SEMTECH HI-FLOW 2

Fugitive Methane Sampler

User Manual

Document: 9510-239

Revision: 1.03

February 2024

The serial number for the HI-FLOW2 Analyzer Unit is located on the port panel on the name plate.

The serial number for the HI-FLOW 2 Handheld Unit is located on its lower side on the name plate, underneath the SEMTECH labels.

For ease of service, keep a record of the serial number and the date of first use.

Analyzer Unit Serial Number:

Handheld Unit Serial Number:

Date:

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REVISION HISTORY

Version	Date	Author	Comment
1.02	1/12/2024	Sheila Bourgoin, Alex Burchart	• Release
1.03	2/16/2024	Sheila Bourgoin	• Accessory pictures updated; service contact info changed.
1.04	May 2024	Carl Ensfield	• Battery Charging after every use • OOOOb testing and calibration reports • Report data fields explained

1 SAFETY

Read the Manual, and carefully review all safety documentation prior to turning on the device.

Inspect the equipment prior to each use. Do not operate if any enclosures, cables, or the Handheld Unit Fan Guard are damaged, loose, or missing.

Wear eye protection. While sampling, the HI-FLOW 2 moves large volumes of air, which may raise dust and debris in the vicinity.

The HI-FLOW 2 is not suitable for identifying hazards to persons, such as the presence of explosive, toxic, or asphyxiating gas. Utilize appropriate safety controls and hazard monitoring when entering hazardous locations or confined spaces, or when measuring potentially flammable gas mixtures.

The HI-FLOW 2 utilizes a battery charger. Disconnect the HI-FLOW 2 from the battery charger before turning on the instrument. The charger is not suitable for outdoor use or hazardous locations.

To prevent any leak of flammable gases into the HI-FLOW 2 enclosure, the integrity of the internal plumbing must be periodically checked. Always perform the ZERO ANALYZERS AND LEAK CHECK procedure in Section 5.3 of the User Manual prior to measuring flammable mixtures or entering hazardous locations.

Use only the supplied battery charger.
Connect to 120/240VAC 50/60 Hz only.
Take caution when inserting or removing the charger from AC voltage.
Charge batteries in indoor, nonhazardous environments only.

The Handheld Unit utilizes a ducted fan to collect gas samples. Keep hair and loose clothing away from the inlet of the Handheld Unit. Do not use the Handheld Unit to collect dust, debris, fluids, or any other nongaseous foreign material.

CLASS 1 LASER PRODUCT

The HI-FLOW 2 utilizes a gas detection module which contains a CLASS 1 LASER. The radiation produced by this laser is fully contained inside the gas detection module. DO NOT disassemble the gas detection module.

Do not remove access panels. Disassembling or attempting to repair the HI-FLOW 2 by persons other than qualified Sensors, Inc. service personnel may compromise the performance and/or safety of the device.

Sensors, Inc. cannot be held responsible or liable for any damage, whether voluntary or involuntary, whether accidental or incidental, caused by non-respect of customary, necessary, regulatory, and other rulings, and behaviors when packing/unpacking, installing, commissioning, operating, maintaining, and servicing the SENSORS devices.

This product has been evaluated as suitable for usage in hazardous locations.

SENSORS, INC. 6812 STATE RD. SALINE, MI 48176 USA 734-295-9683		SEMTECH HI-FLOW 2 Analyzer PN 9180-101 Handheld PN 9181-101
ELECTRICAL AND HAZARDOUS LOCATION SAFETY E115861. GAS MEASUREMENT DEVICE FOR HAZARDOUS LOCATIONS CLASS I, DIVISION 2, GROUP D, T4 OPERATING TEMPERATURE: -10°C TO 45°C (14°F TO 113°F) USE ONLY IN ACCORDANCE WITH USER MANUAL.		
DO NOT INSTALL, REMOVE, OR CHARGE BATTERIES WHILE IN A HAZARDOUS LOCATION.	THIS PRODUCT HAS NOT BEEN EVALUATED FOR LONG-TERM UV EXPOSURE. DO NOT STORE IN DIRECT SUNLIGHT.	
SÉCURITÉ ÉLECTRIQUE ET DANS LES ZONES DANGEREUSES E115861. APPAREIL DE MESURE DE GAZ POUR ZONES DANGEREUSES CLASSE I, DIVISION 2, GROUPE D, T4 TEMPÉRATURE DE FONCTIONNEMENT : -10°C À 45°C (14°F À 113°F) UTILISER UNIQUEMENT CONFORMÉMENT AU MANUEL D'UTILISATION.		
NE PAS INSTALLER, RETIRER OU CHARGER BATTERIES DANS UN ENDROIT DANGEREUX.	CE PRODUIT N'A PAS ÉTÉ ÉVALUÉ POUR UNE EXPOSITION UV À LONG TERME. NE PAS CONSERVER À LA LUMIÈRE DIRECTE DU SOLEIL.	

HAZARDOUS ENVIRONMENT PRECAUTIONS

THE FOLLOWING PRECAUTIONS MUST BE FOLLOWED WHEN USED IN HAZARDOUS LOCATION:

⚠ ENSURE BATTERY IS INSTALLED AND BATTERY COMPARTMENT IS SECURELY IN PLACE PRIOR TO ENTERING A HAZARDOUS LOCATION. DO NOT OPEN BATTERY COMPARTMENT, OR ANY OTHER PANEL, WHILE IN A HAZARDOUS LOCATION.

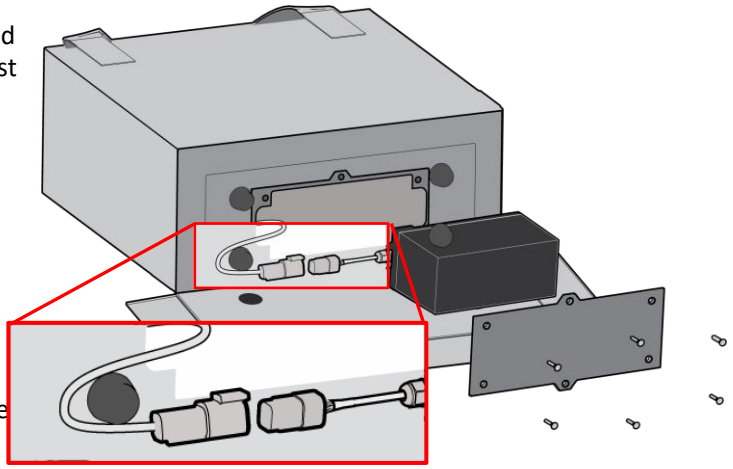
⚠ DO NOT BRING THE BATTERY CHARGER INTO A HAZARDOUS LOCATION. DO NOT CONNECT BATTERY CHARGER TO HIGH-FLOW 2, TO STANDALONE BATTERY, OR TO MAINS POWER WHILE IN A HAZARDOUS LOCATION.

⚠ ALWAYS PERFORM THE ZERO ANALYZERS AND LEAK CHECK PROCEDURE DESCRIBED IN SECTION 5.3 OF THE USER MANUAL PRIOR TO MEASURING FLAMMABLE MIXTURES OR ENTERING A HAZARDOUS LOCATION.

2 QUICK START GUIDE

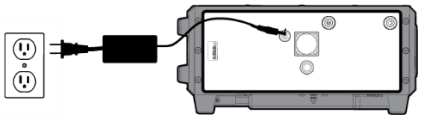
Follow these instructions to prepare your SEMTECH HI-FLOW 2 for use.

1. Unpack the HI-FLOW 2 and inspect for signs of damage.
2. The SEMTECH HI-FLOW 2 is shipped with a partially charged battery. The battery should be fully charged prior to use. Before charging the battery for the first time, the battery must be connected internally.
   a. Place the Analyzer Unit horizontally on a level surface.
   b. Open the Softcase.
   c. Remove (x6) screws with a T20 Torx Bit.
   d. Remove the battery cover panel.
   e. Pull out the battery.
   f. Connect the harnesses.
   g. Return the battery, panel and screws. Close the Softcase.



Charge the battery:

   a. Place the Analyzer Unit horizontally on a level surface.
   b. Plug the battery charger into the charging port on the front panel of the Analyzer Unit. Charge the battery fully. Unplug and store the battery charger when not in use.



⚠ The battery will discharge between uses. Charge the battery before each use. For more information about long term storage, refer to section 6.1.2 “Battery Life and Management”.

3. Once the instrument is fully charged, press the Power Button. The Power Button will illuminate when the device is on.
4. Using a wireless device, such as a computer or tablet, search for the HI-FLOW 2 wireless access point (WAP). The WAP will appear within 60 seconds of turning on the power button.
5. The WAP will be named “HI-FLOW-2” followed by the serial number of the unit.
6. Connect to the WAP using the password “**sensors123**”.
7. Open a web browser to the page “**192.168.42.1:48176**”
8. The SEMTECH HI-FLOW 2 Dashboard will appear.
9. From the SEMTECH HI-FLOW 2 Dashboard, click the menu on the top left side and navigate to Downloads. Select the SEMTECH HI-FLOW 2 User Manual to download a PDF copy of the user manual.
10. Review the SEMTECH HI-FLOW 2 User Manual for operating instructions.

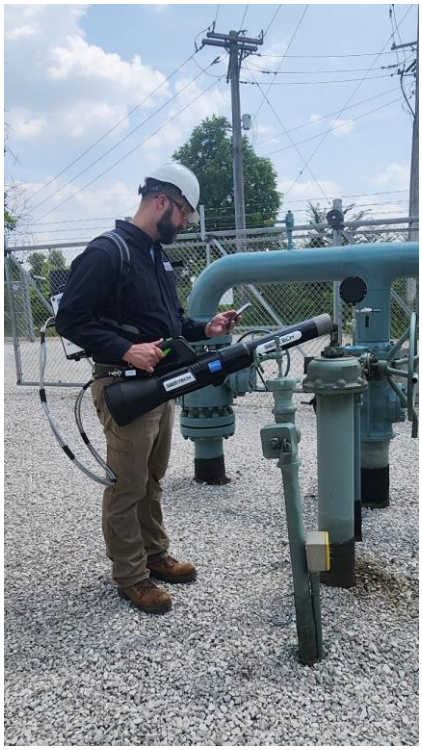
3 OVERVIEW

3.1 GENERAL INFORMATION

SEMTECH HI-FLOW 2 Fugitive Methane Sampler is a device / technology platform that allows for the accurate quantification of the fugitive methane leakage by extractive dilution and gas concentration measurement.

With natural gas comprising on average 90% methane, fugitive methane emissions in its downstream, midstream, and upstream operations are under scrutiny because of safety, economic and climate concerns.

For example, methane is a greenhouse gas (GHG) with a short-term impact many times greater than carbon dioxide (methane's impact is 72 times greater than carbon dioxide on a 20-year basis). In 2019, methane (CH4) accounted for about 10 percent of all U.S. greenhouse gas emissions from human activities according to the U.S. EPA's Overview of Greenhouse Gases.



For the quantification of fugitive gaseous leaks, the overall system comprised:

- The **Handheld Unit,** a high flow sampling device that captures and dilutes the fugitive emission
- The **Analyzer Unit,** a gas analyzer/control module to measure the concentration of the fugitive emission and calculate the corresponding leak.

Connected with an "umbilical connector, the combination allows for the accurate determination of the volume- and mass-based leakage rates of methane.

NOTE: In this manual, the HI-FLOW 2 Handheld Unit is illustrated. Note that other configurations that include higher and lower flow rates, and static/continuous configurations are foreseen but outside the scope of this document. The **Analyzer Unit** in this manual is configured to measure methane emissions.

3.2 OPERATING PRINCIPLES

Fugitive gas emissions from a variety of sources (valves, valve packings, seals, pipe fittings etc.) can be quantified by capturing the gas leaking from the source using a high-volume sampler coupled with the determination of the extracted and diluted gas concentration. The handheld high-volume unit uses an internal fan to draw into the unit the fugitive gas emission with additional make-up air from the surroundings. In addition, the high-volume sampler measures the total volumetric flow rate of the gas mixture passing though the device using an averaging pitot tube. The flowrate can be adjusted by the user by changing the fan speed. Temperature and pressure of the gas mixture is also measured. The measured methane concentration, volumetric flowrate, temperature, and pressure are all used to determine the methane leak rate in real-time.

Further details about the operating principles can be found in Section 9 of this manual.

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3.3 KEY FEATURES & BENEFITS

The HI-FLOW 2 is a robust, portable, battery powered, high volume sampler for the accurate quantification of fugitive methane emissions.

The combination of the Analyzer Unit and the Handheld Unit (with a variety of sampling adapters) allows the entire fugitive methane emission to be captured, diluted, and quantified accurately.

Sensors, Inc.'s SEMTECH HI-FLOW 2 high flow sampler sets the industry standard as the go-to solution for reliable, precise, and compliant methane emissions monitoring.

- Methane specific advanced gas sensor technology (10 ppm to 100% with integrated diluter) (and 0 to 8% with no dilution)
- Battery – LiFEPO4 (spare battery included) rated to 12.8V with 96 Wh capacity and a run time of 4 to 6 hours per battery at 50% duty cycle (Charge time: ca 4 hours)
- Built-in Wi-Fi communication utilizing an SBC Linux framework with web-based GUI for interactive full control on user preferred display (tablet, mobile, laptop, etc…)
- GPS for location data recording during testing
- Built-in scripts for regulatory compliance, sampling protocols, and periodic pre and post checks and audits
- SQL data management architecture with advanced pre-loaded queries for automated report generation (supports measurement campaigns, geofencing, and compliance management)
- API ready (for IoT applications)
- Integrated flow and sampling system, configurable up to ~30CFM
- Ergonomic handheld with balanced weight distribution
- Flexibility with industry accepted sampling adapters / nozzles / hoses
- Umbilical from sampler to analyzer (conveys sample, power, fan control, and serial interface)
- 2 controls on the sampler handle for sampling and fan speed control
- Tri-colored LED lights for handsfree feedback of system operation with configurable fan speed
- PWM controlled fan with manual lock with on/off control

3.4 REGISTER YOUR HI-FLOW 2

A mail-in registration card is provided with the HI-FLOW 2.

4 COMPONENTS

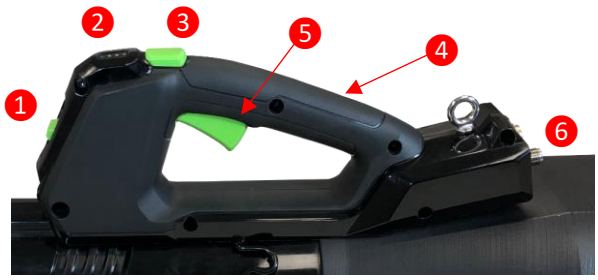
4.1 MAIN COMPONENTS

4.1.1 Handheld Unit

Handheld device with a high-volume vacuum sampling fan and total flow rate monitor

2024 Assembly

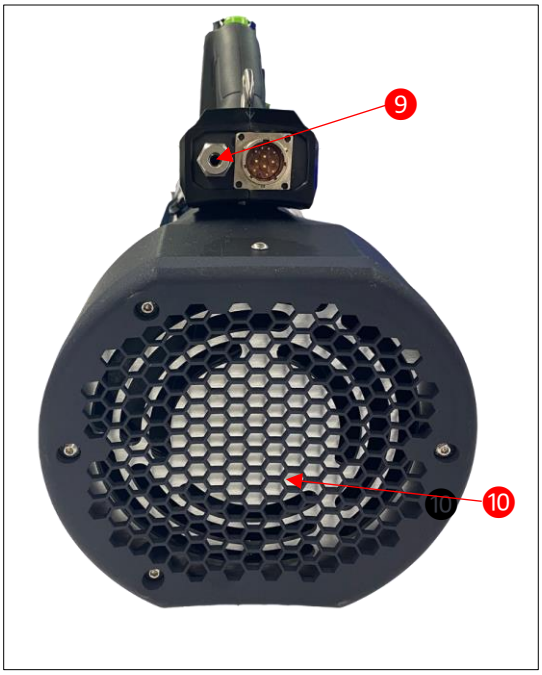
1. Manual Lock for Fan Control Button
2. LED display
3. Measurement ID sequence selector
4. Carrying Handle
5. Fan Control Button (on/off)
6. Umbilical Harness Connections



7. Sampling Accesories Attachment Location
8. Adapter for 2 inch Cam and Groove fitting sampling Hardware

9 Umbilical Harness Connection

10 Outlet Guard (Fan)



4.1.2 HI-FLOW 2 Analyzer Unit

Portable control module (which can be carried, placed on the floor, or mounted to a backpack) housing the gas sensor technologies, control electronics, and battery pack)

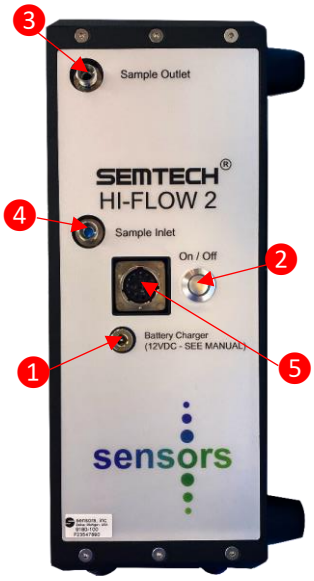
1 Battery Charging Input

2 Power (on/off)

3 Diluted sampled gas exhaust port

4 Pnuematic Connector for Umbilical Harness

5 Electrical Connector for Umbilical Harness



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4.2 ACCESSORY KIT

(Items shown not to relative scale)

4.2.1 Backpack carrier

Front View

Back View

4.2.2 HI-FLOW 2 with accessories

Handheld Unit

Gas Analyzer

Backpack Carrier

Umbilical Harness

Extension Nozzle

Oval Nozzle Extension

Battery

Backfeed Preventor

Battery Charger

9/16” Wrench

Hex Driver

T20 Torx Driver
(For battery replacement only)

First Use Safety Guide

4.2.2.1 RECOMMENDED GAS BOTTLE AND REGULATOR

Sensors recommends using this compact bottle of gas and regulator with the HI-FLOW 2 calibration kit.

GASCO-2.5 Calibration Gas 50% LEL Methane (2.5% Volume) Balance Air 103 Liter Cylinder C-10 Connection, vendor part number 103L-135A-2.5, available from the Cal Gas Direct website

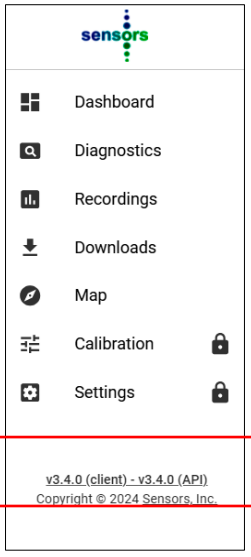
GASCO 70-Series Calibration Gas Regulator Fixed 4.0 LPM C-10 Connection, vendor part number 70-4.0, available from the Cal Gas Direct website). The tubing shown is included with the regulator.

4.2.2.2 CALIBRATION KIT (PURCHASED FROM SENSORS SEPARATE FROM HI-FLOW 2)

Easily perform audit checks and calibrations of the HI-FLOW 2. This kit contains a flow meter to measure gas overflow, three tubing assemblies and an adapter fitting to use on the recommended gas bottle and regulator. Contact Sensors or your local supplier.

4.3 SOFTWARE

The Host software is installed at the manufacturing facility. The software runs in a web browser on a device equipped with Wi-Fi. A cell phone may be a good choice for operating the unit in the field while testing leaks. A desktop or laptop would be a good choice using the Host software to configure settings. To determing the software installed on the HI-FLOW 2, navigate to the bottom of the menu in the host software.



To update software, an administrator can log into the "SETTINGS" page with a password and follow the prompts after clicking icon to the right of "Software Updates. Register your HI-FLOW 2 to be notified of software updates.

5 OPERATING INSTRUCTIONS

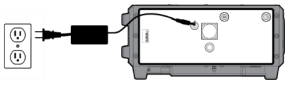
5.1 FIRST USE

5.1.1 Charging the battery

⚠ **Charge the battery indoors in a non-hazardous location.**

⚠ Use ONLY the battery charger supplied by Sensors for this purpose. Charge the battery fully with the unit powered off. This can take up to 7 hours when charging the battery while it is installed in the Analyzer Unit. See section 6.1.2 for additional battery information.

1. Place the Analyzer Unit horizontally on a level surface.
2. Plug the battery charger into the charging port on the front panel of the Analyzer Unit.
3. Unplug and store the battery charger when not in use.



5.1.2 Inspecting the Unit

⚠ Before using the HI-FLOW 2, inspect the components for any signs of damage such as cracks, missing fasteners, loose parts, and exposed wires.

⚠ Do not use the unit if it appears to be damaged. Contact the distributor or manufacturer for service instructions.

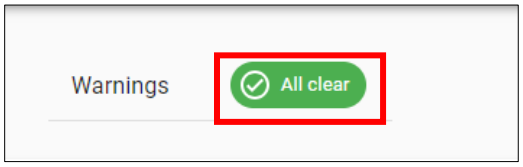
5.2 COMMUNICATION AND HOST SOFTWARE

5.2.1 Communications Wi-Fi connection

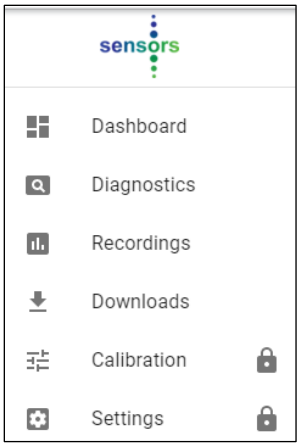
1. Click on “Network & Internet Settings” to show all wireless connections in the proximity. (Or if using a cell phone or tablet, go to “Settings>Wi-Fi)
2. Allow the wireless device to search and select the connection named “HI-FLOW-2” followed by the serial number of the unit.
3. Click on “Connect” button.

The Password for the WIFI connection is **sensors123**

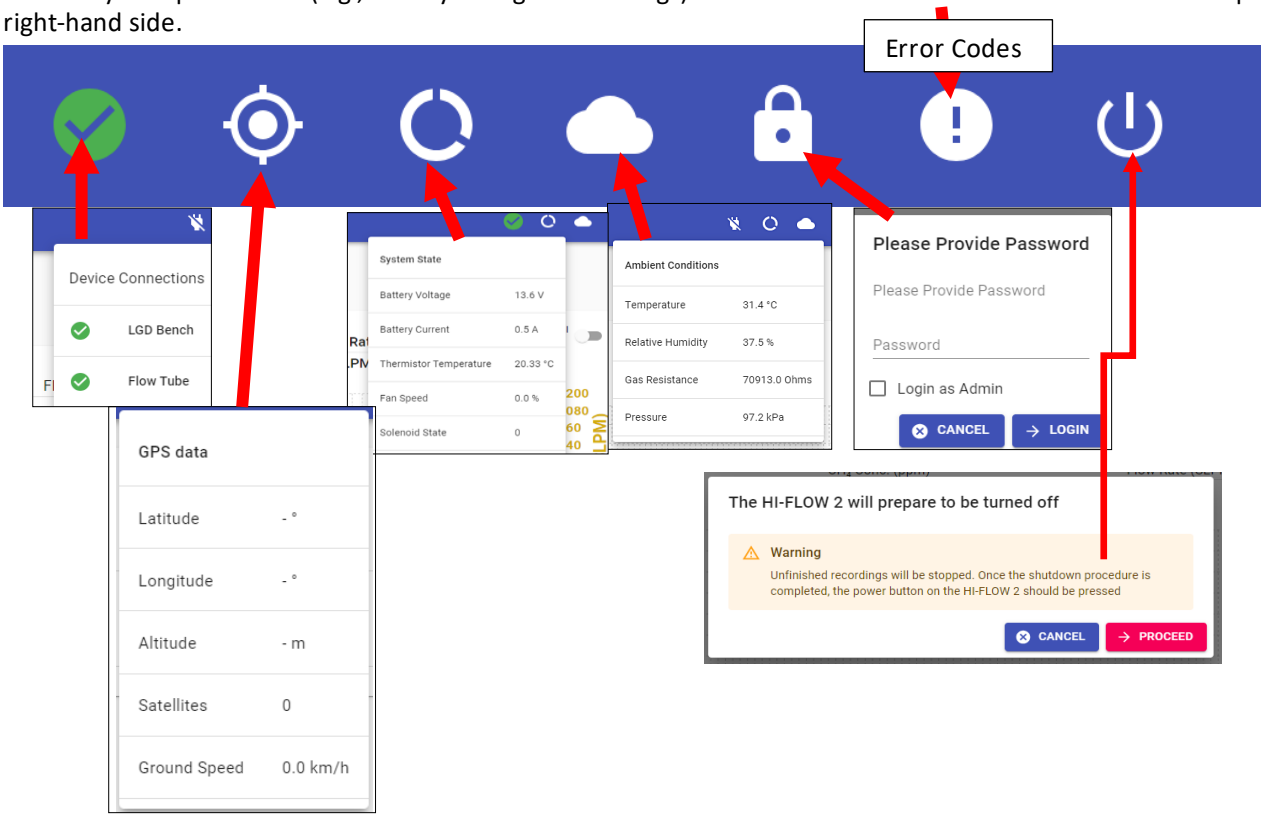
4. After logging into the WIFI, open a web browser and enter in the address: **192.168.42.1:48176**
5. The main screen of the Host Software is referred to as the “Dashboard”. Enter the “Dashboard” page on a web browser and wait for the “Warming up” alert to change to “All Clear”.



By clicking on the icon located at the top left corner of the Host you can navigate between “Dashboard”, “Diagnostics”, “Recordings” “Downloads”, “Map” “Calibration”, “Settings”. The **Calibration** and **Settings** pages are password protected.



Various system parameters (e.g., Battery Voltage Fan settings) can be accessed with the two buttons on the top right-hand side.



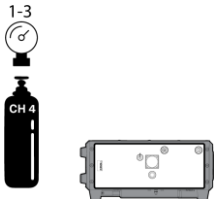
Error Codes are only used at the manufacturing facility.

5.3 MEASURING A METHANE LEAK

5.3.1 Preparing to Measure

1. Charge the unit fully before using. Refer to section 5.1.1 for charging instructions.
2. Turn on the power on the front panel of the gas Analyzer Unit.
3. On a Wi-Fi enabled computer or mobile device, connect to the host software via Wi-Fi.
4. Open a web browser and access the Host Software. (Section 1.6.1.1: Communication and Host Software)
5. Wait for the unit to warm up. The orange alert on the screen will change to green and will say “All Clear”.

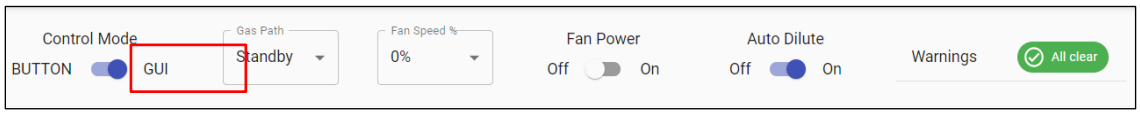
5.3.1.1 CHECK SYSTEM FOR INTERNAL LEAKS



Check the system for internal leaks once a day before use. Perform this step in an area where ambient methane levels are low. Follow all appropriate safety requirements.

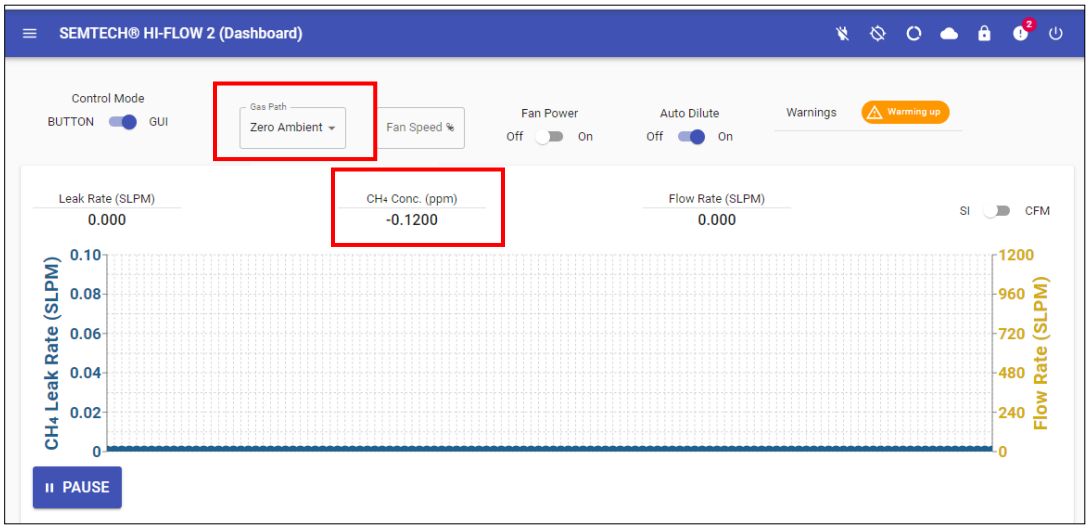
This requires a calibration bottle of methane with concentration in the range of 1000ppm to 4%.

1. Place the HI-FLOW 2 Analyzer Unit horizontally. Connect a Methane Calibration Bottle to the Sample Inlet port of the Analyzer Unit and apply 1- 3 psig of pressure. DO NOT OVER-PRESSURIZE.
2. Change the mode to “GUI”.

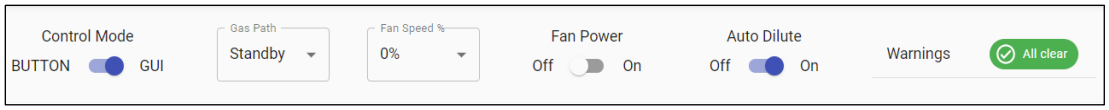


3. Change the Gas Path to “Zero Ambient”.

NOTE: Zero Ambient uses air from inside the Analyzer Unit housing. There will be some sound from the Analyzer Unit while the pumps operate. Allow the pumps to run for at least 40 seconds while it samples the air from inside the Analyzer Unit. It will display the methane concentration it is reading under “CH_4 Conc. (ppm)”. Note the concentration number. It will fluctuate slightly.

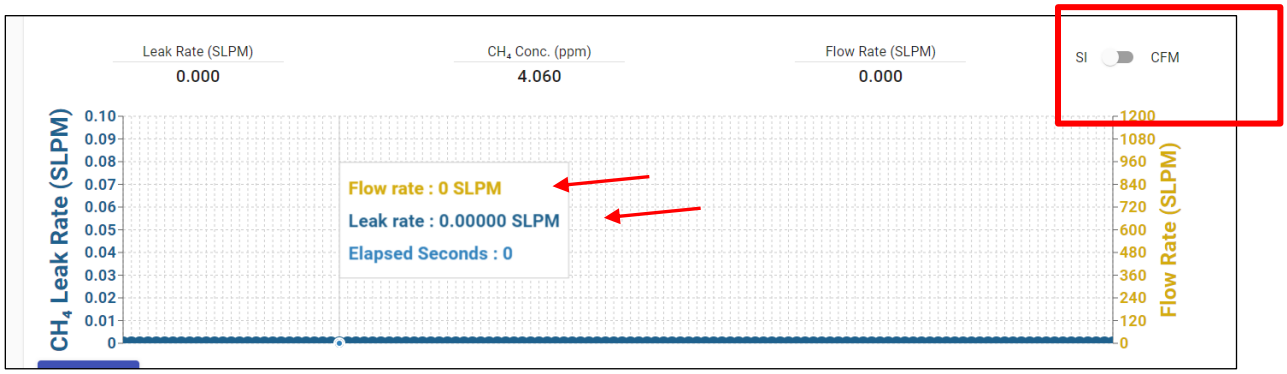


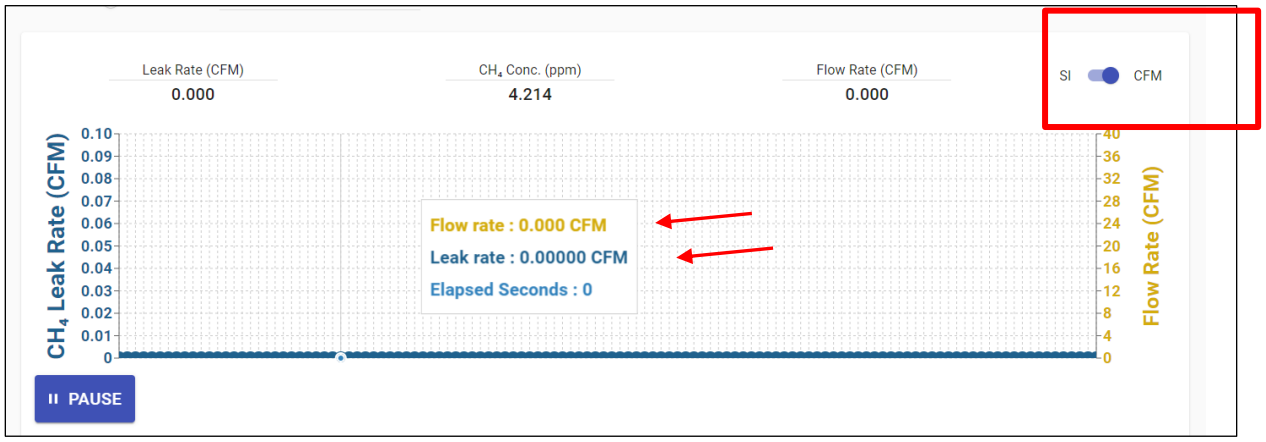
4. Concentration should remain less than **10 ppm.** If concentrations are higher, repeat step 3. If concentrations still rise above 10 ppm in this step, do not use the equipment and contact Sensors, Inc. for service.
5. Change the gas path back to “Standby” and disconnect the Methane Calibration Bottle.



5.3.2 Select a Format for the Data

Before performing tests or recordings, select the data format, either SI or CFM. The control turned off records the flow rate and leak rate in SLPM (Standard Liters Per Minute). When the control is turned on, flow rate and leak rate data are recorded in CFM (Cubic Feet per Minute).

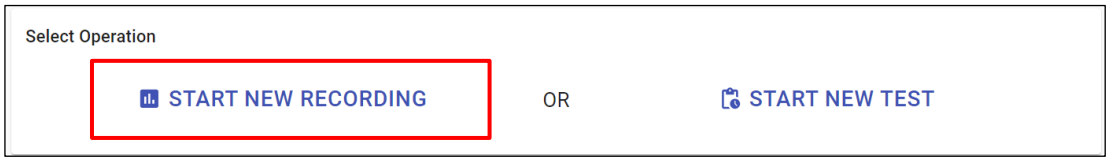




5.3.3 Recording a test or using presets for ACR data

This section covers both recording a test manually or for submission to ACR (formerly American Carbon Registry). Testing orphan wells for ACR is covered in greater detail in section 5.3.3.2.

The Dashboard has two modes for recording data. “START NEW RECORDING” records individual sessions and allows the user to select settings such as fan speeds, control modes. “START NEW TEST” is reserved for testing orphan wells for submission to ACR.



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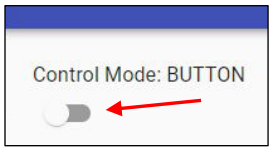
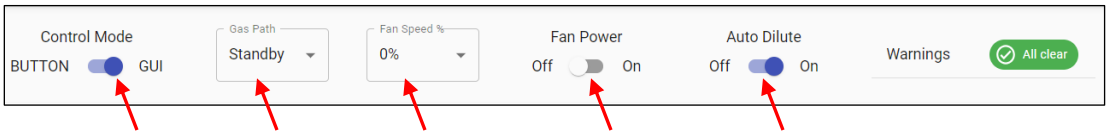
5.3.3.1 RECORDING A TEST (CONTROL MODES)

There are two control modes for testing with the HI-FLOW 2.



Control Mode: Button: This uses the buttons on the Handheld Unit to turn the fan on and off and to control the fan speed. The gas path is controlled automatically. This allows the person using the Handheld Unit to control the fan.

Control Mode: GUI: The fan is controlled from the Host Software interface. The gas path is manually controlled. This may be preferable if it is difficult to view the data on a screen and a second operator controls the fan remotely.



Leak Testing in "BUTTON" mode:

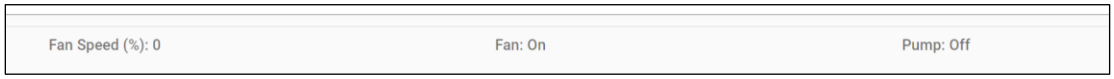
Choose a fan setting for the test. At the time of testing, a series of tests should be run to record the leak at several fan speeds, starting with a higher speed and moving to a lower speed.

- The higher fan speeds should be used for larger leaks. For instance, tests at 90%, 80%, 70% can be recorded and compared.
- Testing smaller leaks can be recorded at medium speeds, moving to lower speeds. For instance, tests at 80%, 70% and 60% can be recorded and compared.
- If the recordings at the lowest speeds are noticeably different from the higher speeds, this means the tests at the lower speed did not read the leak accurately and can be deleted.

Leaks can be measured using pre-configured Fan speed settings. The default is 90%, 80%, 70% and 60%.

The Measurement ID (and fan speed) selected is identified using the LEDs on both the handheld and main module and is clearly identified on the bottom of the "DASHBOARD" page as shown below. To cycle through the settings, press and release the Measurement ID button on the top surface of the handheld Unit handle.

When the Analyzer Unit is powered on and the fan is not running, all the LED lights will glow green. Pressing the button once will switch the first LED to turn green (standby mode). Press the button again and the first LED will turn orange, and the fan will run at 90% when the fan button is pressed. The fan speed and status will be displayed in the Host Software.



When the fan is turned **on**, the selected light will turn orange for 45 seconds. This allows for a sufficient sample of gas for accurate measurement. After 45 seconds, the light turns back to green. The fan control button can be released. To cycle through all the settings, continue to press the Measurement ID button and observe the LED lights.

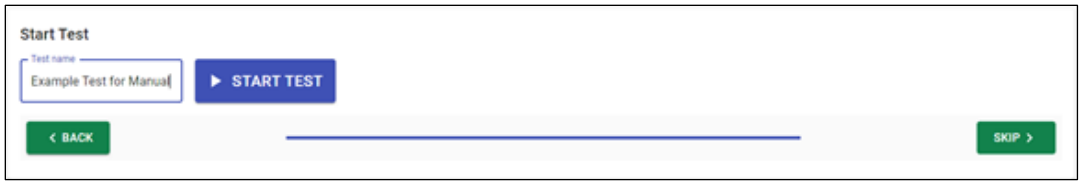
ID	Name	Fan Speed	LED Duration (secs) after fan control is held down.	Color
1	Standby	Off		Green
2	Fan High	90%	45	When fan control button is held down, the LED will stay gold for 45 seconds and then change to green. Allows for enough time to clear the tube of methane and sample a leak.
3	Fan Medium	80%	45	
4	Fan Low	70%	45	
5	Fan Ultra-Low	60%	45	

NOTE: These configurations can be modified through the "SETTINGS" page, which is password protected.

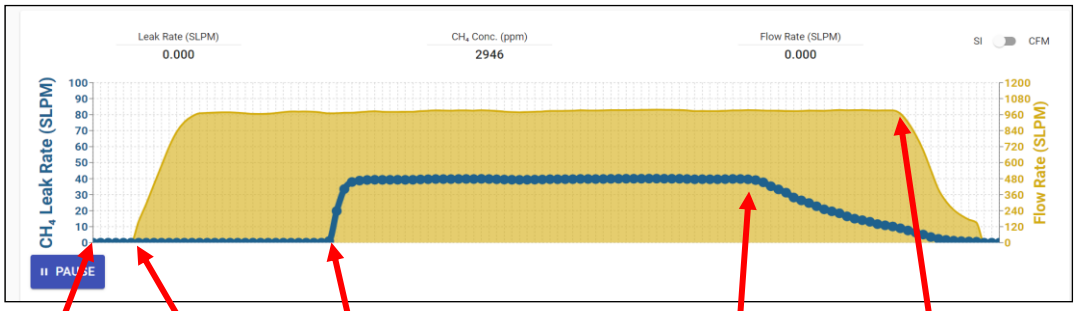
When the desired configuration has been selected (2-5 in the above table) the sampling pump and fan can be turned on using the Fan Control Button 1. This does not latch and must be depressed to keep the fan and pump active. If the button will not depress, check the manual lock button 4 is not in the on position. (This is to prevent the fan from being accidentally active when not required.) Press the Measurement ID button 2 to cycle through the IDs shown in the LED display 3.

The leak measurement procedure combines positioning at the end of the handheld tube and referring to the information from the host software.

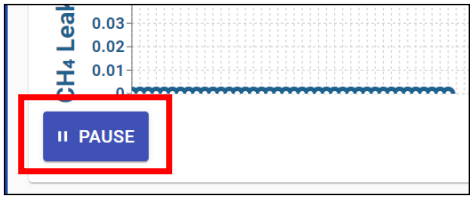
1. If the backpack is being used, the tester should power on the Analyzer Unit and give it a several minutes to warm up. then put it on and fasten the front strap. Check the Host Software for the green "All clear" alert.
2. Decide on the desired fan speeds based on the previous section. It is recommended that the leak is measured at several fan speeds, starting from a faster one and moving to a slower one.
3. On the dashboard in the Host Software, click on "Prepare for a New Test" then click on "START TEST" button. Enter a name for the test. Go through the Zeroing steps if the unit has not previously been zeroed.



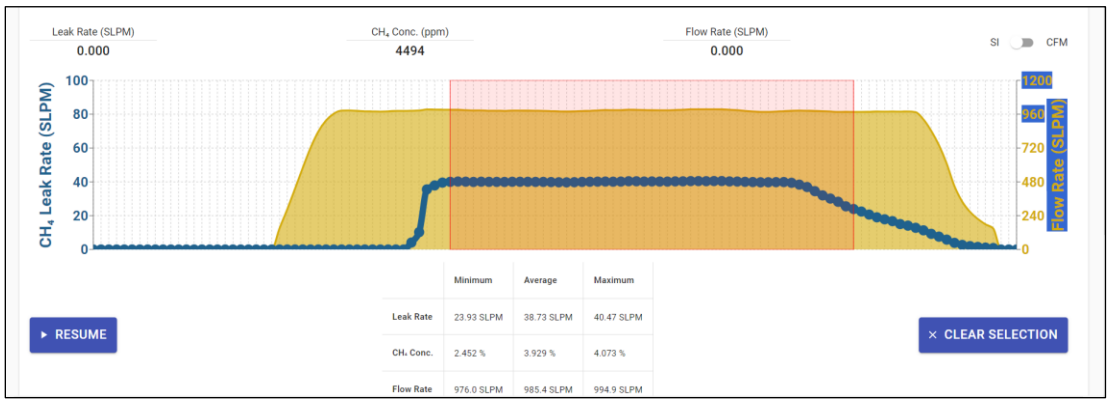
4. Position the end of the hand-held unit **away** from the leak. The fan will be in standby mode. Change from standby to the desired fan speed by clicking the button on the top of the handheld mode to cycle through the speeds. When you have selected the desired speed for this test, squeeze the Fan Control Button. Observe the graph on the screen.
5. The sampled flowrate will increase within 5-10 seconds and becomes steady. The graph will fill in with a gold color, indicating that the fan is running. Continue to hold the fan control button down.
6. The CH4 concentration (blue dots / line) will be visible. When both the flow and CH4 leak rate are steady, move the end of the HI-FLOW 2 to the leak. Sample the leak for at least **20-30 seconds**.



NOTE: Clicking on the "PAUSE" button will stop the graph from drawing on the screen. This will allow the user to get data from the graph. **The graph you see may not match these examples exactly.**



Selecting a section of the graph while paused will also show the minimum, maximum and average of the data across that section.



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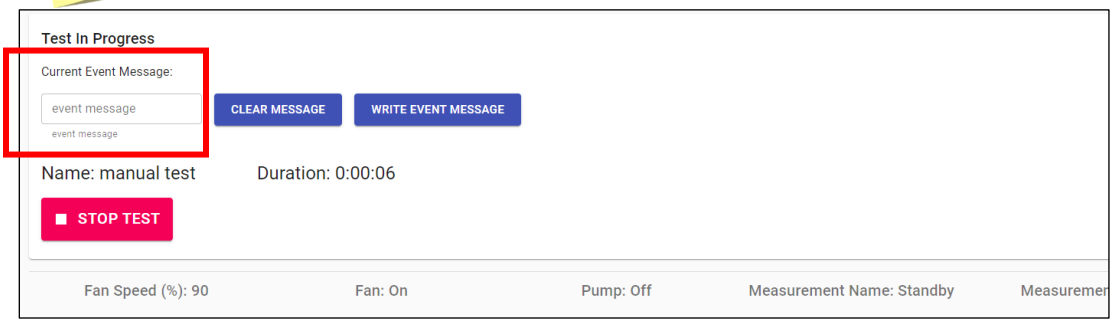
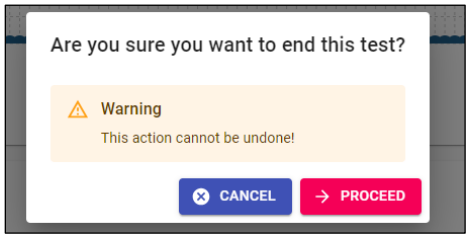
- To select a different range, click on "CLEAR SELECTION"
- To return to the moving graph, click "RESUME. The blue dotted line will rise in the graph showing the methane concentration.

7. Continue to run the fan and move the end of the Handheld Unit away from the leak. This will purge out any CH4 from within the system.
8. When the CH4 concentration is back near background, release the Fan Control Button on the Handheld Unit.

NOTE: During the file recording, the user can enter "event messages" by writing an event message or clearing an old message. **The Current Event Message** is saved to the file at 1 Hz.



9. Click on the "STOP TEST" button on the screen to end recording data. There will be an alert on the screen asking if you want to stop the test. To confirm this, click "PROCEED".



10. Repeat the test at progressively lower fan rates.
11. If the data is going to be downloaded later, and no further testing is going to be done at the time of this test, turn off the power on the Analyzer Unit.

Leak Testing in "GUI" mode:

Choose a fan setting for the recording. At the time of testing, a series of tests should be run to record the leak at several fan speeds, starting with a higher speed and moving to a lower speed.

- The higher fan speeds should be used for larger leaks. For instance, tests at 90%, 80%, 70% can be recorded and compared.
- Testing smaller leaks can be recorded to medium speeds, moving to lower speeds. For instance, tests at 80%, 70% and 60% can be recorded and compared.
- If the recordings at the lowest speeds are different from the higher speeds, this means the tests at the lower speed did not read the leak accurately and can be deleted.

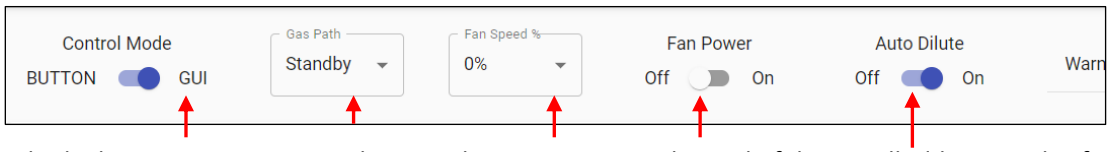
Leaks can be measured using pre-configured Fan speed settings.

The GUI Control Mode controls the fan speed, turns the fan on and off, and controls the gas path manually. The LED lights will not indicate fan speeds as they do in the Button mode.

The default fan speeds are 90%, 80%, 70% and 60%.

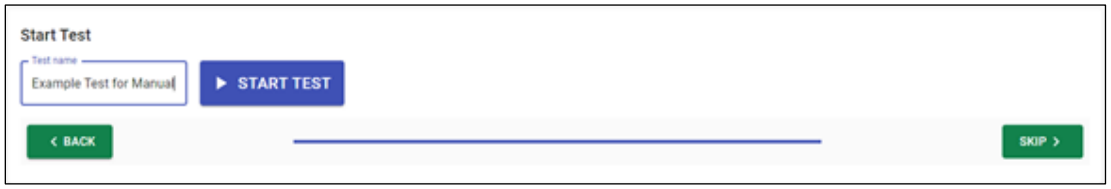
Auto Dilute: This enables the system to automatically shift the dilution if the methane concentration goes above 8%. It is recommended to keep this setting "ON".

NOTE: These configurations can be modified through the "SETTINGS" page, which is password protected.

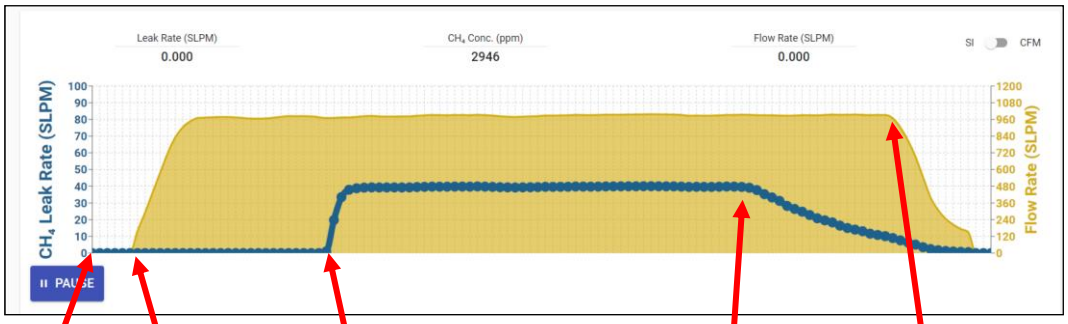


The leak measurement procedure combines positioning the end of the Handheld Unit and referring to the information from the host software.

1. Power on the Analyzer Unit and give it a several minutes to warm up. If the backpack is being used, the tester should put it on and fasten the front strap.
2. Decide on the desired fan speeds based on the previous section. It is recommended that the leak is measured at several fan speeds, starting from a higher percentage, and moving to a lower percentage.
3. On the dashboard in the Host Software, click on "Prepare for a New Test" then click on "START TEST" button. Enter a name for the test. If the unit has not been zeroed, follow the steps to zero the unit.



4. Position the end of the hand-held unit **away** from the leak. To start the fan, change the gas path to "Sample" change the fan speed to desired setting and turn the Fan Power to ON.



Fan: OFF
Gas Path: Standby

Fan: ON
Gas Path: Standby

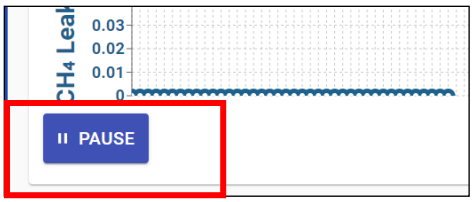
Fan: ON
Gas Path: Sample

Fan: ON
Gas Path: Star

Fan: OFF
Gas Path: Standby

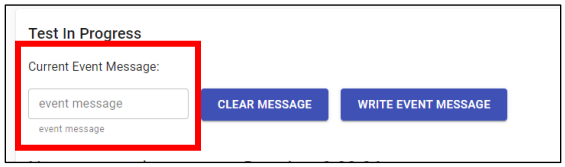
5. The sampled flowrate will increase within 5-10 seconds and becomes steady. The graph will fill in with a gold color, indicating that the fan is running.
6. The CH4 concentration (blue dots / line) will be visible. When both the flow and CH4 leak rate are steady, **move the end of the HI-FLOW 2 to the location of the leak**. Sample the leak for at least **20-30 seconds**.

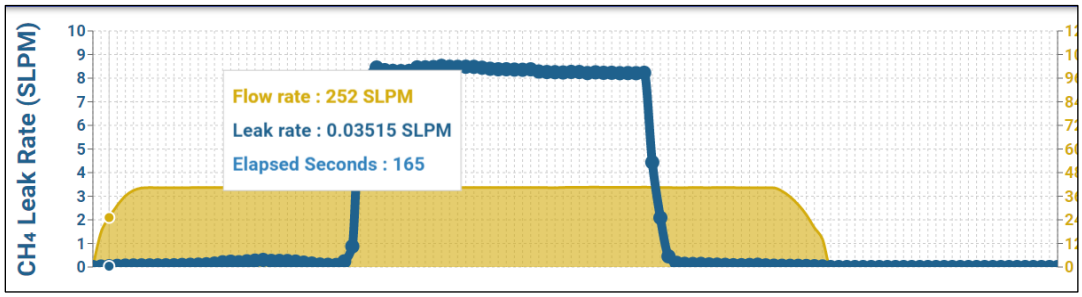
NOTE: Clicking on the "PAUSE" button will stop the graph from drawing. This will allow the user to get data from the graph. Selecting a section of the graph while paused will also show the minimum, maximum and average of the data across that section.



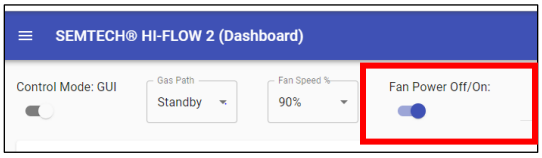
7. The blue dotted line will rise in the graph showing the methane concentration.

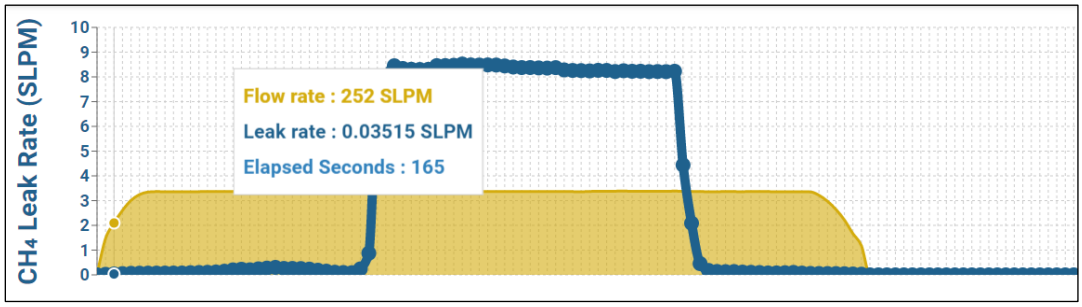
During the file recording, the user can enter "event messages" by writing an event message or clearing an old message. **The Current Event Message** is saved to the file at 1 Hz. An example is shown below with a message "Start Test" being saved before being cleared.



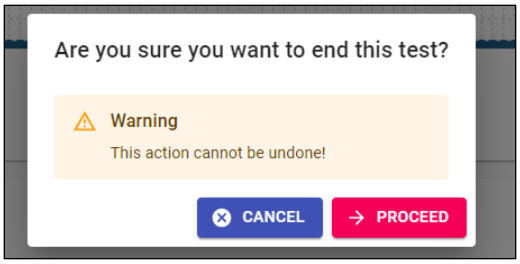


8. Move the end of the tube away from the leak.
9. Continue to run the fan. This will purge out any CH4 from within the system.
10. When the CH4 concentration is back near background, turn the Fan Power **Off** on the screen.





11. Click on the "STOP TEST" button on the screen to end recording data. There will be an alert on the screen asking if you want to stop the test. To confirm this, click "PROCEED".

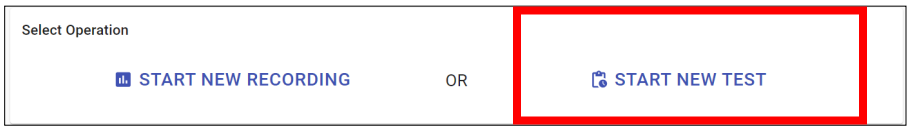


12. Repeat the test at progressively lower fan rates.
13. If the data is going to be downloaded later, and no further testing is going to be done at the time of this test, turn off the power on the Analyzer Unit.

5.3.3.2 RECORDING A TEST TO SUBMIT TO ACR

The SEMTECH HI-FLOW 2 is the only high flow methane sampler to meet the rigorous requirements outlined by ACR. ACR, (formerly American Carbon Registry) is a nonprofit enterprise of Winrock International, a leading carbon crediting program operating in global compliance and voluntary carbon markets. ACR reporting requirements are detailed in "Methodology for the Quantification, Monitoring, Reporting and Verification of Greenhouse Gas Emissions Reductions and Removals from the Plugging of Orphaned Oil and Gas (OOG) Wells", available on the ACR website (https://acrcarbon.org/methodology/plugging-orphaned-oil-and-gas-wells/).

In order to generate reports aimed at meeting ACR's requirements, the HI-FLOW 2 Host Software is set up to run the test and report the results in a format that can be downloaded.

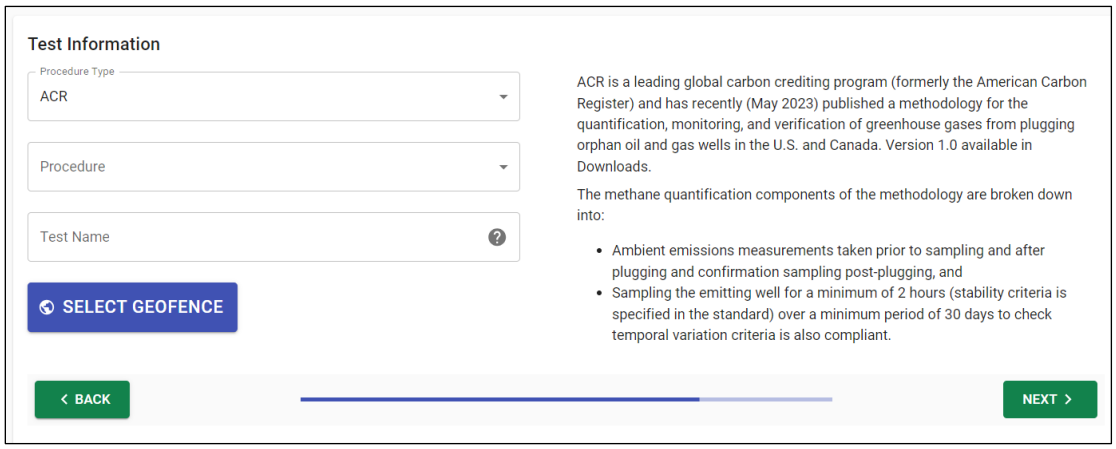


"START NEW TEST" is intended for recording data for submission to ACR for orphan wells testing. The preconfigured tests will run for the correct time automatically. During ACR testing, the buttons on the Handheld Unit and the GUI controls are disabled. The test can be halted at any time, but the test data will only be useful if the test is allowed to run completely. Refer to the table below for descriptions of the ACR test procedures.

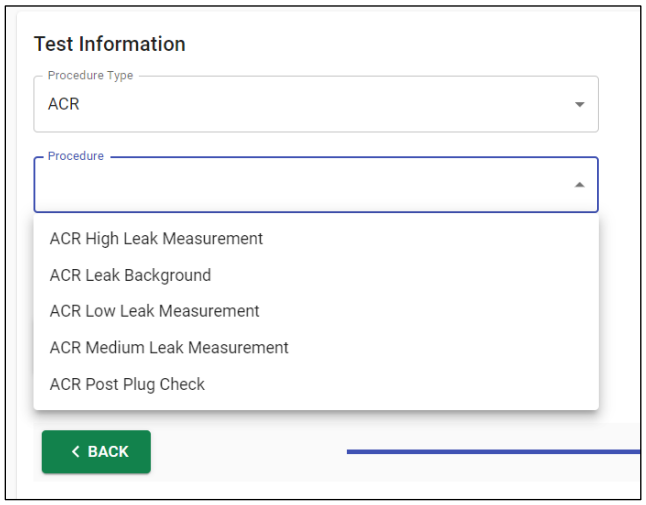
Procedure	Instructions
ACR High Leak Measurement	Leak measurement should be taken at the unplugged well. This test will run for about 2 hours, sampling for 30 one-minute intervals, and requires no user input.
ACR Leak Background	Leak background should be taken upwind of the well that is being measured for this ACR test. This test will run for about 10 minutes and requires no user input.
ACR Low Leak Measurement	Leak measurement should be taken at the unplugged well. This test will run for about 2 hours, sampling for 7 ten-minute intervals, and requires no user input.
ACR Medium Leak Measurement	Leak measurement should be taken at the unplugged well. This test will run for about 2 hours, sampling for 13 five-minute intervals, and requires no user input.
ACR Post Plug Check	Post plug check should be taken within 5 cm of the ground, near the plugged well. This test will run for about 5 minutes and requires no user input.

If the user clicks through to the "Test Information" screen, the user will be prompted to select a procedure type .

1. Select ACR".

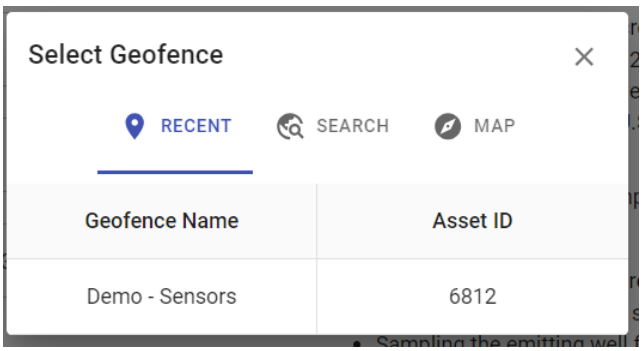


2. Select a type of test from the dropdown menu.



The test will automatically be named with the Procedure type and the date. This can be modified by the user (for example, if the user wanted to include the well number".

A previously created geofence can be selected, selecting the geofence by name, by searching or by selecting the geofence on the map. (For more information about geofences, refer to section 5.4.



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3. Click on the checkbox after reviewing the instructions in this manual and then click on the "START TEST" button.
4. The test will finish and end recording automatically. Clicking the "Finish Test" button will cause the test to end, finishing out the current cycle. Report generation will still be guaranteed, but it may be shorter than the regulation criteria. The "Halt Test" button will end the test immediately and may prevent the report from being generated.

5.3.4 Recording a Test using presets for OOOOb

The HI-FLOW 2 Host Software includes the ability automate the data collection and report generation compliant with EPA NSPS subpart OOOOb Rule (referred to here as OOOOb). This software automation greatly simplifies the tasks for the user, which would otherwise require numerous data recordings and data averaging. This version also automates the bi-annual calibration audits required for OOOOb and generates corresponding reports. The reports are stored on the HI-FLOW 2 for later retrieval whenever necessary. All OOOOb requirements for high flow sampling are easy to fulfill with the current HI-FLOW 2 host software.

In addition to testing reports, daily and bi-annual calibrations are required.

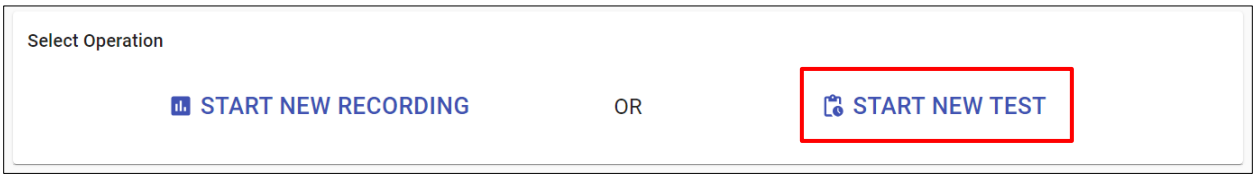
5.3.4.1 OOOOB TEST SEQUENCE

The OOOOb testing sequence will run automatically. It will take approximately 8 minutes, in which it will:

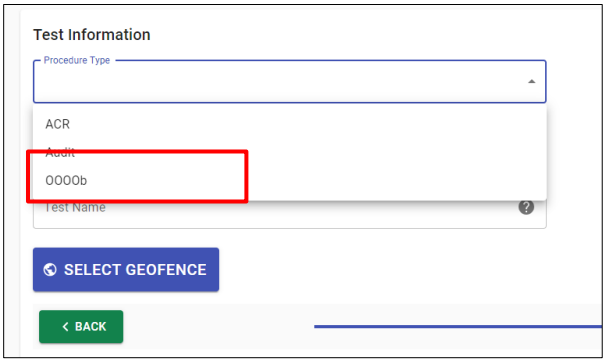
1. Test background levels for methane
2. Flush the tube
3. Sample and measure leak
4. Repeat steps 1-3 a total of 3 times
5. End the test

A report will automatically be generated upon completion of the test sequence. Each of the 3 leak measurements are graphed, adjusted for background measurements, and averaged in accordance with the OOOOb regulations. Each result is summarized in a table. The software also checks to verify that the measurements are consistent within the required tolerance, and pass/fail results are provided.

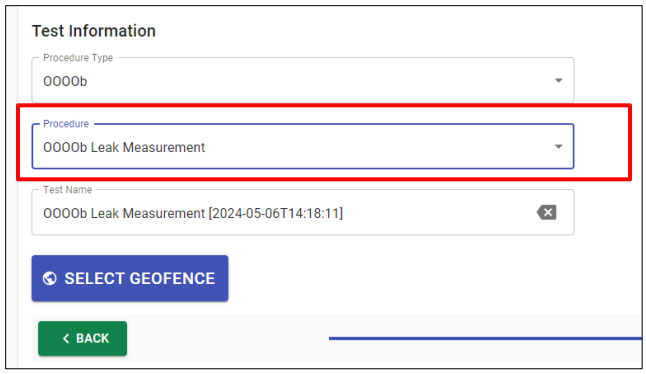
To initiate a OOOOb Compliant test sequence, start a new test:



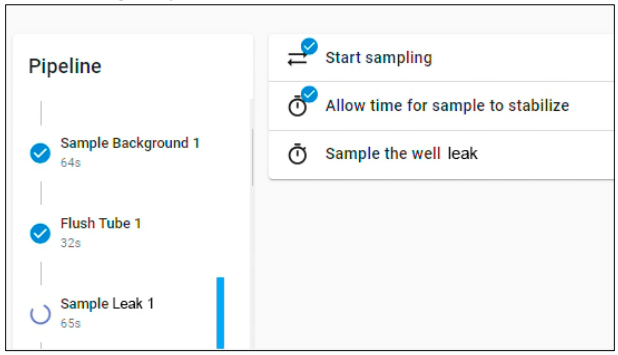
and select OOOOb under "Procedure Type".



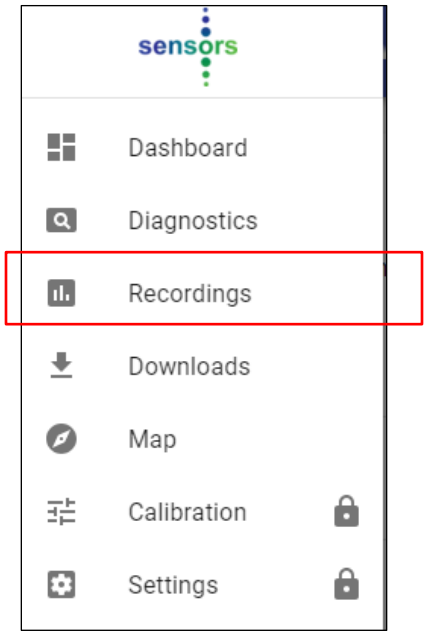
Select "OOOOb Leak Measurement" under Procedure. Once the test starts, the sequence will run automatically.



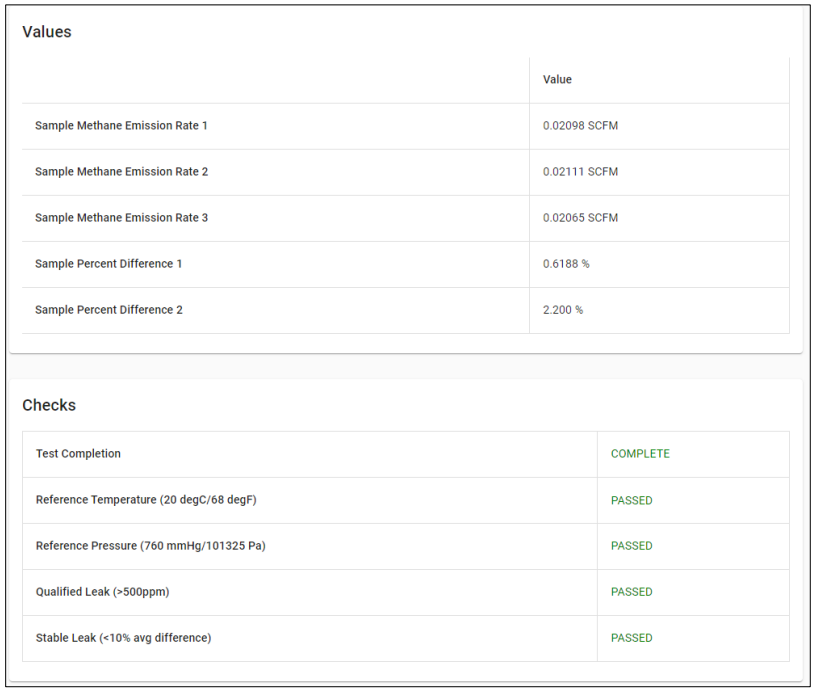
The testing sequence will end after about six minutes.



To access the report, navigate to Recordings. Reports can be downloaded or viewed in the browser as shown in the example that follows.



The report will include both data and PASS/FAIL for the required OOOOb requirements for high flow methane samplers.



Values

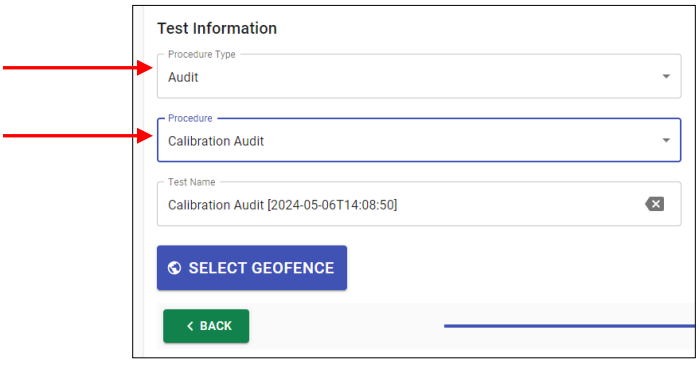
	Value
Sample Methane Emission Rate 1	0.02098 SCFM
Sample Methane Emission Rate 2	0.02111 SCFM
Sample Methane Emission Rate 3	0.02065 SCFM
Sample Percent Difference 1	0.6188 %
Sample Percent Difference 2	2.200 %

Checks

Test Completion	COMPLETE
Reference Temperature (20 degC/68 degF)	PASSED
Reference Pressure (760 mmHg/101325 Pa)	PASSED
Qualified Leak (>500ppm)	PASSED
Stable Leak (<10% avg difference)	PASSED

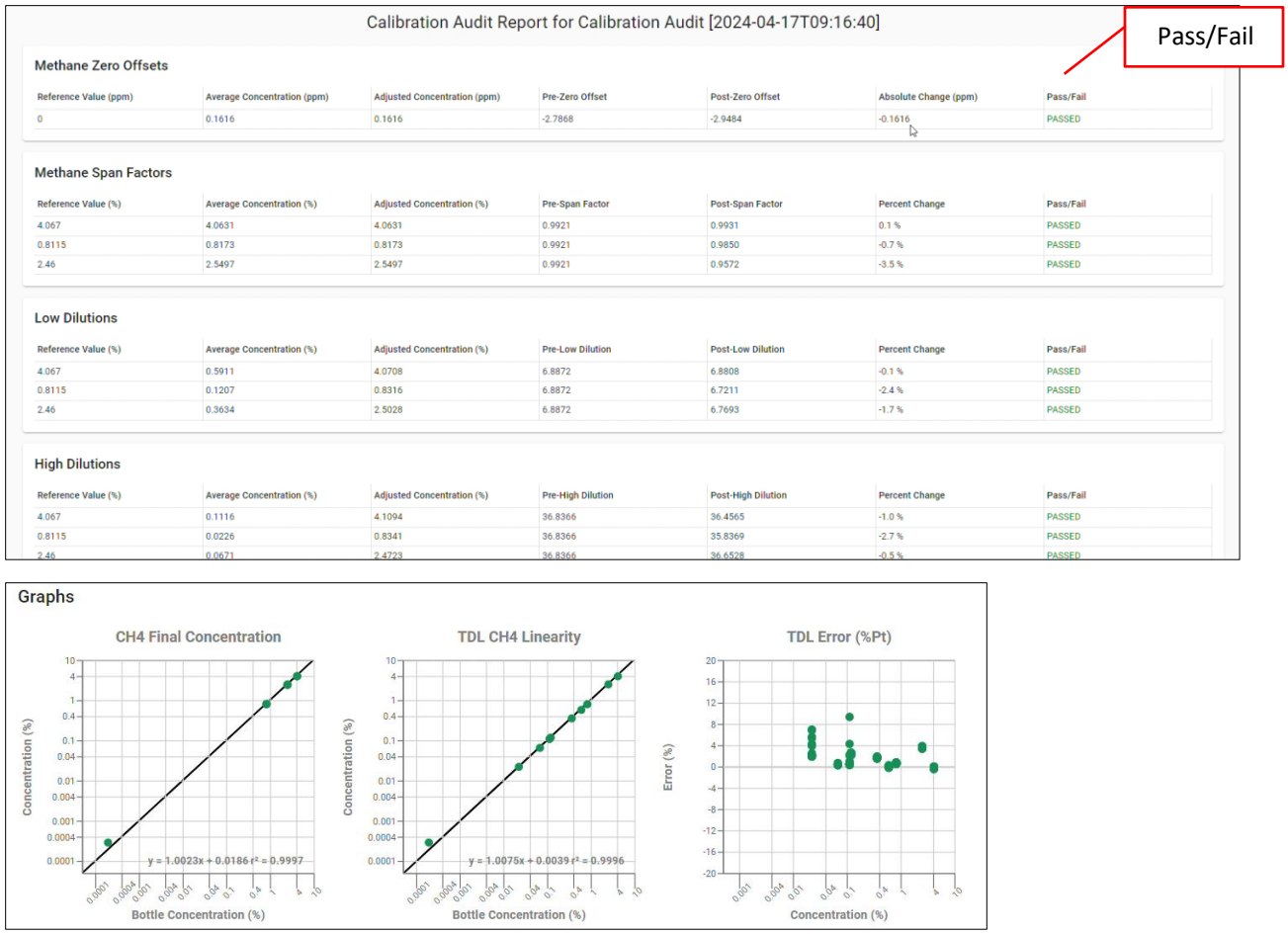
5.3.4.2 CALIBRATION AUDITS FOR OOOOB

The full Calibration audit was designed with OOOOb biyearly regulations in mind, but has generalized use. The audit runs a zero, then span/low dilution/high dilution in cycle on three (configurable) different bottles. The Calibration Audit is accessed through the same steps as testing, but selecting “Audit”>”Calibration Audit”.



To locate reports, Go to “Recordings” on the side menu. Reports can be downloaded to viewed in the browser as shown in the following example.

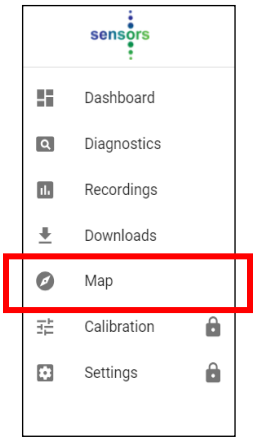
The Calibration Audit Report provides data and Pass/Fail information.



5.4 GEOFENCES

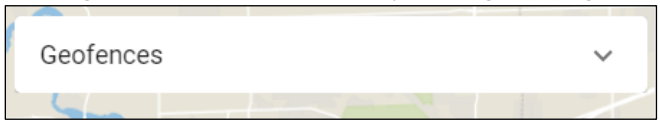
A geofence is a shape made of a set of points that identifies a location using latitude and longitude coordinates. Multiple HI-FLOW 2 recordings can use the same geofence. A geofence can be created without performing a test.

To access the geofence controls, select “Map” from the main menu on the upper left side of the window.



The map data is stored locally on the HI-FLOW 2. It does not depend on the GPS signal to draw geofences. The map has one display mode (basic colors with labels, no satellite view, or topographical information). The geofences that have been recorded by the unit are displayed as a list. Clicking on the name will zoom into the center of that geofence and a pin icon will be displayed with the name given to the geofence. Recorded geofences can be deleted but cannot be edited.

A new geofence can be created by clicking on the geofences button on the map page.



A list of Geofences on the unit will be displayed.

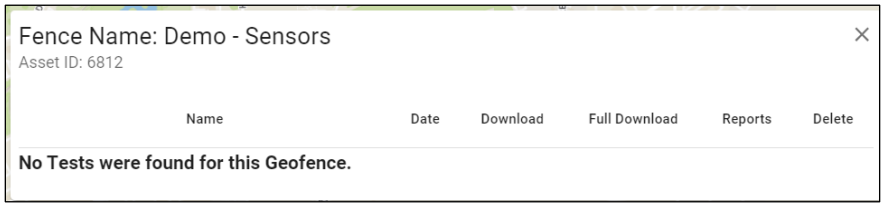
To create a new Geofence:

- click on the Polygon (for an irregularly shaped geofence) tab or
- click on the Circular tab (for a geofence that extends in an equal direction around a point).

The geofence software does not identify the current location. In order to find the current location, refer to the information in the map menu on the top of the screen.

Note that the HI-FLOW 2 will only display data in the top menu if the unit can detect satellites. This may not be possible inside a building or a vehicle.

- The latitude and longitude can be copied and pasted into the geofence fields to locate the current position of the HI-FLOW 2.
- Finding the current location and clicking on the map by referring to landmarks visually will also add an initial point, but this method may not be as precise as entering lat/long data.
- To create a polygon Geofence, click on the initial point and then move the cursor clockwise, click on additional points to define the shape of the polygon.
- To close the geofence, click on the circle of the pin of the first point. The pin color will shift when the cursor on the right part of the pin symbol.
- When the geofence shape is successfully closed, the "SAVE GEOFENCE" button will be activated and will change to blue.
- When the geofence is selected, it will change to a darker color. It can be deleted when it is selected.
- A Geofence can be assigned to a test. To view the tests with a specific Geofence assigned, click on the name of the test in the list on the Map page. The tests will be displayed on the Map page.



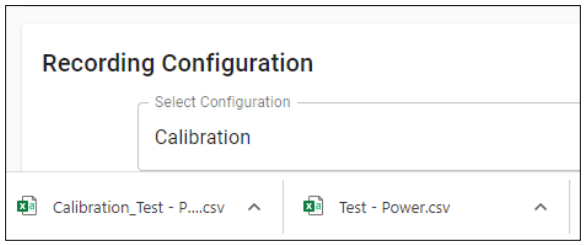
5.5 MANAGING TEST DATA

5.5.1 File Configurations

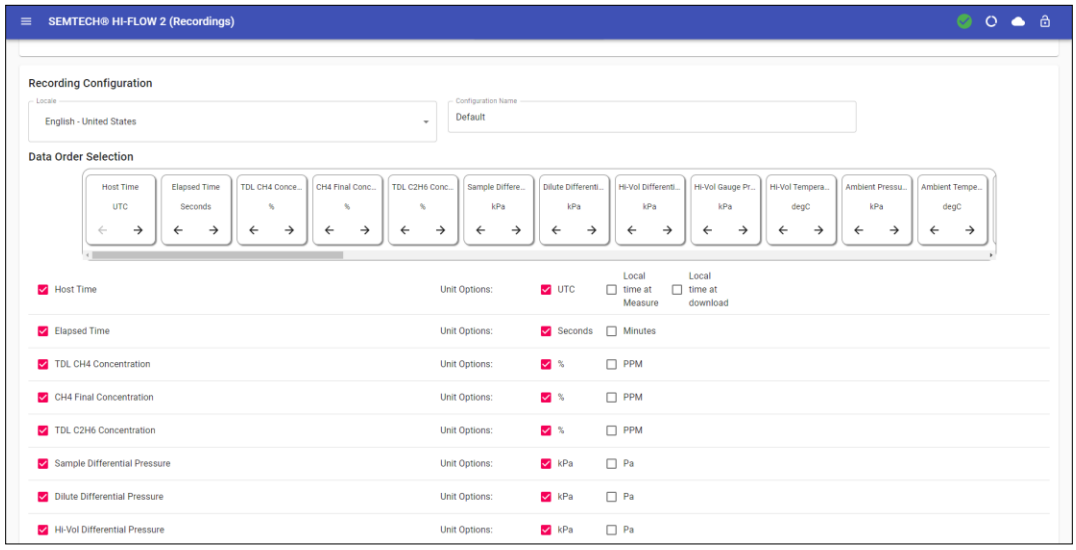
The Recording configuration file provides the ability to change the parameters and units when the file is downloaded. Navigate to the "RECORDINGS" page.

NOTE: The ability to change what parameters are downloaded with selected units (e.g., SI or imperial) is intended to provide flexibility for users in different continents and market applications.

NOTE: If the "Default" file configuration is selected the filename will be downloaded with the name displayed. However, if a custom file configuration is selected, the file name will be prefixed with the configuration name. This is illustrated below with a file named "Test-Power". It is downloaded with two configurations: Default and Calibration.



The Calibration format was created by adding a "NEW CONFIGURATION" and saving it at the bottom of the screen. In this example, the gas concentration data is selected to be downloaded in both % and ppm. The other relevant parameters are also selected with the selected units is applicable. These configurations can be edited.



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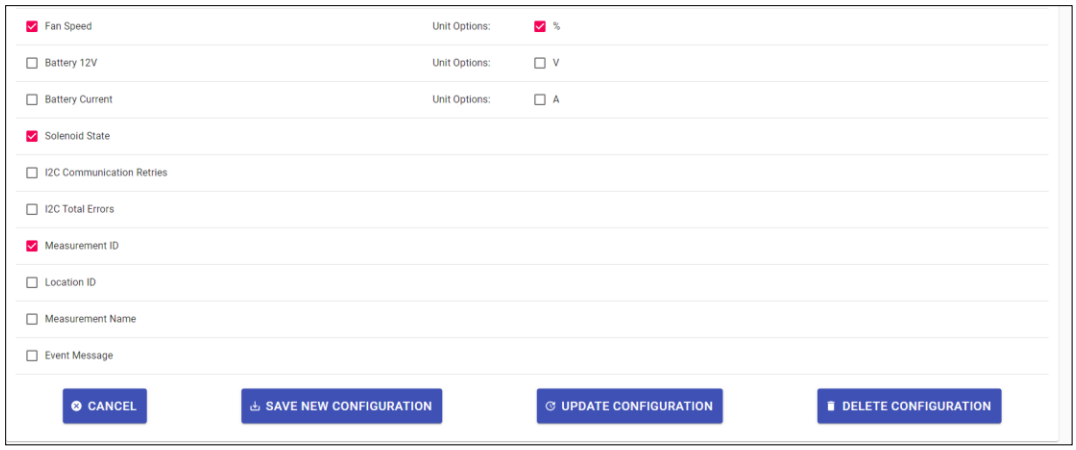
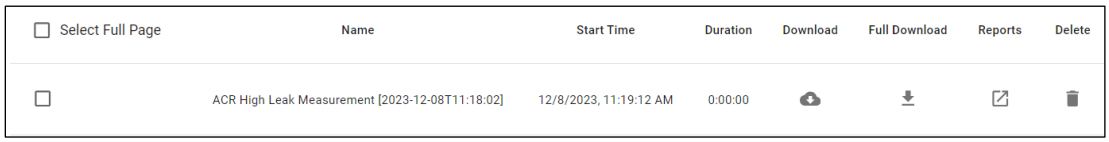


The downloaded configuration data is saved in csv format and can be easily analyzed using tools like Microsoft Excel.

NOTE: Flows reported under Standard Conditions are calculated using a reference temperature of 25°C and pressure of 101.325. For this testing program, the operator will need to manually select and average the methane leak rates for the tests performed.

5.5.2 Managing Recordings



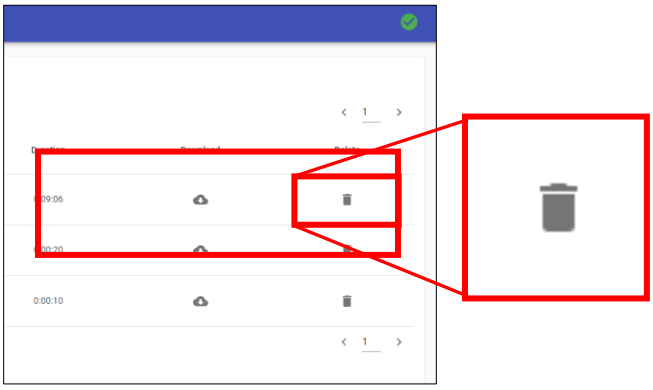
The Recordings page lists all of the recordings on the device, displaying 10 at a time. They are sorted from newest to oldest. The reports can be downloaded, deleted, and viewed through this page.

5.5.2.1 DELETING RECORDINGS

The test results can be reviewed. If tests are recorded at a very low fan speed, it may differ from tests run in the same location at higher speed.

Delete any files that are not needed in Recording History.

- To delete individual files, click on the trashcan icon in the same row as the file name.



- To delete multiple files, select the files and scroll down to the "MOVE SELECTED TO TRASH" button.

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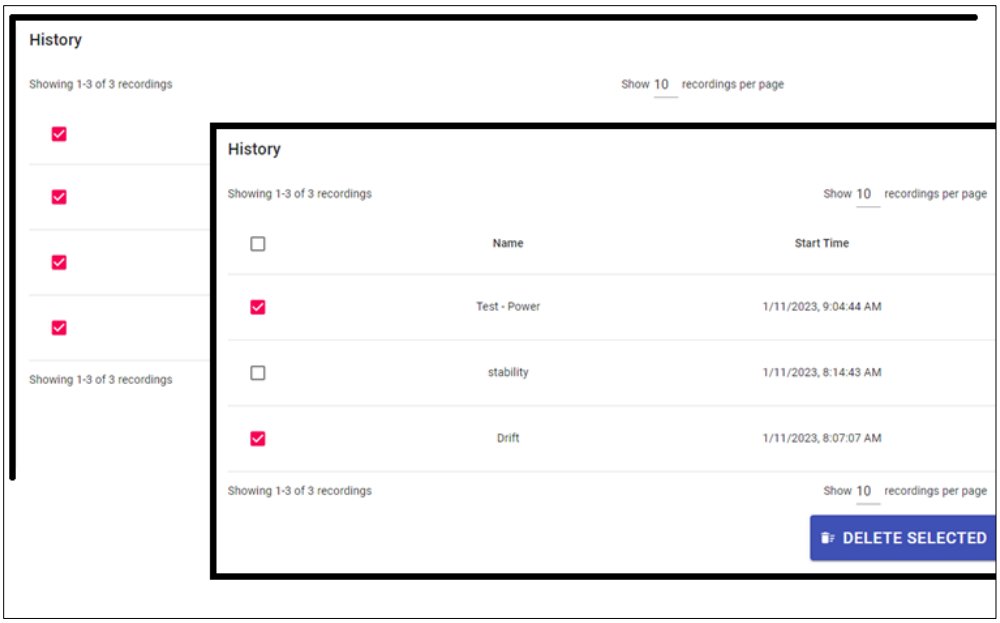
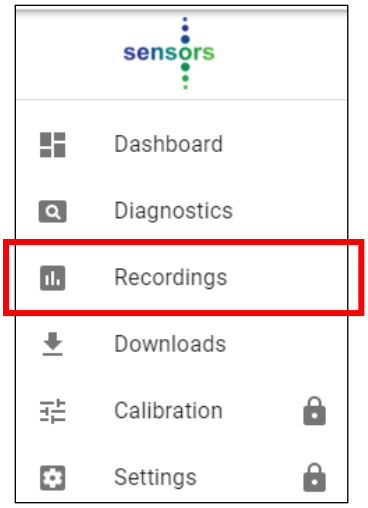


5.5.3 Downloading Test Data

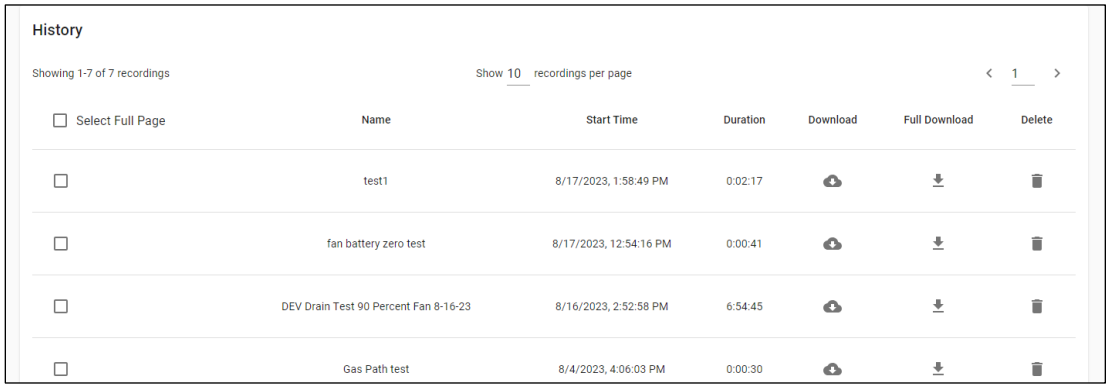
Files from testing can be downloaded.

When recording a file, the system saves the entire dataset on the internal SD Card. These files can be downloaded or deleted on the Recordings page.



NOTE: Data can be downloaded any time the HI-FLOW 2 is powered on and connected to a device through Wi-Fi.

There are two modes for downloading data. Clicking on the cloud icon in the row of a test will download **only the test data.** Clicking on the arrow icon in the row of a test will download the configuration file, along with calibration information, and the test data in a zip file.

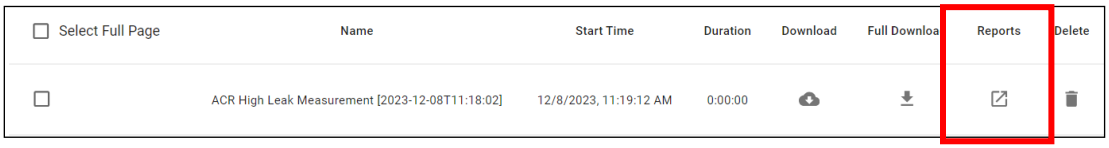


Multiple files can be downloaded or the entire page of recordings can be downloaded. To download multiple files, click in the check box and scroll down to this section:

After the data is downloaded, turn off the Analyzer Unit.

5.5.4 Viewing a recording

To view a report of a recorded test, click on the "expand" button below "Reports" on the Recordings page.



Detailed information about the csv file fields is included in the Technical Appendix Section 9.3 "Test Report Data Fields".

5.6 CALIBRATION AND SETTINGS

There are two levels of access for the password protected pages in the upper left menu. Logging in to the Calibration page only allows access to the Calibration page. Logging into the Settings page allows access to both Calibration and Settings.

⚠ Only trained administrators of the HI-FLOW 2 should modify any settings in these pages.

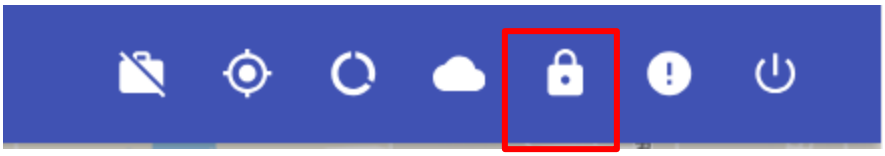
5.6.1 Calibration

The "Calibration" page allows the user to calibrate and troubleshoot internal components of the Analyzer Unit.

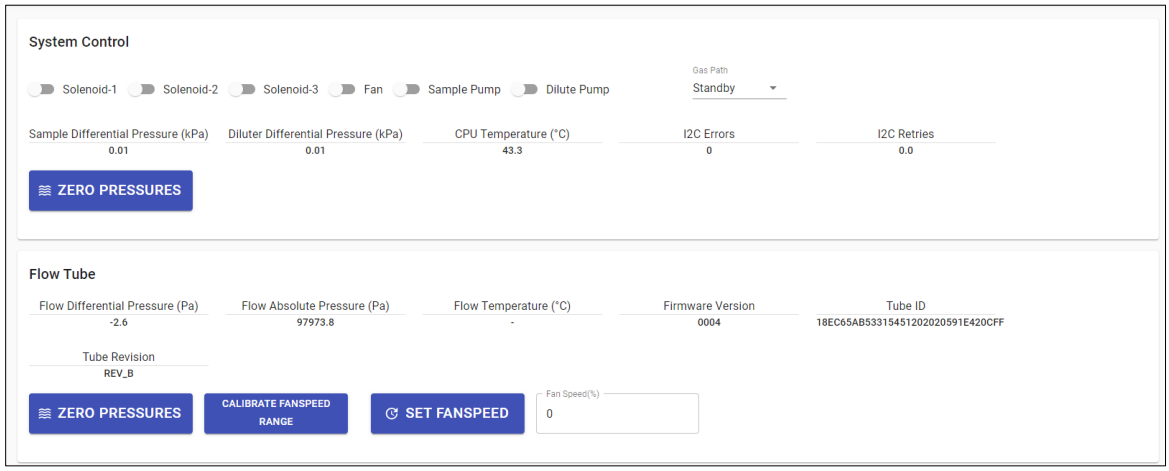
Go to "Calibration" on the menu on the upper left corner of the window.

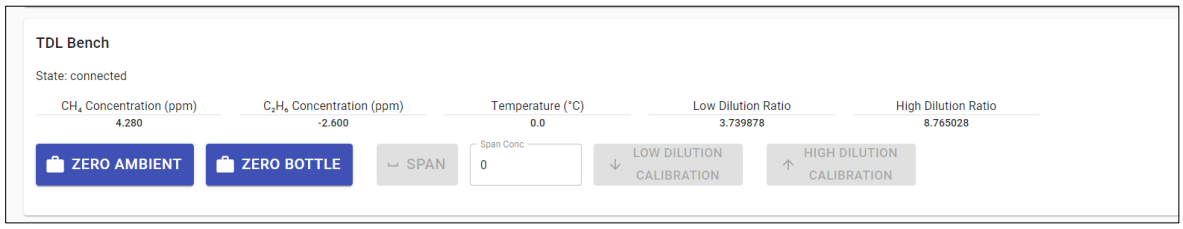
⚠ The Analyzer Unit cover should never be removed except by technicians at Sensors, Inc.
The Calibration page is password protected. This is configurable but default is currently 1234.

When the password is entered the Calibration page is unlocked for the session. The page can be locked by clicking the lock button in the top right-hand corner of the screen.

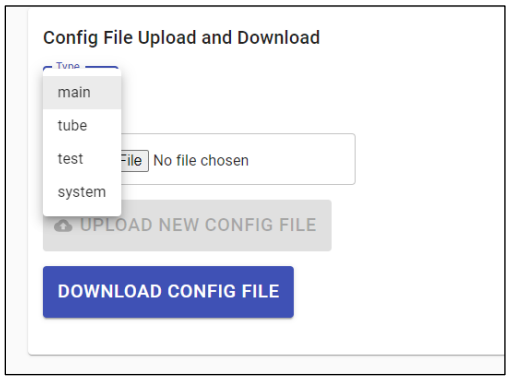


The Calibration screen comprises 3 sections: System Control, Flow Tube and TDL Bench.



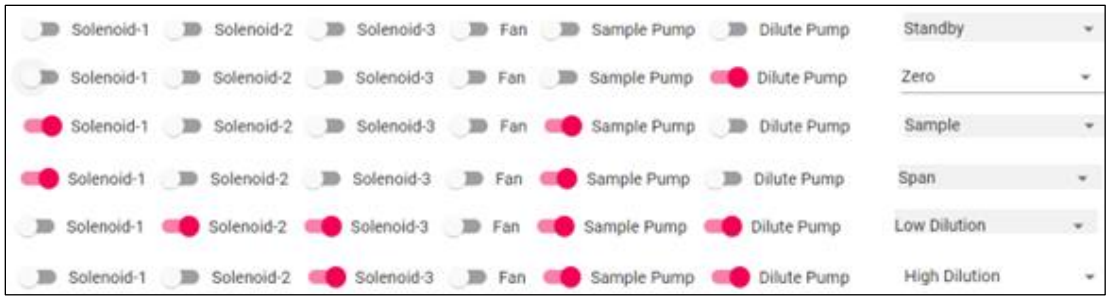


Main, Test and System configurations files can be uploaded and downloaded. Tube Config files can downloaded but not uploaded.

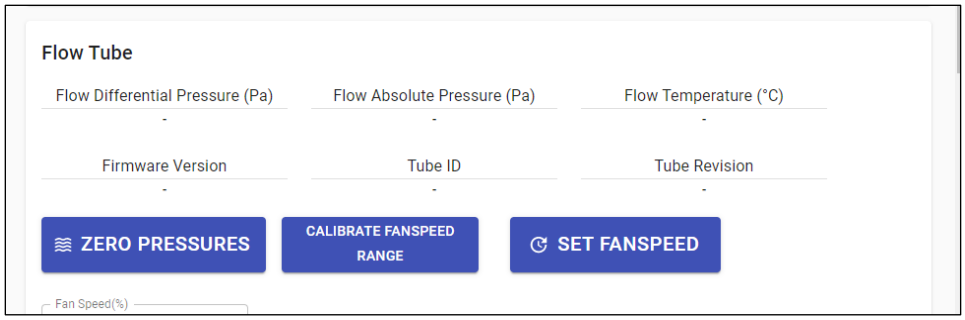


System Control and gas path options:

In the System Control section, the administrator can see and modify the manual configuration of the system by changing the Solenoid-1, Solenoid-2, Solenoid-3, Fan, Sample Pump and Diluter Pump status (Off or On). However, for simplicity, the **Gas Path** drop-down box can be used to select the most common configurations (Standby, Zero, Sample, Span, Low Dilution and High Dilution). The corresponding digital outputs for these are shown below.

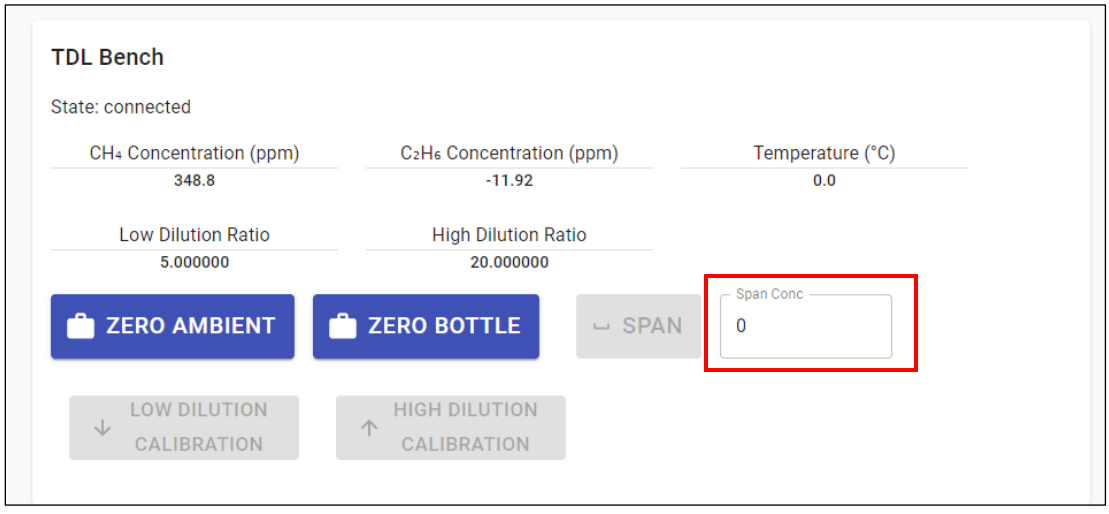


In addition, the administrator can zero the pressure sensors used for the HI-FLOW 2 sampler and set the fan speed by entering a percentage. Note that below 40-50% the Fan speed is generally too low for the averaging Pitot to accurately measure the flowrate.



5.6.1.1 TDL BENCH

The internal methane specific tunable diode bench can be calibrated (zeroed or spanned) using the TDL Bench GUI panel located in the Calibration Screen. When you initially enter this screen, the Span, Low Dilution and High Dilution, control buttons are disabled and greyed out as shown below. To activate this button, the user MUST enter a valid span bottle concentration "Span Conc" in the input box. This should be entered in percentage NOT ppm.



The following sections cover the Zero, Span, Low Dilution, and High Dilution calibration operations.

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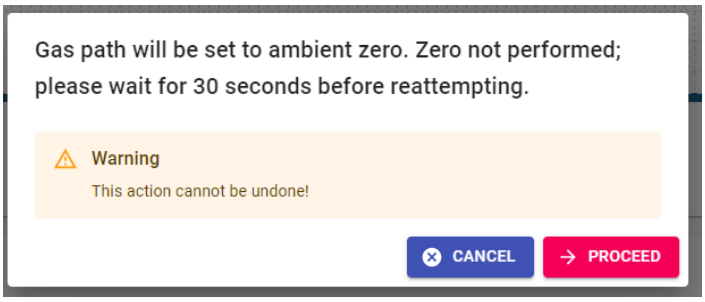
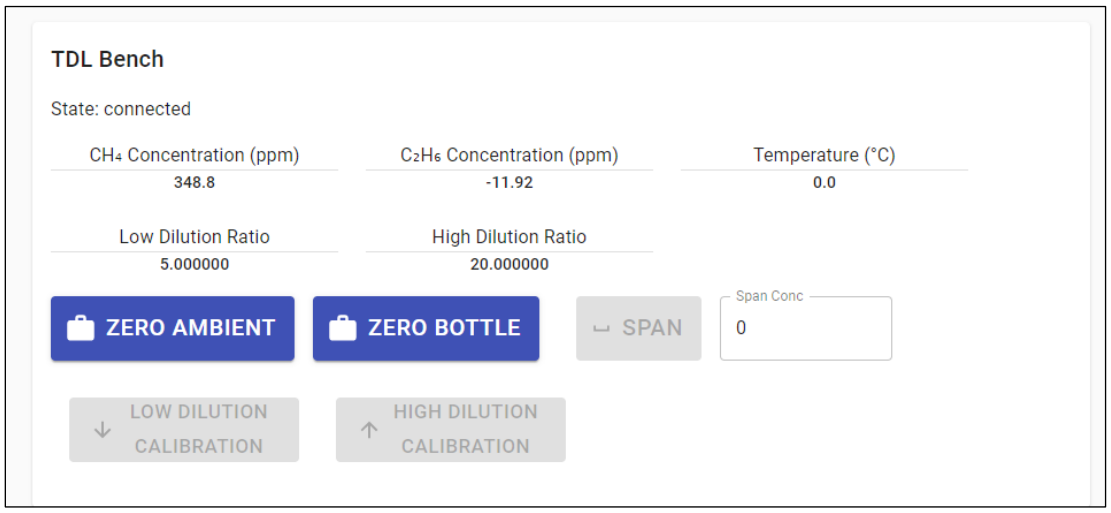
5.6.1.2 ZEROING

To perform a zero, the unit should be purged with clean air. If the user attempts to perform a zero function when the sample gas path is not set to zero, the following dialogue box will show.



Switch the gas path to zero gas and then perform a zero. The system will purge and collect data for 30 seconds and indicate a progress counter.

For most tests having a zero reading below 10ppm is sufficient to continue. Note that some testing locations may have elevated backgrounds.



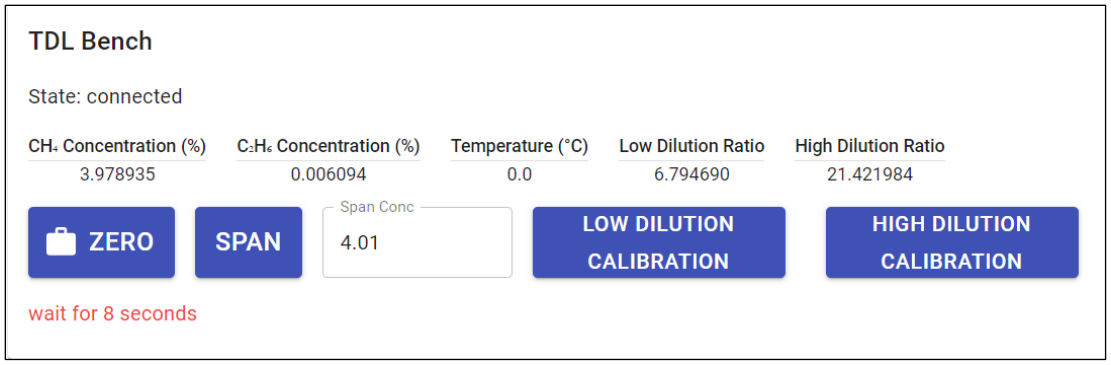
Following a zero routine the unit is displaying -2ppm. DO NOT expect zero ppm to be displayed. No filtering is performed, and the numbers can be both negative or positive.

5.6.1.3 SPAN

The span operation is similar to the zero operation, but calibration gas MUST be provided to the sample inlet Swagelok fitting located on the analyzer. Note that it is preferred that a small excess flow is provided at this location and that both the excess flow and exhaust flows are vented in accordance with local safety guidelines.

The unit is set to SPAN gas path and the reading allowed to stabilize. It is recommended to check that the reading is within 5% of the span bottle before performing the SPAN. The TDL is unlikely to require any significant adjustment and if the reading is outside this limit it is likely that the test set-up / bottle value are at fault.

In the example below, the pre-span value was 3.98% and the post span value 4.007% with a 4.01% reference gas bottle.



It is recommended that the span bottle is in the range of 2 to 4% CH_4. The system is configured with an internal low- and high-dilution system to facilitate the measurement of CH_4 up to 100%. The TDL upper limit is typically set in a configuration file is 8%. If the system measures a methane concentration above 8% the low-dilution configuration is turned on and the sampled gas is diluted by approximately 6:1. If the TDL still reads higher than 8% the high-dilution operation is activated (typically 10: to 20:1).

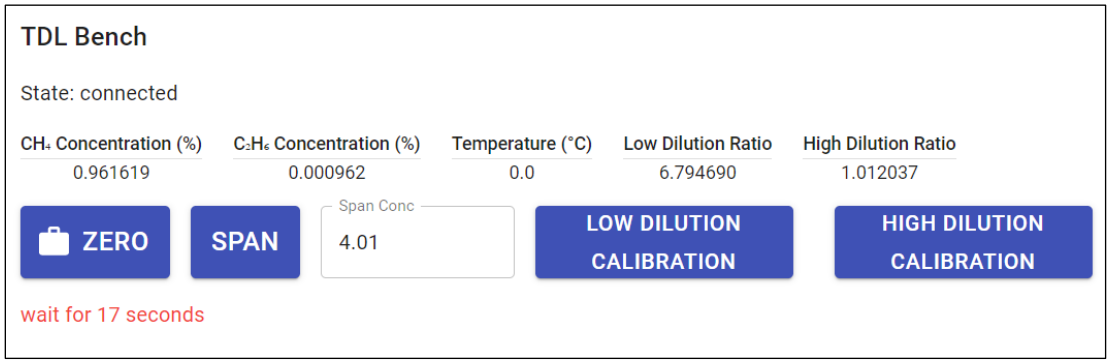
These two different dilution ratios can be calibrated using the span gas. These thresholds are controlled in the system configuration settings.

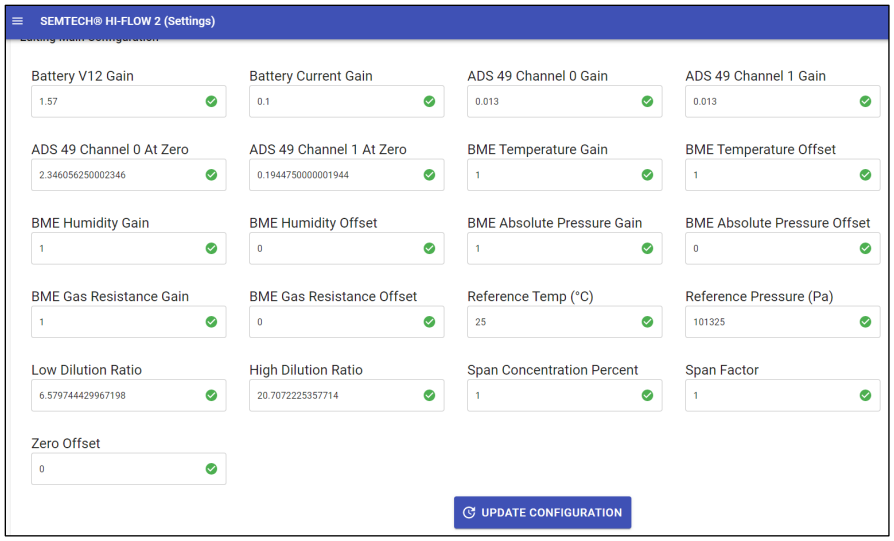
5.6.1.4 NO DILUTION

If the TDL is operating under the upper limit threshold (eg 8%) the system operates with no additional dilution.

5.6.1.5 DILUTION CONTROL

With an excess of span gas flowing at the gas inlet port, the unit is switched to Low-Dilution gas path. After the readings stabilize, click on the Low-Dilution Calibration button. The system will collect data for 30 seconds before making an adjustment to the Low-Dilution Calibration factor.

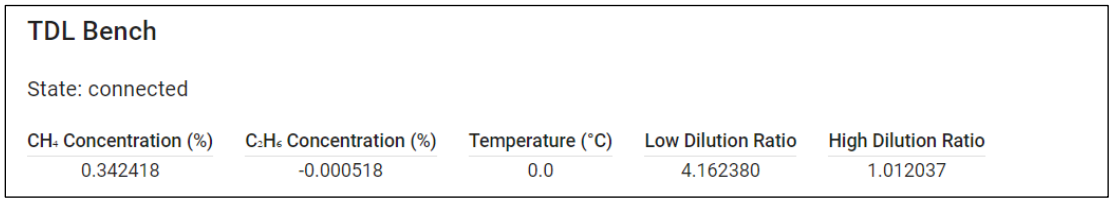


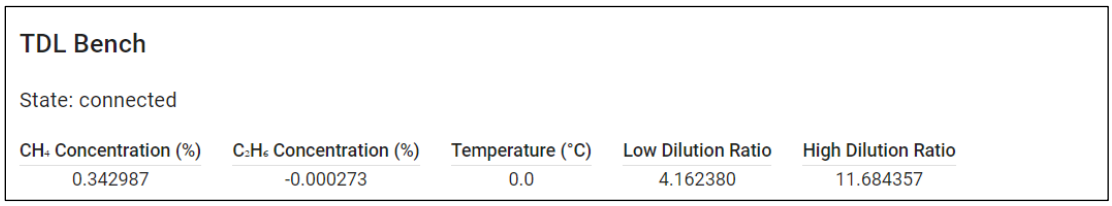


These configuration files should be changed with caution by a trained administrator. The user can download/upload these files. These files are useful for backup.

5.6.1.6 HIGH DILUTION

If an excess of span gas flows at the gas inlet port, the unit switches to High Dilution gas path. After the readings stabilize, and the High-Dilution Calibration button is clicked, the system will collected data for 30 seconds before making an adjustment to the calibration factor. In this example the factor is 1.01 (uncalibrated) before calibration and 11.68 after calibration.

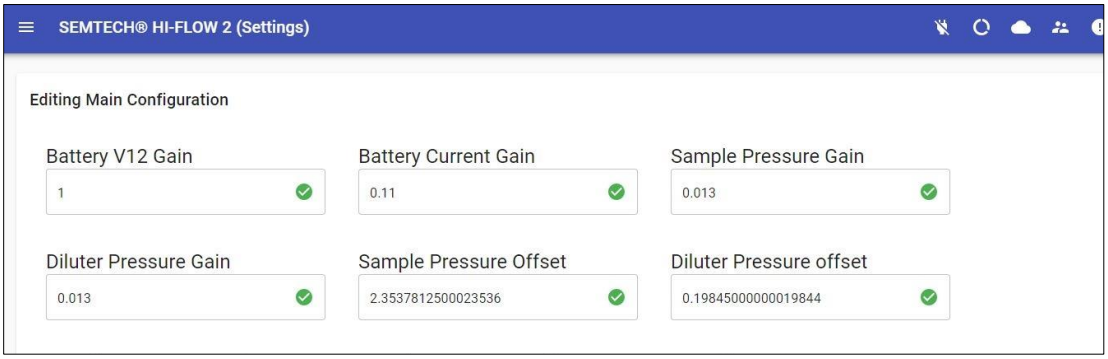




5.6.2 Settings

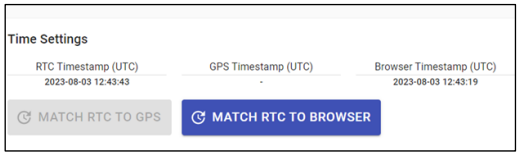
The Settings page gives the administrator access to both the Calibrations page and the Settings page. Pull down the menu on the page to "Settings" and login. This is configurable, but default is currently 0987.

The Settings page allows the administrator the ability to modify many of the settings of the internal components and some parts of the user interface. The edited configurations can be saved, and the unit can operate with the saved configurations.



This screenshot shows some of the controls that can be edited within the Settings page.
Warnings and status messages are displayed on the various pages to alert the user of any potential issues. When additional warnings are present, multiple warning boxes will appear. Many of the warnings are configurable and can be changed in the "Settings" page.

Setting the Real Time Clock: In Settings, select "**MATCH TO BROWSER**".

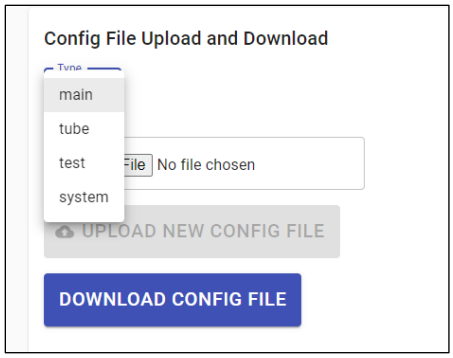


RTC shows the time will be displayed in UTC (Universal Time Coordinated). Confirm that it is correct. This website the current UTC https://www.utctime.net/

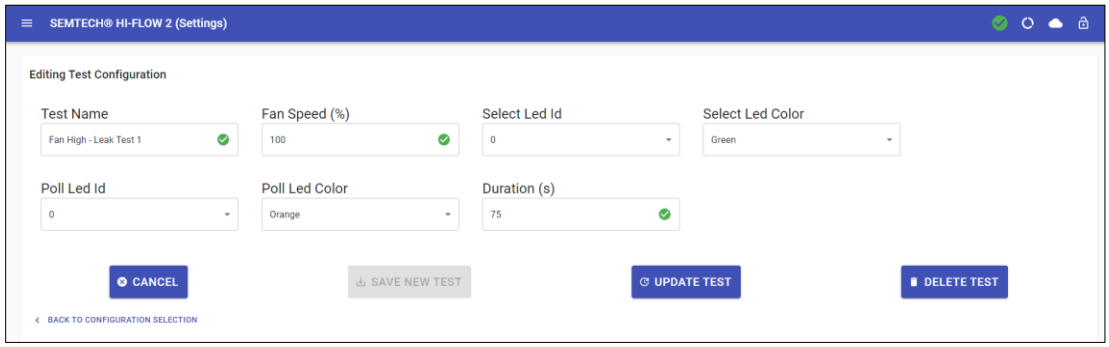
The Real Time Clock can be adjusted to match the time in the browser or GPS. The times may vary slightly because of the time it takes to set the time stamp in the Host Software. Set the RTC to match the browser by clicking on "MATCH RTC TO BROWSER".

5.6.2.1 CONFIG FILE UPLOAD AND DOWNLOAD

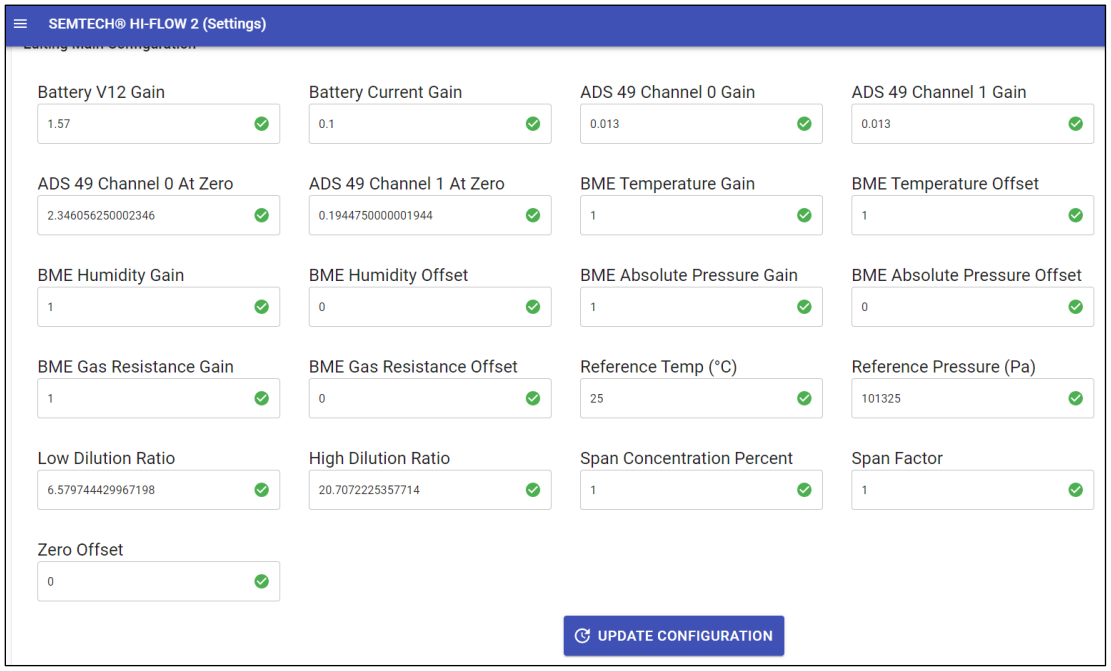
Many of the configuration settings can be edited in the 'Settings' page. In this page three configuration files can be modified - Main, Test, and System. (Tube is not configurable.)



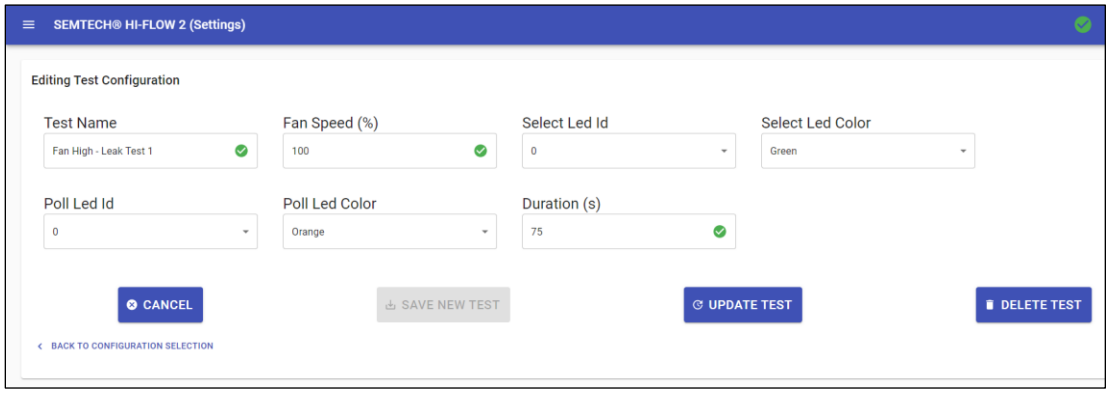
Fan Settings for the Handheld Unit can be modified in the Settings Page.



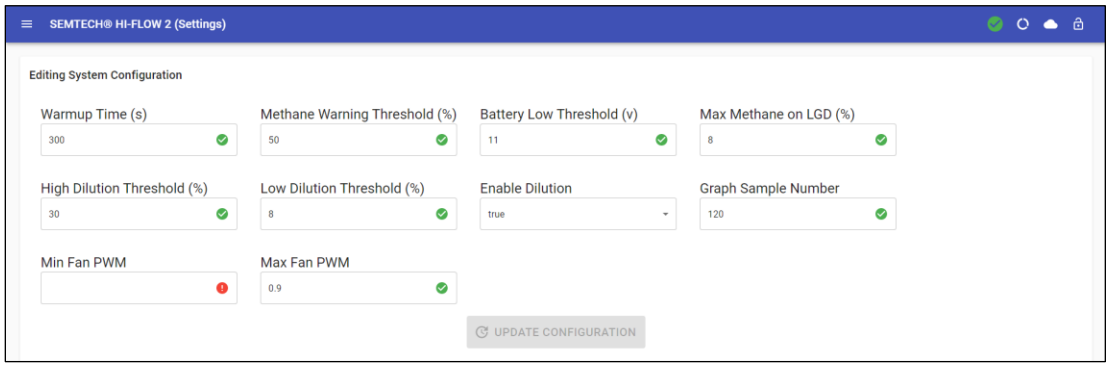
5.6.2.2 MAIN CONFIGURATION



5.6.2.3 TEST CONFIGURATION



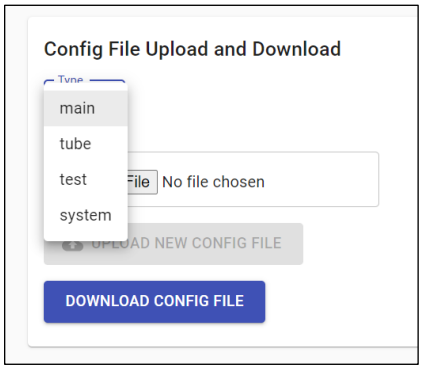
5.6.2.4 SYSTEM CONFIGURATION



5.6.2.5 DOWNLOADING AND UPLOADING CONFIGURATIONS

Main, test, and system configuration files can be downloaded after changes are made to the configurations. Tube configurations cannot be changed.

The database can be downloaded as a backup if the machine is being sent for service. Customers will be given instructions for service if sending the unit is necessary. Do not upload any files to the database, as this can crash the system.



6 DIAGNOSTICS & STORAGE

6.1 TROUBLESHOOTING

6.1.1 Host Software

The Host Software will display alerts if action is needed to operate the equipment. If there are repeated error codes, contact Technical Support at the end of the manual.

The Diagnostics Page may also provide information about the function of the internal components of the Analyzer Unit. **Do not open the Analyzer Unit to attempt to fix the equipment**. Always check connections and follow the operating procedures if the unit does not perform as expected.

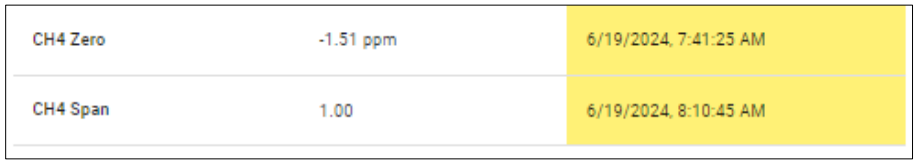
The Diagnostics Page allows a diagnostics report to be generated which can be sent to Sensors to assess the functioning of the HI-FLOW 2.

To create a diagnostics report file:

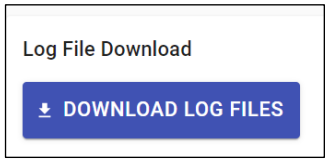
1. Go to the upper left menu and select **Diagnostics.**
2. Under **Recording** enter a test name (for example: the serial number of the unit, the date of the test). A geofence is not necessary for a diagnostics recording but may be useful to organize multiple diagnostics tests.
3. Click Start.
4. When the test recording is done, click on **Stop**, then **Proceed**.
5. To download the report, go to the menu in the upper left corner and select **Recordings**.
    a. Scroll down to the bottom of the page and select **Default** from the **Recording Configuration** menu.
    b. There are two options for downloading. The **Download** icon with the cloud will download only the test data. The **Full Download** option will create a zip file with test data and configuration/calibration files.

6.1.1.1 CALIBRATION DATA ON THE DIAGNOSTICS PAGE

Several Calibration measurements appear on the Diagnostics page. If the dates are highlighted with yellow, the machine has been calibrated more than a month earlier.



CH4 Zero	-1.51 ppm	6/19/2024, 7:41:25 AM
CH4 Span	1.00	6/19/2024, 8:10:45 AM

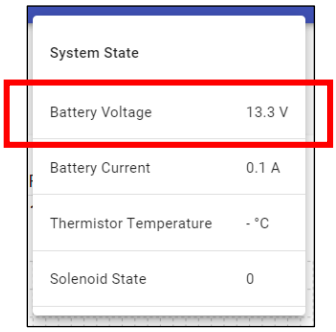


If the dates are highlighted in red, then the HI-FLOW 2 was calibrated longer than a year earlier. Contact service@sensors-inc.com for more information.

In addition to calibration files, a log file can be downloaded and sent to Sensors to assist with troubleshooting. Contact service@sensors-inc.com for more information.

6.1.2 Battery life and power management

Battery voltage can be viewed on the System State menu at the top right of the Host Software screen.



The voltage will vary during usage, depending on the power setting for the fan and sample path. When fully charged, the $LiFePO_4$ batteries provided with the HI-FLOW 2 will show approximately 12.9 volts with the fan at 90% power and the systems set to sample mode with dilution. Note that the battery voltage will read higher if the system is set to Standby with the fan off. With a full charge, the fan can operate continuously at 90% power for 2 – 2.5 hrs. Intermittent usage will extend this duration proportionally.

The battery voltage will decline as the battery discharges during normal use. Once it is below 12.4V, the decline will become more rapid and several events may occur:

- A "Battery Voltage Low" warning may be displayed.
- A "Fan/Pump Use Limited" warning may be also displayed. This means that the software will not allow additional power to be applied. You will not be able to increase fan speed, for instance, or turn on the dilution pump.
- The fan may begin to cycle on and off as the voltage approaches the warning thresholds, depending on the fan speed setting. This is normal. If this begins to occur, you can simply lower the fan speed setting until a steady condition is achieved.
- The fan and pumps will be disabled once the battery voltage drops below 11.3 V.
- The system will automatically perform a safe shut down at 10.3 V.

Charge the battery fully with the unit powered off. This can take up to 7 hours when charging the battery while it is installed in the Analyzer Unit.

⚠ The battery will discharge between uses. Charge the battery before each use.

⚠ **CAUTION:** Only charge the HI-FLOW 2 batteries with chargers/adapters provided by Sensors, Inc. Charge the battery in a non-hazardous location.

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6.2 STORING AND TRANSPORTING THE HI-FLOW 2

The HI-FLOW 2 equipment is a sophisticated measuring device with electronics components. Protect the components from exposure to dust, long periods of exposure to sunlight, moisture, excessive vibration, temperature extremes, and impact. Avoid placing the Analyzer Unit on the ground or unstable surfaces. Use care to avoid pulling solid debris into the Handheld Unit during testing.

Store the HI-FLOW 2 where it is safe from unauthorized use. For long term storage, disconnect and remove the battery:

a. Place the Analyzer Unit horizontally on a level surface.
b. Open the Softcase.
c. Remove (x6) screws with a T20 Torx Bit.
d. Remove the battery cover panel.
e. Pull out the battery.
f. Disconnect the harnesses.
g. Return the battery, panel and screws. Close the Softcase.

7 MAINTENANCE & SERVICE

7.1 ROUTINE MAINTENANCE

Keep the equipment clean and dry.

Accessories are replaceable. Any repair/replacement of internal parts must be done only by the manufacturer. Contact the distributor or manufacturer for instructions.

7.2 SERVICE PARTS

Replacement parts can be obtained through the distributor or manufacturer. Refer to the section "Technical Support" at the end of this manual. Accessories can be obtained from the manufacturer. Internal components must be replaced by returning the unit for service.

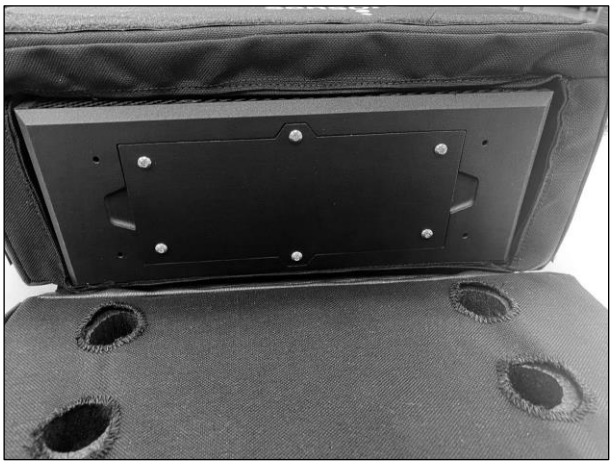
⚠ Do not open the components or attempt to service the equipment yourself.

7.2.1 Battery Replacement

Change the battery in a non-hazardous location. Use only the charger supplied by Sensors. Refer to Section 6.1.2 for additional information about the battery.

1. Power off the Analyzer Unit. Place the unit horizontally on a surface on the feet.

2. The battery pack can be accessed through the bottom panel. Open the soft case bottom flap.


w

3. Remove the screws from the battery panel with the T-20 Torx driver.

4. Slide out the battery pack. Disconnect the battery.

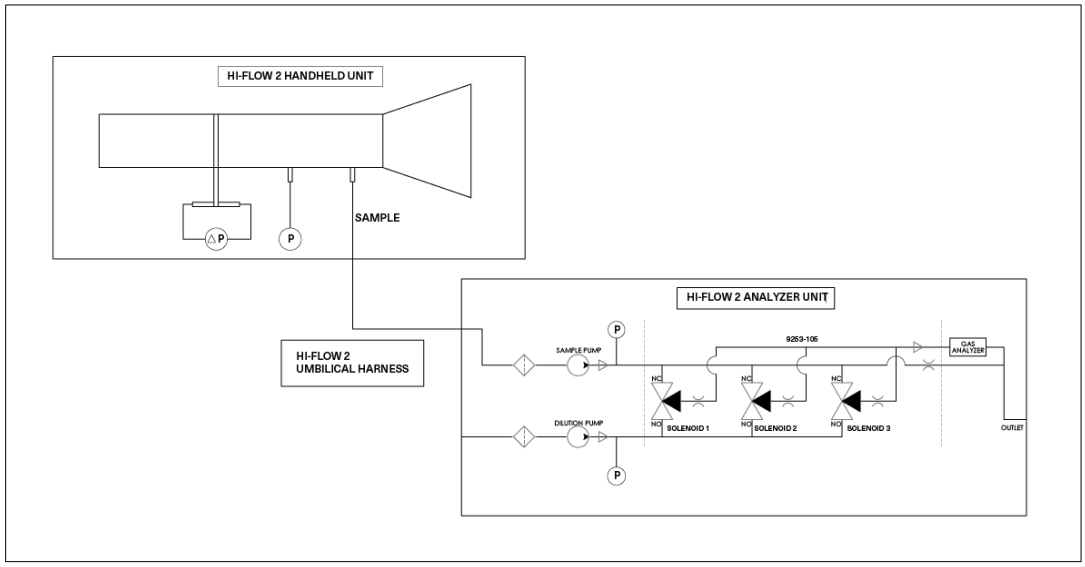
5. Connect the new battery.
6. Carefully move the battery harness into the battery compartment. Check that the side of the battery with the battery information printed on it is facing up. Slide in the new battery pack into the recessed area. Return the battery cover and install and tighten the screws. Do not overtighten.
7. Close the bottom flaps of the soft case. Charge the battery in a non-hazardous location.

8 SPECIFICATIONS

Total Flow Rate*	5-30 CFM (upper limit dependent on accessories)
Measurable Leak Rate*	0.0005 to 25 CFM (0.015 to 700 lpm) (LDL 0.6 g/hr)
Leak Rate Accuracy	<5% of full scale or 15% of point, whichever is lower (for volume or mass rate)
Flow Rate Accuracy	< ±2.5% (with density correction)
TDL Accuracy	< ±2.5% p.t.
Background Correction	Recommended pre- and post- correction with a precision of 2 ppm
Hazardous Classification	Class 1, Division 2, Group D, T4
Complies With	EPA 40 CFR Part 60, NSPS OOOOb, ACR - carbon registry methodology
W x D x H	Analyzer: 12 x 12 x 5.7 in. (30 x 30 x 14.5 cm) / Sampler: 26.3 x 7.5 x 10.5 in. (66.8 x 19 x 12.7 cm)
Weight	Analyzer: 17.5 lbs. (7.9 Kg) / Sampler: 10.8 lbs. (4.9 Kg)
Connection	Wi-Fi
Data Output	Customizable csv files / compressed zip files with configuration data.
Memory	4000 2-hour tests; >10 Gigabytes database (recommended annual cleanup)
Batteries	LiFEPO4 (with spare battery included) rated 12.8V, with capacity of 96 Wh
Run Time:	4 to 6 hours (per battery) at 50% duty cycle
Charging Time:	ca 4 hours
Operating Temperature	-10°C to 45°C (14°F to 113°F) (Battery performance will be reduced at < 0 °C)
Operating Humidity	0 to 80%, non-condensing
Operating Altitude	Up to 2000 meters
Ingress Protection Rating	IP54
Pollution Degree Rating	2 (Temporary conductivity cause by condensation is to be expected)
Concentration range (CH_4 Analyzer)	0 to 100% by volume
Concentration range (CH_4 Leak Detection)	Limited to operator safety criteria
Warm Up Time	≤ 5 min @ 20°C (68°F)
Rise Time (t_{10-90})	< 30 seconds
Gas Temperature Range	-10 to 45°C (14°F to 113°F)
Storage Temperature	-32°C to 55°C (-25.6°F to 131°F)
Acoustic Noise	< 65 dBa
*Inlet restrictions on the handheld sampling unit will reduce the maximum achievable flow.	

9 TECHNICAL APPENDIX

9.1 FLOW DIAGRAM



9.2 MEASUREMENT PRINCIPLES

The fugitive volumetric leak rate can be determined by the following equation:

$$Q = V(C_{Sample} - C_{Background})$$

Equation 1

Where Q is the leak rate (LPM), V is the total high-volume sampler flow rate (LPM), C_{Sample} is the sampled volume fraction concentration (%/100) and $C_{Background}$ is the ambient (surrounding) background concentration (%/100).

To ensure that the device is capturing all the gas that is escaping from the component, two or more measurements are often performed at different total flow rates. For example, the first measurement is taken at the highest possible flow rate, followed by a second measurement at a flow rate that is approximately 70–80% of the first. If the two calculated leak rates are within acceptable limits (e.g., 5% of each other) it can be concluded that the leak is completely captured.

Note that the surrounding air (in the close vicinity of the captured leak) MUST contain very little of the gas being investigated in order that quantification is accurate. From a practical perspective, the background concentration should be no more than 1% of the measured sample concentration or 100 ppm (vol) whichever is larger.

Thus, for fugitive methane leak quantification measurements, the internals of the HI-FLOW 2 sampler will be operated in an area in which explosive gas mixtures (predominately methane) are expected to occur in normal operation. However, the outside of the Handheld Unit and the Analyzer (which will normally be either located on the operator's back or on the ground nearby) will be in an environment where an explosive mixture is not likely to occur in normal operation.

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9.2.1 Methane Concentration Measurements

The methane concentration is measured using a tunable diode laser spectrometer.

The volumetric concentration reported from the bench is converted to standard conditions assuming ideal gas behavior.

$$\boldsymbol{PV = nRT}$$

Equation 2

P = Pressure of sample (any units)

V = Volume of sample (any units)

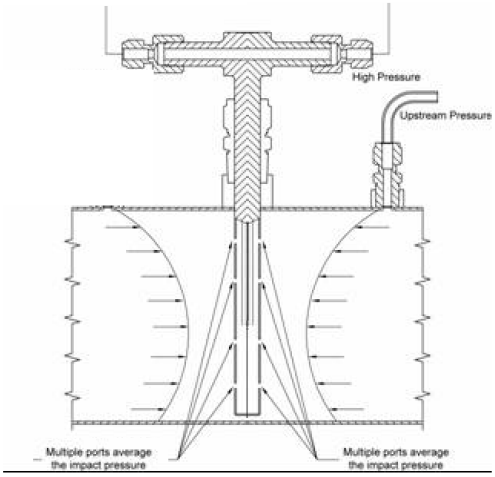
n = molar amount of sample (any units)

T = Temperature of sample (absolute units, e.g., Kelvin)

R = Ideal gas constant

9.2.2 High Volume Sampler Flowrate Determination

- The high-volume sampler flow rate in the Handheld Unit is measured using an averaging pitot tube.
- Benefits of Pitot Tube Meter principle
- Low-power and safe electronics.
- Low pressure drop.
- Minimal change in gas density across meter.
- Minor influence of gas viscosity (Reynolds number discharge coefficient correction).
- Flow geometry is not changed by meter, which simplifies calculations.
- Institutional knowledge.



Averaging Pitot Cross Section

The Pitot measurement operates under Bernoulli principle and by placing a tube into the gas stream and allowing gas to flow into the tube and stop completely, generating a "total pressure" equal to the pressure of the gas in the stream (the "static pressure") plus the pressure the gas exerts when slowed to a stop. The average flow rate of the gas is then calculated as

$$\boldsymbol{Q = A\,K\sqrt{\frac{2}{\rho_s}(p_{total} - p_{static})} = A\,K\sqrt{\frac{2}{\rho_s}\Delta p}}$$

Equation 3

Q = Flow rate ($m^3\ s^{-1}$)

A = Cross sectional area of sample tube (m^2)

K = Pitot Discharge Coefficient (unitless)

ρ_s = Density of sample (kg m^{-3})

p_{total} = Pressure at pitot tube (Pa)

p_{static} = Pressure at static port (Pa)

Δp = Measurement of differential pressure sensor (Pa)

The density of the gas sample, ρ_s, is a function of temperature, pressure, and gas composition. The effect of composition is also significant, as shown in the table – at room temperature, methane is only half the density of air. Additionally, the density of air decreases significantly with the presence of water vapor. It is expected that the gas to be sampled by SEMTECH© HI-FLOW 2 sampler will contain atmospheric gases (O_2, N_2, water vapor, <1% other gases) and natural gas products (>85% methane, <5% ethane, <1% other hydrocarbons, balance N_2).

Air	1.225
Water Vapor	0.013
Methane	0.657
Ethane	1.356

Density of pure gases at room temperature, in kg m-3

Methane and water are likely to be the largest contributors to gas density variation in the measurement. The density calculation must therefore include both a water vapor measurement (via humidity sensor) and a methane measurement (via the methane gas analyzer). As ethane has a density within 10% of air and is unlikely to ever be present in quantities above 10%, it is reasonable to not measure this gas, but include this potential source of error. Using these measurements of water vapor and methane, density is calculated using

$$\boldsymbol{\rho_s = \frac{P}{RT} M_s = \frac{P}{RT}(x_a M_a + x_w M_w + x_m M_m)}$$

Equation 4

P = Pressure of sample at flowmeter (Pa)

T = Temperature of sample at flowmeter (K)

R = Ideal gas constant (m^3 Pa K^{-1} mol^{-1})

M_s = Molar mass of sample (kg mol^{-1})

x_a = Molar (or volumetric) fraction of dry air in sample (unitless)

x_w = Molar (or volumetric) fraction of water vapor in sample (unitless)

x_m = Molar (or volumetric) fraction of methane in sample (unitless)

M_a = Molar mass of dry air in sample (kg mol^{-1})

M_w = Molar mass of water vapor in sample (kg mol^{-1})

M_m = Molar mass of methane in sample (kg mol^{-1})

Using the above equations, the rate of collection of methane into the system, $\dot{n}_{ms}$, can be evaluated.

$$\boldsymbol{\dot{n}_{ms} = x_{CH4} A_{CS} \sqrt{\frac{2P}{(1 - x_w - x_m)M_a + x_w M_w + x_m M_m)RT} \Delta p}}$$

Equation 5

$\dot{n}_{ms}$ = Molar flowrate of methane into the system (mol s^{-1})

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x_m = Molar fraction of methane measured by gas detector array (unitless)

x_w = Molar fraction of water vapor measured by humidity sensor (unitless)

A_{CS} = Cross sectional area of sample tube (m^2)

P = Pressure of sample at flowmeter (Pa)

T = Temperature of sample at flowmeter (K)

R = Ideal gas constant (m^3 Pa K^{-1} mol^{-1})

M_a = Molar mass of dry air (kg mol^{-1}) (a constant)

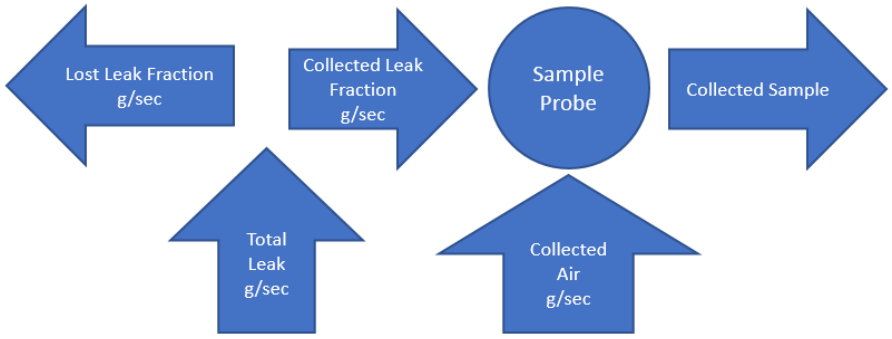
M_w = Molar mass of water vapor (kg mol^{-1}) (a constant)

M_m = Molar mass of methane (kg mol^{-1}) (a constant)

Δp = Measurement of pitot-static differential pressure sensor (Pa)

9.2.3 Capture effectiveness

The flowrate of methane into the instrument is not necessarily the flowrate of the leak itself. Some fraction of the leak may be lost to air, and air collected by the probe may itself contain a small amount of ambient methane. An illustration is shown below.



Mass balance of HI-FLOW 2 Sampler

The instrument must therefore determine:

- The fraction of methane in ambient air
- The fraction of the methane leak captured

The relationship between these values and the instrument flowrate and methane concentration are defined as:

$$\dot{n}_s = \dot{n}_a + f\dot{n}_{ml}$$

Equation 6

$$\dot{n}_{ms} = \dot{n}_s x_{ms} = \dot{n}_a x_{ma} + f\dot{n}_{ml}$$

Equation 7

$\dot{n}_{ms}$ = Molar flowrate of methane in sample (mol s^{-1})

$\dot{n}_s$ = Molar flowrate of sample (mol s^{-1})

$\dot{n}_a$ = Molar flowrate of ambient air collected (mol s^{-1})

x_{ms} = Molar fraction of methane in sample (unitless)

x_{ma} = Molar fraction of methane in ambient air (unitless)

f = Fraction of leak captured (unitless, $0 \le f \le 1$)

$\dot{n}_{ml}$ = Molar flowrate of total methane leak (mol s^{-1})

Distant from the leak, the leak capture fraction $f = 0$ is zero regardless of flowrate. Therefore, $\dot{n}_s = \dot{n}_a$, and $x_{ms} = x_{ma}$. That is, the flowrate of sample and ambient are equal, and the concentration of sample and ambient are equal.

Near the leak, the leak capture fraction varies from $f = 0$ to $f = 1$. Increasing flowrate will capture greater amounts of the leak. It is important to note that the fraction of ambient air captured vs. the methane leak may either increase or decrease at $f < 1$, depending on the geometry of the leak source and the probe. That is, <u>one cannot use the "peak" methane concentration to verify $f = 1$</u>, as x_{ms} may reach a maximum value at conditions below $f = 1$.

The point of total leak capture can instead be found by varying the sampling rate $\dot{n}_s$ and determining how the slope of the measurement $\dot{n}_{ms}$ is affected. By taking the derivative of equation 7, we can see

$$\frac{d\dot{n}_{ms}}{d\dot{n}_s} = \frac{d\dot{n}_a}{d\dot{n}_s} x_{ma} + \frac{df}{d\dot{n}_s} \dot{n}_{ml}$$

Equation 8

When $f = 1$, further increases of sample flowrate will not increase f, such that $\frac{df}{d\dot{n}_s} = 0$. Furthermore, those increases in sample flowrate will be equally matched by increases in ambient flowrate, such that $\frac{d\dot{n}_a}{d\dot{n}_s} = 1$. Therefore, we know that the entire leak has been captured when $\frac{d\dot{n}_{ms}}{d\dot{n}_s} = x_{ma}$. In the trivial case of no ambient methane, total capture is confirmed when the capture rate of methane becomes constant even with increasing fan speed.

9.2.4 Capture Procedure

Given all the above, a measurement procedure can be developed.

The methane content of ambient air can be measured by collecting sample at a nominal fan speed, at a specified distance from the source of the leak. If the methane is ambient, it is evenly distributed in the vicinity, and the concentration will not increase or decrease when the sample flowrate is changed. Varying fan speed can verify the methane being measured is ambient and not from a point source (a leak). This generates the ambient methane concentration x_{ma}.

Once a leak is identified and the sample probe is placed to capture it, the instrument can determine leak fraction by increasing or decreasing fan speed in increments so that it identifies the region where $\frac{d\dot{n}_{ms}}{d\dot{n}_s} = x_{ma}$. At that region, all fugitive methane is being captured, and measurements of $\dot{n}_{ms}$ along that line are equal to the methane leak rate. These measurements may then be averaged together in whatever manner maximizes accuracy and precision.

9.3 TEST REPORT DATA FIELDS

The downloaded configuration data is saved in csv format and can be easily analyzed using tools like Microsoft Excel. Refer to the following table for an explanation of field data.

Field Nane	Units (Selectable)	Description
Host Time	UTC	Datapoint timestamp as recorded on the SBC, in UTC
	Local time at measure	Datapoint timestamp as recorded on the SBC, adjusted to the time zone the browser used to start the recording was in
	Local time at download	Datapoint timestamp as recorded on the SBC, adjusted to the time zone the browser used to download the recording was in
Elapsed Time	Seconds, Minutes	Time since the recording was started, counted via the timestamp difference between the starting datapoint and the current datapoint
TDL CH4 Concentration	%, PPM	CH4 concentration reported by the TLD bench
CH4 Final Concentration	%, PPM	CH4 concentration reported by the TLD bench, Adjusted by the active dilution ratio.
TDL C2H6 Concentration	%, PPM	C2H6 concentration reported by the TLD bench
Sample Differential Pressure	kPa, Pa	Sample differential pressure reading from the main board (Not currently Used)
Dilute Differential Pressure	kPa, Pa	Dilute differential pressure reading from the main board (Not currently Used)
Hi-Vol Differential Pressure	kPa, Pa	Sample differential pressure reading from the handheld Pitot
Hi-Vol Gauge Pressure	kPa, Pa	Gauge pressure reading from the handheld sampler (Used to determine gas density)
Hi-Vol Temperature	degC, degF	Temperature inside the handheld sampler (Used to determine gas density)
Ambient Pressure	kPa, Pa	Barometric Pressure inside the analyzer
Ambient Temperature	degC, degF	Temperature inside the analyzer
Ambient Relative Humidity	%	Relative humidity inside the analyzer
Ambient VOC Level	Ohm	Internal VOC Gas sensor (Not currently used)
Bench H2O Fraction		Water fraction in ambient air used for density calculations
Hi-Vol Density	kg/m3	Gas Density in Handheld Sampler
Hi-Vol Flow Rate	m3/s, LPM, CFM	Volumetric Flow rate in Handheld Sampler
RE		Reynolds Number
KLinear		Linear Discharge Coefficient
KRE Correction		RE Adjusted Discharge Coefficient
Viscosity	m2/s	Gas Viscosity in Handheld Sampler
Velocity	m/s	Gas Velocity in Handheld Sampler
Mass Flow Rate	kg/s	Mass Flow rate in Handheld Sampler
Volume Flow	m3/s, LPM, CFM	Volume Flow rate in Handheld Sampler
Standard Volume Flow	m3/s, LPM, CFM	Volume Flow rate in Handheld Unit converted to Standard Conditions

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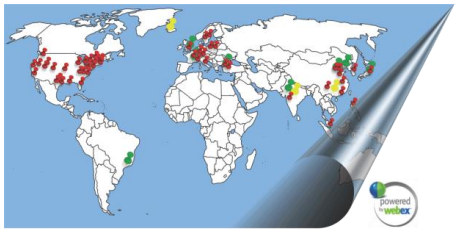
CH4 Standard Volume Leak Rate	m3/s, LPM, CFM	Volume Methane Leak Rate converted to Standard Conditions
CH4 Standard Mass Leak Rate(Actual)	g/s, g/hr, MT/year	Methane Mass Leak Rate
CH4 Standard Mass Leak Rate CO2e(x25)	MT/year	Methane mass leak rate adjusted by the CO2 equivalence rate of x25
CH4 Standard Mass Leak Rate CO2e(x28)	MT/year	Methane mass leak rate adjusted by the CO2 equivalence rate of x28
Fan Speed	%	Duty cycle for the fan
Battery Voltage	V	Voltage read on the analyzer battery, or only battery on single battery device
Battery Current	A	Current read on the analyzer battery, or only battery on single battery device
Solenoid State		Decimal read of the bit flags that determine solenoid state. See Gas Path
I2C Communication Retries		Total number of communication retries in the I2C bus since the device was turned on
I2C Total Errors		Total number of errors in the I2C bus since the device was turned on
Measurement ID		Name of the current measurement in use on the handheld. See test-config for potential values
Location ID		
Gas Path		Gas path in use by the system. Standby, sample, Zero Ambient, Zero Bottle, Span, Low Dilution, or High Dilution
Event Message		Event message as input by the user on the dashboard during a recording
Fan Voltage	V	Voltage read on the fan battery if it exists. Can only be read accurately during fan operation
Fan Current	A	Current read on the fan battery if it exists. Can only be read accurately during fan operation
Fan State		0 if the fan is off, 1 if the fan is on
Latitude	deg	Latitude from the GPS
Longitude	deg	Longitude from the GPS
Altitude	m, ft	Altitude from the GPS
Satellites		The number of satellites the GPS receiver is currently communicating with
GPS Timestamp	UTC	Timestamp received from satellites by the GPS. May read as 2080 if the GPS has initialized but can't get a signal
Ground Speed	km/h, MPH	Movement speed of the device from the GPS
Event Marker		Used by the test procedure system to mark data. Standardly used marks are P for paused, I for awaiting input, STABLE for stable sample data, ZERO for background sample data

10 TECHNICAL SUPPORT

CONTACT SENSORS, INC. FOR SUPPORT

Technical Support: Sensors, Inc.'s technical staff, trained and experienced in the wide array of use of SEMTECH® products and HI-FLOW 2 systems, are available 24 hours a day at one of its locations in the Americas and Europe.

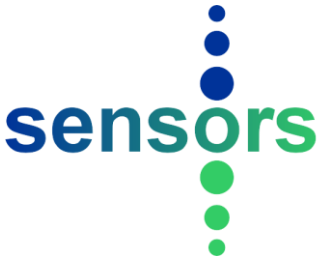
For service questions about the HI-FLOW 2, contact Sensors, Inc. at service@sensors-inc.com or contact your distributor.



Contact Sensors' Product support if you have any questions about using your equipment. In the USA, go to http://www.sensors-inc.com/About/Contact or contact us by phone (734) 429-2100.

In Europe, contact Sensors Europe GmbH by phone +49 (0)2104-14188-0 or go to http://www.sensors-inc.com/About/Contact.

Asia and Latin America, go to http://www.sensors-inc.com/About/Contact to view the complete list of support services and phone numbers.



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