Attachment E.I.2. Near Surface Soil Gas Monitoring Field Meter Manuals

Note: This Attachment contains manuals for field meters PCC intends to utilize. PCC retains the right to substitute functionally equivalent meters to those presented herein.

GEM5000 Gas Analyzer

Operating Manual

QED Environmental Systems, Inc.
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Website: www.landtecna.com

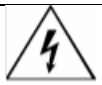
Table of contents

1.0 Manual guidelines

1.1 Hazard warnings and safety symbols

 Warning	Information in this manual that may affect the safety of users and others is preceded by the warning symbol. Caution - Failure to follow the correct information may result in physical injury which in some cases could be fatal. If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

General product label symbols are listed as follows:

	CE conformity-The CE-marking is the manufacturer's statement to the EU authorities that the product complies with all relevant CE-marking Directives.		If the CSA mark appears with the indicator "US" or "NRTL" it means that the product is certified for the U.S. market, to the applicable U.S. standards.
	VDE mark is a symbol for electrical, mechanical, thermal, toxic, radiological and other hazards.		Separate collection, handling and disposal for waste electrical and electronic equipment and its components.
	Electric shock warning.		Refer to operators manual.
	Double insulated construction - does not require an Earth.		Specific marking of explosion protection (ATEX only).
II 2G	Equipment group and category. G = gases; the type of explosive atmosphere.		IECEx licenced mark (IECEx only).
	Fuse.		Equipment for indoor use only.

1.2 Notes

Important/useful information and instructions are shown clearly throughout the manual in a note format. For example:

✍ Note: For further information please contact Technical Support at (800) 968-2026 or email landtec_support@qedenv.com

2.0 Introduction

This manual explains how to use the GEM5000 landfill gas analyzer. The GEM5000 has additional functionality to the GA5000 gas analyzer. The GA5000 measures gas concentrations only, whereas the GEM5000 measures flow and gas concentrations. The GEM5000 measures flow and calculates the calorific values of the gas as well as being a useful tool for balancing the gas field. The GEM5000 gas analyzer may be used to monitor, calculate, adjust and record the flow at each monitoring point.

This instrument may also be used in GA5000 mode of operation if required. The operator may change the analyzer between a gas extraction monitor (a GEM5000 gas analyzer) or a landfill gas analyzer (a GA5000 gas analyzer). The mode of operation can be changed from the 'Special Action' menu. Please refer to section '8.0 – Taking Readings' for further instruction.

The 5000 series of gas analyzers complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

1) This device may not cause harmful interference.

2) This device must accept any interference received, including interference that may cause undesired operation.

2.1 Safety instructions

⚠ **Warning**	The 5000 series of gas analyzers can be used for measuring gases from landfill sites and other sources as described in this manual. The operator may be exposed to harmful gases during the use of the instrument. Inhaling these gases may be harmful to health and in some cases may be fatal. It is the responsibility of the user to ensure that he/she is adequately trained in the safety aspects of the gases being used and appropriate procedures are followed. In particular, where hazardous gases are being used the gas exhausted from the analyzer must be piped to an area where it is safe to discharge the gas. Hazardous gas can also be expelled from the instrument when purging with clean air. The instrument has been designed to be used in explosive atmospheres as defined by the classification. The instrument can be configured to measure low levels of several gases, but may not be certified for use in potentially explosive atmospheres of these gases. It is the responsibility of the operator to determine the protection concept and classification of equipment required for a particular application and whether these gases create a potentially explosive atmosphere.

✍ Note: Gas analyzers are a sensitive piece of scientific equipment, and should be treated as such. If the equipment is used in a manner not specified by the manufacturer, the protection provided by the instrument may be impaired.

2.2 Instructions for safe use

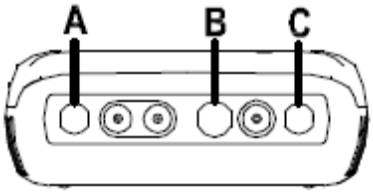
For ATEX and IECEx the 5000 series of gas analysers are certified to Hazardous Area Classification

II 2G Ex ib IIA T1 Gb (Ta = -10ºC to +50ºC)

It is vital instructions are followed closely. It is the responsibility of the operator to determine the protection concept and classification required for a particular application.

(Reference European ATEX directive 2014/34/EU)
The following instructions apply to equipment covered by certificate numbers SIRA 11ATEX2197X and IECEx SIR 11.0089X:

- The equipment may be used with flammable gases and vapours with apparatus group IIA and temperature class T1.
- The equipment can contain gas sensing heads for the detection of particular gases. The inclusion of a sensor does not infer that the equipment is suitable for the use of gases with a temperature class of less than T1.
- The equipment is only certified for use in ambient temperatures in the range -10ºC to +50ºC and should not be used outside this range.
- The equipment must not be used in an atmosphere of greater than 21% oxygen.
- Repair of this equipment shall be carried out in accordance with the applicable code of practice.
- When used in a hazardous area only use GF5.2 temperature probe (SIRA 11ATEX2197X and IECEx SIR11.0089X). For connector C, the GF5.4 anemometer (BVS 04ATEXE194) for use with ATEX only. The analyser should not be connected to any other devices in the hazardous area including the GF-USB lead (connector A) or GF3.9 battery charger (connector B) supplied with the analyzer.



Do not charge, recharge or open in a potentially explosive atmosphere.
In hazardous area only use "Temperature Probe GF5.2" in Connector B.
Connector C (Uo=10V,Io=5mA,Po=50mW,Ci=0,Li=0,Co=100uF,Lo=1000mH),
Connector B (Uo=5V,Io=6mA,Po=7mW,Ci=0,Li=0,Co=100uF,Lo=1000mH)

MAXIMUM NON-HAZARDOUS SUPPLIES:
Connector A - Um=6V Connector B - Um=10.1V

- The safe area apparatus that is to be connected to the USB Port shall be a Safety Extra Low Voltage (SELV) or Protective Extra Low Voltage (PELV) circuit.
- Only a Geotechnical Instrument battery pack part number 20087 or 2011113 is permitted as a replacement. This battery pack is not field replaceable and shall only be changed in a safe area by QED personnel.
- Only Battery Charger type GF3.9 shall be used to recharge the batteries via Connector 'B'.
- If the equipment is likely to come into contact with aggressive substances, e.g. acidic liquids or gases that may attack metals, or solvents that may affect polymeric materials, then it is the responsibility of the user to take suitable precautions, e.g. regular checks as part of routine inspections or establishing from the material's data sheet that it is resistant to specific chemicals that prevent it

from being adversely affected, thus ensuring that the type of protection is not compromised.

- The relative pressure range is +/-500 mbar. Note, however, that the input pressure should not exceed +/- 500 mbar relative to atmospheric pressure and the output pressure should not exceed +/- 100 mbar relative to atmospheric pressure.

For CSA (Canada) the 5000 series of gas analysers are certified to Hazardous Area Classification

CLASS 2258 03 - PROCESS CONTROL EQUIPMENT - Intrinsically Safe and Non-Incendive Systems - For Hazardous Locations

Ex ib IIA:

Model GA 5000, GEM 5000 and BIOGAS 5000 Methane Detectors; portable, battery powered with non-field-replaceable Battery Pack P/N 20087 or 2011113; intrinsically safe and providing intrinsically safe circuits ("[ib]" for Zone 1) to Model GF5.2 Temperature Probe (Connector B) and with entity output parameters as tabulated below; Temperature Code T1; -10 ºC ≤ Tamb. ≤ +50ºC.

Connector	Entity Parameters						
	Uo (V)	Io (mA)	Po (mW)	Co (uF)	Lo (mH)	Ci (uF)	Li (mH)
B	5.0	6	7	100	1000	0	0
C	10.0	5	50	100	1000	0	0

✍ Note: This device has been investigated for electrical safety features only.

For CSA (USA) the 5000 series of gas analysers are certified to Hazardous Area Classification

CLASS 2258 83 - PROCESS CONTROL EQUIPMENT - Intrinsically Safe and Non-Incendive Systems – For Hazardous Locations - CERTIFIED TO U.S. STANDARDS

AEx ib IIA:

Model GA 5000, GEM 5000 and BIOGAS 5000 Methane Detectors; portable, battery powered with non-field-replaceable Battery Pack P/N 20087 or 2011113; intrinsically safe and providing intrinsically safe circuits ("[ib]" for Zone 1) to Model GF5.2 Temperature Probe (Connector B) and with entity output parameters as tabulated below; Temperature Code T1; -10 ºC ≤ Tamb. ≤ +50ºC.

Connector	Entity Parameters						
	Uo (V)	Io (mA)	Po (mW)	Co (uF)	Lo (mH)	Ci (uF)	Li (mH)
B	5.0	6	7	100	1000	0	0
C	10.0	5	50	100	1000	0	0

✍ Note: This device has been investigated for electrical safety features only.

2.3 MCERTS

MCERTS is the UK Environment Agency's Monitoring Certification Scheme. The scheme provides a framework within which environmental measurements can be made in accordance with the Agency's quality requirements. The scheme covers a range of monitoring, sampling and inspection activities.

MCERTS promotes public confidence in monitoring data and provides industry with a proven framework for choosing monitoring systems and services that meet the Environment Agency's performance requirements.

The Environment Agency has established its Monitoring Certification Scheme (MCERTS) to deliver quality environmental measurements. The MCERTS product certification scheme provides for the certification of products according to Environment Agency performance standards, based on relevant CEN, ISO and national standards.

MCERTS certified instruments have been tested by an independent body to ensure that they meet certain performance requirements. In addition the manufacturer of an MCERTS product is regularly audited to ensure that the performance requirements of the certification are being continually met.

The 5000 series of gas analyzers have been certified to Version 3.1 of the 'Performance Standards for Portable Emission Monitoring Systems'.

2.4 CIRIA

The CIRIA guideline 'Assessing the risks posed by hazardous ground gases to buildings' proposes that gas concentrations and flow rates should be monitored.

As an example methodology, they suggest using a gas analyser to first measure flow and pressure and then afterwards to measure gas concentration.

The logging profile option offers frequency of data to be collected within a timed period which, in return, identifies a gas profile of the sample point being monitored, information about whether the sample point is performing correctly, when the peaks occur and whether air is drawn in after a certain period. This logging option is available on firmware software version 1.6.5
Versions of the GA5000 analyzer range with internal flow on firmware version 1.6.5 and above have the ability to take measurements according to the CIRIA guidelines, while still allowing other users to take the measurements as before.

3.0 The GEM5000 Gas Analyzer

3.1 The GEM5000

The GEM5000 gas analyzer is designed to monitor landfill gas extraction systems.

Benefits:

- Allows balancing of gas extraction site.
- Maximize power generation from site.
- Field proven.
- Standardizes monitoring routines.
- Easy transfer of data.
- GPS for compliance.

Features:

- ATEX certified.
- MCERTS certified.
- H_2 compensated CO.
- Calculates flow (m^3/hr) and calorific value (kW or BTU).
- Technician log-in.
- Event log.
- Two instruments in one (GA and GEM mode).
- Measures static and differential pressure.
- Simultaneous display of gases.
- Storage of changes in set-up of gas field.
- Data logging.

Applications:

- Gas extraction fields.
- Flare monitoring.
- Landfill sites.

3.2 GEM5000 standard product

Reference:

A	Hard carry case
B	In-line water trap tubing & filter
C	Gas analyser instrument
D	H2S filter (optional – if the compensated CO cell is fitted)
E	5000 series safety manual
F	Mains battery charger and adaptors: - UK - Europe - US - Australia

4.0 GEM5000 Optional Products and Accessories

4.1 Optional products

The GEM5000 gas analyzer has a number of optional products for purchase which enhance the usability and enable further analysis of data and reading information.

✍ Note: For more information on the features listed in this section please contact Sales at (800) 624-2026 or email info@qedenv.com

4.1.1 Pitot tube (optional)

The GEM5000 gas analyzer enables the use of a pitot tube to aid accurate flow measurement. The pitot tube is used for gas extraction systems and the pressure readings are taken in mbar. High gas flow is calculated in the analyzer in m^3/hr (metres cubed per hour).

4.1.2 Orifice plate (optional)

QED recommends the use of orifice plates as good practice when using the GEM5000 gas analyzer, enabling repeatability in flow measurement via a fixed method. Contact Sales at (800) 624-2026 or email info@qedenv.com if the use of Orifice plates is required.

4.1.3 Temperature probe (optional)

The GEM5000 gas analyzer has the facility to automatically display and record the borehole temperature via an optional temperature probe.

When a temperature probe is fitted the temperature reading will be displayed on the 'Main Gas Read Screen' and recorded with all other data.

✍ Note: Temperature probes with an Ex label are part of the GEM5000 Ex certification SIRA 11ATEX2197X and IECEx SIR11.0089X, and therefore certified for use under the same conditions as the analyzer.

4.1.4 Anemometer (optional)

The GEM5000 gas analyzer has the facility to automatically display and record high flow via an optional anemometer probe. It is designed to plug into the instrument and instantly provide a flow indication. An anemometer probe adds flow measurements to the professional reporting ability of the GEM5000 range along with gas concentrations, pressure and temperature.

The anemometer has a simple connection, a narrow diameter measurement head (11mm), a wide temperature operating range (up to 80°C) and indicates flows up to 40 m/sec.

When an anemometer probe is fitted to the analyzer the flow will be displayed in the 'Main Gas Read Screen' and recorded with all other data.

Flow can be measured in either m/s (gas velocity) or m^3/hr (volume flow rate). In order to calculate the volume flow rate the pipe diameter will need to be entered into the instrument, either manually or via the Landtec Systems Gas Analyser Manager, (LSGAM), software.

✍ Note: The anemometer probe is ATEX certified for use in a potentially explosive atmosphere under Ex certificate BVS 04ATEXE194.

4.1.5 H_2S filter (optional)

The GEM5000 gas analyzer has the capability to use an H_2S filter and is required as standard if the compensated CO cell is fitted and configured at the time the instrument is manufactured. H_2S gas can have a cross-gas effect on the CO reading. By using a filter, the H_2S is removed from the gas sample, therefore providing a more accurate CO reading.

The filter only needs to be used when you are trying to get rid of any possible cross gas effects H_2S might have on other gases. Do not use the filter on all boreholes.

4.1.6 Landtec Systems Gas Analyzer Manager – LSGAM (optional)

Landtec Systems Gas Analyzer Manager (LSGAM) enables the operator to maximize the operation of the gas analyzer. It enables direct communication with the unit, features a simple upload and download facility and is fully compatible with the latest Microsoft™ operating systems.

Features:

- Organization and transfer of borehole IDs and readings to and from the gas analyzer.
- Configuration of the gas analyzer.
- Flexible grouping of the IDs.
- Structured organization of transferred data.
- Automatic detection of instrument type and available options.
- Secure data mode to prevent tampering.
- First time set-up wizard.
- Enable flow measurements for GEM5000 gas analyzers.

4.1.7 GPS (optional)

An optional GPS feature is available for the GEM5000 gas analyzer. It enables the site engineer to automatically locate borehole IDs using GPS satellite signal from predefined borehole IDs uploaded from LSGAM or set on the analyzer when out in the field prior to taking a reading. The GPS reading data is stored for each measurement reading providing an audit trail confirming that a reading was taken.

4.1.8 Bluetooth

The analyzers are fitted with a Bluetooth receiver which enables the operator to download readings and upload IDs without the need to connect the analyzer to a PC via a USB cable.

5.0 GEM5000 Instrument Features

5.1 Physical characteristics of the instrument panel

Front view:

Reference:

A	Main Gas Read Screen
B	Soft-keys
C	Backlight Key
D	Menu Key
E	Pump key
F	LED Light
G	On/Off Key
H	Assistance key
I	Enter Key
J	Scroll up key
K	Scroll down key
L	Key 0 – Space key

Back view:

Reference:

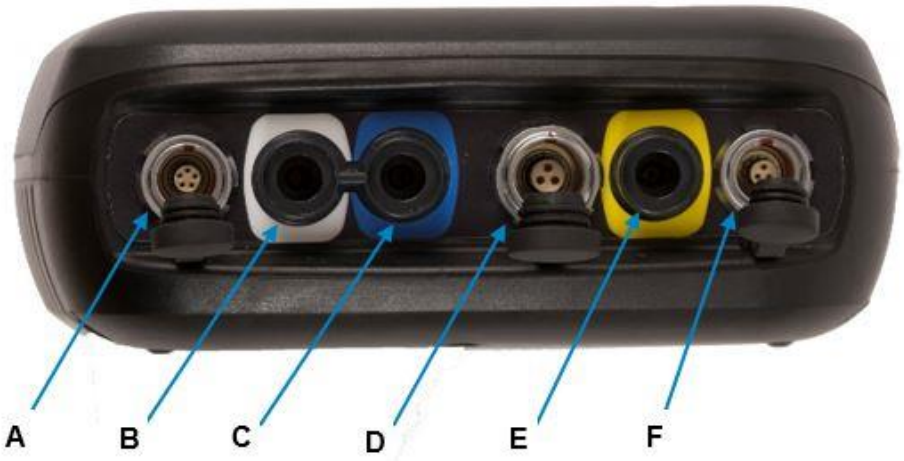
M	Model Number
N	Serial number
O	Part number
P	Certificate number
Q	Recalibrated date

5.2 Analyzer features and keys

A	Main Gas Read Screen	Start and end screen when using the instrument.
B	Soft-keys	The function of the three 'soft-keys' on the front of the instrument panel is determined by menu options taken. Functions vary from screen to screen.
C	Backlight key	Enables the operator to turn the backlight on/off on the analyzer display panel.
D	Menu key	Press the 'Menu' key to view and maintain User, Device and Operation settings.
E	Pump key	Press the 'Pump' key to start or stop the pump.
F	LED light	LED power light is visible on the front of the analyzer when the instrument is powered on.
G	On/Off key	Press the 'On/Off' key for 2 seconds to switch the instrument on and off.
H	Assistance key	Press for on-screen assistance and help.
I	Enter key	Use to accept changes, options, user inputted answers etc.
J	Key 2 – Page Up	Also 'Key 2'. Press scroll up to view further information on the instrument screen.
K	Key 8 – Page down	Also 'Key 8'. Enables the operator to scroll down to display more information.
L	Key 0 – Space key	Also 'Key 0'. Press to enter a space when entering text on the instrument screen.
M	Model Number	Instrument model type identification.
N	Serial Number	Unique identification for the instrument. Verification of the serial number will be required if Technical Support assistance is needed.
O	Part Number	Manufacturer's part number.
P	Certification Number	Displays instrument certification information.
Q	Recalibrated Date	The date displayed is the date the instrument is due to be calibrated.

5.3 Instrument connection points

Top view:



Ref:	Connection Point:	Function:
A	Connector A	Attach the USB cable for PC-to-analyzer connectivity.
B	Inlet Port & Static Pressure Port (White port)	Attach the sample tube to take a gas sample. Also used to measure the static pressure.
C	Differential Pressure Port (Blue port)	Attach the sample tube to measure differential pressure.
D	Connector B	Attach the temperature probe and also used to attach the mains charger to the analyzer for charging.
E	Gas Outlet Port (Yellow port)	The gas outlet port is the point at which the sample gas is expelled. Tubing may also be attached to the port.
F	Connector C	Attach the anemometer.

6.0 General Operational Instructions

6.1 Switching the instrument on

1) To switch on the analyzer, press and hold the 'On/Off' key. The Landtec logo will display followed by the instrument warm up.

2) Following the instrument warm up, the 'Date and Time' screen is displayed prompting the technician to set the date and time and required format.

3) When complete, select the soft-key to 'Exit' and the 'Power On Self-test' screen is displayed followed by instrument status. Instrument status displays the instruments service due date, serial number, options, service scheme and software version. Text will also display stating 'Self-test complete'.

4) Select the soft-key 'Next' to move onto the next screen and the 'Technician Login' screen is displayed.

5) Use the cursor keys to move through the list of ID's. Select either the required 'Technician ID' from the list followed by the soft-key 'Accept', or select 'Default'' followed by the soft-key 'Accept' to continue to the 'Main Gas Read Screen'.

   ✍ Note: The selected technician ID is displayed at the top left corner of the Main Gas Read Screen.

6.1.1 Power on self-test

When switched on, the read-out will perform a pre-determined self-test sequence. During this time many of the analyzer's functions are tested, including:

- General operation
- Gas flow measurement
- Calibration
- Battery charge level

During the self-test the following information is also displayed:

- Manufacturer's service due date
- The last gas check date
- Software version programmed
- Date format
- Serial number
- Operating language
- The currently enabled sales option

✍ Note: The self-test should only be done with the analyzer sampling fresh air.

6.2 Switching the instrument off

1) To switch off the analyzer, press and hold the 'On/Off' key, at which point a clean air purge will be carried out and the instrument will then switch off.

2) If for any reason the analyzer 'locks up' and will not switch off in this manner, press and hold the 'On/Off' key for 15 seconds; this will force the instrument to switch off.

6.3 Instrument status icons

The following icons may be displayed on the instrument screen:

Icon	Description	Icon	Description
	**Battery charge state** Gives the operator an estimation of the battery charge state. For example 100% gives about 8 hours use in the field and 50% would mean that there is approximately 4 hours battery life remaining.		**Battery charge state** Indicates less than 2 hours of charge remaining.
	**Pump status** This icon is displayed along with a counter showing the pump run-time. This counts down where the operator has specified the pump run-time; if not it counts up; the icon turns red when stalled.		**Pump stalled** This icon is displayed when the pump stalls. The instrument's gas inlet (or outlet) may be blocked. This warning is most commonly caused by a water-logged or dirty sample filter. Change the sample filter and check for obvious blockages in the sample tubes. Alternatively, a small amount of adjustment can be made to the low flow detection point to compensate for minor changes in the performance of the pump fitted to the instrument.
	**GPS signal strength** This icon shows the signal strength the analyzer's GPS module is able to provide. Full, okay and fair strength respectively.		**GPS failure** The GPS was unable to get a line of sight lock on enough satellites. Or, it may be that it hasn't had time to get a lock.
	This indicates when Bluetooth has been enabled. The color changes from gray to blue when connected.		**Language** This icon indicates the currently selected operating language. This can be changed via the main menu.
	**Data logging** This icon indicates that the data logging feature is in operation.		**Service overdue** This icon indicates that the analyzer is overdue for service
	**Legacy mode** This icon indicates that the analyzer is in legacy mode and hence is ready to connect to a PC.		**USB disabled** This icon indicates that the analyzer has reached a battery critical state, and hence has turned off its USB connectivity.

6.4 Instrument LED power states

When the instrument is powered on a LED power light is visible on the front of the analyzer, located above the 'On/Off' key. The following LED power light states are as follows:

Steady yellow	Unit turning on. This will extinguish when software has loaded correctly.
Flashing (rapid)	Unit is powering off.
Flashing (slow)	Power off is being delayed for purge/shutdown handling.
Flashing yellow	Unit is turning off due to power button being pressed.
Flashing red	Unit is turning off due to critically low battery.

✍ Note: Pressing and holding the power button for ~20s resets the analyser.

6.5 Changing between parameters

By default, the instrument displays the 'Main Gas Read Screen' (for gas measurement). The instrument will return to this screen after power on or when returning from the menus. The 'Scroll' keys can be used to switch to another measurement screen.

6.6 Entering data

During normal operation the operator may be prompted to enter data or information via the keypad, i.e. entering an ID code or setting an alarm level.

When entering data into the instrument all fields are fixed format and are populated from the left.

Text:
Entering text uses similar multi-tap functionality as a mobile phone. Key the numeric/alpha key pad the required number of times to select the appropriate letter. To key numeric data continue to press the numeric/alpha key until the required number is displayed.

Numeric data:
To enter a new date 09/15/116 the operator would type in 091516 using the numeric keypad in the following sequence:-

* 0_/__/__
* 09/__/__
* 09/1_/__
* 09/15/__
* 09/15/1_
* 09/15/16

Press the 'Enter' key to confirm/accept data keyed.

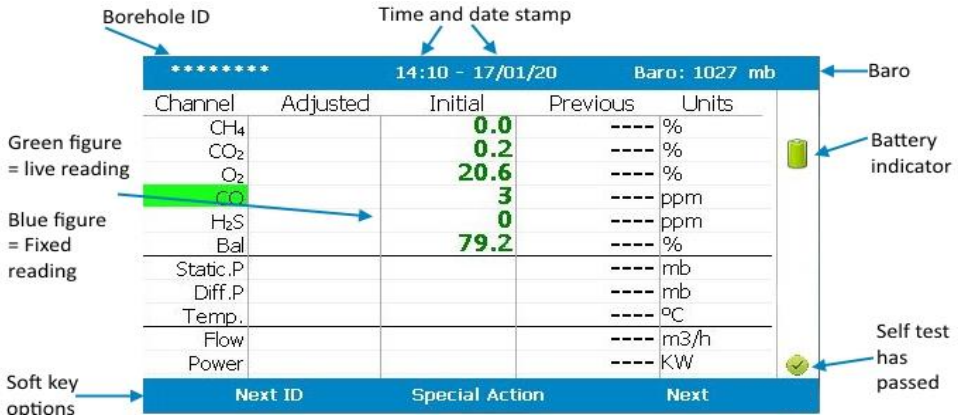
Any mistakes can be corrected using the soft-key 'Delete' which will delete the last digit typed. Alternatively, the sequence can be retyped before the 'Enter' key is pressed and the existing numbers will be pushed off the screen.

✍ Note: The instrument will not allow invalid data to be entered; this should be deleted and re-entered.

6.7 Instrument main gas read screen

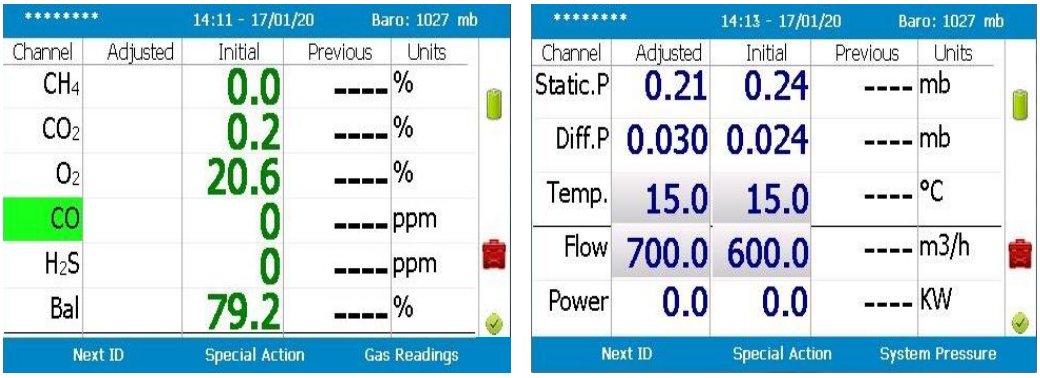
The 'Main Gas Read Screen' is considered to be the normal operating screen and all operations are carried out from this starting point.

The actual data shown on this display will depend on the version of the instrument and the options that have been selected.



Main Gas Read Screen

You can also press key 2 and access a zoomed version of the main read screen, once you have entered this mode, simply use keys 4 and 6 to switch between the gases and pressures. Examples of both screens can be seen below:



Zoomed version

6.8 Storage

The analyzer should not be exposed to extreme temperature. For example, do not keep the analyzer in a hot car. When not in use, analyzers should be kept in a clean, dry and warm environment, such as an office. Protect the analyzer with either the soft carry case or store in the hard carry case provided with the instrument.

The instrument should be discharged and fully charged at least once every four weeks, regardless of indicated charge state.

6.9 Battery/charging

The battery used in the 5000 series of gas analyzers is nickel metal hydride and manufactured as a pack from six individual cells. This type of battery is not so susceptible to the top-off charging 'memory effects' as nickel cadmium batteries, although it is not recommended that the unit is given small top-off charges.

✍ Note: **To reach optimum charge, it is recommended that the instrument is switched off when being charged and remains switched off during the charging process.**

A full charge will take approximately 4 hours from a fully discharged battery.

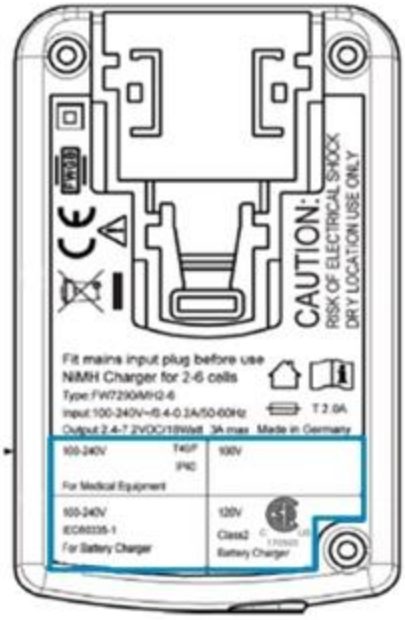
⚠ **Warning**	The battery charger is NOT covered by the Ex certification. The battery must be charged only in a safe area.

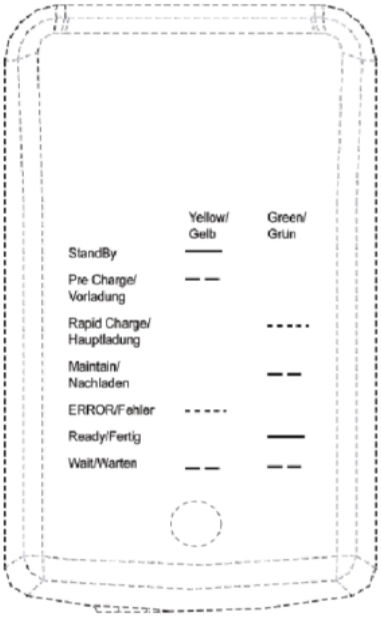
The battery charger is intelligent and will indicate when the unit is charging and charged.

The instrument must be charged ONLY using the battery charger supplied with the instrument. The battery charger supplied is intended for indoor use only. Please ensure adequate ventilation while charging. Typically, a fully charged battery will last 7-8 hours. A quick 30 minute charge can be used to give approximately one hours use in the field but this may shorten the battery life. Temperature can dramatically affect the battery life; please take this into account when estimating battery life.

✍ Note: Connect the charger to the mains attaching the appropriate adaptor.

Power supply front and back drawing:





Charger:	Input voltage:	100-240V AC +/- 10%
	Input frequency:	50-60Hz +/- 10%
	Input current:	0.4A@100VAC .. 0.2A@240VAC
	Output voltage:	10.1VDC max
	Output current:	1.5A max

✍ Note: This charger has been internally restricted to 1.5A

6.10 Cleaning instructions

Do NOT use any cleaning agents to clean the analyzer or battery charger as they may have an adverse effect on the safe use of these devices.

6.11 Memory

The analyzer's memory is stored in a readings and configuration database. The analyzer will prompt when its memory is full, and you will not be able to store any further readings. Please download your readings via LSGAM or the Basic Download Software and then clear the memory.

✍ Note: The analyzer should never be stored for prolonged periods with valuable data in its memory. It is advisable to download all readings to LSGAM at the end of each day's monitoring. To clear the memory, please refer to the LSGAM operating manual.

6.12 Warning and error codes

When switched on the instrument will perform a predetermined self-test sequence taking approximately ten seconds. During this time many of the instrument's working parameters and settings are checked. If any operational parameters are out of specification or if the pre-programmed recommended calibration/service date has passed, errors or warnings may be displayed.

✍ Note: For further information please refer to section '10.0 Problem Solving'.

7.0 Operator Settings

7.1 Menu key

The 'Menu' key enables the operator to select options to set up specific parameters and perform operational tasks prior to sample readings being taken or to view data and information stored in the instrument.

1) Select the 'Menu' key on the front of the analyzer and the following screen is displayed:

2) Press the relevant numeric key on the analyzer keypad to select the required option.

3) To exit this menu, select the soft-key 'Exit' on the front of the analyzer and the operator is returned to Main Gas Read Screen.

7.2 Operation settings

To access the 'Operation settings' menu, select the 'Menu' key on the front of the analyzer. The following menu is displayed:

7.2.1 Timers

The timers function enables the operator to set standard purge times and set auto-power off if the unit is untouched for the period of time specified.

1) Select 'Key 1 – Timers' and the following screen is displayed:

1) Select 'Key 1' to edit the purge time. Enter the 'Pump Running Time' in seconds; this is the length of time you wish to run the pump to draw the sample, e.g. key in 030 then press the 'Enter' key to accept.

2) Select 'Key 2' to edit the auto power off time. Enter the 'Auto power off' in minutes; the instrument will automatically power off to preserve the battery life after the specified time if no activity has occurred on the instrument. Press the 'Enter' key to accept.

3) Select the soft-key 'Exit' key to exit the screen and return to the 'Operation settings' menu.

✍ Note: Setting the purge time and auto power off functions to zero, disables the option. It is not recommended to reduce the purge time to below 30 seconds.

7.2.2 Gas Check

This option displays the 'Gas Check' menu and enables the operator to zero and span the gas channels on the instrument. Historical/previous gas checks data can also be viewed and factory settings can be restored.

1) Select the 'Menu' button on the front of the analyzer to display the 'Device Settings' menu. Press the soft key to display 'Operation Settings'.

2) Select 'Key 2 – Gas Check' and the following menu is displayed:

3) For more information about the Gas Check Menu please refer to section 9.0 – Calibration.

4) Select soft-key 'Exit' to exit operation settings and return to the main screen.

7.2.3 View data

This option enables the operator to view the readings collected and stored on the instrument. Readings many be downloaded to the optional LSGAM software if further analysis is required.

1) Select the 'Menu' button on the front of the analyzer to display the 'Device Settings' menu. Press the soft-key to display 'Operation Settings'.

2) Select 'Key 3 – View Data' and the following screen is displayed:

3) Toggle through the reading by selecting 'Key 4 – Scroll left' and 'Key 6 – Scroll right' on the analyzer. Select 'Key 2 – Page up' and 'Key 8 – Page down' to page through the auxiliary channels listed.

4) Select the soft-key 'Filter' to filter the data by sample point ID, or specify before or after date. Press the soft-key 'Exit' to exit the filter menu and return to the 'View Data' screen.

5) Select the soft-key 'Delete' followed by the appropriate soft-key to delete a single reading or all filtered readings. Press soft-key 'Cancel' to cancel the deletion request.

6) Select the soft-key 'Exit' to exit the view data screen.

7.2.4 Set alarms

This option enables the operator to define the conditions for which an alarm/target will be triggered. These conditions apply to the general operation of the instrument and are not ID specific. A summary of the alarm settings can be found in 'Key 3 – Summary'.

Types of alarms

Common Alarms – Are non-ID specific alarms which apply to all the readings taken with the analyzer.

ID specific alarms – Are ID specific, i.e. they will only trigger when a certain Id is being used.

Tuning/targets – You can also set targets for your gas channels; these will highlight gas channels green as oppose to when they alarm (yellow). These can be common or ID specific.

Setting up alarms/targets

1) Select the 'Menu' button on the front of the analyzer to display the 'Device Settings' menu. Press the soft key to display 'Operation Settings'.

2) Select 'Key 4 – Set Alarms' and the following menu is displayed:

3) Select the corresponding key to select the gas for which you wish to set an alarm/target trigger for, followed by 'Key 1' to change the trigger condition of an alarm.

4) To manually adjust the alarm/target set press (<) 'Key 4 – Scroll left' or 'Key 6 – Scroll right' (>) and enter the trigger value. Once you are happy, press the middle soft key for 'save'.

5) For pressure, temperature and flow alarms, press the left soft key for 'Secondary' and then select the corresponding key to select the channel for which you wish to set an alarm trigger for, followed by 'Key 1' to change the trigger condition of an alarm/target. Once you are happy, press the middle soft key for 'save'.

6) To disable all alarm settings select key 0 – 'Disable All'

✍ Note: ID specific alarms cannot be added/edited on the analyzer, to add/edit ID specific alarms, please use the optional LSGAM Software.

7.2.5 Adjust flow fail

This option enables the operator to adjust the flow fail tolerance of the instrument, i.e. the operator can adjust the sensitivity for when the pump will stop operating on the presence of a blockage or low flow.

1) Select the 'Menu' button on the front of the analyzer to display the 'Device Settings' menu. Press the soft-key to display 'Operation Settings'.

2) Select 'Key 5 – Adjust Flow Fail' and the following screen is displayed:

3) Manual adjustment of the flow fail is available via this option and can be carried out with use of 'Key 4 – Scroll left' (<) less sensitive and 'Key 6 – Scroll right' (>) more sensitive.

4) Select the soft-key 'Save' to store the setting or select soft-key 'Exit' to exit the screen without saving the change.

5) The operator will return to the 'Operation settings' menu.

✍ Note: The default setting displays the bar in the centre. BEFORE altering this setting, please contact Technical Support at (800) 968-2026 or email landtec_support@gedenv.com

7.2.6 Technician login

This option enables the operator to select or change a pre-defined technician login and all subsequent readings will be tagged with this Technician Login ID. The technician ID must already have been created using the LSGAM software and uploaded to the instrument.

1) Select the 'Menu' button on the front of the analyzer to display the 'Device Settings' menu. Press the soft key to display 'User Settings'.

2) Select 'Key 6 – Technician login' and the following screen is displayed:

3) Use the cursor keys to move throughout the list of IDs displayed; select the 'Enter' key to select choice of ID, default if no IDs are listed or soft-key 'Skip' to skip the selection.

4) The operator will return to the 'User settings' menu.

✍ Note: If no technicians are loaded via LSGAM, this section is skipped during start up and the 'Technician ID' icon is removed from the menu.

7.3 Device settings

To access the 'Device Settings' menu, select the 'Menu' key on the front of the analyzer to display the 'Operating Settings' menu followed by the soft-key to display 'Device Settings' menu. The following menu is displayed:

7.3.1 Date and time

This option enables the operator to set the instrument date and time or to receive and update the settings automatically from satellite signal.

1) Select the 'Menu' key on the front of the analyzer to display the 'Device Settings' menu followed by 'Key 1 – Date and Time' and the following screen is displayed:

2) Select 'Key 1 – Set Date' and key in the required date. Type the date using the numeric keypad. Press the soft-key 'Date Format' to toggle and select the required date format i.e. dd/mm/yy. Press the 'Enter' key to confirm and update the date setting.

3) Select 'Key 2 – Set Time' and key in the required time (hh:mm). Type the time using the numeric keypad and press the 'Enter' key to confirm the update.

4) The operator may also change the default time zone. Selecting the 'Key 4 Scroll-left' or 'Key 6 – Scroll right' to move through the different time zones. Press the 'Enter' key to confirm your default setting.

5) Select 'Key 3' to toggle between 'Manual Update' and 'Automatic Update' in order to choose how the date and time is set if updating from satellite signal.

Manual	Used to manually obtain and update the date and time from the satellite signal when requested. Select soft-key 'Set now' to set date and time from satellite when available.
Automatic	Used to automatically update the date and time received from the satellite signal when available. This option is only available when the GPS option is fitted to the analyser at the time of manufacture.

6) Select the soft-key 'Exit' to exit and return to the 'Device Settings' menu.

7.3.2 Bluetooth

This option enables the operator to set and utilize Bluetooth technology. This may be useful when downloading gas readings from the analyzer to the PC instead of connecting the analyzer to a PC via a USB cable. Bluetooth may also be used to transfer Site IDs to other 5000 series gas analyzers if required.

1) Select the 'Menu' key on the front of the analyzer to display the 'Device Settings' menu.

2) Select 'Key 2 – Bluetooth' and the following screen is displayed:

3) Enter the 'Pairing PIN' value when prompted by your computer for the device's pairing code.

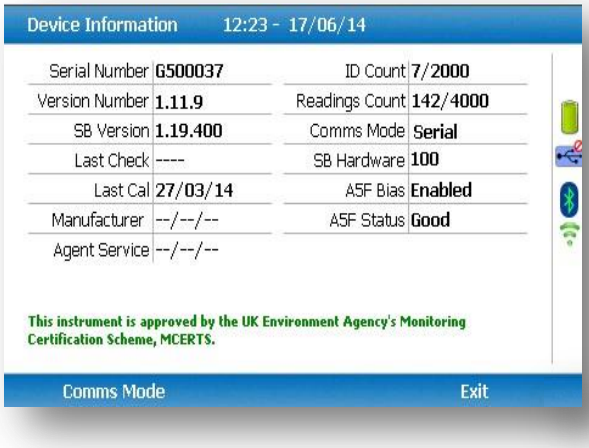
4) Select soft-key 'Exit' to exit the screen and return to the 'Device Settings' menu.

7.3.3 Device information

This option displays default instrument information and settings such as serial number, service due date, last zero calibration date and last span calibration date.

1) Select the 'Menu' key on the front of the analyser to display the 'Device Settings' menu.

2) Select 'Key 3 – Device Information' and the following screen is displayed:



3) The information displayed on this screen is informational only and cannot be edited by the operator. The operator may be asked serial number, service due date and version number information when contacting QED.

✍ Note: The communications setting 'Legacy' mode is for use with GAM >=v1.5. GA5K mode is reserved for future applications – use with 5000 series updater tool

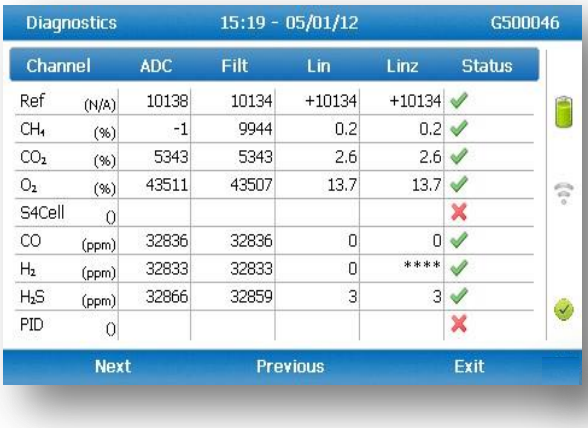
4) Select soft-key 'Exit' to exit the screen and return to the 'Device Settings' menu.

7.3.4 Diagnostics

This option enables the Technical Support Team to identify and resolve issues with the instrument and settings. If required, the operator may be asked to confirm the diagnostics displayed.

1) Select the 'Menu' key on the front of the analyser to display the 'Device Settings' menu.

2) Select 'Key 4 – Diagnostics' and the following screen is displayed:



3) Select soft-key 'Next' to display the next screen, 'Previous' to return to the previous screen, or select soft-key 'Exit' to exit this screen and return to the 'Device Settings' menu.

✍ Note: For further information please contact Technical Support at (800) 968-2026 or email landtec_support@gedenv.com

7.3.5 Navigation (optional)

Navigation is On

This option enables the operator to switch the 'GPS Navigation' functionality on or off. (This is optional and dependent upon purchasing the navigation option).

1) Select the 'Menu' key and the 'Device Settings' menu is displayed.

2) Select 'Key 5 – Navigation On' to switch on the GPS navigation functionality or 'Key 5 – Navigation Off' to switch the GPS navigation functionality off.

Navigation is On

Navigation is Off

✍ Note: For further information please refer to section '8.0 – Taking Readings'.

7.4 User settings

To access the 'User settings' menu, select the 'Menu' key on the front of the analyzer to display the 'Operating Settings' menu followed by the soft-key to display 'User Settings' menu. The following menu is displayed:

To exit the user settings menu select the soft-key 'Exit'.

7.4.1 Operating language

This option enables the operator to specify the operating language displayed for the instrument.

1) Select 'Key 1 – Operating Language' and the following screen is displayed:

Set the required language for the gas analyser by selecting the appropriate function key. Choose from, on the first page:

Key 1	English
Key 2	Spanish
Key 3	French
Key 4	German
Key 5	Italian
Key 6	Portuguese

Use the soft-keys to move to the next page for further language options, including simplified Chinese

2) To exit this option, select the soft-key 'Exit' and the operator is returned to the 'User Settings' menu.

7.4.2 Units of measurement

This option enables the operator to specify the default units of measurement for the instrument.

1) Select 'Key 2 – Units of Measurement' and the following screen is displayed:

2) To set the required units of measurement toggle and choose from the following:

Key 1	Temperature	^{O}C ^{O}F
Key 2	Flow	scfm m3/hr
Key 3	Measurement	Inches Millimetres
Key 4	Pressure	mb "H2O
Key 5	Balance	Balance Residual N2

3) Select soft-key 'Exit' to exit this screen and return to the 'User Settings' menu.

7.4.3 ID selection

The ID selection screen allows the operator to scroll through all IDs, including those uploaded from LSGAM and added directly onto the instrument, and then make a selection. Detailed information regarding the currently selected ID, such as flow device type and pump runtime, are displayed below:-

By selecting 'Key 5' the operator can toggle between showing 30 IDs and showing 5 IDs with more detailed information relating to the chosen ID.

The technician can scroll between the IDs using the following keys on the instrument keypad:

Two (2) and eight (8) move the selection up/down
Four (4) and six (6) move the selection left/right on the list view
One (1) and three (3) move the selection left/right a page in the list view only
Seven (7) and nine (9) move the selection to first/last ID

Five (5) toggles between the 'ID with information' and 'ID list'
Return/enter key selects the desired ID and proceeds to the navigation or reading screen.

If there are no IDs present the technician can either add a new ID or press the enter key on the instrument keypad to return to the previous screen.

Soft keys:

Left - Select 'No ID' and go to the purge/reading screen.
Center - Enabled when there is a list of IDs, allowing the technician to dynamically filter the IDs displayed in the list.
Right - Allows the technician to add a new ID to the instrument 'in the field'.

✍ Note: If your analyzer has firmware version v1.12 or greater, used IDs will have a strikethrough.

Changing the sort order

By default the IDs are sorted in the order in which they were transferred to the instrument. To change the sort order between unsorted, sort by name or sorted by distance to travel press Key 0.


Sorted by original order (not sorted)


Sorted alphabetically


Sorted by distance to travel

✍ Note: Only available when GPS is enabled

For analyzers with firmware v1.12 and above:

1) Press the menu key

2) Press the middle soft key for 'User Settings'

3) Press key 3 – 'ID options

   a. Key 1 to change the sort order
   b. Key 2 to change how the IDs are displayed
   c. Key 3 to clear the line through on the current ID being used
   d. Key 4 to remove the line through on all IDs

7.4.4 Routes

Using the optional LSGAM Software, you can upload a route. This is a predefined list of IDs that you can go through in an order. This feature is useful if you have a certain order to complete your IDS in.

Furthermore if your GA5000 has v1.12 or higher firmware it will strike through your IDs once you have used them.

✍ Note: If the analyzer is set to "route mode" (v1.12 and above), the filter box will no longer be there, as you cannot filter in this mode. It will be replaced by "Route" and the route name.

7.4.5 Adjust backlight

This option enables the operator to adjust the backlight (brightness). Having this set to a darker setting will help preserve the battery power

1) Select 'Key 4 – Adjust Backlight' and the following screen is displayed:

2) Keys 4 and 6 can be used to adjust the brightness of the display screen.

   'Manual' disables the backlight timeout.

3) Select the soft-key 'Save' to store the setting or select soft-key 'Exit' to exit the screen without saving the change.

4) The operator will return to the 'User settings' menu.

Selecting 'Key 1' allows the operator to configure the dimmer settings from 'Auto Dim' to 'Auto Off' in order to help preserve power consumption when data logging.

This icon represents 'Auto Dim' – this enables the backlight idle timeout, which means the backlight will go dim after a specified period of inactivity. This will help save battery life.

This icon represents 'Auto Off' – this switches the backlight off, saving power.

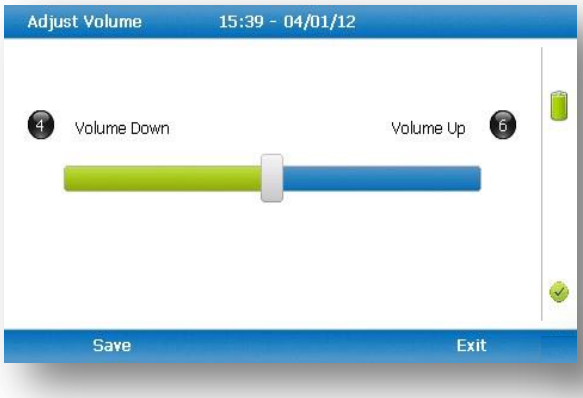
✍ Note: The manually set contrast setting is retained when the read-out is switched off and may require resetting when next switched on.

7.4.6 Adjust volume

This option enables the operator to adjust the volume for the internal speaker, for example the alarm tone. A lower setting will help preserve the battery power.

1) Select the 'Menu' button on the front of the analyzer to display the 'Device Settings' menu. Press the soft-key to display 'User Settings'.

2) Select 'Key 5 – Adjust Volume' and the following screen is displayed:



3) Manual adjustment of the volume is available via this option and can be carried out with use of 'Key 4 - Scroll left' (<) volume down and 'Key 6 - Scroll right' (>) volume up.

4) Select the soft-key 'Save' to store the setting or select soft-key 'Exit' to exit the screen without saving the change.

5) The operator will return to the 'User settings' menu.

7.4.7 User Prompts

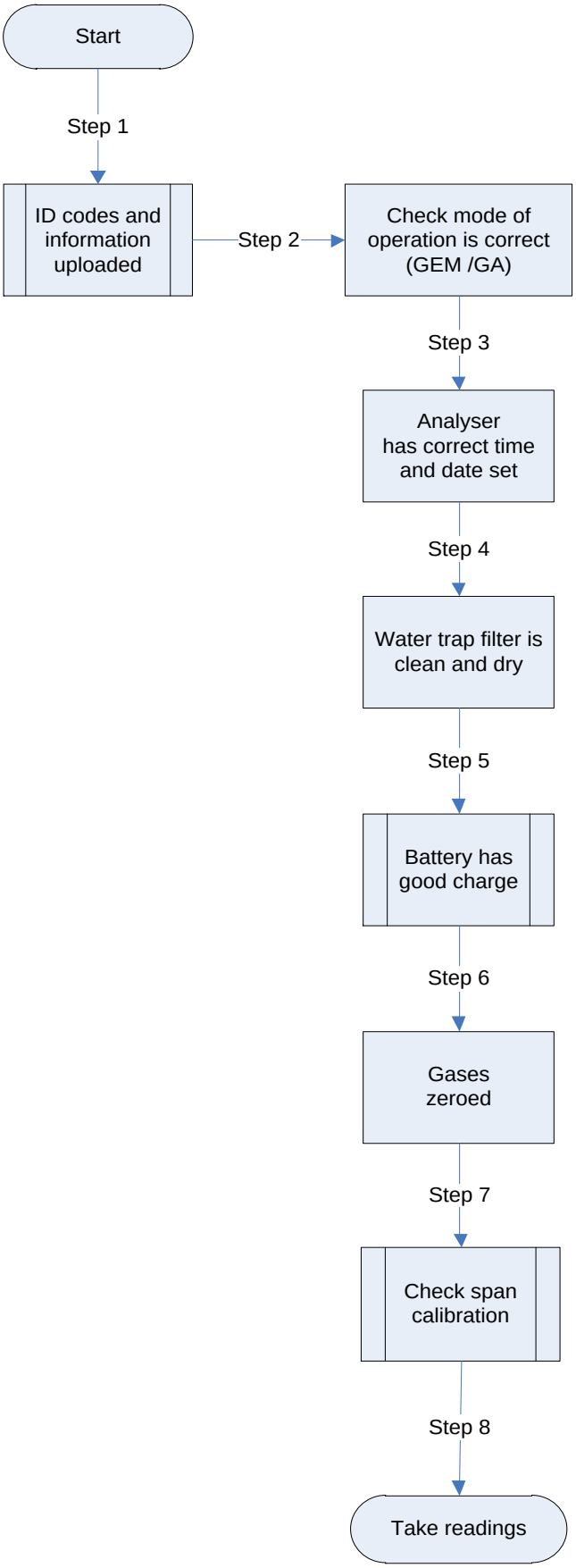
This option enables the operator to either turn on or off the context-sensitive user prompts which are displayed during the gas sample process. The analyzer will have the user prompts on when it is first used, so if they are no required they can be switched off by selecting soft-key '6' and this will now be its default setting. Prompts can be switched back on at any time by returning to this menu and selecting soft-key '6'.

7.5 Exit menu

1) Press the 'Menu' button on the front of the analyzer to exit settings.

8.0 Taking Readings

8.1 Preliminary checks before taking readings (best practice)



Prior to use, it is good practice to ensure that:

Step 1 If using LSGAM - all necessary ID codes and information have been uploaded from LSGAM to the analyzer. Please see section 8.1.1 for more information on this.

Step 2 Check the 'Mode of Operation' is correct. Choose either GEM5000 for gas extraction monitoring analyzer or GA5000 for landfill gas analyzer. Change using 'Special Actions'.

Step 3 The instrument has the correct time and date set.

Step 4 The water trap filter is fitted and is clean and dry.

Step 5 The battery has a good charge (minimum 25% charge, even if only a few readings are required).

Step 6 The gas channels have been zeroed, without gas concentration present.

Step 7 If necessary check the span calibration with a known concentration calibration gas.

Step 8 Take readings.

⚠ **Warning**	Inhaling hydrogen sulphide gas (H_2S) or other harmful gases can cause death. It is the responsibility of the user to ensure that he/she is adequately trained in the safety aspects of using H_2S and other harmful gases. In particular, where hazardous gases are being used the gas exhausted from the analyser must be piped to an area where it is safe to discharge the gas. Hazardous gas can also be expelled from the instrument when purging with clean air.

Good practice

- Travel to site with the gas analyzer in the vehicle's interior - not in the trunk or truck bed, where it may be subjected to extremes of temperature and possible shock damage. Do not place the gas analyzer against anything hot (e.g. gas extraction pipe, car body or in an unattended car during the summer) as this will cause a temperature increase in the gas analyzer and may cause erroneous readings.

- When moving around a site, protect the gas analyzer from strong direct sunlight and heavy rain.

- Always use the water trap! If the water trap becomes flooded, change the filter and ensure all tubes are clear of moisture before re-use.

  ✍ Note: If the exhaust of a 5000 series gas analyzer is connected to a pressurized system then this results in a flow of gas out of the inlet flow port.

8.1.1 Creating an ID

There are two different methods to creating an ID, either via LSGAM or via the instrument.

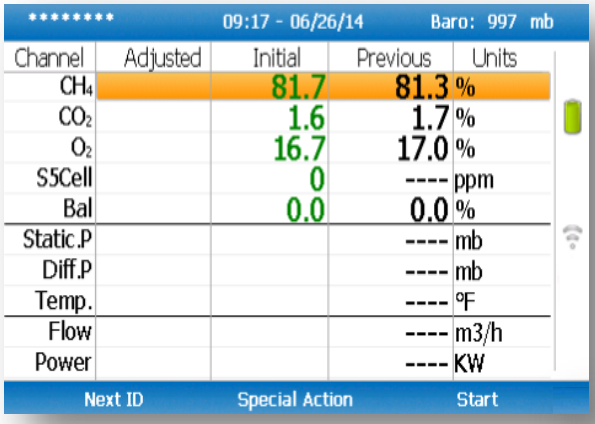
If created on the analyzer, you can only fill out basic information, such as ID code, description and ID type. Whereas on LSGAM, you can assign site and ID questions (please see below), assign flow devices, input GPS coordiantes etc.

To create an ID on LSGAM please consult the LSGAM operating manual. To create an ID on the instrument:

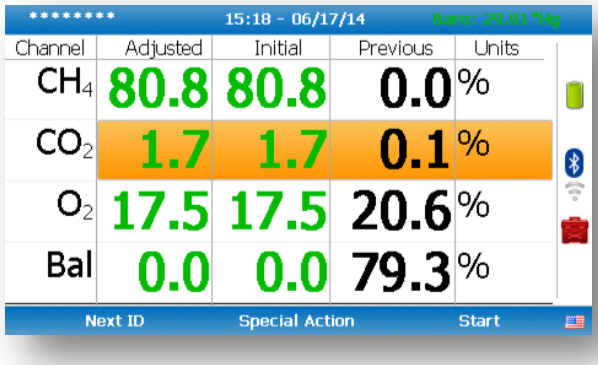
1) Press the left blue arrow key for 'Next ID'
2) Press the right blue arrow key for 'Add'
3) Input an ID code using the keypad
4) Press enter
5) Using the corresponding number to input different properties of the ID
6) Once you are happy, press the middle key for 'add'

8.2 Change screen layout

Use key 2 to toggle between 2 different ways of viewing the gas reading screen:



Default view



You can use key 4 and key 6 to switch between the gases page and the pressure & flow page. This feature is only available on analyzers running on firmware version 1.11 or later.

8.3 Answering site questions

Prior to taking the readings at a particular site, the site questions should be populated, this is only necessary when using site questions, if not, please proceed with the reading as normal. This is accessed via the 'Special Action' menu. The answers to these questions are then stored and appended to each reading stored thereafter, until the site questions are updated for another site. You will need LSGAM software to create site questions and if you are using LSGAM, this data will be uploaded to LSGAM along with the reading data.

8.4 Answering ID questions

Prior to, or after, you have taken the reading, the ID questions should be populated, this is only necessary when using ID questions, if not, please proceed with the reading as normal. When you have uploaded IDs with ID questions assigned to them (LSGAM software required), you will be prompted to answer these questions at the end of the reading, this means that the answer only equates to that reading.

8.5 Special action

This menu enables the operator to perform the additional following functions out of sequence if so desired.

1) From the 'Main Gas Read Screen' select the soft-key 'Special Action' and the following menu is displayed:

✍ Note: The list of special action options displayed on the special action menu is dependent upon device type and sequence.

The following actions may be available:

Action	Function
Key 1 – Simple Gas	This action enables the operator to take a quick gas reading. The pump will start running automatically when this key is selected. The operator can stop the pump by pressing the pump key on the keypad at any time and the reading can then be stored by selecting soft-key 'Store'.
Key 2 – Site Questions	This action enables the operator to update site questions prior to taking a reading.
Key 3 – ID Questions	This action enables the operator to update ID questions specific to sample points prior to taking a reading.
Key 4 – Flow	This action enables the operator to measure internal flow first when taking a reading. Connect the blue hose to the sample point. The yellow hose can be vented a safe distance from the sample point or re-circulated back into the system. Select either soft-key 'Zero Flow',' Flow Options' or 'Start' to commence internal flow. Select soft-key 'Store' to store and record the reading.
Key 5 – Enter Temperature	This action enables the operator to manually enter a temperature reading if not using a temperature probe prior to taking a gas measurement.
Key 6 – Start Logging	This action enables the operator to leave the analyzer unattended to take samples at a predetermined time. The reading interval and pump run times may be edited prior to commencing the logging cycle.

8.5.1 Configuration of the data logging option

1) Connect the gas inlet (white port) to the sample point. The yellow exhaust hose can be vented a safe distance from the sample point; do NOT re-circulate back into the system.
2) By selecting 'Next ID' the operator can select the ID which is being sampled at present.
3) Once the ID has been chosen the analyzer will commence and complete its clean air purge cycle.
4) To gain access to the data logging option the operator will be required to select the 'Special Action' key to obtain the special user options. The data logging option can then be selected via 'Key 6' to configure the logging parameters.
5) Once the operator has confirmed the logging parameters, select soft-key 'Start Logging'.
6) Once the logging function has been activated the analyzer will carry out a 30 second warm-up (displayed below the temperature read out at the right of the main gas read screen) and begin the first sample.
7) If for any reason during the logging cycle the inlet port becomes blocked, the analyzer will sense this as a 'Flow Fail' and the pump will automatically retry until the reading can be obtained. As such care must be taken when positioning the sample tubing to ensure water/moisture ingress does not occur.
8) Select soft-key 'Stop Logging' to stop logging if required.

8.5.2 Profiling option

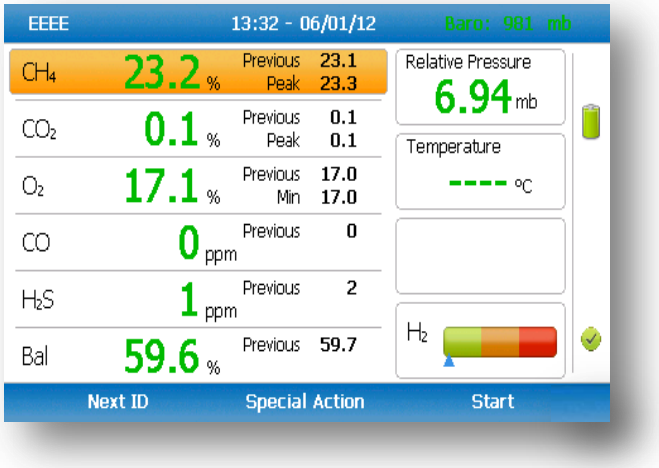
1) The 'Logging Mode' center soft-key toggles between 'Logging Mode' and 'Profiling Mode' and pressing it will change the mode to the one the soft-key describes. For example, when on the profiling page the key will display as 'Logging Mode' and when on the logging page the key will display as 'Profiling Mode'.

2) To edit the parameter the operator will be required to select 'Key 3' to select the number of reading required. Once the number of readings has been updated press the return key to confirm parameter setting.
3) By selecting 'Key 2' the operator can edit the logging interval of their logging preferences and then confirm the amendments by pressing the return key.
4) Once the logging parameters are confirmed, commence the logging by selecting the 'Start Logging' key.
5) If for any reason during the logging cycle the inlet port becomes blocked, the analyzer will sense this as a 'Flow Fail' and the pump will automatically retry until the reading can be obtained. As such care must be taken when positioning the sample tubing to ensure water/moisture ingress does not occur.
6) Select soft-key 'Stop Logging' to stop logging if required.

Select the soft-key 'Exit' to exit this menu and return to the 'Main Gas Read Screen'.

8.6 GEM analyzer in GA mode

The operator may toggle between GEM (a gas extraction monitor) and GA (a landfill gas analyzer) mode of operation if required. From the 'Special Action' menu, select the middle soft-key to toggle between GEM and GA Mode.



✍ Note: For operating instructions on how to use the GA5000 mode of operation, please refer to the GA5000 gas analyzer operating manual.

8.7 The gas flow measurement screen

The GEM5000 gas analyzer enables gas and flow measurements to be recorded by using:

- A flow device i.e. a PITOT tube, Orifice plate, Accu-Flo or anemometer.
- A temperature probe.

The GEM5000 instrument has the extra functionality to measure the calculated calorific value of the gas. The site engineer uses the information recorded by the analyzer to make adjustments to the gas flow for specific boreholes. The initial and adjusted flow rates are recorded.

8.8 How to use an anemometer (optional)

The GEM5000 gas analyzer has the facility to attach an anemometer device enabling the site engineer to measure the flow of gas within an extraction system. The anemometer can be set to display two values; m/s (meters per second) and m^3/hr (metres cubed per hour).

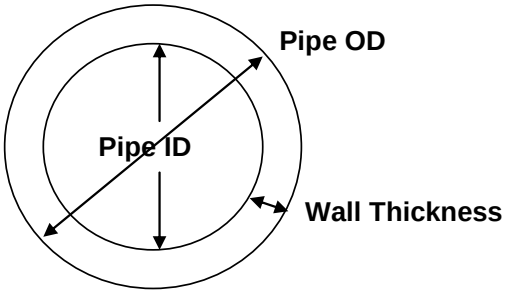
It is best practice to take the gas reading first before taking the flow reading with the anemometer attached.

If using a 'borehole ID' the internal pipe diameter can be predetermined in the optional LSGAM software. Once set, the site engineer cannot edit the pipe diameter setting.

If the site engineer is not using a borehole ID or the pipe diameter is not set in LSGAM the operator will be prompted to enter a pipe diameter with a new ID on the analyzer. Select soft-key 'Next ID' from the Main Gas Read screen, followed by soft-key 'Add' and add a new borehole location.

In order to use the anemometer it is important to know the internal diameter (ID) of the pipe if you want to calculate the flow in m^3/hr (metres cubed per hour). This must be the internal diameter not the outer diameter (OD) i.e. pipe outer diameter minus twice the pipe wall thickness.

For example:



If you do not have any suitable monitoring points you will need to drill (tap of ¾" BSP pipe thread) a hole in the piping of between 25mm and 30mm in diameter to seat the conical fitting on the anemometer (which is roughly between 20mm to 34mm). When not in use the hole can be re-sealed with a ¾" BSP male bung.

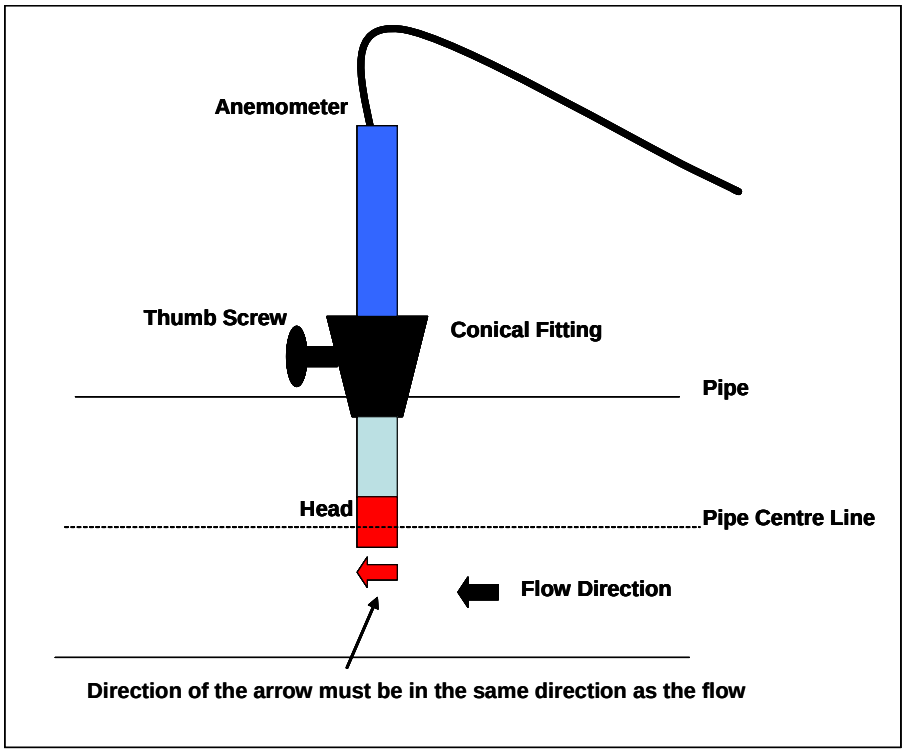
✍ Note: When the anemometer is not in use the conical fitting should be placed over the probe to protect it.

The anemometer must fit centrally (the conical fitting must be set on the probe to half the pipe ID before insertion). The arrow on the tip of the probe must point in the direction of the gas flow.

✍ Note: Use the thumb screw to help align the direction of the probe into the gas stream.

Flow readings are most accurate when there is laminar flow (not turbulent). Turbulence can be caused by a change in pipe direction or restriction. Ideally, upstream you want at least 20 times the pipe ID along the length of the pipe without restriction or bend. Downstream, you want at least five times the pipe ID along the length of the pipe i.e. for a 100mm ID you need 2000mm of clear pipe upstream, 500mm downstream.

Example to show anemometer fitting into the sample point:



Instructions for use:

1) Attach the anemometer to 'Connector C' (refer to section 5.3 – Instrument connection points).

2) Place the anemometer into the pipe (sample point) ready to take the reading.

3) To take a flow measurement when using an anemometer, follow the instructions displayed on the analyzer. When the reading has stabilized press the 'Enter' key to store the reading.

Anemometer cleaning instructions:

General handling tips:

- Protect the probes against severe vibration.
- Do not kink the connector cable (risk of cable breakage).
- Never allow hard objects to contact rotating impellers.
- Always carry out probe cleaning according to the cleaning instructions.
- Never immerse probes in solvent.
- Never blow probes through with compressed air.
- Allow hot probes to cool slowly, never cool by plunging them in cold water etc.

Cleaning instructions:

- Instrument and probe must be switched off or disconnected prior to cleaning.

Vane probes:

- As the probes are highly sensitive measuring instruments, they must be cleaned with great care.
- Fibres or other foreign bodies can be carefully removed with fine tweezers. When doing so, take care not to bend or otherwise damage the vanes or the spindle.
- The adjustment of the bearing screws must never be changed. This can result in an erroneous measurement.
- Never allow hard objects to contact rotating impellers.
- Cleaning agents that extract the plasticizer from the plastic are never to be used for plastic probes (practically all solvents).

Cleaning the probes – best practice:

✍ Note: Use soapy water.

Cleaning example:

1) Carefully, swish the top part of the impeller back and forth in clean soapy water for approximately 10 minutes. Then swish the top part of the impeller back and forth in clean soapy water. If soapy water is used as a cleaning agent it is advisable to wash out the soap solution thoroughly with distilled water.

2) After cleaning the probe, rub it dry with a clean, dry cloth.

8.9 How to use a pitot tube (optional)

The GEM5000 gas analyzer enables the site engineer to take gas measurements using a pitot tube. The pitot tube is used for gas extraction systems and the pressure readings are taken in mbar. Gas flow is calculated in the analyzer in m^3/hr (metres cubed per hour).

Example of a pitot tube

Fitting a pitot tube to the analyzer:

1) It is important to seat the pitot tube into the monitoring point with the tip facing into the gas flow. The pitot tube should also be housed half way down the monitoring pipe. (Please refer to the anemometer instructions, which detail how to calculate the pipe diameter correctly).

2) Make sure that the sample tubing attached to the pitot tube fits correctly.

3) Attach the sample tube from the top connection of the pitot tube to the 'blue port' (the differential port) on the analyser making sure that the gas port connector secure into place.

4) Attach the sample tube from the side of the pitot tube to the 'white port' (inlet port/static pressure port) on the analyser making sure that the gas port connector secures into place.

5) House the pitot gland correctly onto the monitoring point.

6) When taking a gas reading and flow measurement follow the instruction as displayed on the front of the instrument.

✍ Note: Please refer to the following section for a diagram showing how to fit the tubing to the pitot tube.

8.10 How to use an H_2S filter (optional)

8.8.1 Cross gas effects on chemical cells

Measurements of CO are important in landfill management. The GEM5000 analyzer incorporates an improved CO measurement.
Measurements of CO can be affected by two other gases that can be found in landfill gas – hydrogen and hydrogen sulphide.

To reduce the effect of hydrogen, the GEM5000 analyzer uses a technique that is hydrogen compensated. Hydrogen compensation is achievable up to a level of around 2000ppm. Above this level the CO reading will not be compensated for.

In order to assist the operator the GEM5000 instrument also indicates the level of hydrogen present as low, medium or high. If a high hydrogen reading is present then the CO reading may be affected.

The effect of hydrogen sulphide is eliminated by the use of a H_2S filter.

CO measurement

The CO measurement is sensitive to hydrogen sulphide. The presence of hydrogen sulphide can cause the CO reading to elevate (not to be the true value due to the interfering gas). If the presence of hydrogen sulphide is suspected to be causing false CO readings, then it is recommended that the external hydrogen sulphide filter is used while obtaining the CO measurement.

The H_2S filter only needs to be used when you are trying to remove of any possible cross gas effects H_2S might have on other gas channels. Do not use the filter on all boreholes.

When using the H_2S filter you will need to increase the gas sample and clean air purge run-time, as using an H_2S filter decreases the response time of the analyzer.

✍ Note: There is an internal H_2S filter incorporated in the chemical cell that removes the H_2S; however this has a limited life span.

The electrochemical cells used to measure H_2S and CO do suffer from cross-gas effects. Such effects are not accurately specified. However, the following table may be useful as a guide; it represents how many ppm would be read by a cell if 100 ppm of the interfering gas were applied, with no other cross-contaminates being present in the sample.

GEM5000

		Interfering Gas				
		CO	**H_2S**	**SO_2**	**NO_2**	**H_2**
Chemical Cell	**CO (H2 compensated**	100	0 / ~300*	0	0	<1
	CO	100	<4 /~300*	0	-20 to +5	<60
	H2S	<4	100	20	<-25	<0.2

*after internal filter depleted.

✍ Note: Other gases could cause cross-gas effects. If you suspect a cross sensitivity problem please contact Technical Support (800) 968-2026 or email landtec_support@gedenv.com

8.9.2 Cross-gas effects on methane, carbon dioxide and oxygen

Methane is measured using dual beam infrared absorption. Analyzers are calibrated using certified methane mixtures and will give correct readings provided there are no other hydrocarbon gases present within the sample (e.g. ethane, propane, butane, etc.). If there are other hydrocarbons present, the methane reading will be elevated (never lower) than the actual methane concentration being monitored.

The extent to which the methane reading is affected depends upon the concentration of the methane in the sample and the concentration of the other hydrocarbons. The effect is totally non-linear and difficult to predict.

✍ Note: The effect can be reduced by using an H_2S filter as it can reduce higher order hydrocarbons. When using the H_2S filter you will need to increase the gas sample and clean air purge run-time, as using an H_2S filter increases the response time of the analyzer.

Carbon dioxide is measured by infrared absorption at a wavelength specific to carbon dioxide. Therefore, the carbon dioxide reading will not be affected by any other gases usually found on landfill sites.

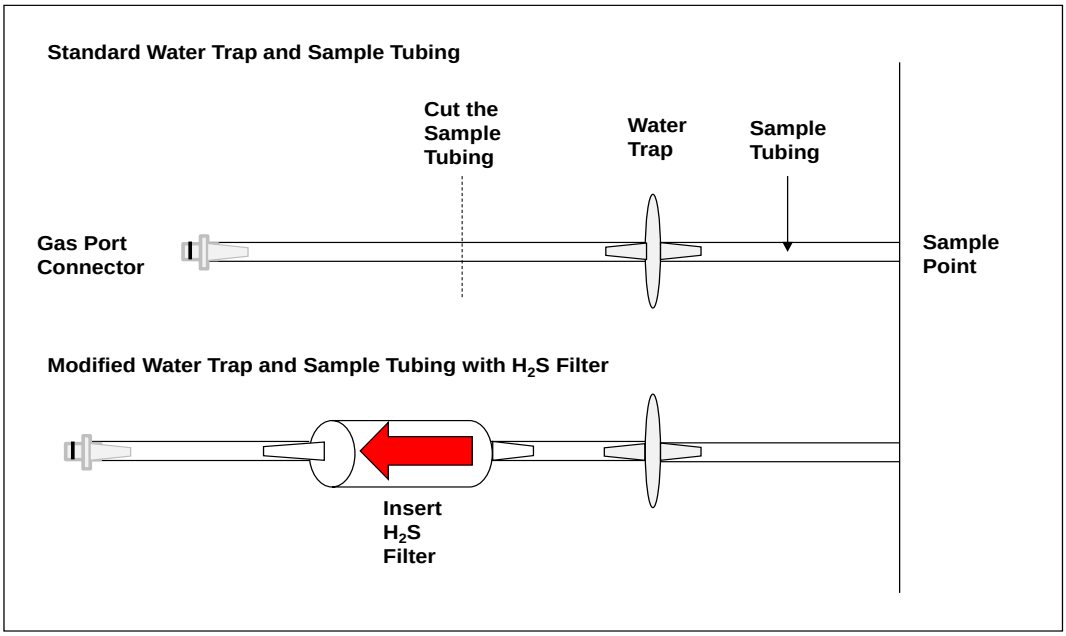
The oxygen sensor is a galvanic cell type and suffers virtually no influence from CO_2, CO, H_2S, NO_2, SO_2 or H_2, unlike many other types of oxygen cell.

The infrared sensors will not be 'poisoned' by other hydrocarbons and will revert to normal operation as soon as the gas sample has been 'purged'.

H_2S filter:

Instructions for use:

The following diagram shows how to modify the standard water trap and sample tubing to fit the H_2S filter.

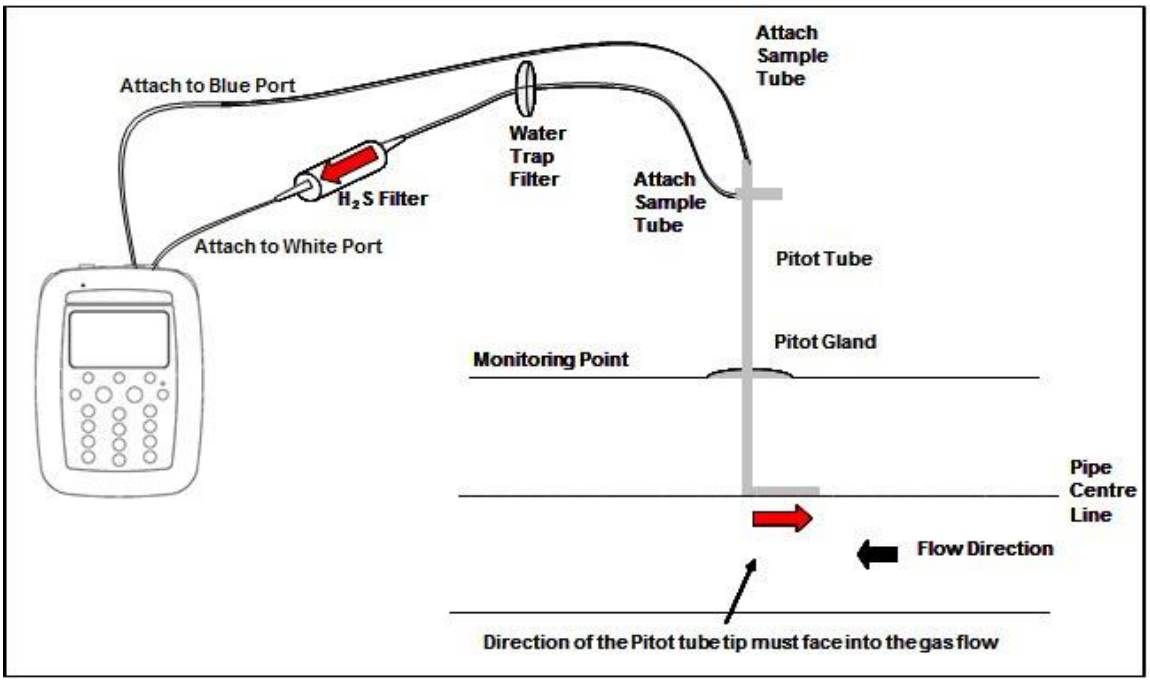


✍ Note: When onsite the site engineer must have an unmodified water trap assembly in addition to the modified water trap with a H_2S filter in order to take readings with and without a filter.

1) Once the H_2S filter is fitted follow the instructions as detailed on the front of the gas analyser displayed when taking readings using a H_2S filter.

   ✍ Note: This is only for analysers fitted with the CO compensated cell.

Fitting a pitot tube to a sample point when using an H_2S filter:



2) Make sure the water trap filter is fitted as close as possible to the pitot tube. This will help protect and trap moisture before it reaches the H_2S filter. Make sure that the water trap filter is clean and dry.

3) Attach the sample tubing into the analyzer.

4) To take flow readings using a pitot tube, please follow the instructions displayed on the front of the instrument. The user will be prompted to complete each step and should follow the instructions on screen.

   ✍ Note: It is important to fit the pitot tube central and parallel with the pipe.

8.11 How to use a temperature probe (optional)

The temperature probe enables the site engineer to measure the temperature of the gas within a sample point. The GEM5000 gas analyzer uses the temperature of the gas to give more accurate flow measurement readings as part of the instrument calculation.

Instructions for use:

1) The temperature probe reading is taken along with the gas measurement reading.

2) The analyzer must be at the 'Main Gas Read Screen'.

3) Attach the temperature probe to 'connector B' (refer to section 5.3 – Instrument connections points).

4) Insert the temperature probe into the sample point (borehole) at the same time as you attach the sample tube to the sample point (two sample points are required for the borehole).

5) Follow the instructions on the front of the instrument when taking your gas and measurement reading.

6) At the point in which the operator presses 'Enter' to store the gas reading the temperature is recorded.

✍ Note: Temperature probe readings can be analysed further when downloaded to LSGAM.

8.12 How to identify a borehole using the GPS feature (optional)

An optional GPS feature is available for the GEM5000 gas analyzer. It enables the site engineer to automatically locate borehole IDs using GPS satellite signal from predefined borehole IDs uploaded from LSGAM. The GPS reading data is stored for each measurement reading.

✍ Note: Borehole IDs may be uploaded from LSGAM with or without location information. If location details are not uploaded the location longitude and latitude coordinates can be stored when the borehole is located and downloaded to LSGAM with the reading measurements.

Screen navigation:

1) Switch on the analyzer and wait for the self-test warm-up to complete and the analyser will display the 'Main Gas Read Screen'.

2) In order to use the navigation function if configured, you must switch 'Navigation - On' on the analyzer. Select the 'Menu' key followed by 'Key 5' to toggle navigation to on. Select the 'Menu' key to exit and return to the 'Main Gas Read Screen'.

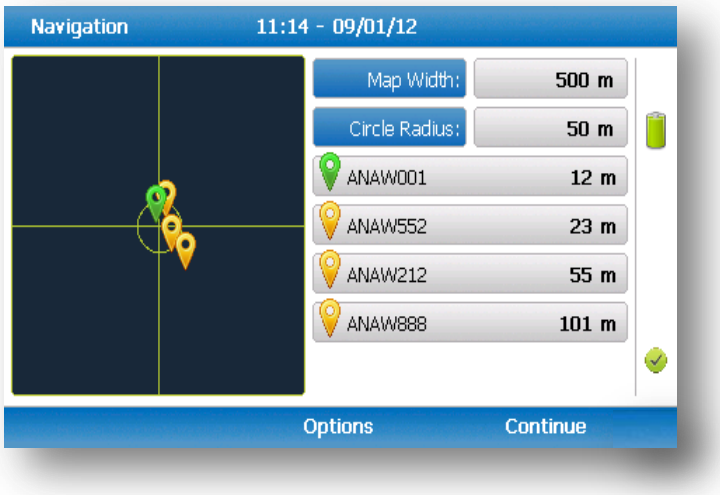
3) Select the soft-key 'Next ID', then select a borehole ID from the list displayed and press the 'Enter 'key to continue.

⚠ **Warning**	Before entering the GPS Navigation Screen for the first time the following health and safety message will be displayed. "Please be aware of the terrain when using this screen. You are responsible for your own safety whilst walking on-site!"

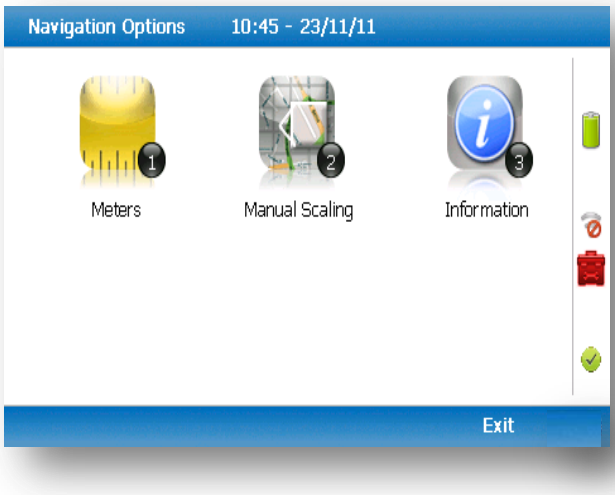
4) After reading the user warning message, select the soft-key 'Dismiss'. Use the tracking display to locate the borehole

✍ Note: There is often a wait time frame of between 30 seconds to two minutes while getting a satellite signal. Be aware that heavy rain, trees overhead etc. will give a bad fix.

5) Once the operator selects a borehole ID the 'GPS Navigation' screen is displayed.



6) If required, select soft-key 'Options' to go to the 'Navigation Options' menu and the following screen is displayed:



Navigation options

Key 1 — Key 1 to toggle between 'Meters', 'Feet' or 'Yards' to define the unit of measurement.

Key 2 — Key 2 to toggle between 'Manual Scaling' and 'Automatic Scaling' to locate a sample point using a satellite signal.

Key 3 — Key 3 to display sample point information:

- Bearing: Direction.
- UTC time: 'Universal Time Code' received from the satellite and displays GMT.
- Latitude: Latitude displays as degrees, minutes, seconds and decimal seconds. The equator is 0.
- Longitude: E (East) or W (West) displays the longitude as degrees, minutes, seconds and decimal seconds. The Greenwich meridian defines the zero point.
- Altitude: Altitude displays in meters, feet or yards.
- Satellite: This is the number of satellites that the system can select. Four satellites will give reasonable position accuracy; eight or more satellites will increase accuracy.
- Horizontal: Estimate of horizontal error on the indicated position. The location is accurate to horizontal error 1.6m.
- Vertical: Estimate of vertical error on the indicated position.
- HDOP: 'Horizontal Dilution of Precision' which measures the accuracy of the indicated position.

Changing the selected ID

It is possible to change the currently selected ID (identified by green icon) by pressing the 2 and 8 and keys to move the cursor up and down the list of visible Ids. To change the selection press Enter. Notice that the selected ID moves to the top of the list and its icon turns green.

Changing the scale

You can change the display's scale by using the 4 and 6 keys to zoom in and out.

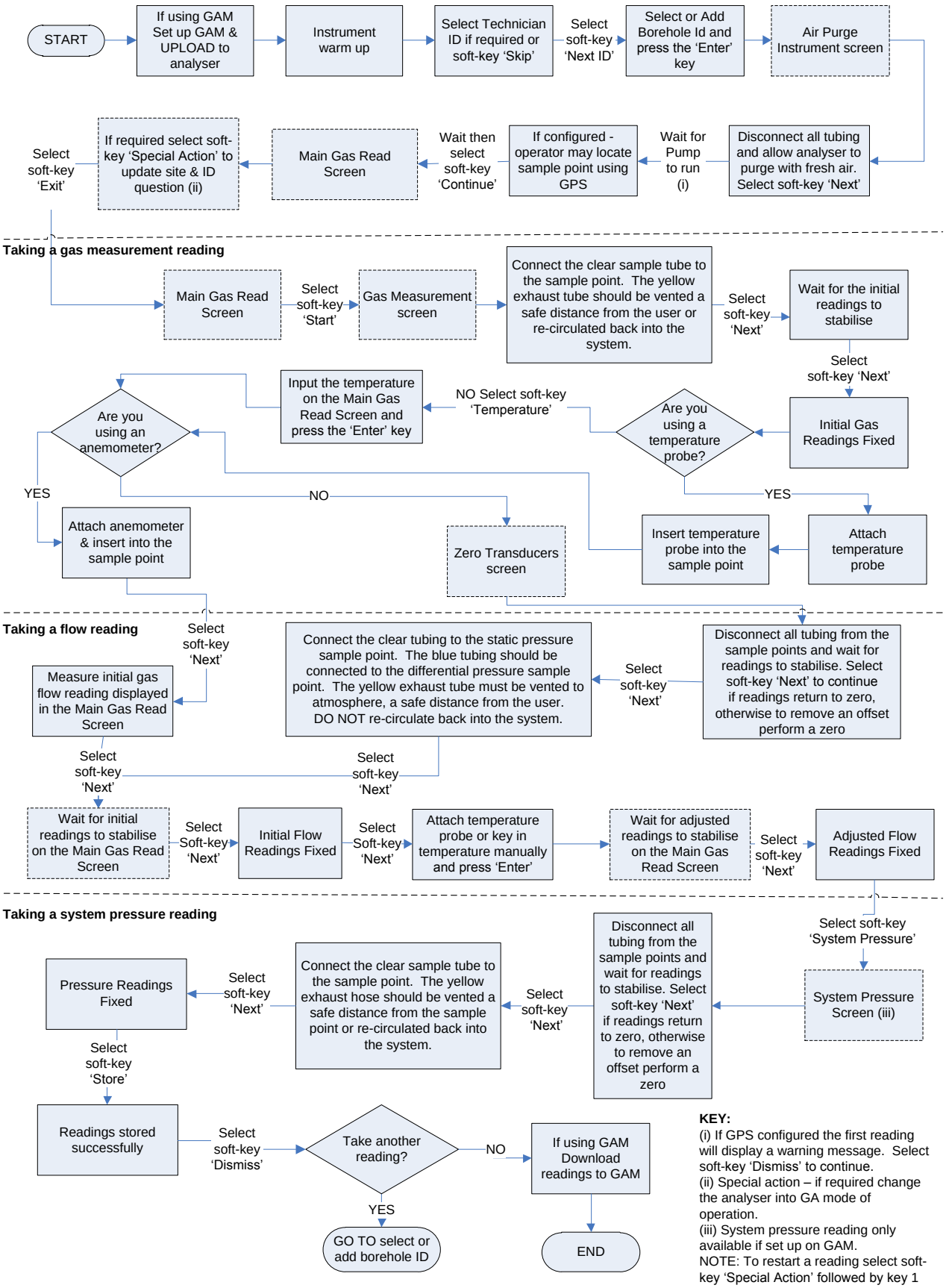
GPS signal strength:

This icon shows the signal strength the analyzer's GPS module is able to provide. Full, okay and fair strength respectively.

GPS failure - the GPS was unable to get a line of sight lock on enough satellites. Or, it may be that it hasn't had time to get a lock.

7) Select soft-key 'Continue' and the operator is returned to the 'Main Gas Read Screen'.

8.13 Taking gas and flow measurement



9.0 Calibration

9.1 Calibration introduction

The GEM5000 gas analyzer is carefully calibrated at manufacture and when returned for service. However, it is sometimes desirable to be able to carry out a calibration process between services.

This section outlines the correct procedures to enable the site engineer to field calibrate the gas analyzer.

✍ Note: This does not replace the factory service and calibration. If this calibration is completed incorrectly it may decrease the accuracy of the gas analyzer.

CH_4, CO_2 and O_2 can be measured by GEM5000 gas analyzer as standard; these channels can be user calibrated. The analyzers have other gas channel options that are specified at manufacture; these too can be calibrated. This section will describe in detail how to calibrate the three standard gas channels plus the CO channel.

The GEM5000 instrument can have a H_2 compensated CO channel. This option requires that H_2 is used in the calibration process and is also set out within this section.

For the other gas channel options contact QED for advice.

Two important terms that are used within this section are 'Zero' and 'Span'.

Zero: The point at which the gas analyzer is calibrated when there is none of the target gases present.

Span: The point at which the gas analyzer is calibrated when a known quantity of the target gas is present.

9.2 Frequency of calibration – best practice

The GEM5000 gas analyzers can be checked against a known concentration of gas, to give confidence that the analyzer is operating as expected at the time and conditions in which it is being used.

It is recommended that the instrument is regularly serviced and calibrated by QED in accordance with the due date on the instrument.

When defining the frequency of user calibration, the following are factors to be considered:

- The frequency of use of the analyzer. (daily?/monthly?)
- The level of confidence and accuracy required for readings to be taken.
- Historical user calibration data.
- Site specific requirements or conditions.
- Historical understanding of expected readings on site.

Zeroing of the gas analyzer should be undertaken at the start of each day's monitoring.

Use historical data to drive your frequency of calibration.
If there is no historical data a good starting point for a daily monitoring round is performing a calibration once every week or every other week.

The results of the calibrations will need to be recorded to monitor over time whether the frequency of calibration needs to be increased or decreased relative to the confidence required.

The confidence required will be driven by the site specific / user requirements.

When undertaking the monitoring with an understanding of the history of the gas levels of that site, a calibration check could be triggered if the readings measured are different to what is expected.

✍ Note: For assistance please contact Technical Support at (800) 968-2026 or email landtec_support@qedenv.com

9.3 Calibration gases

User calibration of a gas analyzer will greatly improve the data accuracy in the range of the calibration gases used. This may cause less accurate readings of concentrations outside this calibrated range. Users should select the correct calibration gas for the expected gas levels on their particular application.

- To improve calibration at lower levels requires the use of gas mixtures 1 and 2.
- To improve higher levels use gas mixture 3.
- For standard CO only 100ppm CO gas is needed.
- For CO (H_2 compensated) both CO 100ppm and H_2 1000ppm gases are needed.

The following table indicates the different gas mixture canisters used for calibration:

Calibration gas	**CH_4**	**CO_2**	**O_2**
Mixture 1	5%	5%	6%
Mixture 2	5%	10%	0%
Mixture 3	60%	40%	0%

Calibration targets for gas cells are dependent on the gas/range and type of cell fitted. Contact Technical Support for assistance.

These are for general use but other gas concentrations can be used.

✍ Note: The above gases and most other gas concentrations can be supplied by QED. For further information please contact Sales at (800) 624-2026 or email info@qedenv.com

⚠ **Warning**	Calibration gases can be dangerous. For each gas used the appropriate material safety data sheet must be read and understood before proceeding.

9.4 Calibration set-up

⚠ **Warning**	Do NOT attach the gas supply to the gas analyzer before putting the analyzer into the 'Gas Check' screen. Select 'Check Spans' from the 'Operation Settings' menu.

The regulator supplied with the calibration kit has been configured to deliver a fixed flow.

As the regulator's flow is factory set, it only requires a few turns to open, no adjustment is necessary.

⚠ **Warning**	**Exhaust port** When the gas analyzer is being calibrated, there are two possible exits for the gas, via the usual manner out of the exhaust (yellow) port of the analyzer or in cases of over-pressurisation the 1/16″ port on the red pressure relief valve located on the regulator. It is recommended that both ports have exhaust tubing attached. The exhaust tubing must emerge in a well-ventilated area. Ensure there are no leaks in the tubing and connections. The calibration of the gas analyzer should be carried out in a safe area with all necessary precautions taken when using potentially dangerous, explosive or toxic gases.

✍ Note: There is also potential for gas to expel from the internal flow (blue) port of the gas analyzer (applies to the GA5000 only).

9.5 Calibration equipment

The diagram below displays the regulator and tubing equipment for user calibration:

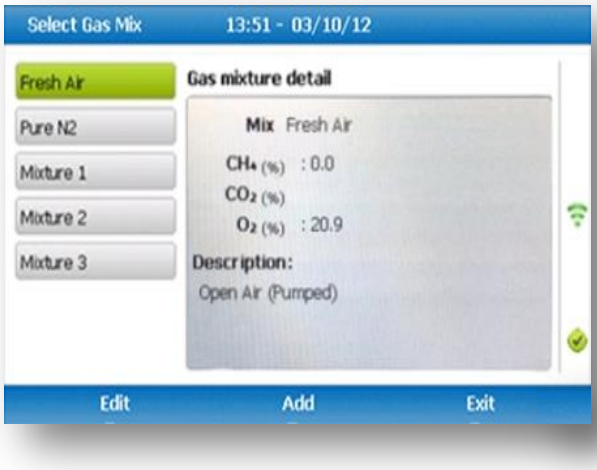
- Certified calibration gas, available in either 29 liter, 34 liter or 58 liter gas canisters are supplied with the Landtec calibration kit. Please refer to the Landtec website www.landtecna.com for further information.
- The regulator supplied with the calibration kit is pre-set for flow and pressure rates that are factory set.
- If you are using a non Landtec supplied regulator, please ensure that it does not supply any greater than 200 mbar pressure.

9.6 Gas analyzer

For the GEM5000 gas analyzer the calibration options can be found by selecting the 'Menu' key followed by soft-key 'Operation Settings'. Select 'Key 2 – Gas Check' then follow the instructions on the analyzer screen by selecting 'Key 2 – Gas Check'.

9.7 Calibration processes – best practice

The following process diagrams outline the calibration steps.

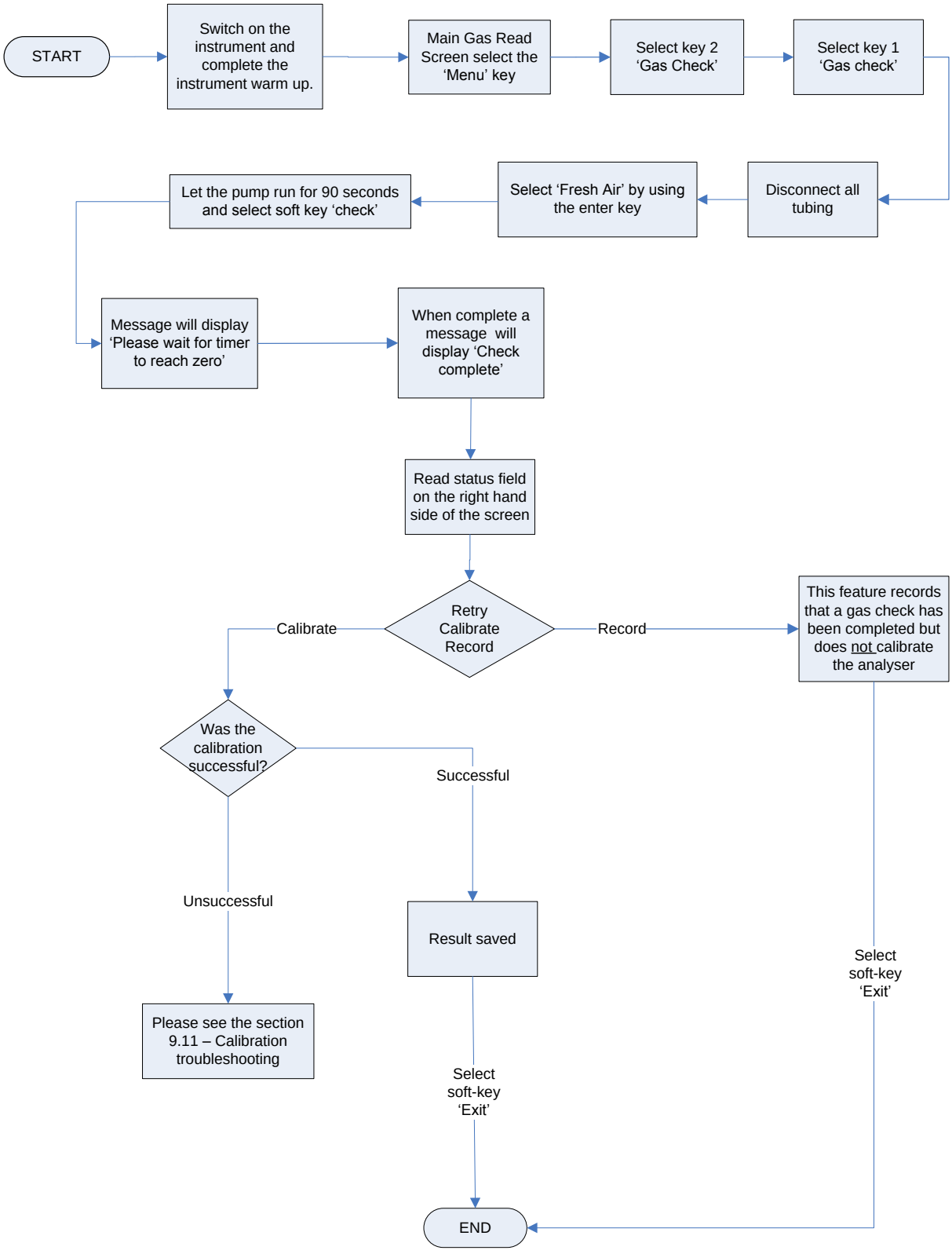


- Ensure that you are regulating calibration gas down to below 200 mbar pressure, if you're not using a Landtec regulator. The use of a pressure relief valve is also highly recommended.

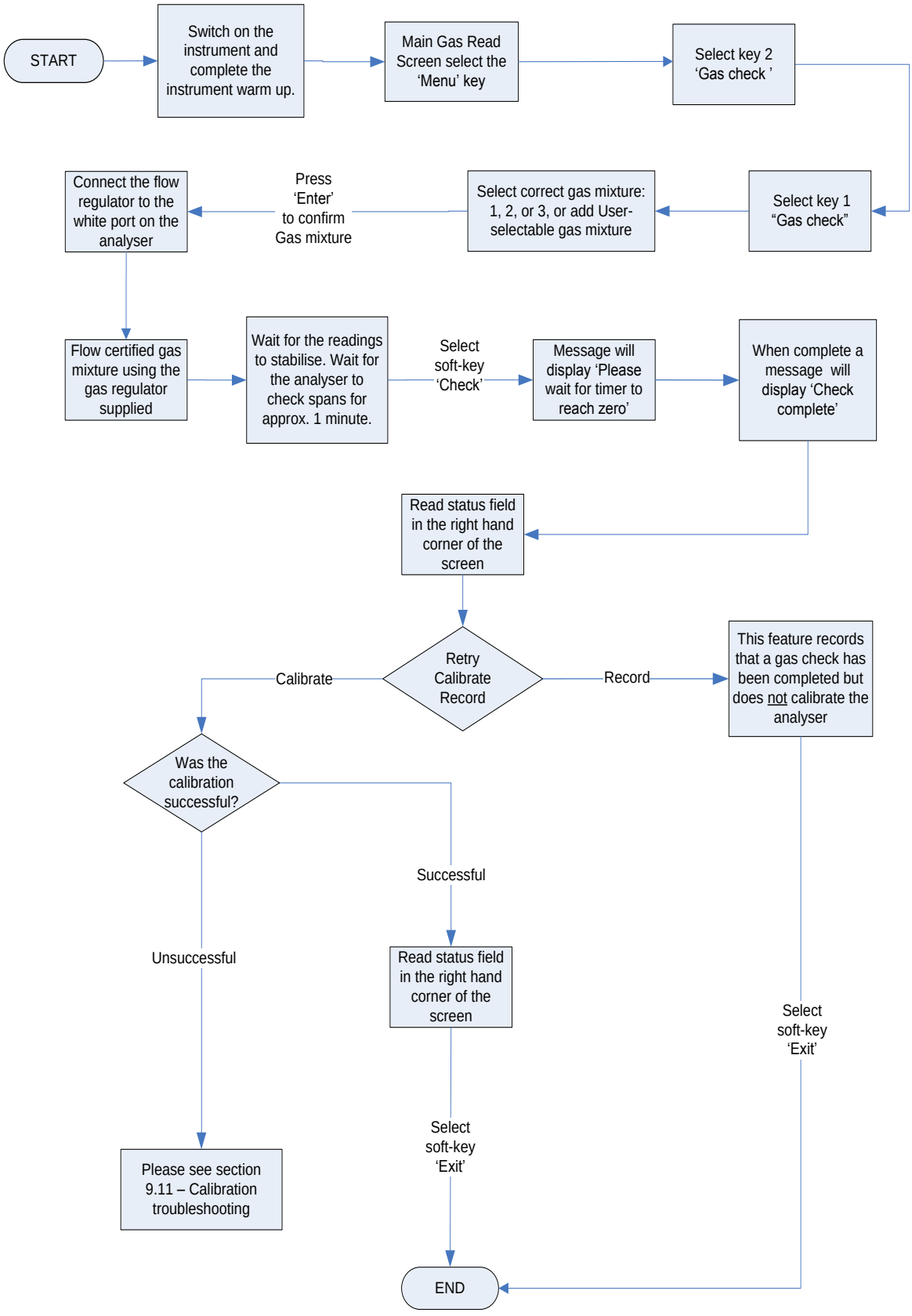
- When calibrating, it is recommended to use a calibration mixture close to the levels you are trying to measure, i.e. if you are trying to measure gas migration on a closed landfill, we'd recommend calibrating with CH4 5%/CO2 5%.

- In regards to frequency, we would recommend that you perform a fresh air calibration before each monitoring session, and a span calibration typical every 4 – 6 weeks.

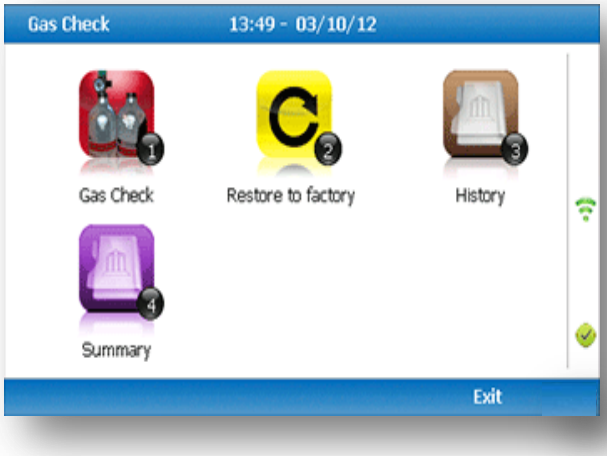
9.7.1 Gas Check in fresh air



9.7.2 Calibration – mixtures 1, 2, & 3



9.8 Restore to factory settings



This option will reset the gas analyzer to all of its factory programmed calibration settings and will clear ALL the user defined calibration points. It will not affect or remove ID's or readings from the analyzer.

1) Select 'Key 2 - Restore to factory' followed by the soft-key 'Confirm' or 'Cancel'.

2) A validation message is displayed 'Reset user calibration?' Press the soft-key 'Confirm' to continue with the factory settings or soft-key 'Cancel' to cancel the operation and return to the Gas Check menu.

9.9 Calibration history

The GEM5000 gas analyzer logs user calibrations in 'History' application. This can be used as an aid to ensuring that gas measurements are valid and accurate. Both good and failed calibration results are recorded for each channel calibrated.

1) Select 'Key 3 – History'.

2) The operator may view the calibration data stored. Use the soft-key 'Filter' to add a sort filter to the history enquiry.

9.10 Calibration summary

The GEM5000 gas analyzer has the facility to log the history of user calibrations.

1) Select 'Key 4 – Summary'.

2) The operator may view the calibration data history stored by ID, technician, timestamp, type and calibration result. Use the soft-key 'Exit' to exit and return to the 'Gas Check' menu.

10.0 Problem Solving

This section outlines various warning and error messages which the operator may receive during general operation of the instrument. For further assistance please contact Technical Support at (800) 968-2026 or email landtec_support@qedenv.com

11.0 Warning and error display

When switched on, the instrument will perform a pre-determined self-test sequence taking approximately 15 seconds. During this time many of the instrument's working parameters and settings are checked.

If any operational parameters are out of specification or the pre-programmed recommended calibration/service date has passed, errors or warnings may be displayed.

Use the 'Scroll up' and 'Scroll down' keys to move through the list if required.

Only three warnings/errors can be displayed at any time.

To ascertain if more errors have occurred use 'Key 8' – Scroll down' and 'Key 2' - Scroll up' through the list.

Warnings displayed:

All warnings displayed will be prefixed by the word WARNING followed by a relevant description.

There are two types of warning that may be displayed:

1. General warnings that may not affect the instrument's function and those where the self-test has detected a function that is outside the usual programmed operating criteria, e.g. battery charge low, memory nearly full.

2. Operational parameters that could affect the performance of the analyzer: Cell out of calibration, CH_4 out of calibration, CO_2 out of calibration.

The most likely reason for the errors is either an incorrect user calibration or sensor failure. If an incorrect user calibration has caused the warning it should be correctable by way of returning the instrument to factory settings, zeroing or carrying out a user calibration as necessary for the relevant function.

12.0 Service

The GEM5000 gas analyzer should be regularly serviced to ensure correct and accurate operation. QED recommends a service and recalibration every **12 months**.

The GEM5000 range is ATEX certified for use in potentially explosive areas. As such it should be serviced only by qualified engineers. Failure to observe this will result in the warranty becoming invalid and could invalidate the ATEX certification.

⚠ **Warning**	If the GEM5000 is serviced by unqualified engineers the ATEX certification may be invalidated and the instrument may be unsafe for use in a potentially explosive atmosphere.

User serviceable parts:

There are no user serviceable parts inside the instrument.

The following parts can be user serviced:

In-line water filter	This should be regularly inspected for obstructions, moisture or damage and changed if needed. The instrument should never be operated without the in-line water filter as this may result in water entering the instrument.
Sample tubing	Always ensure that sample tubes are not contaminated or damaged.
Gas port connectors	Periodically check that the O-rings on the gas port connectors are not damaged. A damaged O-ring can let air into the sample gas and result in incorrect readings. If the O-ring is damaged the complete gas port connector should be replaced.
H_2S filter material	When the filter material changes color to a *light gray* color the filter should be replaced.

13.0 Warranty policy

This instrument is guaranteed, to the original end user purchaser, against defect in materials and workmanship for a period of **3 years** from the date of the shipment to the user.

During this period QED will repair or replace defective parts on an exchange basis.

The decision to repair or replace will be determined by QED.

To maintain this warranty, the purchaser must perform maintenance and calibration as prescribed in the operating manual.

Normal wear and tear, and parts damaged by abuse, misuse, negligence or accidents are specifically excluded from the warranty.

✍ Note: Please contact Technical Support at (800) 968-2026 or email landtec_support@qedenv.com for further information.

14.0 Glossary of terms

5000 series	The 5000 series refers to the GA5000, GEM5000 and the Biogas5000 gas analyzers.
Accu-Flo	A flow device used to aid accurate flow measurement.
Analyzer error messages	Operational errors are prefixed on the analyzer by the word ERROR followed by an error code. Refer to the list of standard error codes for more information.
Analyzer warning	Analyzer warnings are prefixed by the word WARNING followed by a relevant description. There are two types of warning messages displayed; general warnings that may not necessarily affect the instrument's function (for example, battery power low) and operational parameters that could affect the performance of the analyser (for example, CH_4 out of calibration).
Anemometer probe	Device for measuring velocity of gas in the pipe. The GEM5000 analyzer can be set to convert into a flow. See also flow measurement.
ATEX certification	The GEM5000 is ATEX certified to zone 1 & 2 areas above ground not in mines.
Auxiliary channel	This refers to the channels where external devices will be connected or displayed.
Backlight	The analyser has a built-in backlight for low ambient light conditions. This can be toggled on/off using the backlight key.
Barometric pressure	The atmospheric pressure at the given location.
Borehole	Typical location from which a gas sample is obtained.
Calibration	The gas analyzer is carefully calibrated against known standards.
Calibration record	The GEM5000 instrument has the facility to log user calibrations as a validation tool.
CH_4	Methane
Chemical cells	A method of gas detection that works on the basis of a chemical reaction with the target gas.
Clean air purge	Process used to clear out gas from the sample tube and analyser prior to taking a new reading.

CO	Carbon monoxide
CO_2	Carbon dioxide
Data logging	Data logging enables the operator to leave the analyzer unattended to take samples at predetermined intervals for a set period of time
Download	Terminology used for the movement of data from the analyzer to the LSGAM application on the PC.
Dual beam infrared absorption	Method of gas detection by measuring how much infrared is absorbed by the target gas.
Event log	Used as an aid to monitoring the use of the analyser. It can also be used as a diagnostic tool. The event log can be viewed via LSGAM. It cannot be viewed on the analyzer screen.
Exhaust port	The usual manner for the gas to exit the analyzer is via the exhaust port located on the top side of the analyzer. This port should have an exhaust tube attached.
Exhaust tube	Clear plastic tubing used to expel gases from the exhaust port.
Factory settings	Default settings preset at time of manufacture or service.
Firmware	Firmware is the term by which the internal analyzer software is known and is not accessible by the client. This firmware is updated to the latest version when the analyzer is returned for servicing.
Flow measurement	Flow can be measured by either gas velocity m/s or volume flow rate m^3/hr. This measurement of flow relates to the use of the anemometer and not the internal flow measurement technique.
Flow port	For the measurement of gas flow at the sample point.
Landtec Systems Gas Analyser Manager	Also referred to as LSGAM. PC based software which enables the operator to upload and download information to/from the analyser. LSGAM enables operators to maximise the operation of their gas analyzer. It features a simple upload and download facility and is fully compatible with the latest Microsoft™ operating systems. This is optional.

Gas channels	The gases that are analyzed by the instrument.
Gas velocity	The positional rate of change of the gas. Measured using the optional anemometer.
General warnings	Displayed throughout the documentation with a warning symbol. Warning information may affect the safety of operators.
H_2	Hydrogen
H_2S	Hydrogen sulphide
H_2S filter	Filter required for removal of H_2S. When the filter material changes color to a light gray color or if H_2S values are displayed, then the filter should be replaced.
Hydro-carbons	Organic compound consisting of only hydrogen and carbon.
In-line water filter	The component used to help protect the instrument from water ingress.
LCD display	Liquid Crystal Display
LEL	Lower Explosive Limit. Lower explosive limit of methane in air. 5% methane in air is the point at which it becomes explosive. 100% LEL equates to 5% methane.
m/s	Meters per second – measurement of gas velocity.
m^3/hr	Meters cubed per hour – volumetric flow rate measurement.
Main Gas Read Screen	The main analyzer screen for normal operations and all operations are carried out from this screen.
Material data sheet	Document from which information about a certain substance can be obtained.
MCERTS certification	MCERTS is the UK Environment Agency's Monitoring Certification Scheme. The scheme provides a framework within which environmental measurements can be made in accordance with the Agency's quality requirements. The scheme covers a range of monitoring, sampling and inspection activities.
Memory	Location where data and ID information is stored. The analyzer memory should not be used as a permanent storage medium. Stored data should be regularly transferred using the LSGAM download software.

NO_2	Nitrogen dioxide
Operating language	The operator can choose the default operating language for the analyzer. Choices are English, German, Spanish, French and Italian.
PPM	Parts per million
Pump	Used to draw the gas sample from the sample point to the analyzer. Select the pump key on the analyzer to activate.
ID	The user definable identification tag allocated to a sample point.
Relative pressure	The pressure at the sample point 'relative' to atmospheric (barometric) pressure.
Relative pressure transducer	The internal component used to measure the relative pressure.
Residual N_2	The calculation for the residual N_2 used on the latest version of the GEM5000 platform is as follows: Residual N_2 = Balance – (O_2% x 3.76) Where, Balance = 100% - (CH_4% + CO_2% + O_2%) and 3.76 is the ratio of O_2 to N_2 in ambient air (79/21)
Sample tube	The tube used to obtain a sample of gas from the sample point to the analyzer.
Span	The point at which the gas analyzer is calibrated when a known quantity of the target gas is present.
Span multi gas	Term by which the span calibration of the three main gas channels is known. This option must only be used when the calibration gas being used is a combination of CH_4 CO_2 O_2.
Technician ID	An alpha-numeric code tagged to each gas reading. Facility only available via LSGAM. This is an optional feature.
Temperature probe	External device used to measure the gas temperature at the sample point. This is optional.
Update site data	Enables the operator to answer pre-defined questions relating to the site, environment etc. These questions are defined via LSGAM software.

Upload	Terminology used for the movement of data from the PC via LSGAM software application to the analyzer.
Volume flow rate	The volume of a gas that passes through a given surface per unit of time e.g. m^3/hr
Warm-up self-test	Pre-determined self-test sequence to test the analyser functions which takes place after the analyzer is switched on.
Warranty	The instrument is under guarantee against defect in materials and workmanship for a period of 3 years from the date of shipment to the operator and is subject to the recommended service and recalibration requirements.
Water trap	Device used to protect the instrument from water or moisture ingress.
Zero	The point at which the gas analyzer is calibrated when there is none of the target gas present.
Zero transducers	This option allows the relative pressure transducer to be zeroed.

geotech

Landfill Gas Monitor

Landtec GEM™ 5000 Portable Gas Analyzer

The GEM™ 5000 is designed specifically for use on landfills to monitor Landfill Gas (LFG) collection and control systems. The GEM™ 5000 samples and analyzes the methane, carbon dioxide and oxygen content of landfill gas with options for additional analysis.

FEATURES

- Measures % CH_4, CO_2 and O_2 Volume, static pressure and differential pressure
- Calculates balance gas, flow (SCFM) and calorific value
- High accuracy and fast response time
- Lighter and more compact
- Certified intrinsically safe for landfill use
- Calibrated to ISO/IEC 17025
- CO and H_2S (on Plus models only)
- 3 year warranty
- Annual recommended factory service
- Available with GPS and additional gas detection

BENIFITS

- Designed specifically for use on landfills to monitor landfill gas (LFG) extraction systems, flares, and migration control systems.
- No need to take more than one instrument to site
- Can be used for monitoring subsurface migration probes and for measuring gas composition, pressure and flow in gas extraction systems
- The user is able to set up comments and questions to record information at site and at each sample point
- Ensures consistent collection of data for better analysis
- Streamlined user experience reduces operational times

APPLICATIONS

- Landfill Gas Collection & Control Systems
- Environmental Compliance
- Landfill Gas to Energy
- Subsurface Migration Probes

GEM 5000 MODELS

Model	Meter with AC Charger – No Kit
5000	CH_4, CO_2, 0_2, static and differential pressure
5000+	Adds CO (0-2000 ppm), and H_2S (0-500 ppm)
5000+1	Adds CO (0-2000 ppm), and H_2S (0-1000 ppm)
5000+5	Adds CO (0-2000 ppm), and H_2S (0-5000 ppm)
5000+10	Adds CO (0-2000 ppm), and H_2S (0-10000 ppm)
5000Nav	Adds Built-in GPS
5000Nav+	Adds Built-in GPS, CO (0-2000 ppm), and H_2S (0-500 ppm)
5000Nav+1	Adds Built-in GPS, CO (0-2000 ppm), and H_2S (0-1000 ppm)
5000Nav+5	Adds Built-in GPS, CO (0-2000 ppm), and H_2S (0-5000 ppm)
5000Nav+10	Adds Built-in GPS, CO (0-2000 ppm), and H_2S (0-10000 ppm)

GM5K-Kit	GEM 5000 Kit Includes: Hoses, heavy duty water trap filter, soft case, electronic manual accompanies software, LANDTEC System Gas Analyzer Manager (LSGAM) software, USB download cable and hard-case.

CALL GEOTECH TODAY (800) 833-7958

Geotech Environmental Equipment, Inc.
2650 East 40th Avenue • Denver, Colorado 80205
(303) 320-4764 • FAX (303) 322-7242
email: sales@geotechenv.com • website: www.geotechenv.com

geotech

Landfill Gas Monitor
Landtec GEM™ 5000 Portable Gas Analyzer

SPECIFICATIONS

Gas Ranges

Gases Measured	CH_4	By dual wavelength infrared cell with reference channel		
	CO_2	By dual wavelength infrared cell with reference channel		
	O_2	By internal electrochemical cell		
	CO	By internal electrochemical cell		
	H_2S	By internal electrochemical cell		
Ranges	CH_4	0-100% (vol)		
	CO_2	0-100% (vol)		
	O_2	0-25% (vol)		
	CO	0-2000 ppm***		
	H_2S	0-500 ppm***		
Gas Accuracy*	CH_4	0-5% ±0.3% (vol)	0-70% ±0.5% (vol)	70-100% ±1.5% FS
	CO_2	0-5% ±0.3% (vol)	0-60% ±0.5% (vol)	60-100% ±1.5% FS
	O_2	0-25% ±1.0% (vol)		
	CO (H_2)**	0-2000 ppm ±1.0% FS		
	H_2S	0-500 ppm ±2.0% FS		

* Typical accuracy after calibration as recommended in the operations manual.
** Hydrogen compensated Carbon Monoxide measurement.
*** Additional ranges available, call for more information.

Other Parameters

	Unit	Resolution	Comments
Energy	BTU/hr	1000 BTU/hr	Calculated from specific parameters
Static Pressure	in. H_2O	0.1 in. H_2O	Direct Measurement
Differential Pressure	in. H_2O	0.001 in. H_2O	Direct Measurement

Important Note: The information in this document is correct at the time of generation. Specification may change without prior notice as a result of continuing development.

Pump

Flow	Typically 550cc/min.
Flow with 80 in. H_2O vacuum	Approximately 80cc/min.

Environmental Conditions

Operating Temperature Range	14°F–122°F (-10°C–50°C)
Operating Pressure	-100 in. H_2O, +100 in. H_2O (-250 mbar, +250 mbar)
Relative Humidity	0-95% non-condensing
Barometric Pressure	±14.7 in. Hg (±500 mbar) from calibration pressure
Barometric Pressure Accuracy	±1% typically

Power Supply

Battery Life	Typical use 8 hours from fully charged
Charge Time	Approximately 4 hours from complete discharge

Certification Rating

ATEX	II 2G Ex ib IIA T1 Gb (Ta= -10°C to +50°C)
ISO17025	ISO/IEC17025:2005 Accreditation #66916
CSA	Ex ib IIA T1 (Ta= -10°C to +50°C) (Canada), AEx ib IIA T1 (Ta= -10°C to +50°C) USA

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GMP252 Carbon Dioxide Probe

For ppm-level measurements

Features

- Measurement range 0 ... 10 000 ppm CO_2
- Intelligent, stand-alone probe with analog and digital outputs
- Compatible with Indigo transmitters and Insight PC software
- Wide operating temperature range, −40 ... +60 °C (−40 ... +140 °F)
- IP65-classified housing
- Integrated temperature measurement for CO_2 compensation purposes
- Compensations also for pressure, oxygen, and humidity
- Sensor head heated to prevent condensation

Vaisala CARBOCAP® Carbon Dioxide Probe GMP252 is a new intelligent probe for measuring carbon dioxide. This robust, standalone measurement device is designed for use in agriculture, refrigeration, greenhouses, and demanding HVAC applications.

Benefits

- Superior long-term stability
- Reliable and accurate
- Calibration certificate included

GMP252 is suitable for harsh and humid CO_2 measurement environments where stable and accurate ppm-level CO_2 measurements are needed. GMP252 is based on Vaisala's patented, latest-generation CARBOCAP technology that enables exceptional stability. A new type of infrared (IR) light source is used instead of the traditional incandescent light bulb, which extends the lifetime of GMP252.

GMP252 incorporates an internal temperature sensor for compensation of the CO_2 measurement according to ambient temperature. The effects of pressure and background gas can also be compensated for. The measurement range is 0 ... 10 000 ppm CO_2 (measurements up to 30 000 ppm CO_2 are available with reduced accuracy). The operating temperature range of the probe is wide (−40 ... +60 °C (−40 ... +140 °F)), and the probe housing is classified as IP65. Condensation is prevented as the internal sensor head is heated.

GMP252 is resistant to dust and most chemicals, such as, H_2O_2 and alcohol-based cleaning agents.

Ease of use

GMP252 is a compact probe with easy and fast plug-in, plug-out installation. The surface of the probe is smooth, which makes it easy to clean. The probe provides several output options, including analog current and voltage outputs and digital RS-485 output with Modbus® protocol.

GMP252 can be connected to Indigo series transmitters for an extended selection of outputs and configuration options. See www.vaisala.com/indigo.

For easy-to-use access to field calibration, device analytics, and configuration functionality, the probe can be connected to Vaisala Insight PC software. See www.vaisala.com/insight.

Applications

GMP252 is ideal for agriculture, refrigeration, greenhouses, and demanding HVAC applications where stable and accurate ppm-level CO_2 measurements are needed.

A flow-through adapter with gas ports is available as an accessory, enabling tubing for easy and flexible remote measurement with a separate pump. A multiplexer can also be added for sampling gas from several locations. [1)]

1) Third-party pump and multiplexer not provided by Vaisala.

Technical data

Measurement performance

Measurement range	0 ... 10 000 ppm CO_2 (up to 30 000 ppm CO_2 with reduced accuracy)
Accuracy [1]	
0 ... 3000 ppm CO_2	±40 ppm CO_2
3000 ... 10 000 ppm CO_2	±2 % of reading
Up to 30 000 ppm CO_2	±3.5 % of reading
Calibration uncertainty	
at 2000 ppm CO_2	±31 ppm CO_2
at 10 000 ppm CO_2	±105 ppm CO_2
Long-term stability	
0 ... 3000 ppm CO_2	±60 ppm CO_2/year
3000 ... 6000 ppm CO_2	±150 ppm CO_2/year
6000 ... 10 000 ppm CO_2	±300 ppm CO_2/year
Temperature dependence 0 ... 10 000 ppm CO_2	
With compensation, −10 ... +50 °C	±0.05 % of reading/°C
With compensation, −40 ... +60 °C	< ±0.1 % of reading/°C
Without temperature compensation at 2000 ppm CO_2 (typical)	−0.5 % of reading/°C
Pressure dependence	
With compensation at 0 ... 10 000 ppm CO_2, 500 ... 1100 hPa	±0.015 % of reading/hPa
Without compensation (typical)	+0.15 % of reading/hPa
Humidity dependence	
With compensation, 0 ... 10 000 ppm CO_2, 0 ... 100 %RH	±0.7 % of reading (at +25 °C (+77 °F))
Without compensation (typical)	+0.05 % of reading/%RH
O_2 dependence	
With compensation, 0 ... 10 000 ppm %CO_2, 0 ... 90 %O_2	±0.6 % of reading (at +25 °C (+77 °F))
Without compensation (typical)	−0.08 % of reading/%O_2
Start-up, warm-up, and response time	
Start-up time at +25 °C	< 12 s
Warm-up time for full spec.	< 2 min
Response time (T90):	
With standard filter	< 1 min
Flow-through option with > 0.1 l/min	30 s
With spray shield	< 3 min
Flow rate dependence (for flow-through option)	
< 1 l/min flow	no effect
1 ... 10 l/min flow	< 0.6 % of reading l/min

1) At 25 °C and 1013 hPa (incl. repeatability and non-linearity).

Inputs and outputs

Analog outputs	• 0 ... 5/10 V (scalable), min. load 10 kΩ • 0/4 ... 20 mA (scalable), max. load 500 Ω
Digital output	Over RS-485: • Modbus • Vaisala Industrial Protocol
Operating voltage	
With digital output in use	12 ... 30 V DC
With voltage output in use	12 ... 30 V DC
With current output in use	20 ... 30 V DC
Power consumption	
Typical (continuous operation)	0.4 W
Maximum	0.5 W

Operating environment

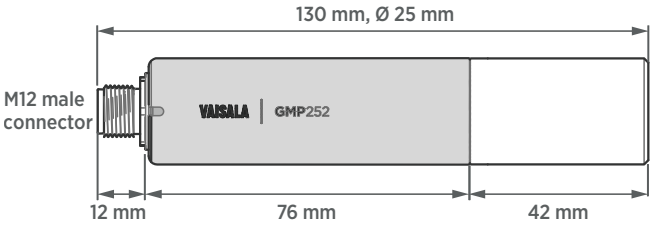
Operating temperature of CO_2 measurement	−40 ... +60 °C (−40 ... +140 °F)
Storage temperature	−40 ... +70 °C (−40 ... +158 °F)
Humidity	0 ... 100 %RH, non-condensing
Condensation prevention	Sensor head heating when power on
IP rating, probe body	IP65
Chemical tolerance (temporary exposure during cleaning)	• H_2O_2 (2000 ppm, non-condensing) • Alcohol-based cleaning agents (for example ethanol and IPA) • Acetone • Acetic acid
Pressure	
Compensated	500 ... 1100 hPa
Operating	< 1.5 bar
Gas flow (for flow-through option)	
Operating range	< 10 l/min
Recommended range	0.1 ... 0.8 l/min

Compliance

EU directives	EMC, RoHS
EMC compatibility	EN 61326-1, basic electromagnetic environment
Compliance marks	CE, RCM, WEEE

Mechanical specifications

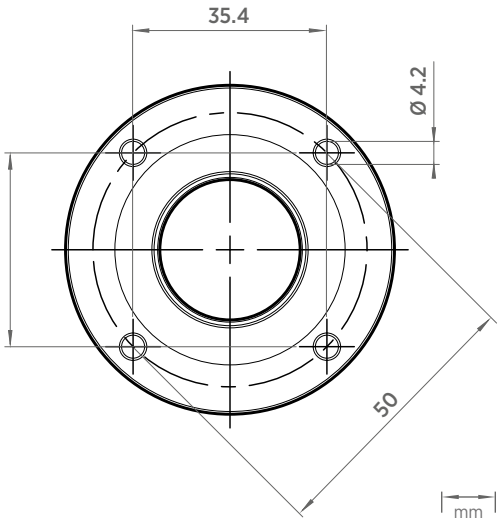
Weight, probe	58 g (2.05 oz)
Connector type	M12 5-pin male
Materials	
Probe housing	PBT polymer
Filter	PTFE
Connector	Nickel plated brass
Dimensions	
Probe diameter	25 mm (0.98 in)
Probe length	130 mm (5.12 in)



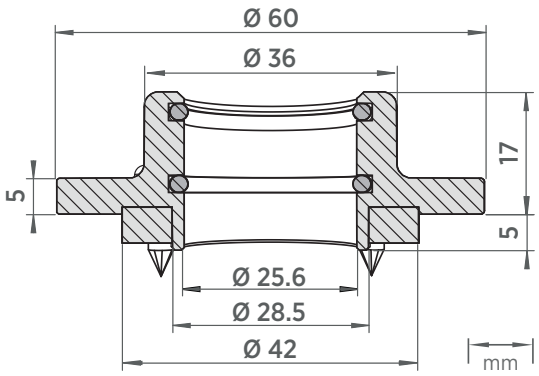
Spare parts and accessories

Porous sintered PTFE filter for GMP252	DRW244221SP
Probe cable with open wires (1.5 m)	223263SP
Probe cable with open wires (1.5 m), shielded	254294SP
Probe cable with open wires (3 m)	26719SP
Probe cable with open wires (10 m)	216546SP
Probe cable with open wires and 90° plug (0.6 m)	244669SP
Probe cable with open wires and 90° plug (1.5 m)	255102
Flow-through adapter with gas ports	ASM212011SP
Indigo USB adapter [1)]	USB2
MI70 connection cable for probe	CBL210472
Flat cable for GMP250 probes, M12 5-pin	CBL210493SP
Probe mounting clips (2 pcs)	243257SP
Probe mounting flange	243261SP
Calibration adapter	DRW244827SP
Spray shield	ASM212017SP
Radiation shield DTR250	DTR250
Radiation shield DTR250 with pole mounting kit	DTR250A

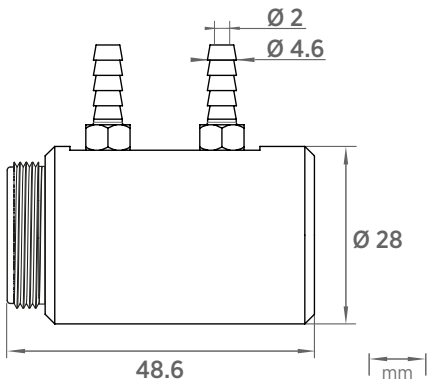
1) Vaisala Insight software for Windows is available at www.vaisala.com/insight.



Dimensions of probe mounting flange (243261SP)



Probe mounting flange cross section



Flow-through adapter with gas ports (ASM212011SP).
Suitable for tubes with 4 mm inner diameter.

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Using the LI-870 CO_2/H_2O Analyzer

LI-COR®

Using the LI-870

CO_2/H_2O Analyzer

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Printing History

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Notes on Safety

This LI-COR product has been designed to be safe when operated in the manner described in this manual. The safety of this product cannot be assured if the product is used in any other way than is specified in this manual. The product is intended to be used by qualified personnel. Read this entire manual before using the product.

Equipment markings:	
	The product is marked with this symbol when it is necessary for you to refer to the manual or accompanying documents in order to protect against injury or damage to the product.
	The product is marked with this symbol when a hazardous voltage may be present.
	The product is marked with this symbol if a Chassis Ground connection is required.
	The product is marked with this symbol to indicate that a direct current (DC) power supply is required.
WARNING	Warnings must be followed carefully to avoid bodily injury.
CAUTION	Cautions must be observed to avoid damage to your equipment.
Manual markings:	
Warning	Warnings must be followed carefully to avoid bodily injury.
Caution	Cautions must be observed to avoid damage to your equipment.
Note	Notes contain important information and useful tips on the operation of your equipment.

CE Marking:

This product is a CE-marked product. For conformity information, contact LI-COR Support at envsupport@licor.com. Outside of the U.S., contact your local sales office or distributor.

California Proposition 65 Warning

WARNING: This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.

Federal Communications Commission Radio Interference Statement

WARNING: This equipment generates, uses, and can radiate radio frequency energy and if not installed in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC rules, which are designed to provide a reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user, at his own expense, will be required to take whatever measures may be required to correct the interference.

Waste Electronic and Electrical Equipment (WEEE) Notice

This symbol indicates that the product is to be collected separately from unsorted municipal waste. The following applies to users in European countries: This product is designated for separate collection at an appropriate collection point. Do not dispose of as household waste. For more information, contact your local distributor or the local authorities in charge of waste management.

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Section 1. Overview of the LI-870

Section 2. Using the LI-870

Section 3. Troubleshooting

Section 4. Maintenance

Appendix A. Specifications

Appendix B. Equations summary

Appendix C. Warranty

Section 1.
Overview of the LI-870

The LI-870 is a CO_2/H_2O Gas Analyzer that is designed for use with the Smart Chamber and LI-8250 Multiplexer in soil gas flux systems. This document provides basic operating instructions for the LI-870. Refer to the Smart Chamber and LI-8250 manuals for additional information.

What's what

If you have just taken delivery of your LI-870, check your packing list to ensure the following items have been included.

LI-870 CO_2/H_2O Analyzer

Part number: 870-01

The LI-870 is a portable gas analyzer designed for use with the Smart Chamber or LI-8250 Multiplexer for soil CO_2 flux measurements.

The LI-870 measures CO_2 in air at concentrations from 0 to 20,000 ppm using non-dispersive infrared gas analysis technology. This technology is well-established in other LI-COR products, including the widely-published LI-8100A Automated Soil CO_2 Flux System, LI-830 and LI-850 CO_2 and CO_2/H_2O Gas Analyzers, and LI-COR eddy covariance analyzers. Water vapor measurements are used in corrections to report CO_2 concentrations with high accuracy. Power to the LI-870 is supplied from the Smart Chamber or LI-8250 Multiplexer. The LI-870, in turn, provides CO_2 data to the Smart Chamber or LI-8250 Multiplexer for storage and processing.

LI-870 cable and tube assembly

Part number: 9982-010

A 1.2 meter cable and tubing assembly is included with the LI-870 to connect the LI-870 with the Smart Chamber or LI-8250 Multiplexer. This assembly includes:

- Sealed USB-A to USB-B cable (part number 392-17654).
- Sealed 2.5 × 5 mm IP68 power cable (part number 9982-008).
- Two lengths 1.2 meter 1/4" Bev-A-Line® tubing (part number 222-01824) with quick-connect fittings (part numbers 300-07124 (male) and 300-07125 (female)).

The assembly components are zip tied in plastic conduit.

Shoulder strap

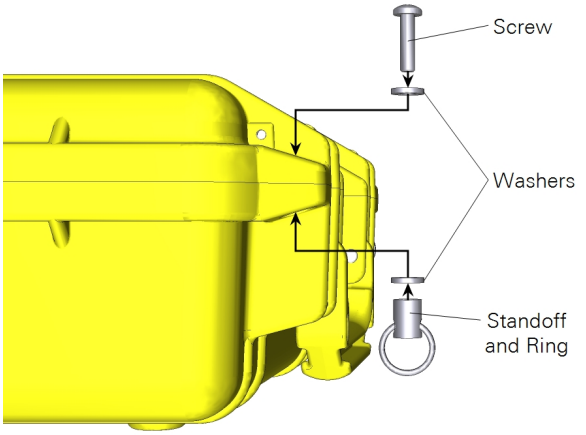
Part number: 604-18146

The shoulder strap is to carry the LI-870.

Split ring assembly

Part number: 9882-019

The LI-870 ships with a split ring and standoff assembled for attaching the shoulder strap. The rings are attached near the clasps of the case. Each assembly consists of a machined standoff (part number 9882-019), screw (part number 122-07715), split ring (part number 610-10353), and two washers (part number 167-00154).



Spares kit

Part number: 9982-020

A spares kit is shipped with the LI-870 and contains the following.

Description	Quantity	Part Number
1/4" Bev-A-Line® IV Plastic Tubing (12 meters)	1	8150-250[a]
1/4" Quick-connect Straight Union	2	300-03123
Quick Connect Plug 0.165 with Hose Barb (Male)	1	300-07124
Quick Connect Plug 0.165 with Hose Barb (Female)	1	300-07125
Optical Bench Cleaning Kit	1	9980-066
USB-A to USB-B, Unsealed, 2 meter	1	392-06652

Software

The LI-870 can be calibrated using the LI-830/LI-850 user interface software, which is available from the LI-COR support site at licor.com/830-850-support. Select software, and find the installer appropriate for your operating system. This software is available for both Windows® and macOS® operating systems and is used to calibrate your LI-870 and view live data.

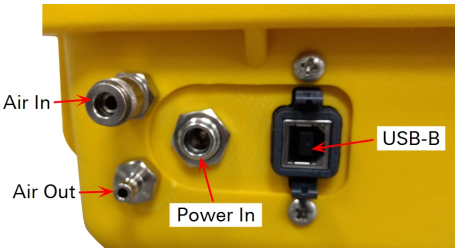
[a]Additional tubing can be repurchased as a 15 meter roll.

Section 2.
Using the LI-870

The basic operation of the LI-870 involves connecting the USB data cable, connecting the tubing, and connecting the power cable between the LI-870 and Smart Chamber or LI-8250 Multiplexer, as described here.

Connecting the cable assembly

Connecting the LI-870 to the Smart Chamber or LI-8250 Multiplexer is simple, only requiring a few steps.

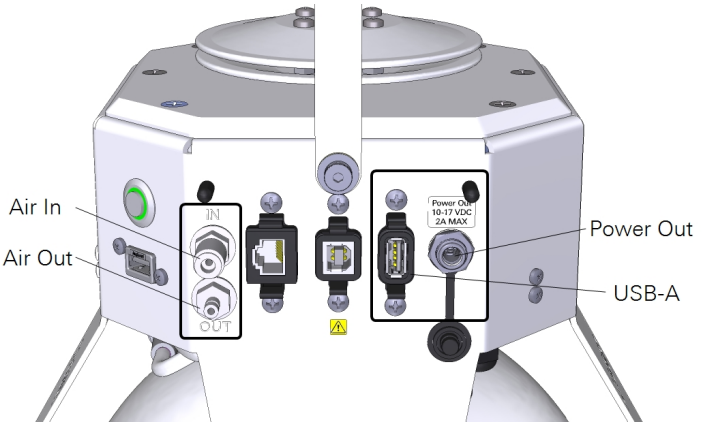


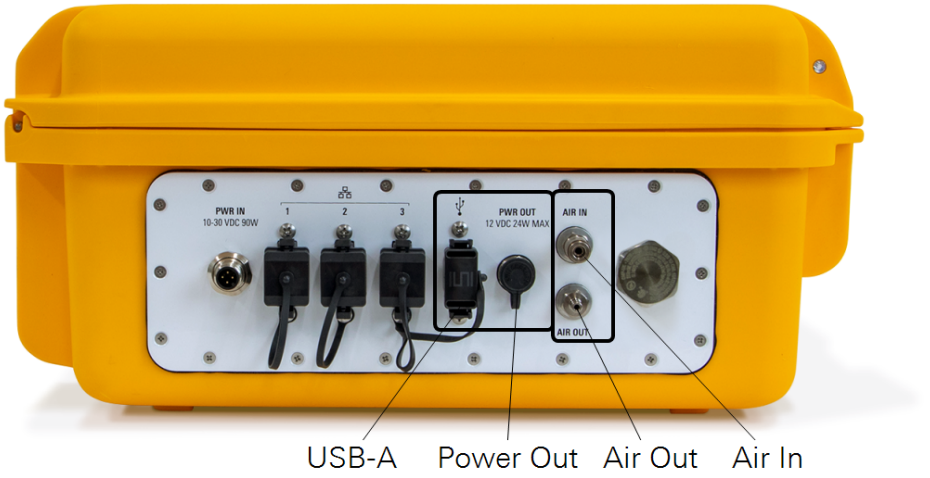
First, attach each end of the cable assembly to the LI-870. The USB-B end of the USB-A to USB-B cable is attached to the LI-870, while the USB-A end is attached to the Smart Chamber or LI-8250.

> **Note:** Only use the supplied USB-A to USB-B cable from the LI-870 to cable assembly (part number 9982-010).

Next, attach the cable assembly to the Smart Chamber or LI-8250. Connect the steel quick connect fittings for the air tubing, and thread the power cable on to the power-in and power-out connectors on each panel. Tighten snugly to ensure a water-

tight seal. Follow the detailed instructions in the Smart Chamber or LI-8250 instruction manual for additional details.





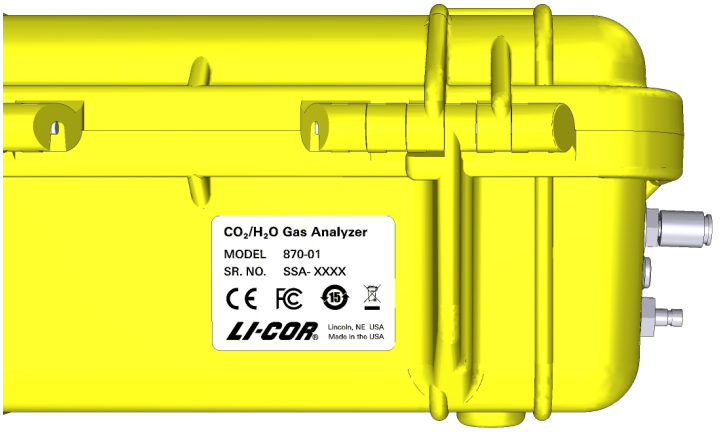
Warning: *The power output is 10-17 VDC ⎓ with a center positive pin ⊖—⊙—⊕. The output has a 2 amp maximum and is designed to only power the LI-870 CO_2/H_2O Analyzer Accessory. Only use the power cable supplied with the LI-870 cable assembly (P/N 9982-010), and do not attempt to power any other devices with the Smart Chamber or LI-8250. Drawing a current in excess of 2 amps will trip the self-resetting breaker. If you trip the self-resetting breaker, you will need to wait for a few minutes before attempting to re-power the LI-870.*

Powering the analyzer and making measurements

After connecting the power cable, you should power on your Smart Chamber or LI-8250 and launch the user interface software. Power to the LI-870 is supplied directly from the Smart Chamber or LI-8250.

Identifying the LI-870 serial number

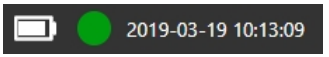
In the **Settings** page of the Smart Chamber or LI-8250 interface, you will need to connect to your LI-870 using the serial number. The label is on the bottom of the case.



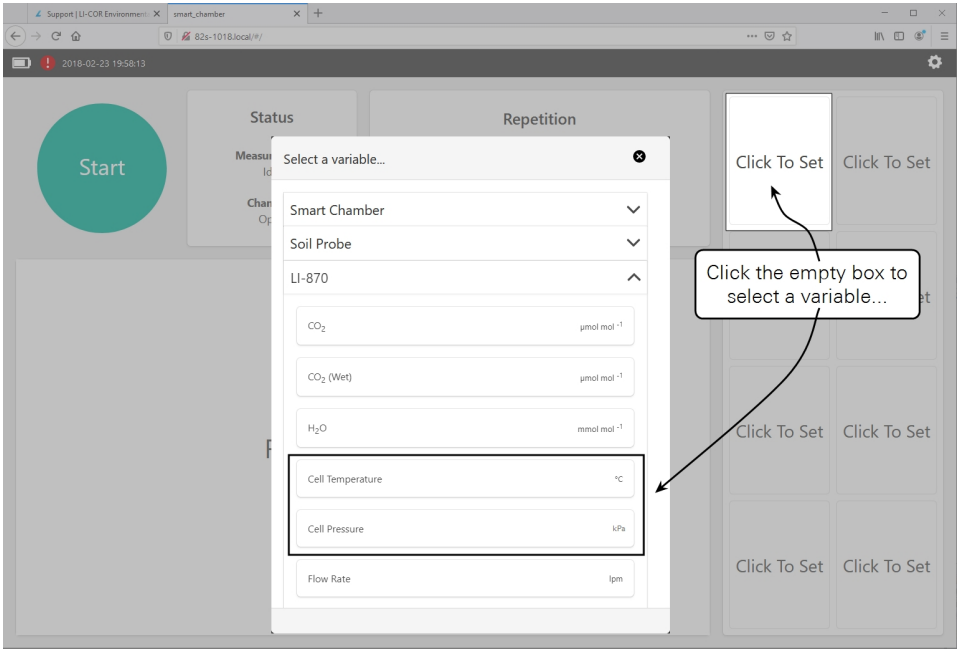
Warm up time

The LI-870 will boot up as soon as power is supplied from the chamber. The optical bench should be allowed to warm up prior to taking measurements. The LI-870 optical bench is temperature- and pressure-controlled, so a sudden influx of ambient air into an optical bench that has not been allowed to warm up and stabilize will likely produce noisy data. For this reason, it is critical that your analyzer is allowed to warm up prior to taking measurements. In most cases, 10 to 15 minutes of warm up time will allow the optical bench to stabilize, but warmup time depends largely on ambient temperature.

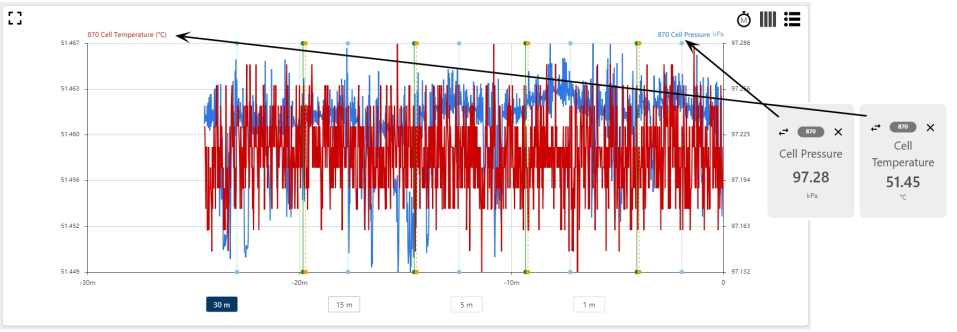
In the Smart Chamber and LI-8250 interface, you can see when your LI-870 optical bench has stabilized when the dot in the upper-left portion of any screen by the time stamp is green. If the bench is not stabilized, this dot will be red.



You can also visualize the optical bench temperature and pressure from the **Home Page** of the Smart Chamber or LI-8250 interface to assess whether they have stabilized. After connecting to the Smart Chamber or LI-8250, from the **Home Page**, select **Click to Set**. In the **Select a variable**... window that opens, open the LI-870 list, and you can select **Cell Temperature** and **Cell Pressure**.



These variables will now be in the grid on the **Home Page**. Click them again to graph the values live.



The axes auto-scale, so pay close attention to the axis labels to assess stability. In the example graph above, the bench temperature, for example, is stabilized within roughly ± 0.1 °C from the median value/middle of the graph. Once the values have stabilized like this, you can begin taking measurements following the instructions in the Smart Chamber or LI-8250 manual.

Storing the LI-870

The post-purge function of the Smart Chamber is designed to allow for ambient air to flush CO_2- and water vapor-rich air from the cable assembly tubing and analyzer after each measurement. When you are performing your last measurement(s) of the season, or when you return to the lab or desk after taking your last measurements, you should perform a measurement or two with the Smart Chamber to allow dry ambient air to flow through your chamber. This will help to remove humidity before storage.

Note: For more information on post-purge, consult the Smart Chamber manual or find resources online at licor.com/env/support.

The LI-870 should be stored in non-condensing conditions. If the instrument is stored in high humidity or moderate humidity for a long time while powered off, some optical components may temporarily become saturated with humidity. If this occurs, the instrument may need to run for several days before readings return to normal. If possible, store the instrument in an air conditioned environment.

Section 3.
Troubleshooting

In this section, we describe how to identify some potential problems with the LI-870 and how to resolve them. If you can't find a solution here, if you need further assistance performing maintenance, or if you have other questions, contact your local distributor or LI-COR technical support for more help.

Smart Chamber or LI-8250 software not recognizing LI-870

Power is supplied from the Smart Chamber or LI-8250, and assuming your connection is completed correctly, the gas analyzer is always powered on when the Smart Chamber or LI-8250 is powered on. The Smart Chamber or LI-8250 will automatically recognize your device with no further steps needed. Simply expand the **LI-870** drop-down in the **Connections** menu of the **Measurement Settings** page of the Smart Chamber or LI-8250 software, select your instrument serial number, and press **Update.**

If you open the drop-down menu and your instrument does not appear,

- Is your power cable fully connected to both devices? Make sure the cable is fully inserted and the threaded nut is snugly fastened.
- Is your USB cable fully connected to both devices? Ensure that the connectors on both sealed cables are clipped to the prongs on each device.

If your cables are fully connected but you still cannot identify your device, you can open your device to see if power is being supplied. Next to the connection panel inside the case, a red LED light will be blinking if power is being supplied.

Note: Do not open the LI-870 enclosure in the field. This can cause the temperature and pressure of the optics to become destabilized. More importantly, this can allow dust and debris into your analyzer. If possible, you should confirm whether your analyzer is working properly and troubleshoot any issues before taking it out to the field.

If your Smart Chamber or LI-8250 is on and your cables are properly connected, the light should be blinking. If it is not blinking, something could be wrong with your power cable, the chamber power-out connector, analyzer power-in connector, or other electronics inside the case. Check for dust and debris in the connectors and for damage to the cable itself. For power-related issues, it is recommended that you call LI-COR technical support for further instructions.

If the light is blinking but you still cannot identify your device through the Smart Chamber or LI-8250 software, check your USB cable for damage. Is there dust or debris in the cable heads or the connectors? Try refreshing the interface software, clearing your browser cache, and rebooting your Smart Chamber or LI-8250. If you still cannot connect, contact LI-COR technical support.

Unable to Zero or Span the Instrument

Is there dirt in the optics? If the optical cell becomes contaminated, the instrument will drift in either the zero or span. See *Cleaning the optical bench* on page 4-1 for details on cleaning your optical bench.

Instrument Reports -50 ppm CO_2 or Measurements Jump Around

If the instrument measures -50 ppm or the measurements are going between negative and positive values, or just simply not making any sense, the optical source may have failed or be in the midst of failure. Contact technical support for additional troubleshooting help.

Section 4.
Maintenance

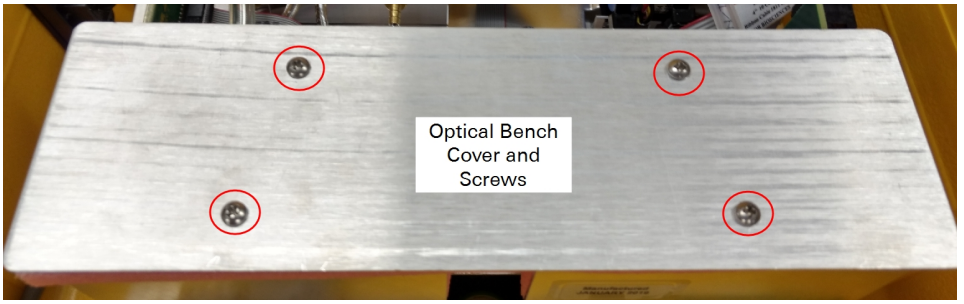
Cleaning the optical bench

The LI-870 optical bench can be removed and cleaned with just a few steps if necessary. Generally speaking, you shouldn't undertake this procedure unless you've ruled out other potential problems. While the process itself is not difficult, you will have to set the instrument zero and span after reassembling the optical bench.

An optical bench cleaning kit (part number 9980-066) is included with your LI-870 spares kit. You will also need a small Phillips screwdriver. Follow these steps to remove and clean your optical bench and replace the O-rings. Note that the images included in this section were taken from a prototype LI-870. The wiring and plumbing in your instrument may appear slightly different.

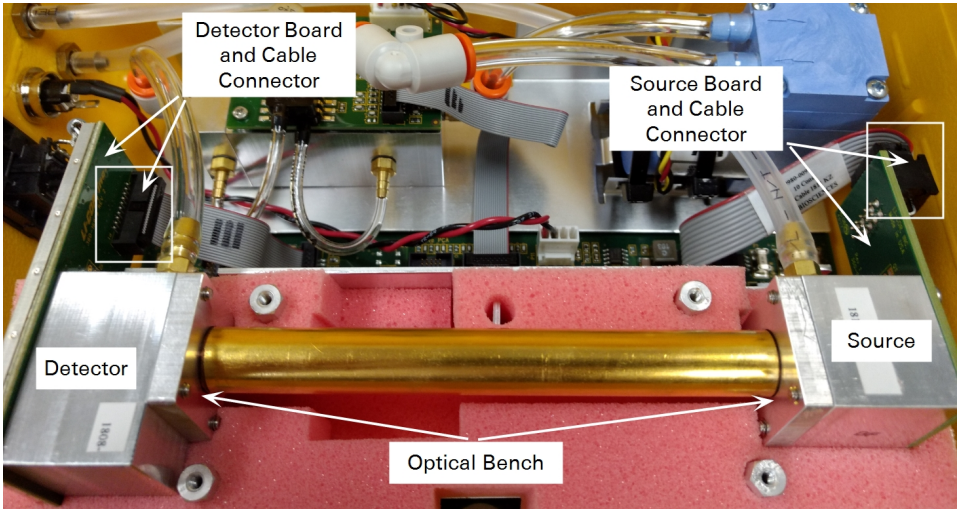
Warning: *Be sure that you are properly grounded to avoid electrostatic discharge that can damage the electronics. Use an anti-static wrist strap, electrostatic discharge grounding mat, or occasionally touch bare metal that has a clear path to ground, such as an unpainted computer case.*

1. Unplug your instrument from the Smart Chamber or LI-8250. If you've been operating the instrument recently, you should allow the optical bench to cool down to room temperature.
2. Open the analyzer and remove the plate covering the optical bench.

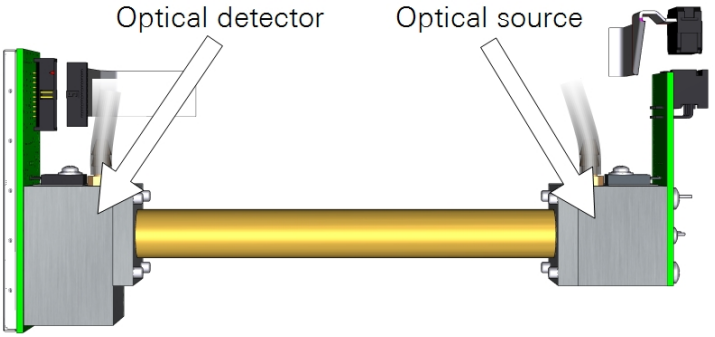


The bench cover is held in place by four screws. Remove these screws, remove the plate and foam, and set aside. The insulated optical bench will now be visible.

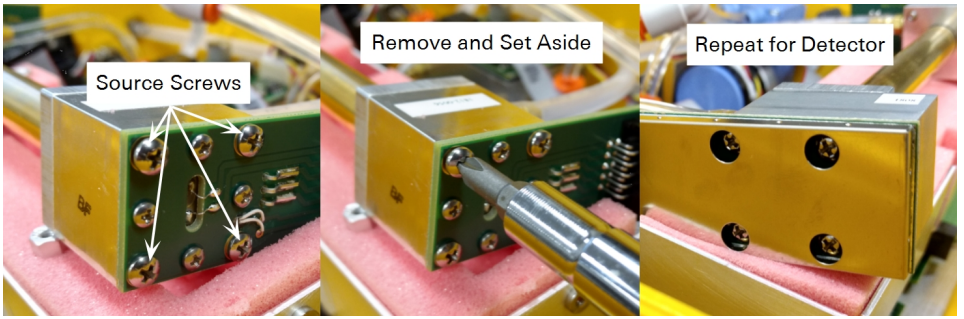
3 Gently lift the optical bench out of the insulating foam and remove the cable connectors from the source and detector circuit boards.



4 Gently grasp the plugs and pull them free.

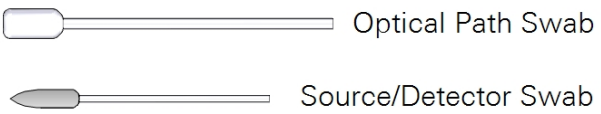


5 Remove the screws that secure the source and detector (4 each), then separate the source and detector housings (with circuit boards attached) from the optical path.



6 Clean the optical bench, source, and detector.

7 Retrieve an optical path swab from the accessories kit.



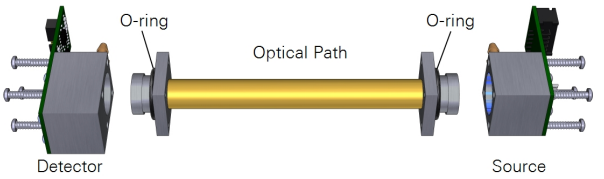
Dip one end into a 50:50 ethanol:water mixture (mild dish washing soap and water will work too) and carefully swab both ends of the optical path. Then, dip a Source/Detector swab into the solution and then swab around the source and detector to remove any residue.

Warning: *Do not use abrasive cleansers. Abrasive cleaners can irreparably damage the gold plating on the optical path, source, or detector.*

8 Inspect the hose barbs and tubing.

If the tubes are dirty or damaged, cut a new length of tubing from the extra tubing included in your spares kit, and replace them. Carefully remove them from the hose barbs. If the tubes are in good condition and clean, you may be able to reuse them. If the hose barbs are dirty, remove them and clean them with rubbing alcohol or soapy water. Use caution and do not scratch the hose barbs because scratches may cause leaks.

9 Inspect the O-Rings.



Four O-rings are included in the Optical Bench Cleaning Kit (part number 9980-066), and additional O-rings can be purchased from LI-COR. Replace them if they are smashed flat or damaged in any way.

10 Let the optical components dry and reassemble the optical bench.

Attach the source and detector. The orientation of the optical path cylinder is unimportant — either end can be inserted into the source and detector housing. Tighten each of the screws snugly.

11 Place the optical bench back into the foam, re-insert the cable connectors to the source and detector, and screw the cover plate back to complete the re-assembly.

12 Perform a zero and span calibration (see *User calibration* on page 4-6 for instructions).

Connecting to LI-870 for calibration

Though the primary interface for the LI-870 is through the Smart Chamber or LI-8250 software, you may also connect your LI-870 to the LI-COR LI-830/850 software to view data and for user calibration.

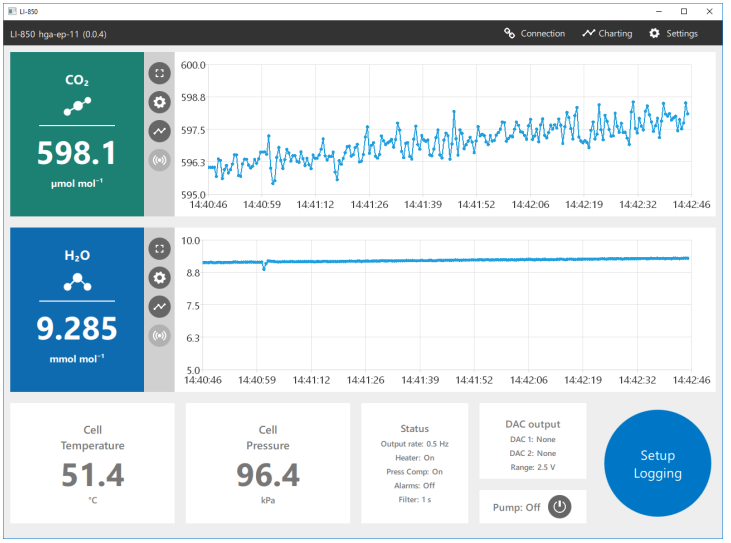
After downloading and installing the software from the LI-COR support site (licor.com/env/support), launch the software. It should display **No Analyzer Connected**.

Note: You must connect the power cable from a powered-on Smart Chamber or LI-8250 to power to analyzer when using the software.

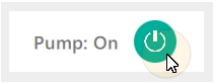
Connect your analyzer to your computer using the USB-B to USB-A cable included with your purchase. You may see a notification that says **Setting up device**, or something similar. After the automatic device setup is complete, go back to the software, and click **Connect**. In the box that opens, expand the **Connect to** drop-down menu, and you will see your device.

> **Important:** The LI-830/850 software will recognize your LI-870 as an LI-850. This is normal. Go ahead and click **Update**, and you will connect to your LI-870.

After connecting, the software presents you with live data and graphs.



Here you can see important diagnostic information like **Cell Temperature** and **Cell Pressure**. You can also turn the pump on by clicking the power button next to **Pump**: in the bottom-right of the software.



The software offers a variety of other features you may choose to explore. A more thorough explanation of the software is available at the LI-COR support site. However, for LI-870 soil applications, you will likely only the use the software for instrument calibration.

User calibration

If the instrument is not measuring as expected, or if you have disassembled the optical bench for any reason, you should check the zero and span settings and set them if necessary. The zero and span are an offset and slope. The zero value ensures that the instrument shows zero when the gas has a zero concentration. A change in the zero will affect every measurement. The span setting ensures a correct measurement at a known non-zero concentration. A change in the span affects higher concentration measurements more than lower ones. The recommended order of operation for user calibration is

1. Set the H_2O zero.
2. Set the CO_2 zero.
3. Set the H_2O span.
4. Set the CO_2 span.

For user calibration, additional tubing (part number 222-01824) and quick connects (part numbers 300-07124 (male) and 300-07125 (female)) are included with your spares kit.

Setting the H_2O zero and spans

The water vapor span can be set with a dew point generator such as the LI-610. The procedure is the same as setting the CO_2 zero and spans, only this uses known concentrations of water vapor rather than CO_2.

Caution: Setting the zero and span incorrectly for either CO_2 or H_2O will adversely impact the performance of your instrument. If you do not have the proper equipment to span the analyzer, it is best to leave it alone.

Setting the CO_2 zero

Always perform the zero first. To set the zero, you'll need either a tank of dry air that is free of CO_2 or a CO_2 scrubbing chemical such as wet soda lime and a desiccant such as Drierite.

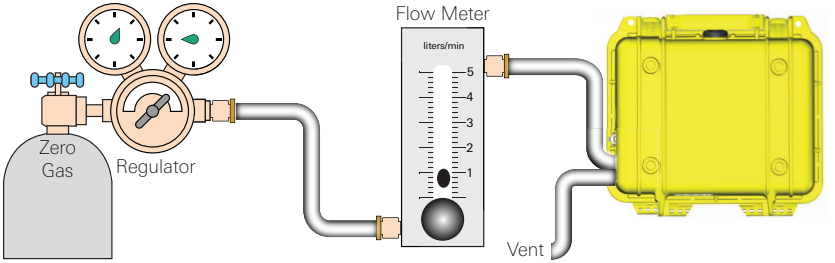
1. Plumb the zero-gas tank or scrubber to the air inlet.

   Be sure to use an air filter to prevent contaminants from entering the optical path.

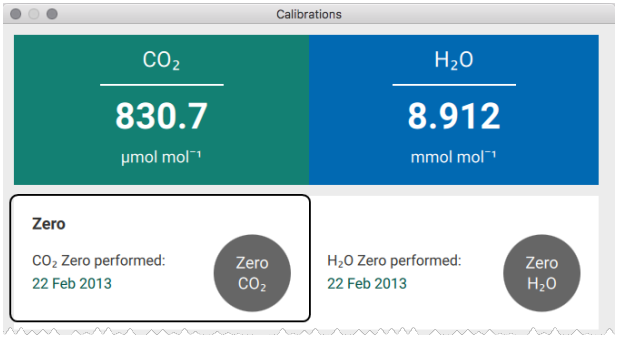
- If using tank air, the pressure of the tank is sufficient to flow the gas through the analyzer. Allow at least 0.75 liters per minute to flow through the cell (no more than 1.0 lpm).
- If using a scrubbing chemical, use a pump to draw air through the analyzer.

2 Install a 10 to 20 cm length of tubing to the air outlet.

This vent prevents ambient air from diffusing upstream into the optical cell.



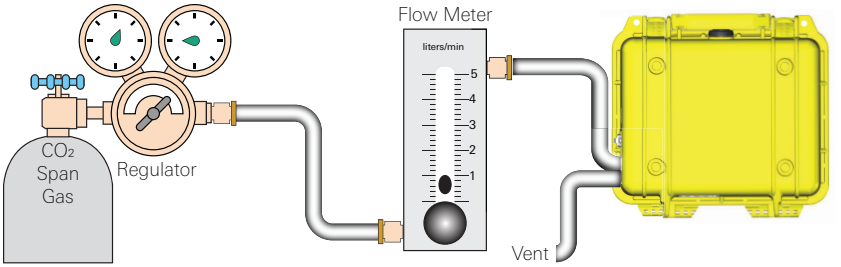
3 When the CO_2 concentration has stabilized, click the **Zero CO_2** button.



Setting the primary CO_2 span

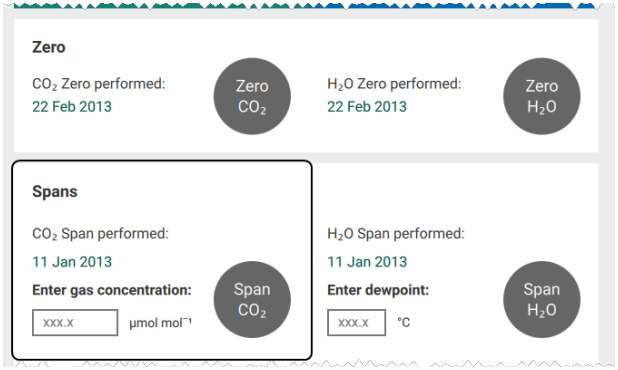
When choosing a span gas, we recommend a gas concentration that is close to - but still slightly above - the upper limit of what you expect to measure. For example, if you are measuring near-ambient levels, choose a span gas that is near 400 ppm CO_2 (as opposed to 18,000 ppm). Similarly, if you are measuring concentrations near 15,000 ppm CO_2, a span gas with 100 ppm would not be ideal.

4 After zeroing, flow a gas with a known CO_2 concentration through the analyzer at a rate of 0.5 liters per minute.



5 Enter the CO_2 concentration of the span gas into the software.

6 When the CO_2 reading has stabilized, click **Span CO_2**.



Setting the secondary CO_2 span

You can set a second span (using a gas that has a CO_2 concentration that is higher or lower than the primary span gas) to improve the precision of the analyzer. The process is exactly the same as setting the primary span, only you'll enter a different concentration and click **Span2 CO_2**.

Recovering from a bad zero or span

If your attempt to zero or span does not go as planned, you can restore the factory default zero and span settings. The information you need is provided on the calibration sheet (included with the instrument or available for download from www.licor.com/env/support/). Under **Settings > Calibrations > Advanced**, enter the factory zero and span values for your instrument.

Appendix A.
Specifications

General

Case dimensions: 28.4 cm L × 27.9 cm W × 12.4 cm H (11.2 in × 11 in × 4.9 in)
Weight: 2.31 kg (5.1 lbs.)
Measurement rate: 1 per second (1 Hz)
Operating temperature range: -20 to 45 °C, without solar loading
Relative humidity range: 0 to 95% RH, non-condensing
Measurement principle: Non-dispersive infrared (NDIR)
Operating pressure range: 50 to 110 kPa
Flow rate (nominal): 0.75 liters min^{-1}
Power Requirements:

- **Input voltage:** 10-17 VDC, 2 A max
- **After warmup (without pump):** 0.33 A @ 12 VDC (4.0 W) average
- **After warmup (with pump):** 0.42 A @ 12 VDC (5.0 W) average
- **Power source**: 8200-01S Smart Chamber or LI-8250 Multiplexer

CO_2 Measurements

Measurement range: 0 to 20,000 ppm
Accuracy: Within 1.5% of reading

H_2O Measurements

Measurement range: 0 to 60 mmol mol^{-1}
Accuracy: Within 1.5% of reading

Appendix B.
Equations summary

The LI-870 computes CO_2 concentrations using an equation of the form

$$c = f(\alpha'')(T + 273.15) \quad \text{B-1}$$

where c is concentration, $f()$ is the calibration function, α" is the absorptance, $g(\alpha,P)$ is the pressure correction, $S(\alpha)$ is the span, and T is the temperature (°C) of the gas in the cell, typically 51.5 °C. Absorptance is computed from

$$\alpha'' = \alpha' g(\alpha', P) \quad \text{B-2}$$

α' is a span corrected absorptance, and g(α',P) is the pressure correction.

$$\alpha' = \alpha S(\alpha) \quad \text{B-3}$$

$S(\alpha)$ is the span function, and raw absorptance α is computed from

$$\alpha = \left(1 - \frac{V}{V_o} Z\right) \quad \text{B-4}$$

where V and V_o are the raw detector sample and reference readings, and Z is the zeroing parameter.

Span is a linear function of absorptance.

$$S(\alpha) = S_o + S_1 \alpha \quad \text{B-5}$$

H_2O Equations

Absorptance α_ω for water vapor is computed from

$$\alpha_w = \left(1 - \frac{V_w}{V_{wo}} Z_w\right) \qquad \text{B-6}$$

$$\alpha'_w = \alpha_w S_w\left(\alpha_w\right)$$

$$\alpha''_w = \alpha' g_w\left(\alpha'_w, P\right)$$

where V_W and V_{WO} are the sample and reference raw detector readings, and Z_W is the zero parameter. The pressure correction for water vapor is an empirical function $g_W()$ of absorptance and pressure P:

$$g_w(\alpha'_w, P) = \frac{P_o}{P\left(1+0.8\alpha'_w\left(\frac{P_o}{P}-1\right)\right)} \qquad \text{B-7}$$

The value of P_o is 99 kPa. When the pressure correction is not enabled, $g_W()$ is simply 1.0. Water vapor concentration W (mmol mol^{-1}) is computed from

$$W = f_w\left(\alpha''_w\right)\left(T + 273.15\right) \qquad \text{B-8}$$

where $f_W(x)$ is a third order polynomial whose coefficients are given on the calibration sheet.

$$f_w\left(x\right) = a_{w1}x + a_{w2}x^2 + a_{w3}x^3 \qquad \text{B-9}$$

CO_2 Equations

The measurement of CO_2 is a bit more complicated than for H_2O because of the influence of water vapor. There is a slight direct cross sensitivity in the CO_2 signal to H_2O. This is measured at the factory and accounted for in the computation of absorptance (equation B-10). There is also a band broadening effect that is accounted for in the computation of concentration (equation B-14).

CO_2 absorptance αc is computed from

$$\alpha_c = \left(1 - \left(\frac{V_c}{V_{co}} + X_{wc}\left(1 - \frac{V_w}{V_{wo}} Z_w\right)\right) Z_c\right) \qquad \text{B-10}$$

$$\alpha'_c = \alpha_c S_c(\alpha_w)$$

$$\alpha''_c = \alpha'_c g_c(\alpha'_c, P)$$

where V_c and V_{co} are the raw detector signals for sample and reference, Z_c is the CO_2 zero parameter, and X_{wc} is a cross sensitivity parameter for the effect of water vapor on CO_2. Its value is reported on the calibration sheet as **XS=**.

The empirical pressure correction function $g_c()$ depends on CO_2 absorptance and pressure:

When $P = P_o$, $g_c() = 1$.

When $P < P_o$

$$g_c(\alpha_c, P) = X$$

$$X = \frac{1}{A + B\left(\frac{1}{z-\alpha_c} - \frac{1}{z}\right)} + 1$$

$$A = \frac{1}{a(p-1)} \qquad \text{B-11}$$

$$B = \frac{1}{\frac{1}{b+cp} + d}$$

$$p = \frac{P_0}{P}$$

where a = 1.10158, b = -6.1217E-3, c = -0.266278, d = 3.69895, and z is the asymptotic value of absorptance, obtained from the calibration coefficients (equation B-15).

$$z = a_{c1} + a_{c3} \qquad \text{B-12}$$

When $P > P_o$

$$g_c(\alpha_c, P) = \frac{1}{X}$$

$$P = \frac{P}{P_0} \qquad \text{B-13}$$

where X, A, and B are computed as in equation B-11. CO_2 concentration C (µmol mol^{-1}) is computed from

$$C = f_c\left(\frac{\alpha''_c}{\psi(W)}\right)\psi(W)\,(T + 273.15) \qquad \text{B-14}$$

where $f_c(x)$ is a function whose inverse is a double rectangular hyperbola, and whose coefficients (*a1*…*a4*) are given on the calibration sheet.

$$f_c^{-1}(C) = \frac{a_{c1}C}{a_{c2}+C} + \frac{a_{c3}C}{a_{c4}+C} \qquad \text{B-15}$$

Solving equation B-15 for C yields the calibration function

$$f_c\left(x\right) = \frac{\left(a_2a_3+a_1a_4\right)-\left(a_2+a_4\right)x-\sqrt{(a_2-a_4)^2x^2+Dx+(a_2a_3+a_1a_4)^2}}{2(x-a_1-a_3)} \qquad \text{B-16}$$

Where

$$D = 2\,(a_2 - a_4)\,(a_1a_4 - a_2a_3) \qquad \text{B-17}$$

$\psi(W)$ accounts for band broadening by water vapor.

$$\psi(W) = 1 + (h(\alpha'_c) - 1)\,\frac{W}{1000} \qquad \text{B-18}$$

The band broadening coefficient $h(\alpha'_c)$ has been determined to be 1.45 for the instrument for CO_2 concentrations near ambient. At higher concentrations, the value decreases. We capture this behavior with an empirical relationship (equation B-19).

$$h(\alpha'_c) = \frac{1}{(0.64b_w-0.64)e^{-3\left(\frac{z}{\alpha'_c}-1\right)}+\frac{1}{b_w}} \qquad \text{B-19}$$

Where z is from equation B-12, and b_w is the low concentration band broadening coefficient: 1.45. This is the value shown on the calibration sheet as *BB* = 1.45. The typical relationship between $h(\alpha'_c)$ and CO_2 concentration is shown in *Figure B-1* on the facing page. ('Typical' because the exact relationship depends on the relationship between absorptance and CO_2, which is the calibration curve.)

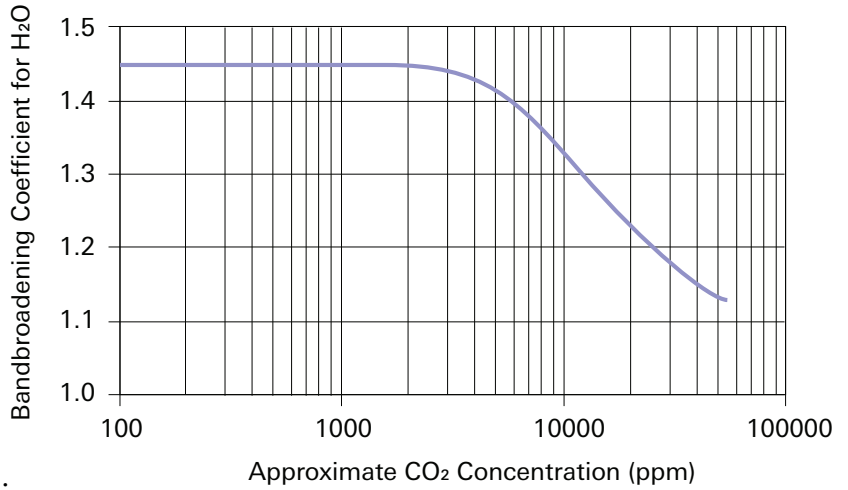


Figure B-1. The typical relationship between $h(\alpha'_c)$ *and* CO_2 *concentration.*

Note: We formulated equation B-19 with $0.64b_w - 0.64$ instead of the simple equivalent (0.29) because this allows band broadening corrections to be turned off by setting b_w to 1. When $b_w = 1$, $h(\alpha_c) = 1$ everywhere. Also, to avoid computational problems (underflows, overflows, and division by zero) we constrain the argument α_c when computing $h(\alpha_c)$ to be $0.1 < \alpha_c \leq z$. α_c - 0.1 is typically equivalent to about 600 ppm.

Calibration Equations

The following equations describe the implementation of zero and span calibrations.

Zeroing H_2O

When the command for zeroing water is received, the LI-870 computes the water zero from equation B-20, where $\overline{V}_w$ and $\overline{V}_{wo}$ are averaged for 5 seconds.

$$Z_w = \frac{\overline{V}_{wo}}{\overline{V}_w} \qquad \text{B-20}$$

Zeroing CO_2

When the command for zeroing CO_2 is received, the instrument computes the CO_2 zero term from equation B-21, where $\overline{V}_c$, $\overline{V}_{co}$, $\overline{V}_w$, and $\overline{V}_{wo}$ are averaged for *5* seconds.

$$Z_c = \frac{1}{\left(\frac{\overline{V}_c}{\overline{V}_{co}} + X_{wc}\left(1 - \frac{\overline{V}_w}{\overline{V}_{wo}} Z_w\right)\right)} \quad \text{B-21}$$

Spanning H_2O

When the command for setting the span for H_2O is received, along with the target concentration W_T, from the target concentration, the target absoprtance α_T is computed from

$$\alpha_{wT} = f_w^{-1}\left(\frac{W_T}{T+273.15}\right) \quad \text{B-22}$$

LI-870 computes S_{w0} from equation B-23 , where $\overline{\alpha}_w$ is averaged over five seconds.

$$S_{w0} = \frac{\beta_w}{\overline{\alpha}_w} - S_{w1}\overline{\alpha}_w \quad \text{B-23}$$

where

$$\beta_w = \frac{\alpha_{wT}}{g_w(\alpha_{wT}, P)} \quad \text{B-24}$$

The instrument retains the following values, which are used for subsequent secondary spans:

$$\alpha_{w1} = \overline{\alpha}_w \quad \text{B-25}$$

$$\beta_{w1} = \beta_w$$

Secondary Span H_2O

When the secondary span command for H_2O is received, the instrument computes new values for both S_{w0} and S_{w1}. First, it measures a new $\overline{\alpha}_w$ and computes a new β_w from equation B-24. Then, it uses these plus the retained values (α_{w1} and β_{w1} from the previous normal span) to compute

$$S_{w1} = \frac{\frac{\beta_w}{\overline{\alpha}_w} - \frac{\beta_{w1}}{\alpha_{w1}}}{\overline{\alpha}_w - \alpha_{w1}} \quad \text{B-26}$$

Given the new span slope S_{w1}, it updates the span offset S_{w0} by equation B-23.

Spanning CO_2

When the command for setting the CO_2 span is received, along with the target concentration C_T, the instrument computes S_{c0} from equation B-28, where $\overline{\alpha}_c$ and $\overline{W}$ are averaged for 5 seconds.

$$\alpha_{cT} = f_c^{-1}\left(\frac{C_T}{(T+273.15)\psi(\overline{W})}\right) \quad \text{B-27}$$

$$S_{c0} = \frac{\beta_c}{\overline{\alpha}_c} - S_{c1}\overline{\alpha}_c \quad \text{B-28}$$

where

$$\beta_c = \frac{\alpha_{cT}\psi(\overline{W})}{g_c(\alpha_{cT}, P)} \quad \text{B-29}$$

Note that

$$\psi(\overline{W}) = 1 + (h(\alpha_{cT}) - 1)\frac{\overline{W}}{1000}$$

$$= \left(1 + \left(\frac{1}{(0.64b_w - 0.64)e^{-3\left(\frac{z}{\alpha_{cT}} - 1\right)} + \frac{1}{b_e}} - 1\right)\frac{\overline{W}}{1000}\right) \quad \text{B-30}$$

We need αcT to compute $\psi(\overline{W})$, but αcT depends on $\psi(\overline{W})$. We resolve this by using an approximation (equation B-31) instead when computing equation B-30

$$\alpha_{cT} \approx f_c^{-1}\left(\frac{C_T}{(T+273.15)}\right) \quad \text{B-31}$$

The instrument retains the following values, which are used for subsequent secondary spans, if necessary:

$$\alpha_{c1} = \overline{\alpha}_c \quad \text{B-32}$$

$$\beta_{c1} = \beta_c \quad \text{B-33}$$

Secondary Span CO_2

When the secondary span command for CO_2 is received, the instrument computes new values for both S_{c0} and S_{c1}. First, it measures a new $\overline{\alpha}_c$ and computes a new β_c from equation B-29. Then it uses these, plus the retained values (α_{c1} and β_{c1} from the previous normal span) to compute

$$S_{c1} = \frac{\frac{\beta_c}{\overline{\alpha}_c} - \frac{\beta_{c1}}{\alpha_{c1}}}{\overline{\alpha}_c - \alpha_{c1}} \qquad \text{B-34}$$

Given the new span slope S_{c1}, it updates the span offset S_{c0} by equation B-28.

Appendix C.
Warranty

Each LI-COR, Inc. instrument is warranted by LI-COR, Inc. to be free from defects in material and workmanship; however, LI-COR, Inc.'s sole obligation under this warranty shall be to repair or replace any part of the instrument which LI-COR, Inc.'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 LI-COR, Inc. in Lincoln, Nebraska, 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 LI-COR, Inc.
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 LI-COR or a DISTRIBUTOR'S customer, packs and ships or delivers the instrument to LI-COR, Inc. at LI-COR Inc.'s factory in Lincoln, Nebraska, U.S.A. within 30 days after LI-COR, Inc. has received written notice of the defect. Unless other arrangements have been made in writing, transportation to LI-COR, Inc. (by air unless otherwise authorized by LI-COR, Inc.) is at customer expense.
5. No-charge repair parts may be sent at LI-COR, Inc.'s sole discretion to the purchaser for installation by purchaser.
6. LI-COR, Inc.'s liability is limited to repair or replace any part of the instrument without charge if LI-COR, Inc.'s examination disclosed that part to have been defective in material or workmanship.

There are no warranties, express or implied, including but not limited to any implied warranty of merchantability of fitness for a particular purpose on underwater cables or on expendables such as batteries, lamps, thermocouples, and calibrations.

Other than the obligation of LI-COR, Inc. expressly set forth herein, LI-COR, Inc. disclaims all warranties of merchantability or fitness for a particular purpose. The foregoing constitutes LI-COR, Inc.'s sole obligation and liability with respect to damages resulting from the use or performance of the instrument and in no event shall LI-COR, Inc. or its representatives be liable for damages beyond the price paid for the instrument, or for direct, incidental or consequential damages.

The laws of some locations may not allow the exclusion or limitation on implied warranties or on incidental or consequential damaged, so the limitations herein may not apply directly. This warranty gives you specific legal rights, and you may already have other rights which vary from state to state. 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 a user who is a customer or eighteen months from the date of shipment to LI-COR, Inc.'s authorized distributor, whichever is earlier.

This warranty supersedes all warranties for products purchased prior to June 1, 1984, unless this warranty is later superseded. To the extent not superseded by the terms of any extended warranty, the terms and conditions of LI-COR's Warranty still apply.

DISTRIBUTOR or the DISTRIBUTOR's customers may ship the instruments directly to LI-COR if they are unable to repair the instrument themselves even though the DISTRIBUTOR has been approved for making such repairs and has agreed with the customer to make such repairs as covered by this limited warranty.

Further information concerning this warranty may be obtained by writing or telephoning Warranty manager at LI-COR, Inc.

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