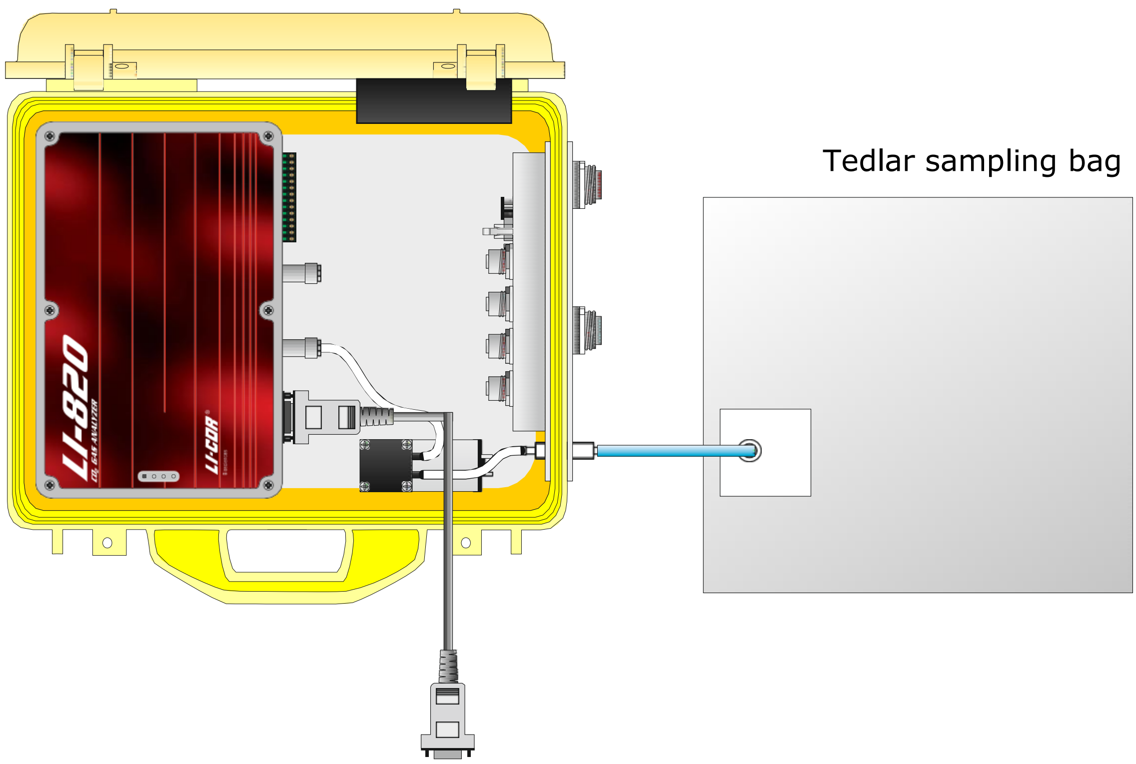


6) Run the LICOR windows application on your Windows laptop;
7) Press *File-Connect*. You'll be asked to input the serial port which corresponds to the USB-RS232 adapter (COM1 in the previous example). Set the sampling frequency to 1 Hz.

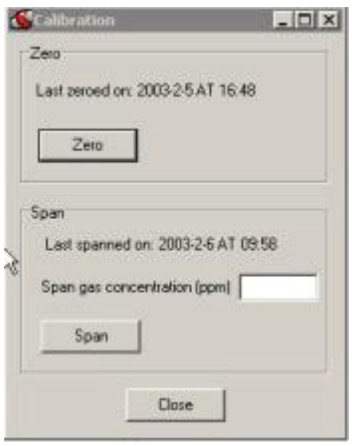
The application shows the current concentration reading as well as the cell temperature and pressure. Note: the heater must be ON.



8) Check the temperature of the cell and wait until it gets to the operating temperature;
9) Press *View-Calibration* to open the calibration window.
10) Fill the "zero" bag with nitrogen (or equivalent). Connect the bag at the inlet port of the fluxmeter as shown in the picture. The CO_2 concentration should drop.



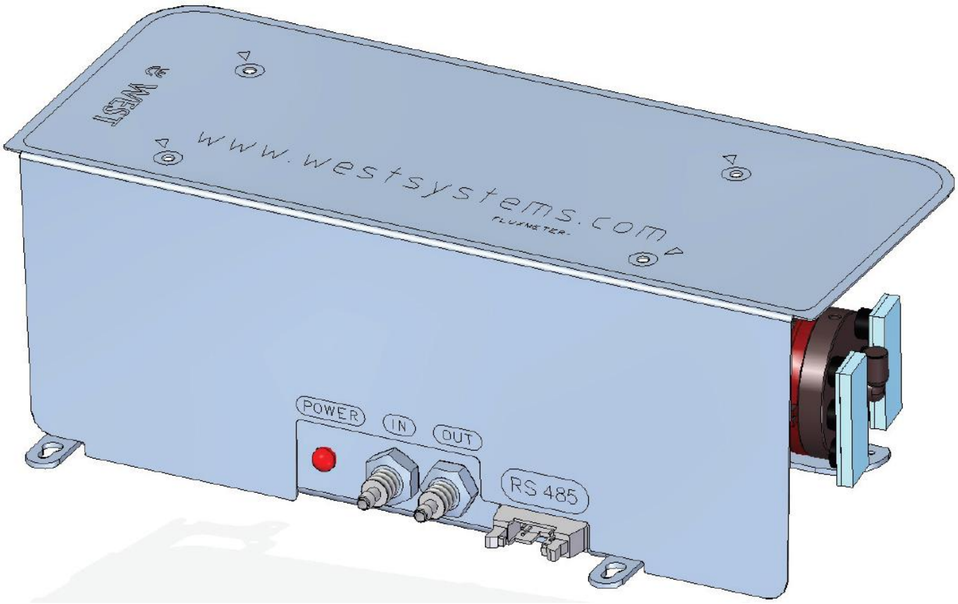
11) Wait for the CO2 concentration to get stable and press the button Zero. Wait for a few seconds until the operation is completed.
Remove the sampling bag from the inlet port.



12) Fill the "span" bag with the calibration mixture. Connect the bag at the inlet port of the fluxmeter. The CO_2 concentration should rise.
13) Fill the *Span gas concentration (ppm)* field with the actual CO_2 concentration of your mixture (e.g. if the CO_2 content is 2%, input 20000).
14) Wait for the CO2 concentration to get stable and press the button Span. Wait for a few seconds until the operation is completed.
15) Remove the sampling bag from the inlet port. The analyzer is now calibrated. Repeat the calibration check.

9. WS-CH4-TLD Methane Detector

The detector is based on a TLD (tunable laser diode) coupled with a multipass cell. The Tunable Diode Laser Absorption Spectroscopy detection method is based on the principle of absorption of the light by a medium which is described by the Beer Lambert law.
The operational wavelength of the laser diode is 1650nm. The signal is then optimized by adding a multipass optical cell, which allows increasing the pathlength in the gas.



The IN and OUT gas fittings can be used with rilsan 6x4 mm tubes or silicon 5x3.2 tubes. Please respect inlet and outlet ports.

Always make sure that a filter (porosity 0.20 µm or less) is applied between the inlet on the fluxmeter and the inlet of WS-CH4-TLD detector. If water, dust, dirt or any other polluting substance comes inside the cell, it will alter the behaviour of the mirrors. In the best case, it will be necessary to send the instrument to West Systems for a cleaning, which is a long and expensive procedure.
Never open the protective case of the WS-CH4-TLD. Some components like the optical fiber could be damaged if touched or moved.

The RS485 cable provides both power supply and communication

RS485 Connector

Pin 1	Gnd
Pin 2	Gnd
Pin 3	+Power supply
Pin 4	+Power supply
Pin 5	Gnd
Pin 6	Gnd
Pin 7	RS485 B
Pin 8	RS485 B
Pin 9	RS485 A
Pin 10	Rs485 A

9.1 Detector specifications

Resolution: 0.1 ppm
Concentration measurement range: from 0.1 ppm to 10% vol*
Accuracy: ±10%
Operating temperature: -10°C...+45°C
Selectivity to methane

Flux Measurement range: from 1 to 900,000 millimoles/m2 per day

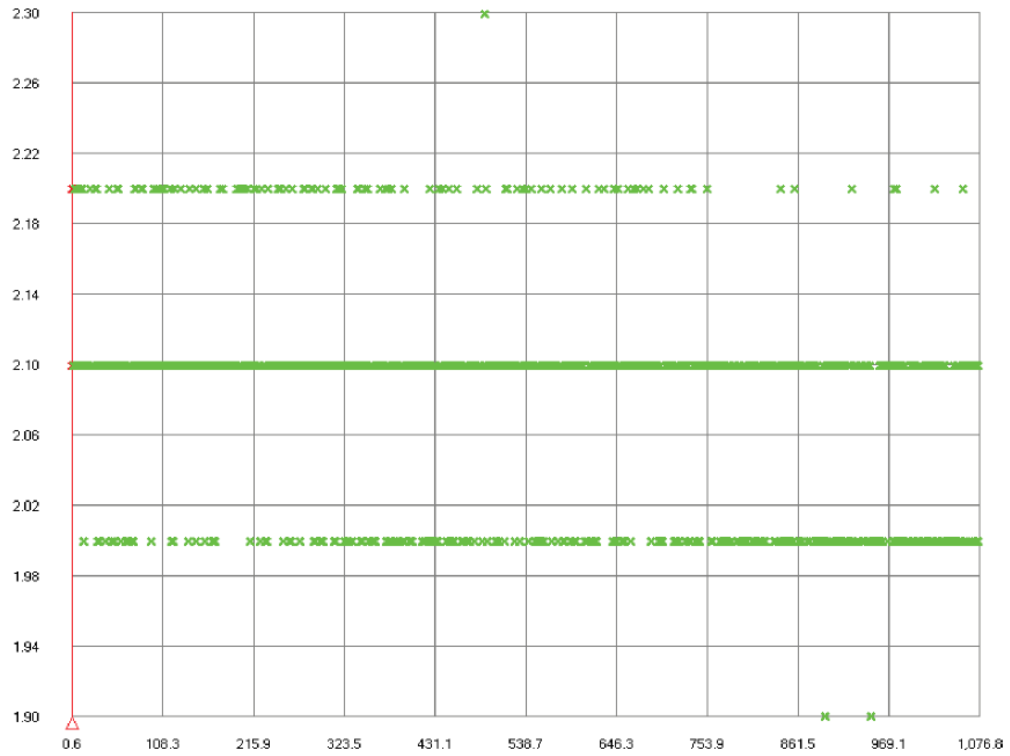
Range	Unit	Precision
0-1000	mmoles/m per day	±25%
1000 – 150,000	mmoles/m per day	±10%
150,000 – 900,000	mmoles/m per day	±20%

*The detector is actually able to measure concentration up to 100% vol, which is not purpose of soil emission measurement.

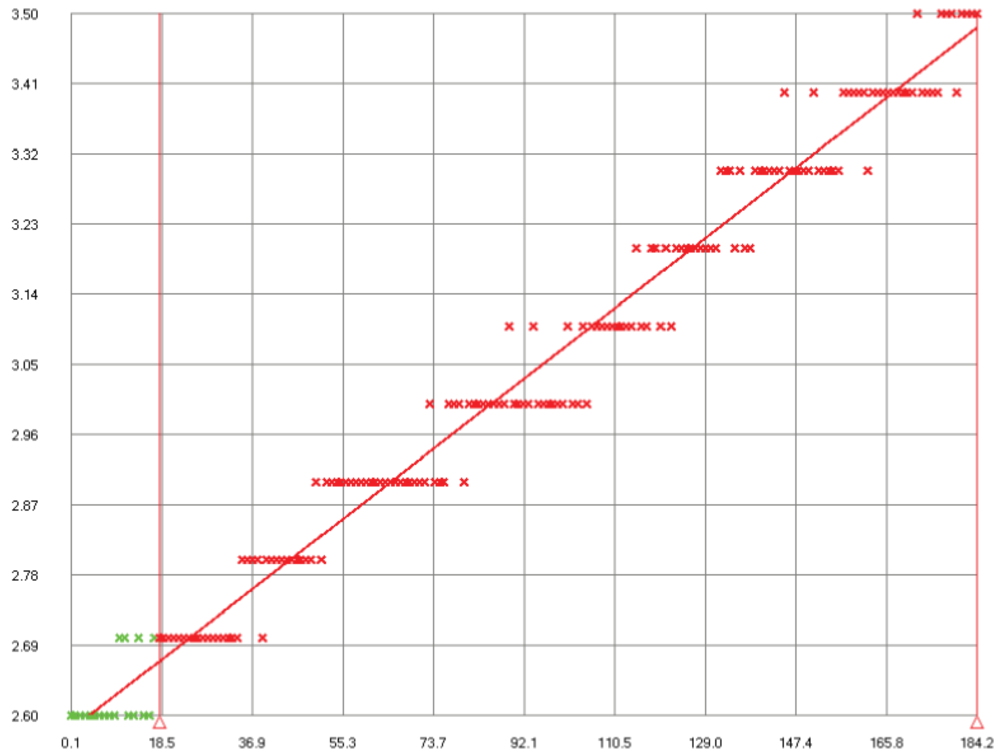
Start-up time
The methane detector is ready to measure in less than a minute. During the warm-up time, the shown methane concentration is 0.

9 WS-CH4-TLD Methane detector

The following plot (ppm vs. seconds) shows a stability test while injecting atmospheric air for about 1,000 seconds.



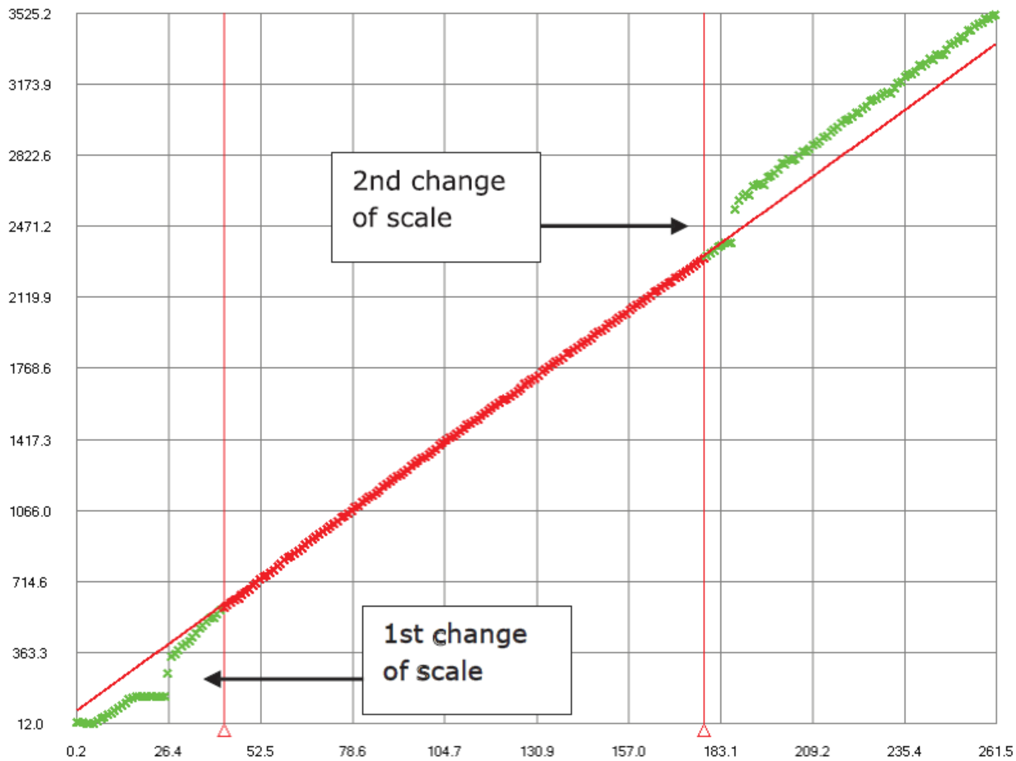
The plot (ppm vs. seconds) shows an accumulation curve while measuring a flux of 1.7 mmoles/m2 per day



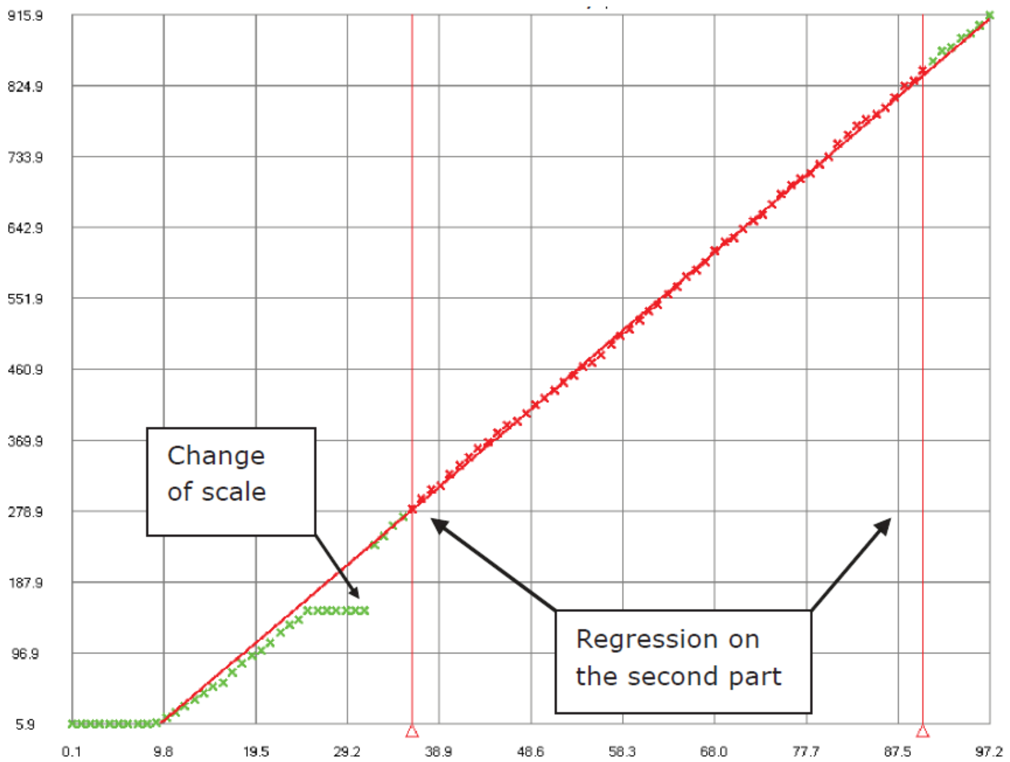
In order to guarantee the measuring of CH4 concentration in a wide range (0-100% vol), the sensor needs to apply different settings on the laser diode.This adaptations produce a gap of a few seconds during which a valid concentration value is not available.

9.2 Computing flux

The sensor presents a first change of scale around 140-150 ppm and a second change around 2300-2400 ppm. During a change of scale, the value remains constant for about 10 seconds.



If you cross that threshold during the accumulation curve, please apply the interpolation on the second part of the curve. Do not include the ten-seconds gap into the linear regression in order to prevent measure errors. Extend the duration of the accumulation curve if necessary.



9.3 Calibration

The subjects regarding calibration of your portable instrument for the measurement of diffuse flux will be discussed in this chapter.
As explained previously in Chapter 4 the flux measurement is proportional to the slope of the concentration curve versus time. The proportionality factor depends on the volume/surface ratio of the accumulation chamber used for the measurement, as well as the barometric pressure and air temperature at the moment of the measurement.
The most important aspect to understand is that the flux is proportional to the gradient of concentration over time: ppm/second. This aspect allows us to simplify the control of the response of the used gas sensors.
Each time a measurement campaign is initiated the instrumental response of the gas sensors must be verified. If the error is not acceptable, the instrument has to be sent to West Systems for calibration.
To simplify the explanation see the following example.

Calibration control example

Before verifying the calibration turn on the instrument and leave it on for a minimum of 5 minutes to stabilise the temperature of the detectors. In order to injext a mixture into the detector, we suggest filling a gas sampling bag (e.g. Tedlar bag) from the cylinder and then let the pump of the fluxmeter flow the gas inside the detectors. In this way, it's possible to recreate a scenario as mush as possible similar to the on field measurement.

Step 1: Verifying the zero

Inject a flow of nitrogen, or synthetic air, into the instrument and read the concentration on the palmtop screen. Obviously, it is important that the injected mixture doesn't contain methane.
The method for injecting standard gas mixtures is explained in detail in the following pages.

Step 2: Verification of the span:
Inject a standard mixture containing methane in a concentration possibly close to the values you reach when measurering maximum fluxes (example 10,000 ppm). Let's suppose that the performed test gave the following results:
Injecting a mixture at zero concentration of CH the detector returns a reading of 0 ppm.
Injecting a mixture containing a 10,000 ppm concentration of CH detector returns a reading of 9930 ppm.
At a variation of concentration set at 10,000 ppm the instrument has a slightly different response: 9930 ppm. The evaluation error is of about 70 ppm, which in percentage points over the span corresponds to -0.6%

The error in evaluating the increment in concentration manifests as a systematic error in the evaluation of flux and, therefore, must be corrected by calibrating the instruments when it is too high (> 5%).

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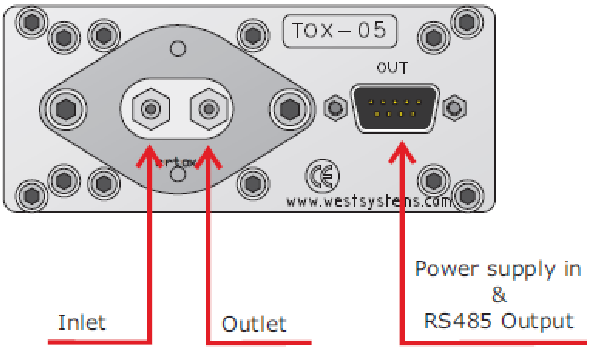
10. WS-TOX-H2S Hydrogen sulfide detector



Pin	Signal
1	Gnd
2	+VDC
3	Gnd
4	RS485-B
5	RS485-A
6	Gnd
7	+12V
8	Gnd
9	RS485-B

Legend
Gnd: Ground reference for power supply and RS485
+VDC: 10-28 Volts Power supply input
RS485-A: Digital signal output A
RS485-B: Digital signal output B

Sensor specifications
Ambient conditions:
Air temperature -30°C to 50 °C
Air pressure 800 hPa to 1200 hPa
Air RH 15% ... 90% non condensing
Expected sensor life > 24 months
Chemical cell order code: WEST H2S-BH
Detector order code: WEST TOX-05-H2S-BH
Factory calibration : 25 ppm
RMS Noise < 0.02 ppm
Zero Offset < ±0.05 ppm
Max Overrange 200 ppm

The chemical cell reaction is:

$$H_2S + 2O_2 = H_2SO_4$$

The gas sample specific consumption is very low:

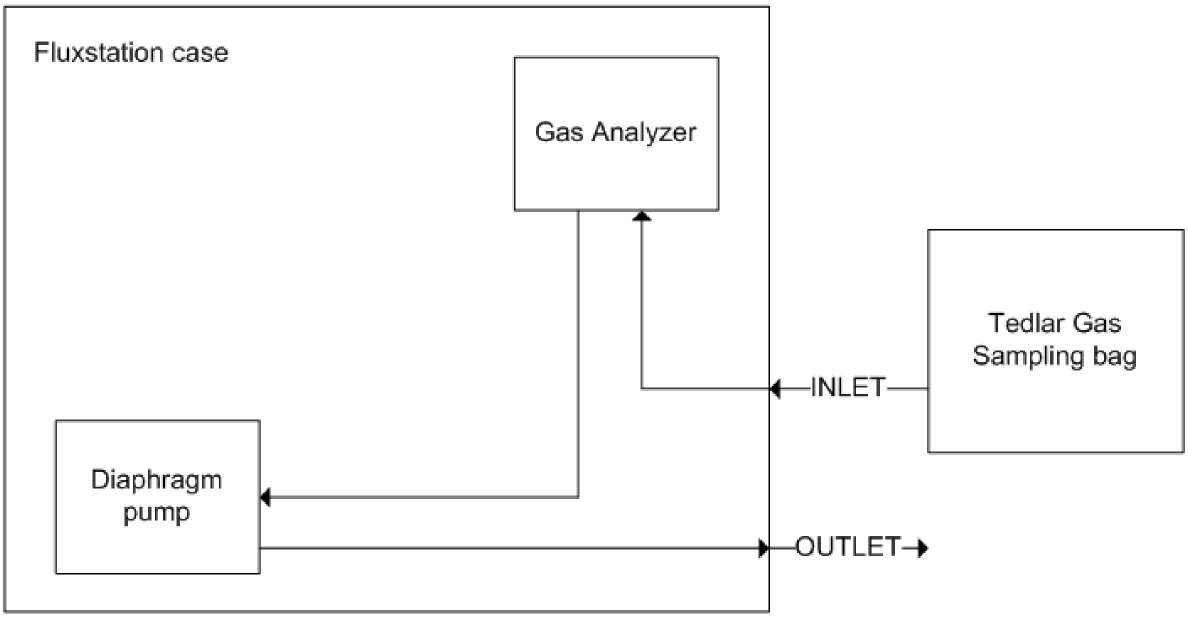
2.5×10^{-10} moles/sec per ppm

Due to this consuption the H_2S flux is methodically understimated by a -10% with the accumulation chamber A and by a -5% when using the accumulation chamber B. For this reason we recommend using the accumulation chamber B except when the flux is very low.

Cross sensitivity
Unfortunately, the hydrogen sulfide detector is affected by cross sensitivity with several gas species. In the table below these cross sensitivity are reported:

		Test @ ppm	Reading ppm
SO_2	Sulfur Dioxide	20	< 2
NO	Nytrogen monoxide	50	< 1.5
NO_2	Nytrogen dioxide	10	< -3
Cl_2	Chlorine	10	< -2.5
H_2	Hydrogen	400	< 1
C_2H_4	Ethylene	400	< 0.4
CO	Carbon monoxide	400	< 4
NH_3	Ammonia	20	< 0.02

Example: if the detector is exposed to a 20 ppm concentration of sulfur dioxide the reading can reach a maximum of 10 ppm.
The reading is negative when exposed to chlorine or nytrogen dioxide.



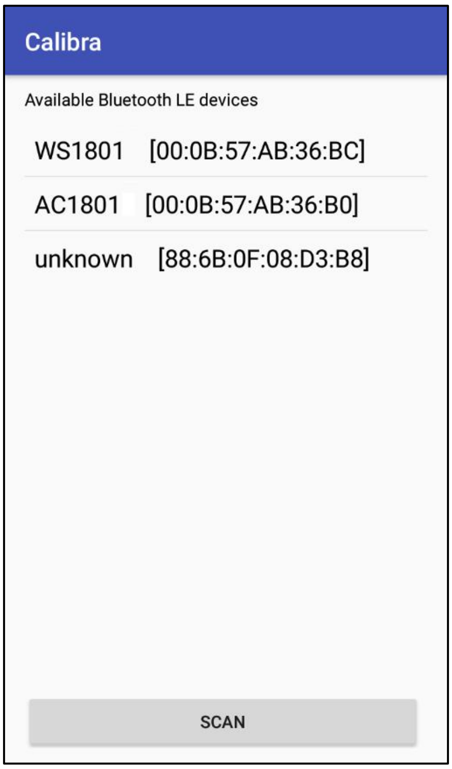
10.1 Calibration

Check the calibration using the same procedure explained in chapter 8.1.
We recommend the use of Tedlar sampling bags for injecting the calibration mixures.
For the check of the zero, a bottle of Nitrogen or synthetic air can be used.
For the check of the span, you can use a mixture containing between 10 and 25 ppm.
If the calibration check fails (error > 5%), it is recommended to calibrate the detector. Follow the procedure below.

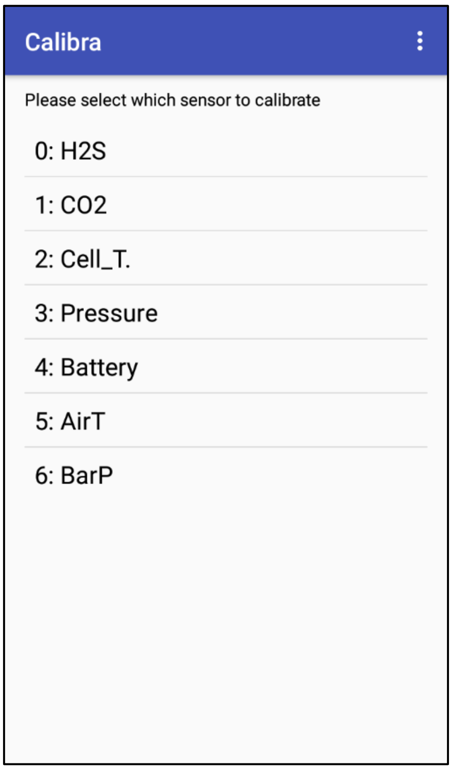
1) Switch on the fluxmeter and start a measurement with FluxManager, in order to get the pump flowing.

2) Let the instrument warm-up, with pump on, for 30 minutes.

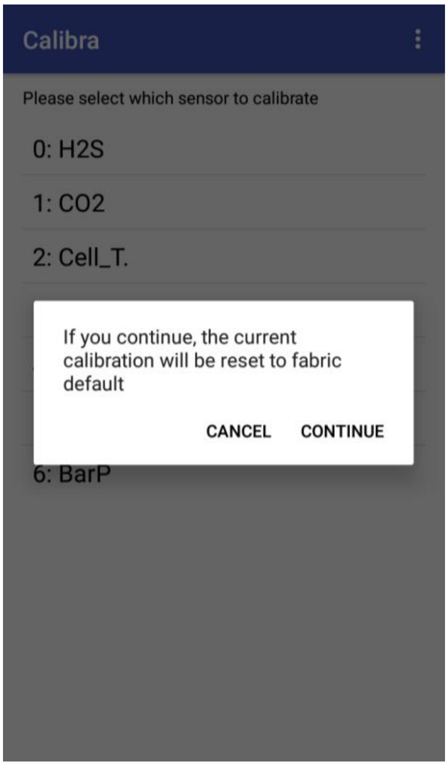
3) Start the Calibra application. If the app is not installed on the device, install it following the same procedure indicated in chapter 3.1 The Calibra app is freely available on Google Play Store.



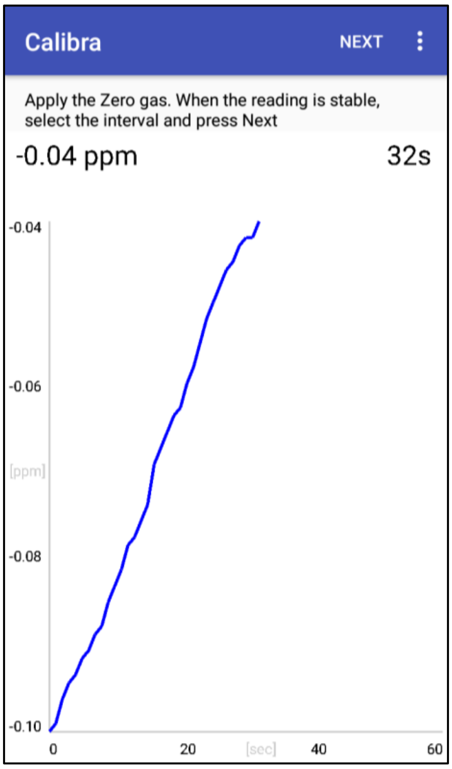
4) The app shows the Bluetooth devices in range. Tap on the serial number of the fluxmeter (WS1801 in the example) in order to start the connection.
The Bluetooth LED should turn from flashing to steady blue.



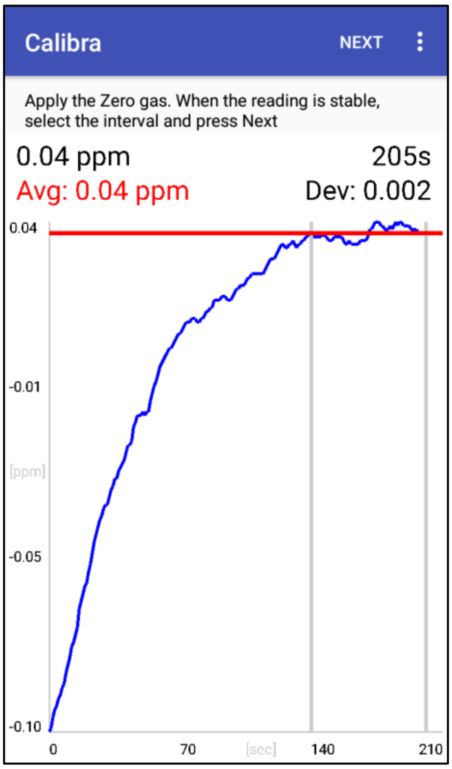
5) Once connected, the app shows all the available sensors.
Tap on the H_2S detector to start the calibration.



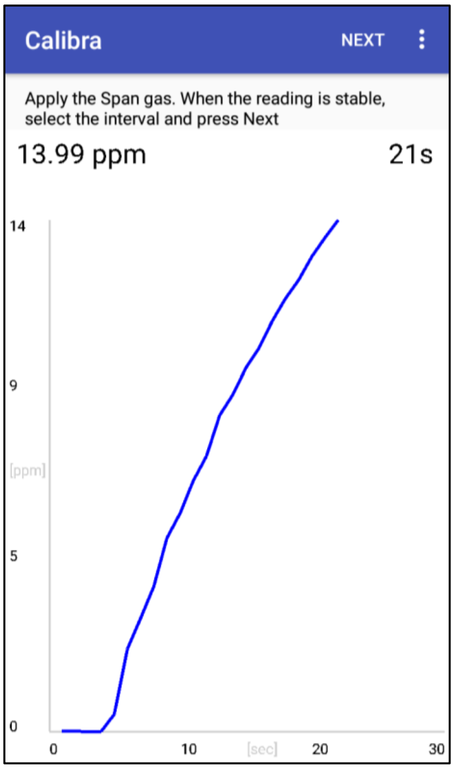
6) Warning: as soon so the calibration starts, the calibration parameters stored in the H_2S detector will be reset to fabric default.
By clicking continue, the previous calibration data will be overwritten.
Continue only if you have everything that is needed for completing the calibration (the zero and span mixtures).



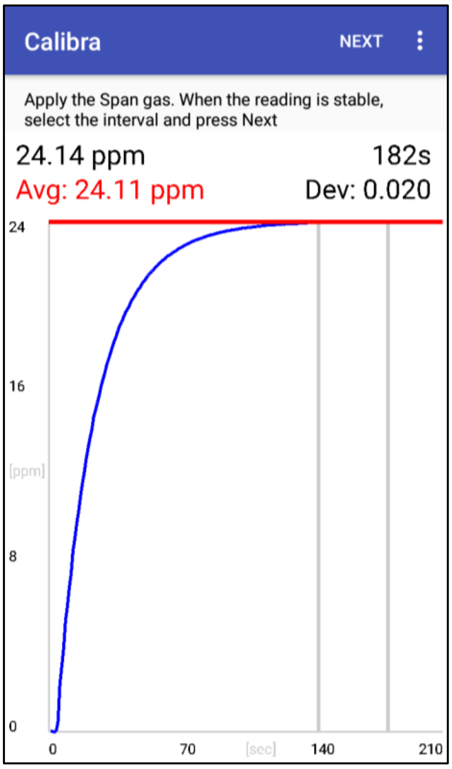
8) Connect the zero gas Tedlar bag to the fluxmeter inlet.
Wait for the reading to get stable.



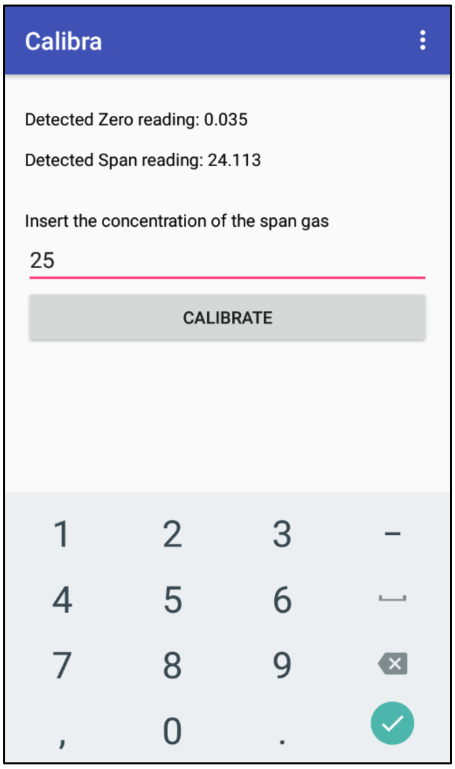
9) When the signal is finally stable, select the interval by tapping on the screen.
The average and standard deviation of the selected period is shown on the display.
A lower standard deviation indicates a good signal stability.
Only the average value will be taken into consideration for the calibration.
The data that remains outside of the left and right cursors will be juts ignored.
Press the *NEXT* button to confirm the interval and go on.



10) Connect the span gas Tedlar bag to the fluxmeter inlet.
The gas concentration should start increasing.
Wait for the reading to get stable.
In the example, the H_2S concentration of the span gas mixtures is 25 ppm.



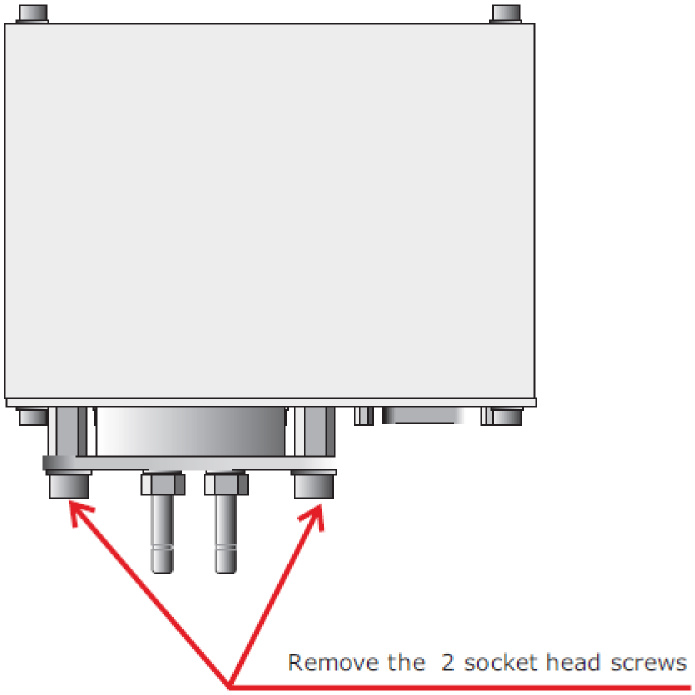
11) When the signal is finally stable, select the interval by tapping on the screen.
The average and standard deviation of the selected period is shown on the display. A lower standard deviation indicates a good signal stability.
Only the average value will be taken into consideration for the calibration.
The data that remains outside of the left and right cursors will be juts ignored.
Press the *NEXT* button to confirm the interval and go on.

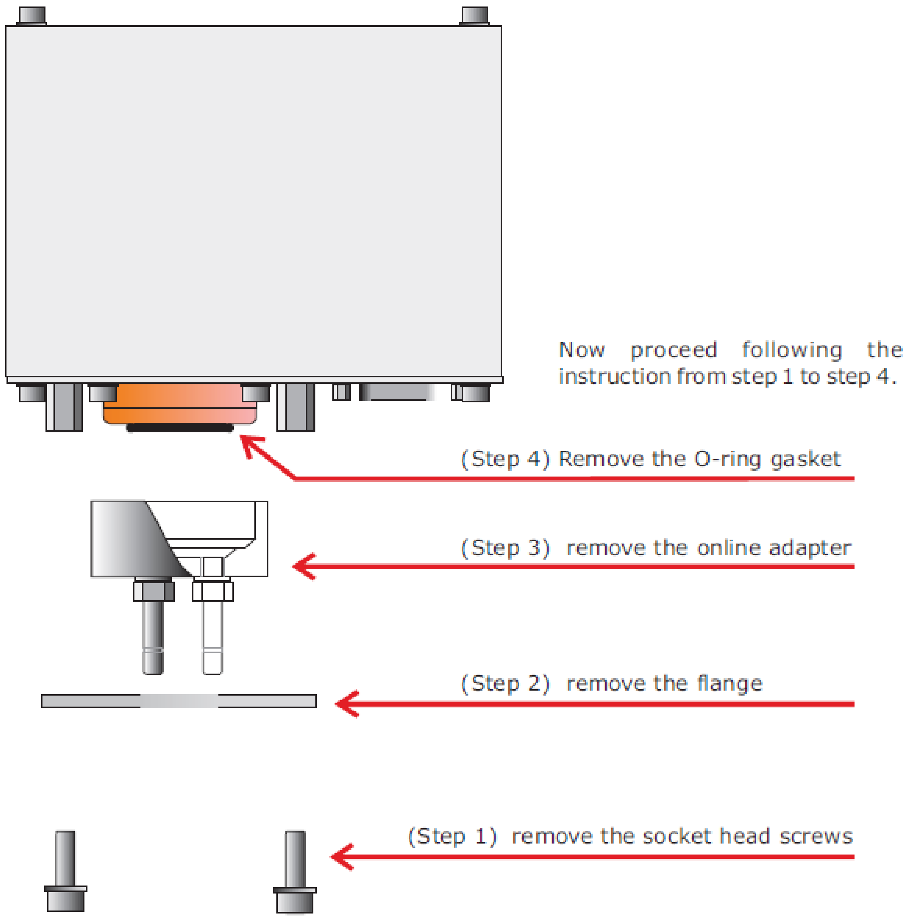


12) In the final screen, the app shows the average values that were selected for the zero and span gas mixtures.

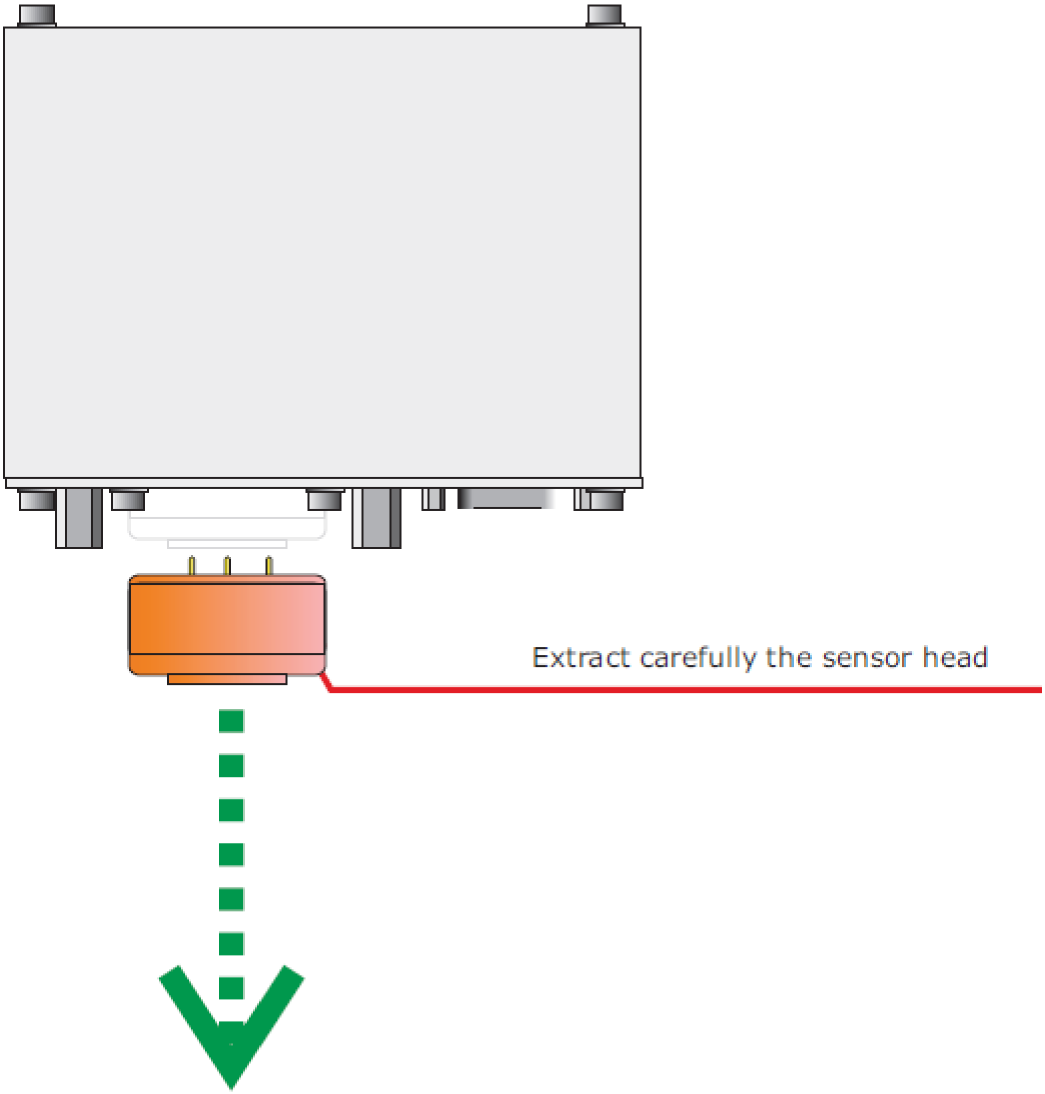
Input the H_2S concentration in ppm of the span calibration mixures (25 in the example).
Press the *CALIBRATE* button to apply the calibration to the sensor.
The calibration values are stored in the H_2S detector non-volatile memory.

10.2 Replacing the sensor head





10 WS-TOX-H2S Hydrogen sulfide detector



Now install the new sensor head (WS-H2S-BH Head) and re-assemble the detector. Please check the O-Ring status and check the sealing of the sensor head/on line adapter.

After changing the head, a recalibration of the detector is necessary.

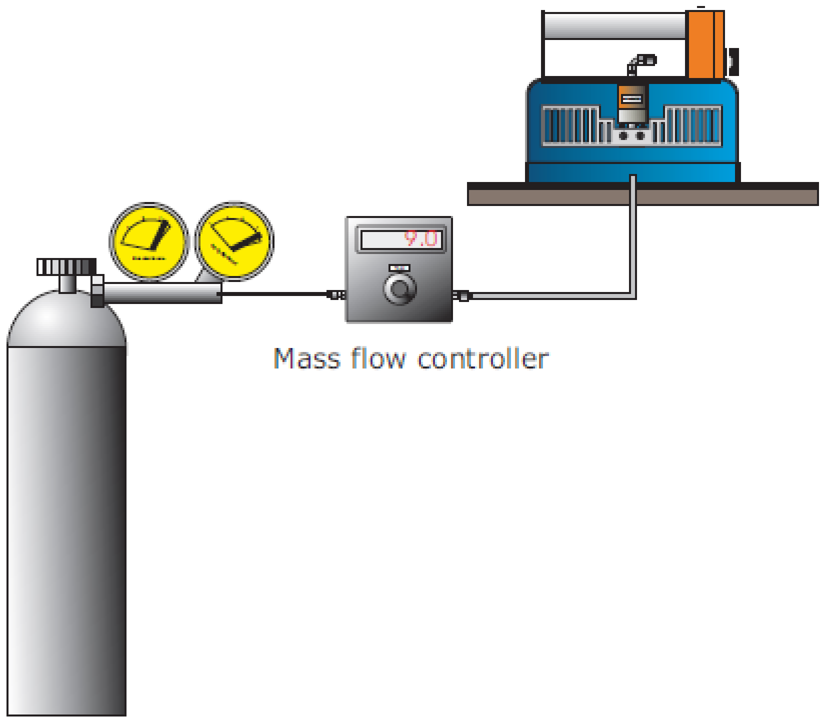
10.3 Flux measurement

H_2S fluxes from soil are simulated by injecting a known flow of gas into the accumulation chamber. The interface between the accumulation chamber and the calibration table is built to minimize the gas leakage.
For flux between 0.0002 and 0.02 moles/m^2/day the injected flux is controlled and measured with a precision mass flow controller. This MFC is electronically stabilized (Accuracy 3%).

For fluxes between 0.06 moles/m^2/day and 0.6 moles/m^2/day the injected flux is controlled by means of a mechanical flow reducer and measured using a bubble flowmeter (Accuracy 3%) before and after the flux measurement with the accumulation chamber.

A thermometer and barometer were utilized to measure the barometric pressure and the air temperature during the experiment in order to select the correct accumulation chamber conversion factor.

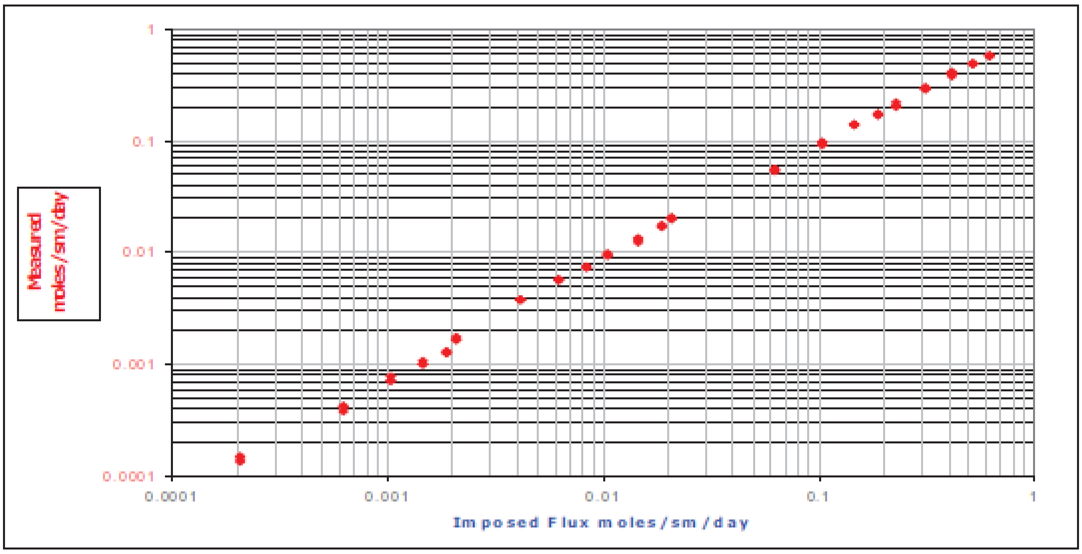
The same procudure was utilized to check the instrumental response to Carbon Dioxide.



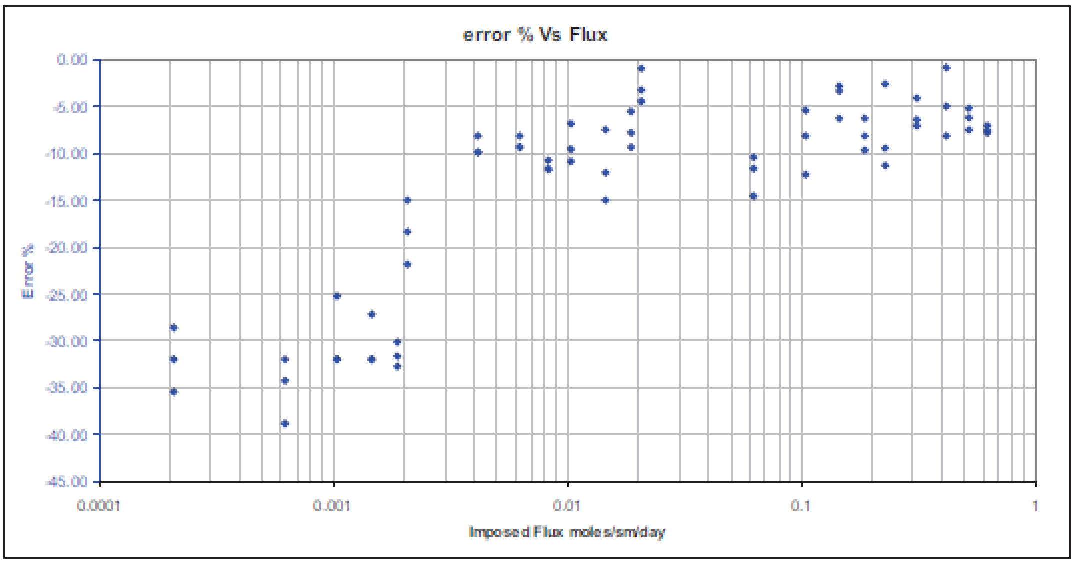
Standard mixture of hydrogen sulfide/carbon dioxide/nitrogen cylinder and pressure reducing valve.

10 WS-TOX-H2S Hydrogen sulfide detector

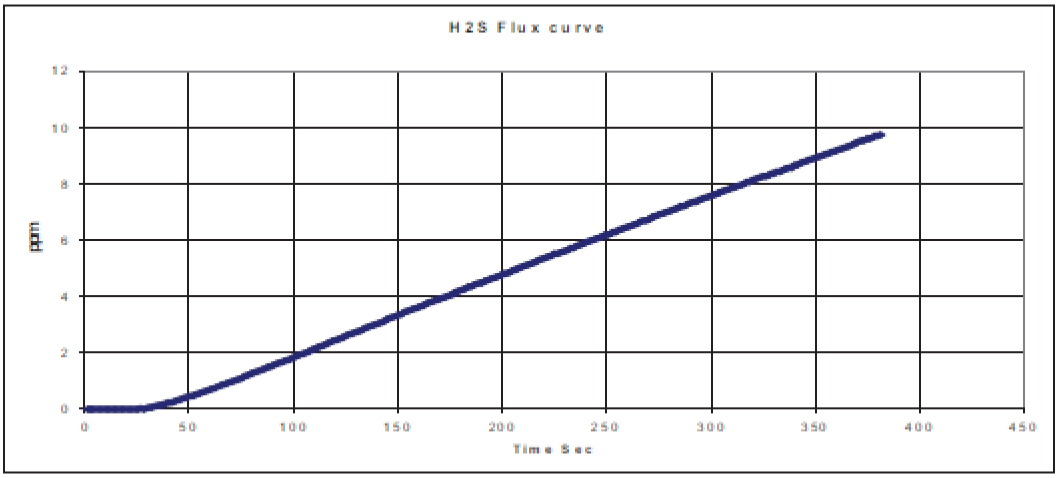
The simulated flux experiment was done using the accumulation chamber B that's more accurate for the hydrogen sulfide measurement.
Room temperature: Between 20.2 and 21.4 °C
Air relative humidity 52-54%
Barometric pressure between 1013.1 and 1013.8 HPa
Accumulation Chamber B constant at 1013 and 20°C: 0.707 (moles/m^2/day)/(ppm/sec)



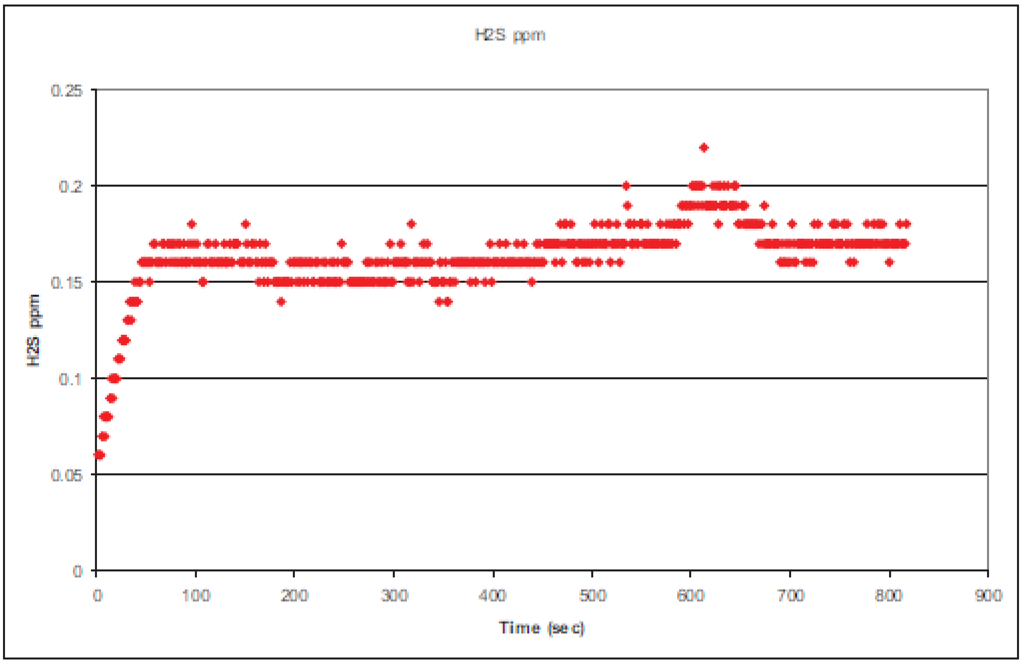
In the plot below the error evaluating flux vs flux are shown



In the plot below a typical hydrogen sulfide flux curve: the slope is 0.028 ppm/sec and the flux is 0.019 moles/sm/day

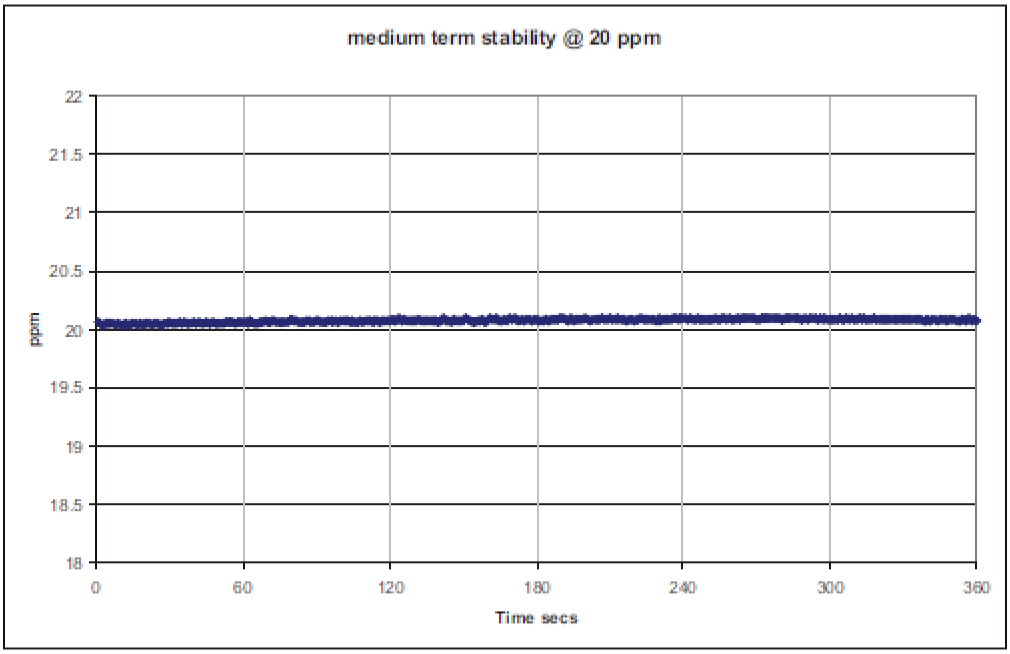


In the plot below the "base line" of the hydrogen sulfide detector output is reported. The initial drift is due to the sensor temperature adjustement when the pump is switched on. The injected gas mixture was the laboratory air.

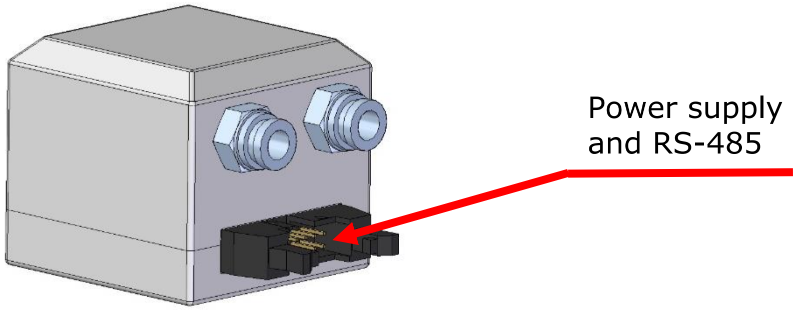


10 WS-TOX-H2S Hydrogen sulfide detector

In the plot below the stability of the hydrogen sulfide detector output is reported. The injected gas mixture at 1 liter per minute was 20 ppm of H2S in nitrogen.



11. WS-VOC Volatile Organic Compounds detector



The connector provides both power supply and the communication lines to the sensor. The cable pinout is shown in the following table:

Pin	Signal
1	Gnd
2	Gnd
3	+VDC
4	+VDC
5	Gnd
6	Gnd
7	RS485-A
8	RS485-A
9	RS485-B
10	RS485-B

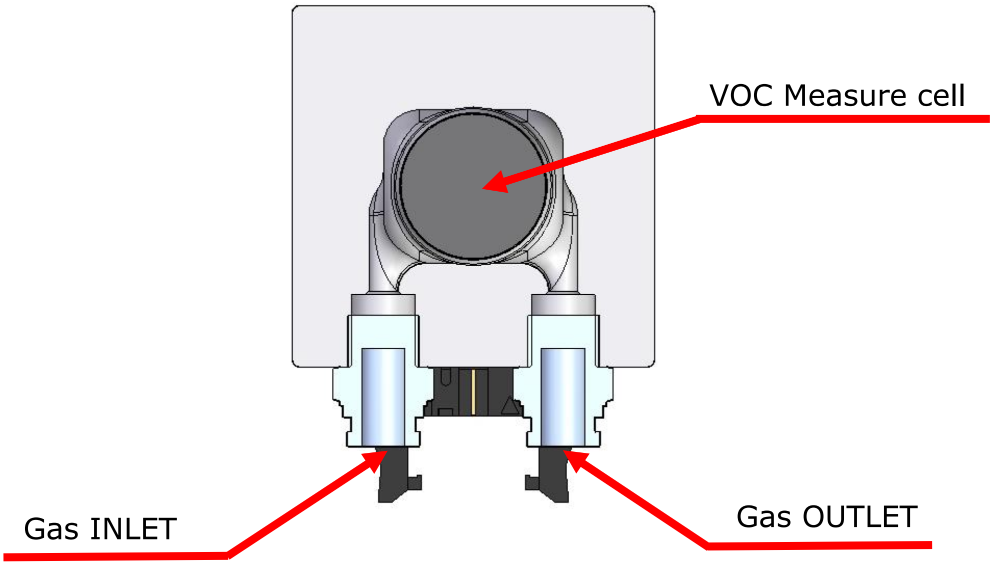
Legend

Gnd: Ground reference for power supply and RS485

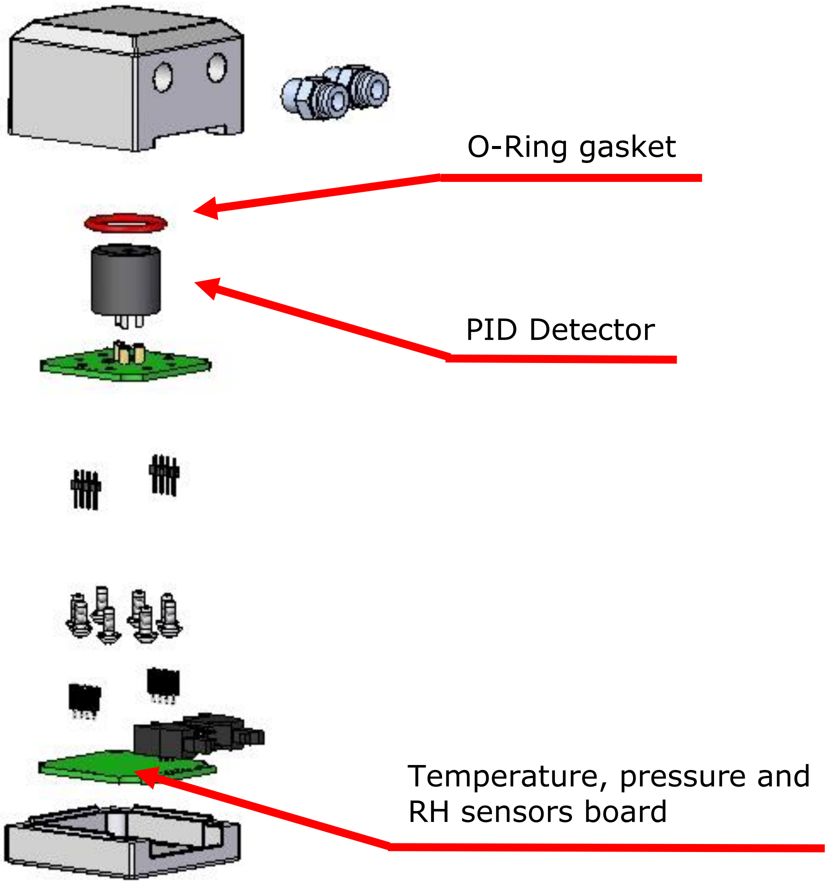
+VDC: 10-28 Volts Power supply input

RS485-A: RS-485 negative data line

RS485-B: RS-485 positive data line



11 WS-VOC Volatile Organic Compounds detector



11.1 Specifications

VOC Measurement range: 0…50 ppm Isobutylene
Detection limit: 1 ppb Isobutylene
Operating temperature range: from -40 to +55 °C

Temperature, relative humidity and pressure sensors are installed inside the measurement cell. The sensitive element is installed in contact with the gas sample.

Temperature
Measurement range: from -40 to 125°C
Accuracy: ±0.2%

Relative humidity:
Measurement range: from 0 to 100%
Accuracy: ±1.5%

Pressure:
Measurement range: from 50 to 110 kPa
Accuracy: ±0.4 kPa

11.2 Measuring principle

Volatile organic compounds (VOC) are a large family of carbon-containing compounds which are emitted into the atmosphere from a variety of industrial processes. They are commonly found as a vapor at room temperature.
The WS-VOC sensor allows the measurement of such compounds by using a PID (Photo-Ionization Detector), equipped with a Krypton lamp at **10.6 eV**.
Generally speaking, a PID uses an ultraviolet light source (9.6 eV, 10.6 eV or 11.7 eV) to break down chemicals to positive and negative ions (Ionization) that can very sensitively be measured with a detector, which measures the charge of the ionized ions and converts the signal into electric current.
A PID is a **broadband VOC detector**; it is sensitive to a wide variety of compounds. The majority of VOCs can be detected by a PID, with the exception of some low molecular weight hydrocarbons. On the other side, some inorganic compounds or semi-volatile organic compounds can be also detected by a PID. In general, a PID will detect **any compound with an ionization energy which is lower than the one of the lamp photons**.

11.3 Warm-up

The WS-VOC sensor requires a warm-up of about 30 minutes. Please follow the warm-up procedure each time the instrument is started:

1) Switch on the fluxmeter. Wait for the initialization to complete.
2) Start the FluxManager app, connect and press the Start button. In this way, the pump is turned on and start flowing atmospheric air inside the sensors.
3) Wait 30 minutes. For this reason we recommend to start the warm-up as first action after reaching the field, or before that, during the transport.

When the 30 minutes have passed, the signal is stable enough and it's possible to proceed with the chamber measurements.

The optimal range for the pumping flow is from 0.5 LPM to 3 LPM.
The WS-VOC sensor is sensitive to fast pressure variations. In order to prevent signal drifts, the pump needs to remain ON for the entire session.
For this reason, the turning off of the pump is inhibited by the FluxManager software. Once the first measure is initiated (warm-up), the pump will not turn off until the instrument is manually shut down using the physical fluxmeter On/Off button.
Note: such inhibition of the pump shutdown is only applied if the WS-VOC is present in the fluxmeter configuration. If that is not the case, the pump is automatically turned off at the end of the cleaning time that follows each flux measurement.

11.4 VOC fluxes measurement

In order to achieve valid measurements of VOC emission from soil, please operate according to the following recommendations:

1) Execute the recommended warm-up procedure
2) Remove, if possible, the traces of grass in the area where the chamber will be put. The presence of grass could alter the results of the measure,

since it makes up for a contribution which has a different origin than the one which is usually inspected.

3) In presence of a real VOC soil emission, the VOC concentration increases in a linear or exponential shape during the whole measurement, following the theory of the accumulation chamber method (see chapter 4.1).
   A linear increase of concentration at the beginning of the measurement, followed by an inflection and a decrease of the concentration, is caused by an instrumental artifact usually produced by a variation of one or more environmental parameters. This case does NOT indicate a VOC detectable emission, so it is not correct to apply the linear regression on first part of the measure.
4) **The VOC flux measurement duration has to be within 480 and 600 seconds**.
   In the case described at point (3), if the operator had stopped the measurement after 2-3 minutes (when the VOC concentration was following a linear increment), he would have made a mistake applying the linear regression and calculating a flux (false positive). Extending the duration of the measure up 8-10 minutes helps preventing this kind of errors.
5) When measuring VOC emissions, the carbon dioxide accumulation curve is very important, since it allows to verify the correct functioning of the chamber and to assess the correct accumulation. In almost any type of soil it is possible to detect a CO_2 flux.
   If the CO_2 curve does not show a linear or exponential increment, check the chamber positioning on the soil and the functioning of the pneumatic circuit. If the CO_2 curve shows an increment, in presence of a VOC emission the VOC curve should show a similar shape (linear in the first phase, and tending to *CSoil*, see chapter 4.1).

11.5 Calibration check

The frequency of the maintenance operations depends mainly on the environmental working conditions. In many cases it could be enough to calibrate the detector every 6 or 12 months. However, if high VOC concentrations are detected, we advise to check the calibration more frequently, ideally before each campaign.

To check the calibration or to re-calibrate the sensor, the following equipment is needed:

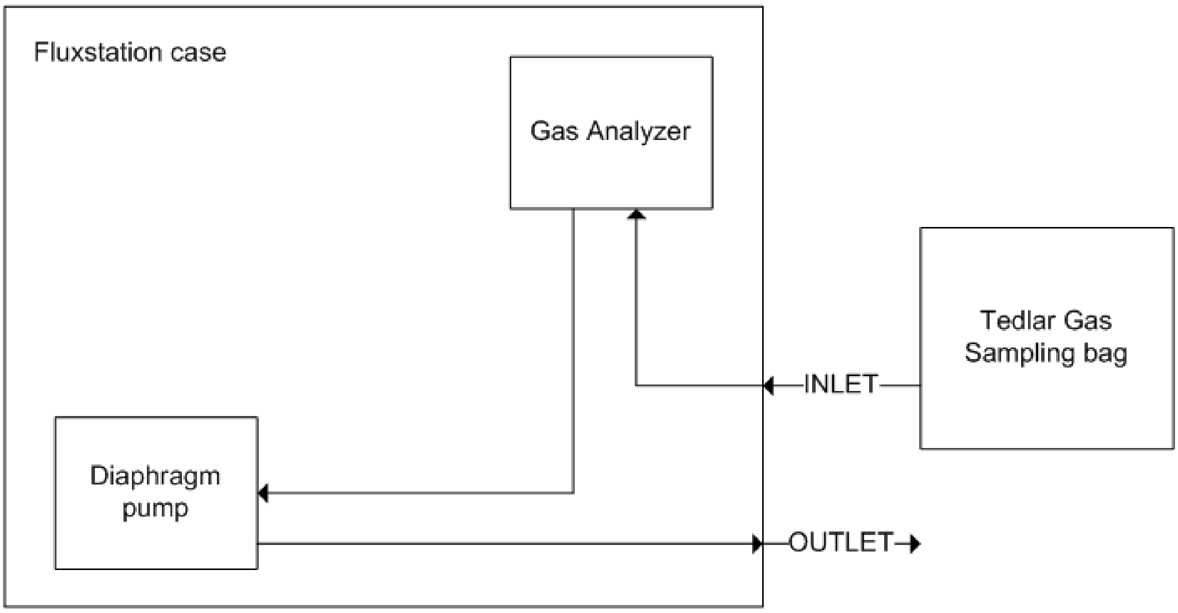
- Two Tedlar gas sampling bag
- A cylinder of nitrogen or synthetic air (for the calibration of the zero).
- A cylinder of isobutylene, balanced with air or nitrogen. The suggested isobutylene concentration range is from 5 to 50 ppm. The optimal is 10 ppm, but it depends on the concentrations that are expected in the monitored environment.

As explained previously in Chapter 4, the flux measurement is proportional to the slope of the concentration curve versus time. The proportionality factor depends on the volume/surface ratio of the accumulation chamber used for the measurement, as well as, the barometric pressure and air temperature at the moment of making the measurement.

The most important aspect to understand is that the flux is proportional to the gradient of concentration over time: ppm/second. This aspect allows us to simplify the control of the response of the gas analyzers.
Each time a measurement campaign is initiated the instrumental response of the gas sensors must be verified and, if necessary, their calibration fine-tuned.

To simplify the explanation, see the following example:

Step 1: Verifying the zero
Fill the first Tedlar bag with nitrogen, or synthetic air. Connect the Tedlar bag to the instrument inlet, as shown in the following diagram.



Start a measurement with the FluxManager app. This operation also starts the pump. Read the VOC concentration on the screen, as explained on chapter 3. Obviously, it is important that the injected mixture does not contain traces of VOC.

Step 2: Verification of the span
Fill the second Tedlar bag with a standard mixture containing approximately 10 ppm of isobutylene, connect the bag to the fluxmeter inlet and check the response of the instrument.
Example:
Injecting the zero mixture, the detector returns a reading of 0.2 ppm.
Injecting a mixture containing 10 ppm concentration of isobutylene, the detector returns a reading of 9.9 ppm.
Given a 10 ppm concentration variation, the instrument has a slightly different response: 9.7 ppm (= 9.9 – 0.2 ppm). The evaluation error is of about 0.3 ppm, which in percentage points over the span corresponds to -3%.

The error in evaluating the increment in concentration manifests as a systematic error in the evaluation of flux and, therefore, must be corrected by calibrating the instruments when it is too high (> ±5%).

During the calibration check, the user must verify the absence of the following issues:

- The detector has significantly lost sensitivity.
- The sensor baseline presents drifts, even after the warm-up.
- The sensor reading is not stable.

If one of the following cases occurs, the sensor needs to be sent back to the factory for maintenance. Such operation can include:

- Cleaning of the lamp
- Replacement of the lamp
- Replacement of the electrode stack
- Recalibration of the detector.

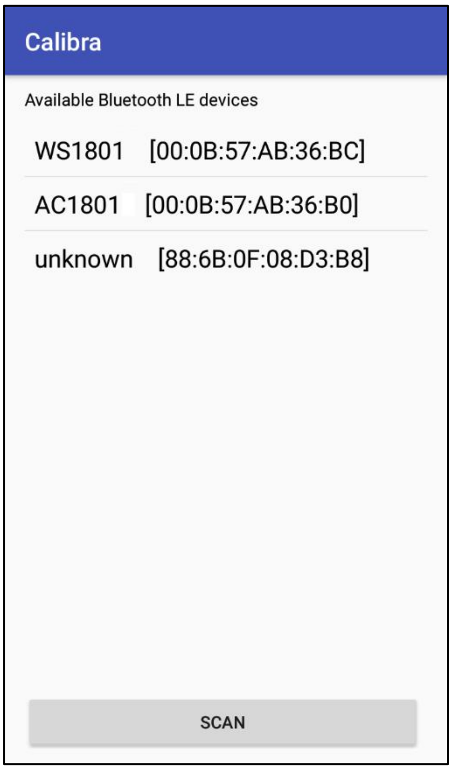
11.6 Calibration

If the calibration check has returned a negative outcome (error > ±5%), it is recommended to recalibrate the sensor.
Apply the following procedure.

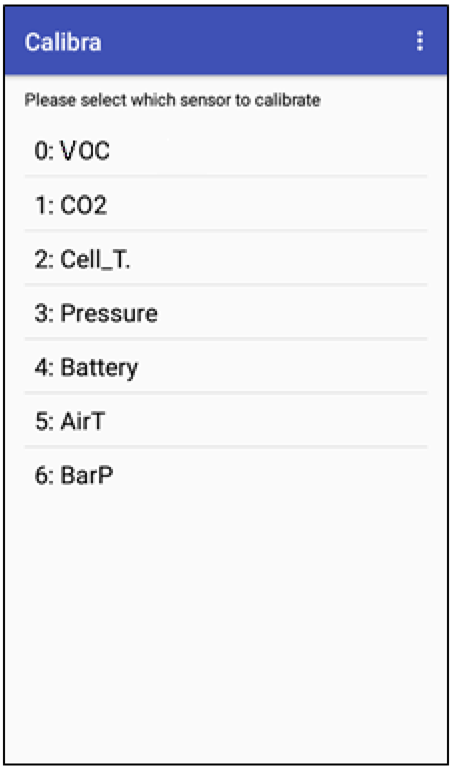
1) Switch on the fluxmeter and start a measurement with FluxManager, in order to get the pump flowing.

2) Let the instrument warm-up, with pump on, for at least 30 minutes.

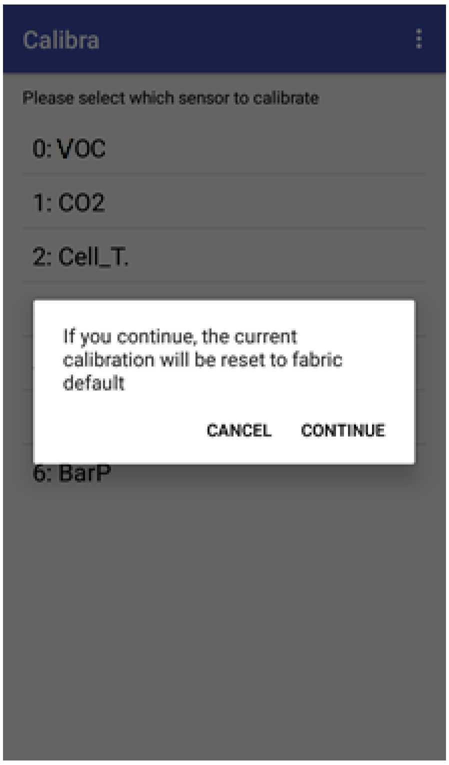
3) Start the Calibra application. If the app is not installed on the device, install it following the same procedure indicated in chapter 3.1. The Calibra app is freely available on Google Play Store.



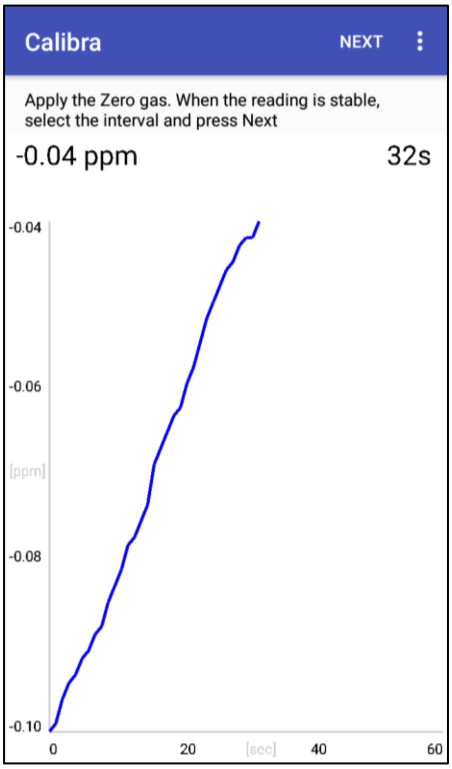
4) The app shows the Bluetooth devices in range. Tap on the serial number of the fluxmeter (WS1801 in the example) in order to start the connection.
The Bluetooth LED should turn from flashing to steady blue.



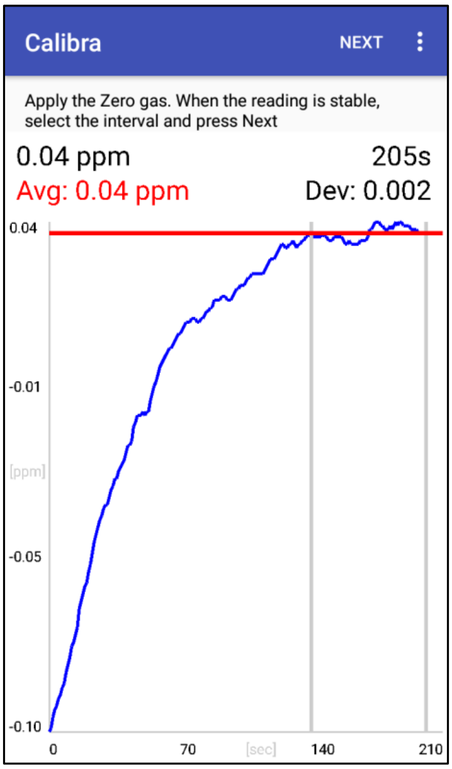
5) Once connected, the app shows all the available sensors.
Tap on the VOC detector to start the calibration.



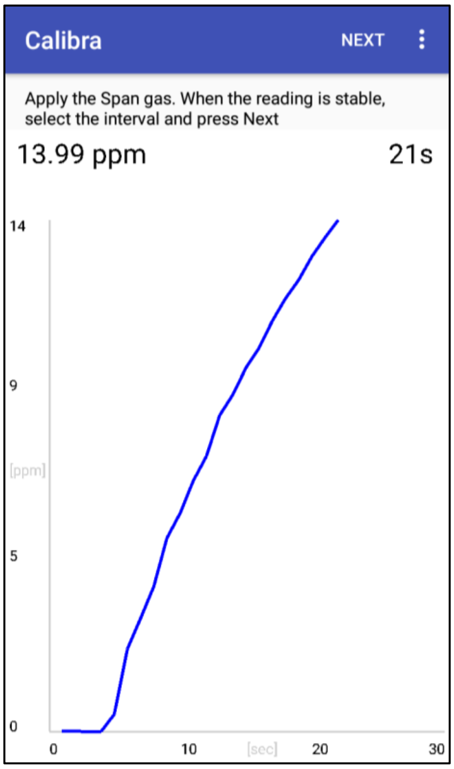
6) Warning: as soon so the calibration starts, the calibration parameters stored in the VOC detector will be reset to fabric default.
By clicking continue, the previous calibration data will be overwritten.
Continue only if you have everything that is needed for completing the calibration (the zero and span mixtures).



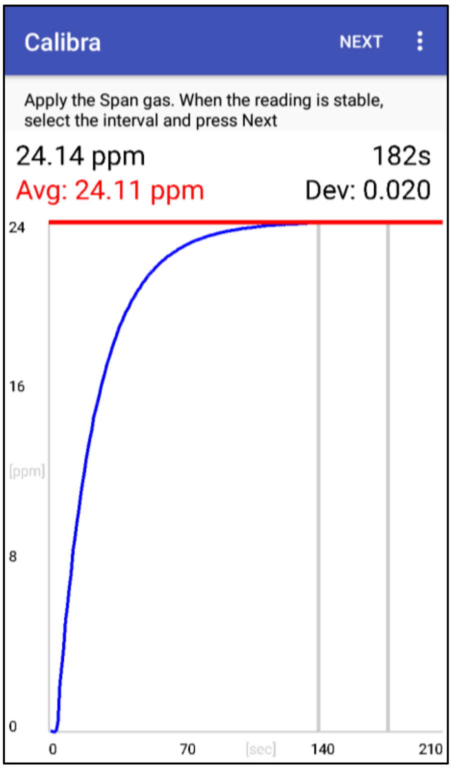
8) Connect the zero gas Tedlar bag to the fluxmeter inlet.
Wait for the reading to get stable.



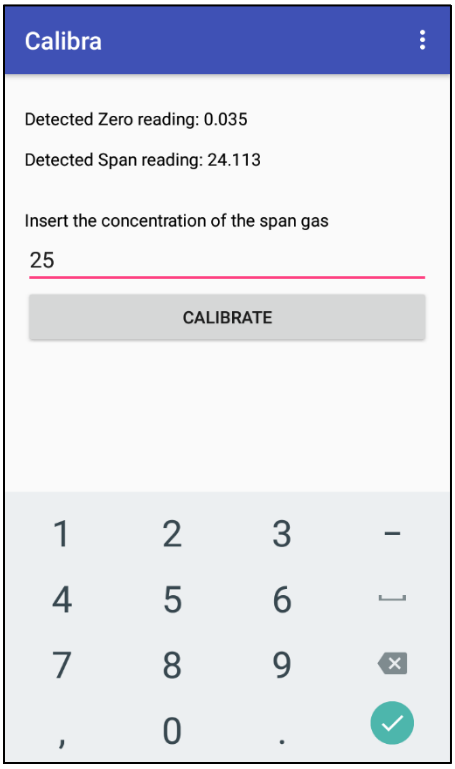
9) When the signal is finally stable, select the interval by tapping on the screen.
The average and standard deviation of the selected period is shown on the display.
A lower standard deviation indicates a good signal stability.
Only the average value will be taken into consideration for the calibration.
The data that remains outside of the left and right cursors will be juts ignored.
Press the *NEXT* button to confirm the interval and go on.



10) Connect the span gas Tedlar bag to the fluxmeter inlet.
The gas concentration should start increasing.
Wait for the reading to get stable.
In the example, the isobutylene concentration of the span gas mixtures is 25 ppm.



11) When the signal is finally stable, select the interval by tapping on the screen.
The average and standard deviation of the selected period is shown on the display. A lower standard deviation indicates a good signal stability.
Only the average value will be taken into consideration for the calibration.
The data that remains outside of the left and right cursors will be juts ignored.
Press the *NEXT* button to confirm the interval and go on.



12) In the final screen, the app shows the average values that were selected for the zero and span gas mixtures.

Input the concentration in ppm of the span calibration mixtures (25 in the example).
Press the *CALIBRATE* button to apply the calibration to the sensor.
The calibration values are stored in the VOC detector non-volatile memory.

11.7 VOC correction factors

The sensitivity of the PID varies according to the type of lamp and the VOC species which are present in the sample.
The table included at the end of the paragraph shows the ionizing energy (IE) and the response factor (RF), for the most common volatile organic compounds. The values are relative to the 10.6 eV lamp, which is mounted inside the WS-VOC sensor.
The WS-VOC sensor is calibrated using isobutylene, but the PID is a broadband VOC detector, with a sensitivity that differs for each VOC. If you know what VOC you are measuring, the table below allows to calculate the concentration for your specific VOC.
The response factor (RF) expresses the ratio between the PID response to the particular compound and the PID response to the calibration gas (isobutylene). If the RF is < 1, the PID response to a certain concentration of that particular compound is higher than the response to the same concentration of isobutylene. On the contrary, if the RF is > 1, the PID response to that compound is lower than the response to isobutylene.
Example:
Benzene RF is 0.5, meaning that the PID response to benzene is double than the one to isobutylene. If the sensor is exposed to 10 ppm of benzene, the reading will be 20 ppm of isobutylene-equivalent. To correct such response, the 20 ppm reading must be multiplied by the 0.5 response factor.
20 ppm (PID reading) x 0.5 (RF) = 10 ppm (actual concentration)

The correction factor for a gas mix containing PID detectable gases A, B, C… with response factors RF(A), RF(B), RF(C), in relative proportions a, b, c is given by:

$$RF(mix) = 1 / [(a/RF(A) + b/RF(B) + c/RF(C)\ldots]$$

11 WS-VOC Volatile Organic Compounds detector

Chemical name	IE [eV]	RF
Acetaldehyde	10.23	5.5
Acetamide	9.69	2
Acetic acid	10.66	28
Acetic anhydride	10.14	4
Acetoin	~9.8	1
Acetone	9.69	1.17
Acetophenone	9.29	0.6
Acetyl bromide	10.24	8
Acetylglycine, N-	9.40	2
Acrolein	10.22	3.2
Acrylic Acid	10.60	21
Alkanes, n-, C6+	~10	1.2
Allyl acetoacetate	~10	1.5
Allyl alcohol	9.63	2.3
Allyl bromide	9.96	3
Allyl chloride	10.05	4.5
Allyl glycidyl ether	~10	0.8
Allyl propyl disulfide	~8.5	0.4
Ammonia	10.18	8.5
Amyl acetate	9.90	1.8
Amyl alcohol	10.00	2.6
Amyl alcohol, tert-	9.80	1.5
Anethole	~9	0.4
Aniline	7.70	0.5
Anisole	8.21	0.59
Anisyl aldehyde	~9	0.4
Arsine	9.89	2.5
Asphalt, petroleum fumes	~9	1
Benzaldehyde	9.49	0.7
Benzene	9.24	0.5
Benzene thiol	8.32	0.7
Benzoic acid	9.30	0.7
Benzonitrile	9.62	0.7
Benzoquinone, o-	9.30	1
Benzoquinone, p-	10.01	1
Benzoyl bromide	9.65	2
Benzyl 2-phenylacetate	~9	0.5
Benzyl acetate	~9	0.6
Benzyl alcohol	8.26	1
Benzyl chloride	9.14	0.7
Benzyl formate	9.32	0.8
Benzyl isobutyrate	~9	0.5
Benzyl nitrile	9.39	1
Benzylamine	7.56	0.6
Biphenyl	8.23	0.4
Borneol	~9	0.8
Bromine	10.55	15
Bromo-2,2-dimethylpropane, 1-	10.04	2
Bromo-2-chloroethane, 1-	10.57	3
Bromo-2-methylpentane, 1-	10.09	2
Bromoacetone	9.73	1

Chemical name	IE [eV]	RF
Bromoacetylene	10.31	4
Bromobenzene	8.98	0.32
Bromobutane, 1-	10.13	1.6
Bromobutane, 2-	10.01	0.97
Bromocyclohexane	9.87	2
Bromoethane	10.29	1.6
Bromoethanol, 2-	10.00	2
Bromoethyl methyl ether, 2-	10.00	2.5
Bromoform	10.48	2.8
Bromopentane, 1-	10.10	1.1
Bromopropane, 1-	10.18	1.5
Bromopyridine, 3-	9.75	2
Bromopyridine, 4-	9.94	2
Bromotrimethylsilane	10.00	2
But-2-ynal	10.20	3
But-3-ynal	9.85	1.5
Butadiene diepoxide, 1,3-	10.00	4
Butadiene, 1,3-	9.07	0.8
Butane, n-	10.63	40
Butanedione, 2,3-	9.56	0.84
Butanoic acid	10.17	5
Butanol, 1-	10.04	3.9
Butanol, 2-	10.10	3
Buten-3-ol, 1-	9.50	1.8
Butene nitrile, 3-	10.20	~3
Butene, 1-	9.58	1.5
Butene, 2-	9.10	1.3
Butene, cis-2-	9.13	1.3
Butene, trans-2-	9.13	1.3
Butenoic acid, 3-	9.75	2
Butoxyethanol, 2-	8.68	1.1
butoxyethoxyethanol	~9	1
Butoxyethylacetate, 2-	~9.8	3
Butyl acetate	9.91	2.5
Butyl acetate, sec-	9.91	1.8
Butyl acetate, tert-	~9.7	1.05
Butyl acrylate	~9.6	1.5
Butyl butyrate	~9.7	1.8
Butyl chloroformate	~10.4	3.2
Butyl cyclohexan-1-ol, 4- tert-	~8.8	1.4
Butyl cyclohexyl acetate, 2- tert-	~10	0.9
Butyl ether, n-	9.28	0.82
Butyl glycidyl ether	~10	2
Butyl iodide	9.23	1
Butyl isocyanate	10.14	2.5
Butyl lactate	9.80	2.5
Butyl mercaptan, n-	9.15	0.5
Butyl mercaptan, tert-	9.03	0.4
Butyl methacrylate	~9.5	1
Butyl propionate, n-	~9.7	1.9
Butylamine, n-	8.71	1

Chemical name	IE [eV]	RF
Butylamine, sec-	8.70	0.9
Butylamine, tert-	8.64	1.2
Butylbenzene	8.69	0.5
Butylbenzene, sec-	8.68	0.4
Butylbenzene, tert-	8.69	0.4
Butylene carbonate, 1,2-	~10.4	18
Butylphenol, o-sec-	7.80	0.9
Butyn-1-ol, 2-	9.78	1.5
Butyn-2-one	10.17	3
Butyraldehyde	9.86	1.7
Butyrolactone, gamma-	10.26	15
Butyryl chloride	~10.4	3
Camphene	8.86	0.5
Camphor	8.76	0.4
Carbon disulfide	10.08	1.4
Carbon suboxide	10.60	10
Carbon tetrabromide	10.31	3
Carene	8.40	0.5
Carvacrol	~9	0.8
Carvone, R-	9.77	1.6
Caryophyllene	~9	0.4
Chloramine	9.85	2
Chloro-1,1-difluoroethene, 2-	9.80	1.5
Chloro-2-propanone, 1-	9.92	1
Chloroacetaldehyde	10.16	3
Chlorobenzene	9.07	0.45
Chlorobutane, 1-	10.64	10
Chlorobutane, 2-	10.57	5.8
Chlorocyclohexane	10.10	2
Chloroethanol, 2-	10.50	10
Chloroethyl methyl ether, 2-	10.25	2.6
Chloromethoxyethane	10.30	4
Chloroprene	8.79	1.3
Chloropyridine, 2-	9.00	1
Chlorostyrene, o-	~8.5	0.4
Chlorotoluene, m-	8.70	0.5
Chlorotoluene, o-	8.83	0.5
Chlorotoluene, p-	8.69	0.4
Chlorotrifluoroethylene	9.81	1
Cinnamic aldehyde	~9	0.4
Cinnamyl acetate	~9	0.4
Cinnamyl alcohol	8.10	0.4
Citral	~8.7	1.7
Citronellal	~9	0.9
Citronellol	~8.5	1
Citronellol acetate	~9	1.5
Citronellol formate	~9	1.5
Citronellyl isobutyrate	~9	0.9
Coumarin	~9	0.4
Creosote	~9	1
Cresol, m-	8.36	2.2

Chemical name	IE [eV]	RF
Cresol, o-	8.14	1.1
Cresol, p-	8.31	1.1
Cresyl acetate, p-	8.60	1
Cresyl ethyl ether, p-	~9	0.8
Cresyl methyl ether	~9	0.8
Crotonaldehyde	9.73	1
Crotonyl alcohol	9.13	0.8
Cycloalkanes	~10	1.5
Cyclobutanone	9.35	1.2
Cyclobutene	9.43	3
Cycloheptane	9.82	1.1
Cyclohex-2-enedione, 1,4-	9.77	1
Cyclohexane	9.98	1.3
Cyclohexanethiol	~9	0.5
Cyclohexanol	10.00	1.6
Cyclohexanone	9.16	1
Cyclohexene	8.95	0.9
Cyclohexyl acetate	~9.5	1.2
Cyclohexylamine	8.37	1
Cyclooctadiene	~9.5	1
Cyclopentadiene	8.56	0.8
Cyclopentane	10.52	10
Cyclopentanone	9.26	0.9
Cyclopentene	9.01	1.5
Cyclopentene-1,3-dione, 4-	9.60	1
Cyclopropylamine	8.80	1.5
Cymene, p-	8.29	0.4
Decahydronaphthalene	9.14	0.9
Decanal	~9	0.9
Decane, n-	9.65	1.2
Decanol		1.2
Decyne, 1-	9.91	0.43
Diacetone alcohol	~9.6	0.9
Diazine, 1,2-	9.65	3
Diazine, 1,3-	9.33	3
Dibenzoyl peroxide		0.8
Dibromoacetylene	9.65	2
Dibromochloromethane	10.59	10
Dibromocyclohexane, 1,2-	10.02	3
Dibromocyclopentane	10.06	3
Dibromodichloromethane	10.40	4
Dibromoethane, 1,2-	10.35	2
Dibromoethene, 1,1-	9.78	1.5
Dibromoethene, 1,2-	9.63	1.5
Dibromomethane	10.41	1.9
Dibutyl hydrogen phosphate		4
Dichloro-1,2-difluoroethene, 1,2- (cis)	10.20	2
Dichloro-1-propene, 2,3-	~10.5	1.4
Dichloro-2,2,-difluoroethene, 1,1-	9.69	1
Dichloroacetylene	9.90	5
Dichlorobenzene, o-	9.06	0.5

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Chemical name	IE [eV]	RF
Dichlorobenzene, p-	9.06	0.5
Dichloroethene, 1,1-	10.00	1
Dichloroethene, 1,2-	9.65	0.4
Dichloroethene, cis-1,2-	9.66	0.8
Dichloroethene, trans-1,2-	9.65	0.4
Dichloromethane	11.32	70
Dichloromethylamine	9.52	2
Dicyclohexylamine	~8.5	0.9
Dicyclopentadiene	7.74	0.9
Diesel fuel	8	0.8
Diethoxyethane, 1,1-	9.78	1.5
Diethyl carbonate	~10.3	7
Diethyl ether	9.53	1.1
Diethyl maleate	~10	2
Diethyl malonate	10.20	4
Diethyl phosphite	10.31	2
Diethyl phthalate	~9	1
Diethyl sulfate	~10.5	3
Diethyl sulfide	8.43	0.6
Diethyl sulfone	9.96	2
Diethylacetylene	10.03	2
Diethylamine	8.01	1.4
Diethylaminoethanol, 2-	8.58	2.7
Diethylaminopropylamine, 3-	~9	5
Diethylene glycol monoethyl ether	~9	0.6
Diethylenetriamine	~9	1
Diethylhydroxylamine	~10	1.5
Diethylsilane	9.80	2
Dihydrogen selenide	9.89	1
Diglycidyl ether	~9.6	3
Dihydroeugenol	~9	0.4
Dihydrojasmone	~9	0.6
Dihydromyrcenol	~9	0.8
Dihydroxybenzene, 1,2-	8.56	1
Dihydroxybenzene, 1,3-	8.63	1
Diiodomethane	9.46	1.2
Diisobutyl ketone	9.04	0.8
Diisobutylene	8.91	0.7
Diisopropyl ether	9.20	0.92
Diisopropylamine	7.73	0.7
Diisopropylbenzene	~8.8	0.5
Diketene	9.6	2.2
Dimethoxybenzene, 1,4-	~9	1.3
Dimethoxyethane, 1,2-	9.20	0.9
Dimethoxymethane	10.00	2.8
Dimethyl carbonate	10.52	60
Dimethyl disulfide	8.46	0.2
Dimethyl ether	10.03	1.3
Dimethyl phosphite	10.53	8
Dimethyl phthalate	9.64	1
Dimethyl sulfoxide	9.10	20

Chemical name	IE [eV]	RF
Dimethylacetamide N,N-	8.81	1.3
Dimethylacetylene	9.58	1
Dimethylamine	8.24	1.5
Dimethylaminoethanol, 2-	8.80	1.5
Dimethylaniline, NN-	7.12	0.6
Dimethylboron bromide	10.25	4
Dimethylbutyl acetate	~9.5	1.6
Dimethylcycloheptane, 1,2-	10.21	1.3
Dimethylcyclohexane,1,2-	9.41	0.55
Dimethylcyclopentane	9.92	1.2
Dimethylethylamine, NN-	7.74	1.6
Dimethylformamide	9.13	1.3
Dimethylhydrazine, 1,1-	8.05	1
Dinitrobenzene, m-	10.40	3
Dinitrobenzene, p-	~10.58	5
Dinonyl phthalate		1
Dimethylmethylphosphonate	9.94	5
Dimethyloctan-1-ol, 3,7-	~9	1.2
Dimethyloctan-3-ol, 3,7-	~9	1.2
Dimethylpentane, 2,4-	~9.8	1
Dimethylsilane	10.30	2
Dimethylthiophosphoryl chloride	~9	1
Di-n-butylamine	7.69	6
Di-n-propylamine	7.8	1.5
Dioxane, 1,4-	9.13	1.45
Dioxolane	9.13	2.7
Dipentene	~8.6	0.9
Diphenyl ether	8.09	1.5
Dipropyl ether	9.30	1
Dipropylene glycol	~10	4
Disilane	9.74	2
Disulfur dibromide	9.23	1.5
Disulfur dichloride	9.40	3
Di-tert-butyl-p-cresol		1
Di-tert-butyl-p-cresol	7.8	0.3
Divinylbenzene	~8.2	0.4
Divinylbenzene, 1,3-	~8.3	0.3
Dodecane	~8.8	1
Dodecanol		0.9
Epichlorohydrin	10.2	5
Epoxypropyl isopropyl ether, 2,3-	~10	1.2
Estagole	~9	0.7
Ethanol	10.43	11
Ethanolamine	10.47	3
Ethoxy-2-methylpropane, 1-	9.3	1
Ethoxy-2-propanol, 1-	~9.6	2.4
Ethoxy-butane, 2-	9.32	1
Ethoxyethanol, 2-	9.60	2
Ethoxyethyl acetate, 2-	~10	3
Ethyl 2,2,2-trifluoroethyl ether	10.27	5
Ethyl 2-methylbutyrate	~9	1.4

11 WS-VOC Volatile Organic Compounds detector

Chemical name	IE [eV]	RF
Ethyl acetate	10.01	4.5
Ethyl acetoacetate	~9.5	3
Ethyl acrylate	10.3	2.3
Ethyl benzoate	8.9	0.9
Ethyl butyrate	~9.9	1.4
Ethyl chloroformate	10.64	80
Ethyl cyanoacrylate	~10	1.5
Ethyl decanoate	~9.6	1.8
Ethyl formate	10.61	35
Ethyl hexanoate	~9.75	1.6
Ethyl hexanol, 2-	~9.8	1.5
Ethyl hexyl acrylate, 2-	~9	1
Ethyl iodide	9.34	0.3
Ethyl isopropyl ketone	9.10	0.8
Ethyl lactate	~10	2.1
Ethyl mercaptan	9.29	0.6
Ethyl methacrylate	~9.5	1.06
Ethyl methyl carbonate	10.40	18
Ethyl morpholine, 4-	~8	0.6
Ethyl octanoate	~9.7	2.3
Ethyl phenyl acetate	~9	1.2
Ethyl propanoate	10.01	2.5
Ethyl tert-butyl ether	9.39	0.8
Ethyl-2-methyl benzene, 1-	~8.7	0.5
Ethyl-3-ethoxypropionate	~9.5	3
Ethylacetylene	10.18	3
Ethylamine	8.86	1
Ethylbenzene	8.76	0.56
Ethylcyclohexane	9.54	0.8
Ethylene	10.51	8
Ethylene carbonate	10.40	40
Ethylene glycol	10.16	9
Ethylene glycol diacetate	~10	4
Ethylene glycol monopropylether	~9	3
Ethylene oxide	10.56	15
Ethylenediamine	8.60	10
Ethyleneimine	9.20	2
Ethylhexanal, 2-	~9	1.5
Ethylhexanoic acid, 2-	~10	5
Ethylhexenal, 2-	~9	1.3
Eucalyptol	~9	0.6
Eugenol	~9	0.4
Eugenol methyl ether	~9	0.4
Fenchol	~9	0.4
Ferrocene	6.88	0.8
Fluorobenzene	9.2	0.74
Fluorobenzoic acid, 4-	9.91	2
Formamide	10.20	2
Furan	8.88	0.4
Furfural	9.21	0.8
Furfuryl alcohol	~9.9	2

Chemical name	IE [eV]	RF
Furfuryl mercaptan	~9	0.5
Gasoline	~9.9	0.9
Geranial	~9	0.6
Geraniol	~9	0.7
Geranyl acetate	~9	1.2
Germane	11.34	10
Glutaraldehyde	~9.6	0.9
Glycidyl methacrylate	~10	1.2
Glycolaldehyde	~10.4	5
Glyoxal	10.2	1
Guaiacol	~9	0.8
Heptan-2-one	9.33	0.85
Heptan-3-one	9.02	0.73
Heptane, n-	9.92	2.2
Heptanol	~9.8	1.7
Heptene, 1-	9.34	0.88
Heptylcyclopentan-1-one, 2-	~9	0.8
Heptyne, 1-	10.04	2
Hex-1-en-3-ol	~9	0.9
Hexachlorodisilane	10.40	8
Hexamethyldisilazane,1,1,1,3,3,3-	8.60	1
Hexamethyldisiloxane	9.60	0.3
Hexamethylene diisocyanate	~9	1.5
Hexamethyleneimine	8.41	1.1
Hexan-2-one	9.34	0.8
Hexane, n-	10.13	3
Hexanoic acid	10.12	4
Hexanol	9.89	2
Hexene, 1-	9.44	0.98
Hexenyl acetate, cis-3-	~9	1
Hexenyl butyrate, cis-3-	~9	1.5
Hexylaldehyde	9.72	1.2
Hydrazine	8.93	3
Hydrogen iodide	10.39	5
Hydrogen peroxide	10.58	4
Hydrogen selenide	9.88	2
Hydrogen sulfide	10.46	4
Hydroquinone	7.94	0.8
Hydrogen telluride	9.14	2
Hydroxybutanal, 3-	~9	2
Hydroxycitronellal	~9	1
Hydroxyethyl acrylate	~10	1.2
Hydroxylamine	10.00	2
Hydroxypropyl acrylate, 2-	~9	1.5
Iminodiethanol 2,2'-		1.6
Indene	8.81	0.5
Indole	7.76	0.4
Iodine	9.31	0.2
Iodobenzene	8.73	0.2
Iodoethene	9.3	1.2
Iodoform	9.25	1.5

Chemical name	IE [eV]	RF
Iodomethane	9.54	0.4
Isoalkanes, C10-C13	~9.6	1
Isoamyl acetate	~9.7	1.5
Isoamyl salicylate	~9	1
Isoamylene	8.69	0.82
Isobornyl acetate	~9	0.5
Isobutane	10.57	8
Isobutanol	10.12	3
Isobutyl acetate	9.90	2
Isobutyl acrylate	~9.5	1.2
Isobutylbenzene	8.68	0.4
Isobutylene	9.24	1
Isobutylene epoxide	10.00	3
Isobutyraldehyde	9.74	1.2
Isobutyric acid	10.24	4.4
Isodecanol	~9.8	0.9
Isoeugenol	~9	0.4
Isoheptane	9.84	1.2
Isojasmone	~9	0.7
Isomenthone	9.86	0.6
Isononanal	~9.6	0.9
Isononanol	~9.8	1.5
Isooctane	9.86	1.1
Isooctanol	~9.8	1.7
Isopentane	10.32	4
Isopentanol	9.86	2
Isopentene	9.12	0.8
Isophorone	9.07	0.8
Isophorone diisocyanate	~9	0.6
Isoprene	8.85	0.8
Isopropanol	10.17	4
Isopropanolamine	~ 9.6	1.5
Isopropoxyethanol, 2-	~10.3	1.2
Isopropyl acetate	9.99	2.4
Isopropyl chloroformate	~10.2	1.6
Isopropyl mercaptan	9.15	0.6
Isopropyl nitrite	10.23	4
Isopropylamine	8.72	1
Isopropylaminoethanol, 2-	~9	2
Isopropylcyclohexane	9.33	0.7
Isopropylglycol acetate	~9.5	1.2
Isothiazole	9.55	3
Isovaleraldehyde	9.72	1.3
Isovaleric Acid	~10.2	5.5
Jasmal	~9	1.4
Jasmone, cis-	~9	0.5
Jet Fuel Jp-4	~9	0.8
Jet Fuel Jp-5	~9	0.7
Jet Fuel Jp-8	~9	0.7
Kerosene	~8	0.8
Ketene	9.62	3

Chemical name	IE [eV]	RF
Linalool oxide	~9	0.6
Linalyl acetate	~9	1.1
Maleic anhydride	9.9	2
Mandelic acid		0.8
Menthol	~9	0.5
Menthone	~9	0.4
Mercaptoacetic acid	~9.8	1
Metaldehyde	~9.7	2
Methacrylamide	~10	2
Methacrylic acid	10.15	2.3
Methacrylonitrile	10.34	5
Methoxy-1-butanol, 3-	~9.56	3
Methoxy-1-propanol, 2-	9.30	2
Methoxy-2,2-dimethylpropane	9.3	0.9
Methoxybutyl acetate, 3-	~9	2
Methoxyethane	9.72	1
Methoxyethanol, 2-	9.6	2.7
Methoxyethene	8.95	1
Methoxyethoxyethanol, 2-	10.00	1.4
Methoxyethyl acetate	~9.6	2.7
Methoxyethyl ether, 2-	9.80	1
Methoxymethylethoxy-2-propanol	~10	1.3
Methoxypropan-2-ol, 1-	~9.6	1.6
Methoxypropane, 2-	9.45	1.2
Methoxypropyl acetate	~9	1.6
Methyl 2-methylpropanoate	9.86	2
Methyl acetate	10.27	7
Methyl acetoacetate	9.81	3
Methyl acrylate	10.25	3.6
Methyl anthranilate	~9	0.4
Methyl benzoate	9.32	1.2
Methyl bromide	10.54	1.9
Methyl dimethylacrylate	~9.6	2.5
Methyl ethyl ketone	9.51	0.96
Methyl ethyl ketone peroxides	~9	0.8
Methyl heptyne carbonate	~9	1.3
Methyl ionone	~9	0.4
Methyl isobutyl ketone	9.30	0.9
Methyl isocyanate	10.67	5
Methyl isopropyl ketone	9.31	0.99
Methyl isothiocyanate	9.25	0.6
Methyl mercaptan	9.44	0.7
Methyl methacrylate	9.7	1.31
Methyl phenyl acetate	~9	0.4
Methyl propargyl ether	9.78	2
Methyl propionate	10.15	3.8
Methyl propynoate	10.30	10
Methyl salicylate	7.65	0.8
Methyl sulfide	8.69	0.8
Methyl tert-butyl ether	9.24	1
Methyl thiocyanate	9.96	2

Chemical name	IE [eV]	RF
Methyl thioglyconate	~10	1
Methyl undecanal, 2-	~9	1.1
Methyl vinyl ketone	9.65	0.6
Methyl-1-butene, 3-	9.51	0.8
Methyl-2-butanol, 3-	9.88	3.3
Methyl-2-hexenoic acid, trans-3-	~10	1.5
Methyl-2-propen-1-ol, 2-	9.24	1.3
Methyl-2-pyrrolidinone, N-	9.17	0.9
Methyl-4,6-dinitrophenol, 2-		3
Methyl-5-hepten-2-one, 6-	~9.4	0.63
Methylamine	8.97	1.5
Methylbutan-1-ol, 3-	9.8	2.3
Methylbutanal, 2-	9.59	1.2
Methylbutyric acid, 2-	~10.2	6
Methylcyclohexane	9.85	1.1
Methylcyclohexanol	9.80	2.4
Methylcyclohexanol, 4-	9.8	2.4
Methylcyclohexanone, 2-	9.05	1
Methylcyclopentane	9.85	1.5
Methylenepentane, 3-	9.06	0.9
Methylheptan-3-one, 5-	~9.1	0.77
Methylhexan-2-one, 5-	9.28	0.7
Methylhydrazine	8.00	1.3
Methyl-N-2,4, 6-tetranitroaniline,N-		3
Methylpent-3-en-2-one, 4-	9.10	0.6
Methylpentan-2-ol, 4-	~9.8	1.4
Methylpentane, 2-	10.12	3
Methylpentane, 3-	10.08	2.5
Methylpentane-2,4-diol, 2-	~9.6	4
Methylpropanoyl chloride, 2-	~9	6
Methylpyrrole, N-	7.95	0.9
Methylstyrene	8.30	0.5
Methylthiopropional, 3-	~9.5	2
Mineral oil	~9	0.8
Mineral spirits	~9	0.8
Monoisobutanolamine	~9	1.6
Morpholine	8.88	4
Myrcene	~8.2	0.5
Naphtha, hydrotreated heavy	~10	1
Naphthalene	8.14	0.4
Naphthol methyl ether, 2-	~9	0.5
Neopentane	10.21	3
Neopentyl alcohol	9.72	2
Nitric oxide	9.27	8
Nitroaniline 4-	8.56	0.8
Nitrobenzene	9.92	1.7
Nitrogen trichloride	10.1	1
Nitrogen dioxide	9.58	10
N-Methylolacrylamide	~10.3	2
Nonane	9.72	1.4
Nonanol (mixed isomers)	~9.8	1.2

Chemical name	IE [eV]	RF
Nonene (mixed isomers)	~9.3	0.6
Nonene, 1-	~9.4	0.6
Norbornadiene, 2,5-	8.38	0.6
Ocimene	8.60	0.6
Octachloronaphthalene		1
Octamethylcyclotetrasiloxane	~10	0.3
Octamethyltrisiloxane	10.04	0.3
Octane	9.8	1.6
Octanol (mixed isomers)	~9.8	1.5
Octene (mixed isomers)	~9.4	0.7
Octene, 1-	9.43	0.7
Oxalyl bromide	10.49	5
Oxydiethanol, 2,2-	~10.3	2
Paraffin wax, fume	~10	1
Paraffins, normal	~9.5	1
Paraldehyde	~9.7	2.2
Pentacarbonyl iron	~8	1
Pentan-2-one	9.38	0.99
Pentan-3-one	9.31	0.77
Pentanal	9.74	1.5
Pentandione, 2,4-	8.85	1.2
Pentane	10.35	7
Pentanoic acid	10.53	8
Pentanol, 2-	9.78	2
Pentanol, 3-	9.76	1.7
Pentene, 1-	9.49	0.92
Pentylcyclopentan-1-one, 2-	~9	1
Pentylcyclopentane	9.91	1.1
Pentyne, 1-	10.10	3
Peracetic acid	~10.5	2
Perfluorobutadiene	9.50	3
Perfluoro-tert-butylamine	10.40	5
Petroleum ether	~10	0.9
Phellandrene	~8.2	0.8
Phenethyl methyl ether, 2-	~9	0.6
Phenol	8.51	1.2
Phenoxyethanol, 2-	~8.5	4.5
Phenyl chloroformate	~9	1.1
Phenyl ethyl isobutyrate, 2-	~9	1.5
Phenyl propene, 2-	8.35	0.4
Phenyl-2,3-epoxypropyl ether	~8.6	0.8
Phenylenediamine, p-	6.87	0.6
Phenylacetaldehyde	8.80	0.7
Phenylacetic acid	8.26	1
Phenylcyclohexane	8.1	0.4
Phenylethyl acetate, 1-	~9	0.7
Phenylethyl alcohol, 2-	~10	1.2
Phosphine	9.96	2
Phthalonitrile	9.9	1.2
Picoline, 3-	9.04	0.7
Pine oil	~9.5	1

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Chemical name	IE [eV]	RF
Pinene, α-	8.07	0.34
Pinene, β-	8.10	0.5
Piperazine	8.72	0.8
Piperidine	8.03	1
Piperylene	8.60	0.9
Prop-2-yn-1-ol	10.50	3.7
Propadiene	9.83	1
Propan-1-ol	10.20	5.4
Propanamide	~9.5	2
Propane-1,2-diol	10.00	3
Propanolamine	~9.5	1.5
Propargyl chloride	9.82	2
Propen-1-imine, 2-	9.65	2
Propene	9.73	1.4
Propiolic acid	10.45	8
Propionaldehyde	9.95	1.7
Propionic acid	10.44	8
Propoxy-2-propanol, 1-	~9.5	1.2
Propyl acetate, n-	10.04	3
Propyl benzene	8.72	0.5
Propyl benzene, 2-	8.71	0.6
Propyl butanoate	~9.6	1.3
Propyl formate	10.54	19
Propyl iodide	9.26	1
Propylamine, n-	8.5	1.1
Propylbenzene (all isomers)	8.70	0.5
Propylene carbonate	~10.5	15
Propylene glycol ethyl ether acetate	~9.6	1.2
Propylene oxide	10.22	6
Propyleneimine	9.00	1.4
Propyne	10.36	4
Pyrazine	9.29	3
Pyridine	9.25	0.7
Pyridinol, 4-	9.75	3
Pyridylamine, 2-	8.10	0.8
Pyrrole	8.02	0.6
Pyrrolidine	8.77	4
Pyruvaldehyde	9.60	0.7
Rose oxide, cis-	~9	0.8
Sec-amyl acetate	~9.9	5
Stibine	9.89	1.5
Styrene	8.40	0.45
Sulfur dichloride	9.47	2
Terphenyl, p-	7.80	0.6
TAC	~9	0.5
Terpineol, α-	~9	0.8
Terpinolene	8.10	0.6
Terpinyl acetate, α-	~9	1.2
Tert-amyl methyl ether	~9	0.8
Tert-butanol	10.25	1.6
Tert-butyl bromide	9.92	0.99

Chemical name	IE [eV]	RF
Tert-butyl formate	10.52	8
Tetrabromoethane, 1,1,2,2-	~10	2
Tetracarbonylnickel	8.28	1
Tetrachloroethylene	9.33	0.4
Tetrachloronaphthalene, 1,2,3,4-		1
Tetrachloropyridine, 2,3,5,6-	~9	1
Tetraethyl orthosilicate	9.77	3
Tetraethylenepentamine		0.6
Tetrafluoroethylene	10.12	15
Tetrahydrofuran	9.41	2.3
Tetrahydronaphthalene	8.46	0.4
Tetrahydropyran	9.25	3
Tetrahydrothiophene	8.38	0.7
Tetramethyl orthosilicate	~10	2
Tetramethyl succinonitrile	~11	1
Tetramethylbenzene, 1,2,4,5-	8.06	0.3
Tetramethylbutane, 2,2,3,3-	9.8	1
Tetramethylgermane	9.34	2
Tetramethylguanidine, N,N,N',N'	8.43	0.6
Tetramethylsilane	9.8	2
Thioacetic acid	10.00	2
Thiocarbonyl fluoride	10.45	6
Thiocyanogen	10.50	8
Thioformaldehyde trimer	9.35	1.5
Thiophene	8.86	0.5
Thiophosgene	9.61	1
Thymol	~9	0.7
Titanium-n-propoxide	~9	3
Toluene	8.82	0.56
Toluene-2,4-diisocyanate	8.82	1.6
Toluenesulfonyl chloride, p-	~9	3
Toluidine, o-	7.40	0.5
Tolylaldehyde, p-	9.33	0.8
Triazine, 1,3,5-	10.01	6
Tributyl phosphate	8.91	5
Tributylamine	7.4	1.3
Trichlorobenzene, 1,2,4-	9.04	0.6
Trichloroethylene	9.45	0.6
Trichlorophenoxyacetic acid, 2,4,5-		1
Triethyl phosphate	9.79	3.5
Triethyl phosphite	8.30	1.5
Triethyl silane	9.50	2
Triethylamine	7.50	1.3
Triethylbenzene	~8.3	0.4
Triethylene aluminum	~10	1
Trifluoroethene	10.14	5
Trifluoroethyl methyl ether, 2,2,2-	10.53	10
Trifluoroiodomethane	10.28	2
Trimethoxymethane	9.5	4
Trimethoxyvinylsilane	~9.5	1
Trimethylamine	7.82	0.5

Chemical name	IE [eV]	RF
Trimethylbenzene mixtures	8.41	0.3
Trimethylbenzene, 1,3,5-	8.39	0.4
Trimethylcyclohexane, 1,2,4-	9.35	1
Trimethylene oxide	9.65	1.5
Trimethylsilane	9.9	1
Trioxane	10.3	2
Turpentine	~8.5	0.6
Turpentine oil	~8	0.6
TVOC	~10	1
Undecane	9.56	1.1
Vanillin	~9	1
Vinyl acetate	9.19	1.5
Vinyl bromide	9.8	1.5
Vinyl chloride	9.99	2.1
Vinyl ethyl ether	8.98	1
Vinyl fluoride	10.37	2
Vinyl-2-pyrrolidinone, 1-	9	4.5
Vinylcyclohexene	8.93	0.47
Vinylene carbonate	10.08	3.5
Vinylidene difluoride	10.29	5
Vinylsilane	10.1	1.5
Xylene mixed isomers	8.56	0.54
Xylene, m-	8.56	0.5
Xylene, o-	8.56	0.5
Xylene, p-	8.44	0.55
Xylidine, all	7.5	0.7

12. References

If you'd like to have your paper(s) reported here please send us the paper abstract and we'll include it in the next releases. Thanks.

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