AQLite Air Monitoring Package: *AQLite-Standard*

OPERATION MANUAL

Model AQLite-Standard

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IDENTIFICATION RECORDS

Record the following information for future reference:

Unit serial number: _____

Warranty start date: _____
(date of receipt)

PRINTING HISTORY

This manual covers the AQLite-Standard Air Monitor used for measurement of ozone (O_3), carbon monoxide (CO), carbon dioxide (CO_2) and particulate matter (PM_1 and $PM_{2.5}$) in air. New editions of this manual are complete revisions that reflect updates to the instrument itself, as well as clarifications, additions and other modifications of the text.

Revision A-1..... October 2021

Revision A-2 *Updated Sections A.1.3 and C.1 to describe the Data Portal.* ..... January 2022
Updated Sections A.1.3 and C.1 to describe the Data Portal.

Revision B-1.....April 2022
Change required averaging time of ozone monitor to 2 seconds, Section D.2. Updates to serial menu commands, Section D.1. Corrected website URL in Section A.1.3.1. Update to Data Portal contact info in Section C.1. Delete step for time zone setting in Section D.3. Updates and corrections in Section D.4.

Revision B-2..... June 2022
Clarification of uses of the USB cable, Section A.1.3.2. New location of antenna shown in new pictures in Section A, Section D, and Section G, Figure G.1.

Revision B-3..... June 2023
Add L, T commands to the serial command list. Link to the Model 108-L Ozone Monitor FEM designation provided in Section A.1.1 and Appendix 1, Section 2.

Revision C-1 .....July 2023
Major update to reflect new sensor package configuration and AQLite functioning (several new photos and new text). New serial menu structure. Added General Specifications to the Overview.

Revision C-2 *Updated hyperlinks* .....December 2023

Revision D-1 .....December 2023
Updated for new Data Portal (Section C-1). Addition of smartphone app for the AQLite (Section C-3). Addition of Section F.1.2 regarding Maintenance, and update of Section F.2.1 on Troubleshooting.

Revision D-2 .....December 2023
Formatted Data Portal (Section C-1) and added sections C.1.3 -C.1.5.

Revision D-3 .....April 2024
Clarification to wiring connections on ozone monitor's 10-pin terminal (Sections F.1.2 and F.2.1).

Revision E-1..... October 2024
Modified sensor options to remove SO_2, NO_2. Removed Li-ion battery from sensor package to improve performance of the instrument. Replace cellular with router for use in data upload communication. Updated power and weight specs, Section A.1.4. Updated several pictures.

Revision E-2..... October 2024
Corrected AC wiring shown in bullet 3 of Section B.1.2, step 9 (page 9).

Revision F-1.....March 2025
Updated Section B.1 and several pictures to reflect the new power connector. Remove weather station option. Removed Bluetooth feature and delete Bluetooth/smartphone Section C.3. In Appendix 1: updated ozone cross section in Section 1.1; corrected Section 1.2 description of how to disable the adaptive filter of the ozone instrument; and set ozone upper range limit in Section 2 to 1 ppm.

TRADEMARKS & PATENTS

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CONFIDENTIALITY

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WARRANTY STATEMENT

2B Technologies warrants its products against defects in materials and workmanship. 2B Technologies will, at its option, repair or replace products that prove to be defective. The warranty set forth is exclusive and no other warranty, whether written or oral, is expressed or implied. 2B Technologies specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

Warranty Period

The warranty period is one (1) year from date of receipt by the purchaser, but in no event more than thirteen (13) months from original invoice date from 2B Technologies.

Warranty Service

Warranty Service is provided to customers via web ticket, email, and phone support, Monday - Friday, from 9:00 a.m. to 5:00 p.m., Mountain Time USA. The preferred method of contacting us is through our web ticketing software at:

https://2btech.io/support

This way all technical staff at 2B Tech will be alerted of your problem and be able to respond. When you receive an email reply, please click on the Ticket link provided to continue to communicate with us directly over the internet. The web ticket approach to customer service allows us to better track your problem and be certain that you get a timely response. We at 2B Tech pride ourselves on the excellent customer service we provide.

You may also contact us by email at techsupport@2btech.io or by phone at +1(303)273-0559. In either case, a web ticket will be created, and future communications with you will be through that ticket.

Initial support involves troubleshooting and determination of parts to be shipped from 2B Technologies to the customer in order to return the product to operation within stated specifications. If such support is not efficient and effective, the product may be returned to 2B Technologies for repair or replacement. Prior to returning the product, a Repair Authorization Number (RA) must be obtained from the 2B Technologies Service Department. We will provide you with a simple Repair Authorization Form to fill out to return with the instrument.

Shipping

2B Technologies will pay freight charges for replacement or repaired products shipped to the customer site. Customers shall pay freight charges for all products returning to 2B Technologies.

Conditions

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance, adjustment, calibration or operation by the customer. Maintenance, adjustment, calibration or operation must be performed in accordance with instructions stated in this manual. Usage of maintenance materials purchased from suppliers other than 2B Technologies will void this warranty.

Limitation of Remedies and Liability

The remedies provided herein are the Customer's sole and exclusive remedies. In no event shall 2B Technologies be liable for direct, indirect, special, incidental or consequential damages (including loss of profits) whether based on contract, tort or any other legal theory. The AQLite Air Monitor manual is believed to be accurate at the time of publication and no responsibility is taken for any errors that may be present. In no event shall 2B Technologies be liable for incidental or consequential damages in connection with or arising from the use of the AQLite Air Monitor manual and its accompanying related materials. Warranty is valid only for the country designated on the 2B Technologies quote or invoice.

WARNINGS

ENGLISH

***WARNING*:**
Any operation requiring access to the inside of the equipment, could result in injury. To avoid potentially dangerous shock, disconnect from power supply before opening the equipment.

WARNING:
This symbol,  on the instrument indicates that the user should refer to the manual for operating instructions.

WARNING:
If this instrument is used in a manner not specified by 2B Technologies, USA, the protection provided by the instrument may be impaired.

ESPAÑOL

ATENCION:
Cualquier operación que requiera acceso al interior del equipo, puede causar una lesión. Para evitar peligros potenciales, desconectarlo de la alimentación a red antes de abrir el equipo.

***ATENCION*:**
Este símbolo,  en el instrumento indica que el usuario debería referirse al manual para instrucciones de funcionamiento.

ATENCION:
Si este instrumento se usa de una forma no especificada por 2B Technologies, USA, puede desactivarse la protección suministrada por el instrumento.

FRANÇAIS

ATTENTION:
Chaque opération à l'intérieur de l'appareil, peut causer du préjudice. Afin d'éviter un shock qui pourrait être dangereux, disconnectez l'appareil du réseau avant de l'ouvrir.

ATTENTION:
Le symbol,  indique que l'utilisateur doit consulter le manuel d'instructions.

ATTENTION:
Si l'instrument n'est pas utilisé suivant les instructions de 2B Technologies, USA, les dispositions de sécurité de l'appareil ne sont plus valables.

DEUTSCH

WARNHINWEIS:
Vor dem Öffnen des Gerätes Netzstecker ziehen!

WARNHINWEIS:
Dieses,  auf dem Gerät weist darauf hin, dab der Anwender zuerst das entsprechende Kapitel in der Bedienungsanleitung lesen sollte.

WARNHINWEIS:
Wenn das Gerät nicht wie durch die Firma 2B Technologies, USA, vorgeschrieben und im Handbuch beschrieben betrieben wird, können die im Gerät eingebauten Schutzvorrichtungen beeinträchtigt werden.

ITALIANO

ATTENZIONE:
Qualsiasi intervento debba essere effettuato sullo strumento può essere potenzialmente pericoloso a causa della corrente elettrica.
Il cavo di alimentazione deve essere staccato dallo strumento prima della sua apertura.

ATTENZIONE:
Il simbolo,  sullo strumento avverte l'utilizzatore di consultare il Manuale di Istruzioni alla sezione specifica.

ATTENZIONE:
Se questo strumento viene utilizzato in maniera non conforme alle specifiche di 2B Technologies, USA, le protezioni di cui esso è dotato potrebbero essere alterate.

DUTCH

OPGELET:
Iedere handeling binnenin het toestel kan beschadiging veroorzaken. Om iedere mogelijk gevaarlijke shock te vermijden moet de aansluiting met het net verbroken worden, vóór het openen van het toestel.

OPGELET:
Het symbool,  geeft aan dat de gebruiker de instructies in de handleiding moet raadplegen.

OPGELET:
Indien het toestel niet gebruikt wordt volgens de richtlijnen van 2B Technologies, USA gelden de veiligheidsvoorzieningen niet meer.

CHINESE

警告：
任何需要接触设备内部的操作均可能造成人身伤害。为避免可能的触电危险，请在打开设备前切断电源。

警告：
这个符号  在仪器上表示用户应参考说明书上的操作指南。

警告：
如果仪器没有按照美国 2B 科技公司指定方式操作，仪器的保护性能会减弱。

JAPANESE

警告：
機器の内部で操作する時、怪我できます。**危険な衝撃を回避するために、機器を開ける前に、電源を切断してください。**

警告：
機器でこの記号  を見れば、マニュアルを読んでください。

警告：
この機器は 2B テクノロジー会社、USA の指定でしなければ、機器の保護が損なえます。

UNPACKING THE SHIPPING BOX

Please read all the following information before attempting to install the AQLite Air Monitor. For assistance, please call 2B Technologies at (303)273-0559.

NOTE:

Save the shipping carton and packing materials that came with the AQLite Air Monitor. If the AQLite Air Monitor must be returned to the factory, pack it in the original carton. Any repairs as a result of damage incurred during shipping will be charged.

Shipping Box Contents

Open the shipping box and verify that it contains all of the items on the shipping list. If anything is missing or obviously damaged, contact 2B Technologies immediately by email at techsupport@2btech.io or by phone at +1(303)273-0559.

A. Overview

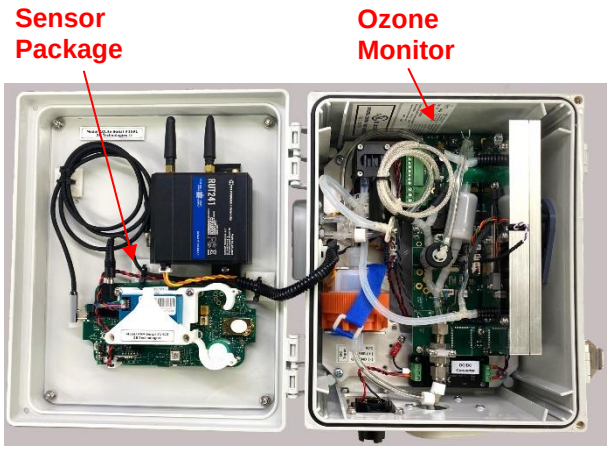
A.1 The AQLite-Standard Air Monitor

The AQLite-Standard Air Monitor is a compact and versatile package that combines an Environmental Protection Agency (EPA)-Federal Equivalent Method (FEM) instrument for measuring ozone (O_3) with sensors for high-quality yet affordable measurements of particulate matter (PM_1 and $PM_{2.5}$) and CO_2. It is also customizable with other sensor options for CO and total VOCs.

The AQLite can be installed virtually anywhere—on a light post or building, or in remote field sites for example—and can be powered by line power or by the user's battery or solar panel charging station.

The AQLite-Standard integrates sensors such as those used in the 2B Technologies Personal Air Monitor (PAM) with the FEM-quality ozone measurements of the 2B Technologies Model 108-L Ozone Monitor in a rugged, weatherproof enclosure.

AQLite-Standard = PAM sensors + 108-L Ozone Monitor + rugged enclosure



We recommend reading this brief overview before proceeding to use your AQLite.

A.1.1 Ozone Measurements Using the 2B Technologies Model 108-L

The Model 108-L Ozone Monitor is provided in all versions of the AQLite (Standard, Basic, and customizable versions). It provides accurate measurements of ozone in air from a few parts-per-billion by volume (ppb) to 1 parts-per-million (ppm) based on the well-established technique of absorption of ultraviolet light at 254 nm. It is ideally suited for measuring concentrations of ozone in ambient air, which range up to ~200 ppb in highly polluted air.

The Model 108-L has been approved by the U.S. Environmental Protection Agency (EPA) as a Federal Equivalent Method (FEM) for measuring ambient ozone (modification of FEM EQOA-0914-218). Its circuit board and associated components are housed in the AQLite enclosure for deployment indoors or outdoors. The AQLite configuration is designed for measurements of ambient levels of ozone only.

By incorporating the Model 108-L Ozone Monitor with sensors for other measurements (next section), the AQLite provides multi-pollutant monitoring including highly accurate measurements of ozone, which cannot be reliably measured using sensor technology.

Below is a labeled photo of the Ozone Monitor in the AQLite showing major components. See Appendix 1 of this manual for a schematic of the Ozone Monitor, a description of the theory of operation, its specifications in the AQLite, and more details.

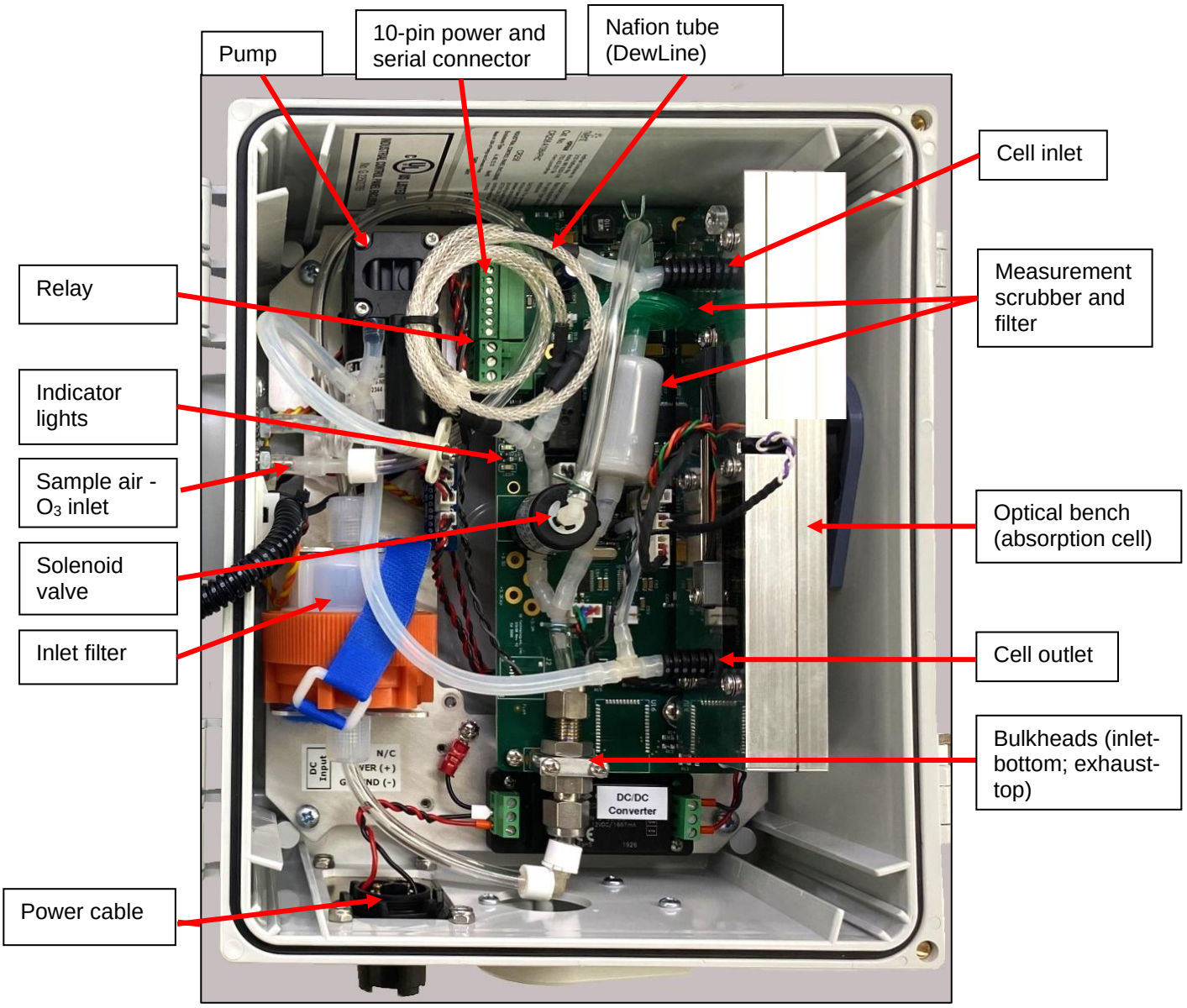
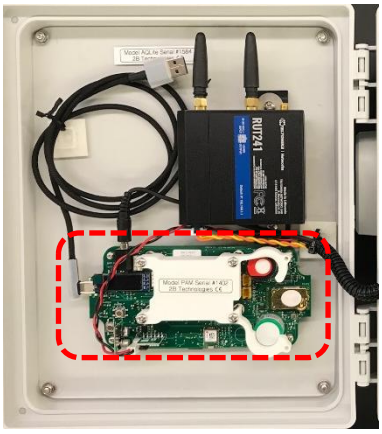


Figure A.1. Model 108-L Ozone Monitor in the AQLite

A.1.2 Sensor Package: CO_2, PM_1, $PM_{2.5}$, and Two Custom Sensor Choices



The AQLite-Standard uses sensors to measure air pollutants. The sensor package is mounted on the inside of the door of the AQLite Air Monitor, as shown at right.

The sensors and other components of the AQLite-Standard are shown in the photo below. More detail about the AQLite sensors can be found in Appendix 2. The sensor measurements included with the AQLite-Standard are: carbon dioxide (CO_2), particulate matter (PM_1 and $PM_{2.5}$), and enclosure conditions (pressure, temperature, relative humidity). Note that although the AQLite data stream contains data for PM_{10}, PM_{10} is not accurately measured by sensors because of the difficulty of sampling large particles without loss due to impaction. We recommend that the user neglect the PM_{10} output. Note that the measured T and RH reflect the conditions within the AQLite, not ambient values.

The sensor suite can be customized to add 2 additional sensors, if the user wishes to measure other pollutants (carbon monoxide (CO), total VOCs). Contact 2B Technologies to discuss alternate configurations of the sensor package. The sensor package now has a convenient mini-LED display that enables quick checking of several functions.

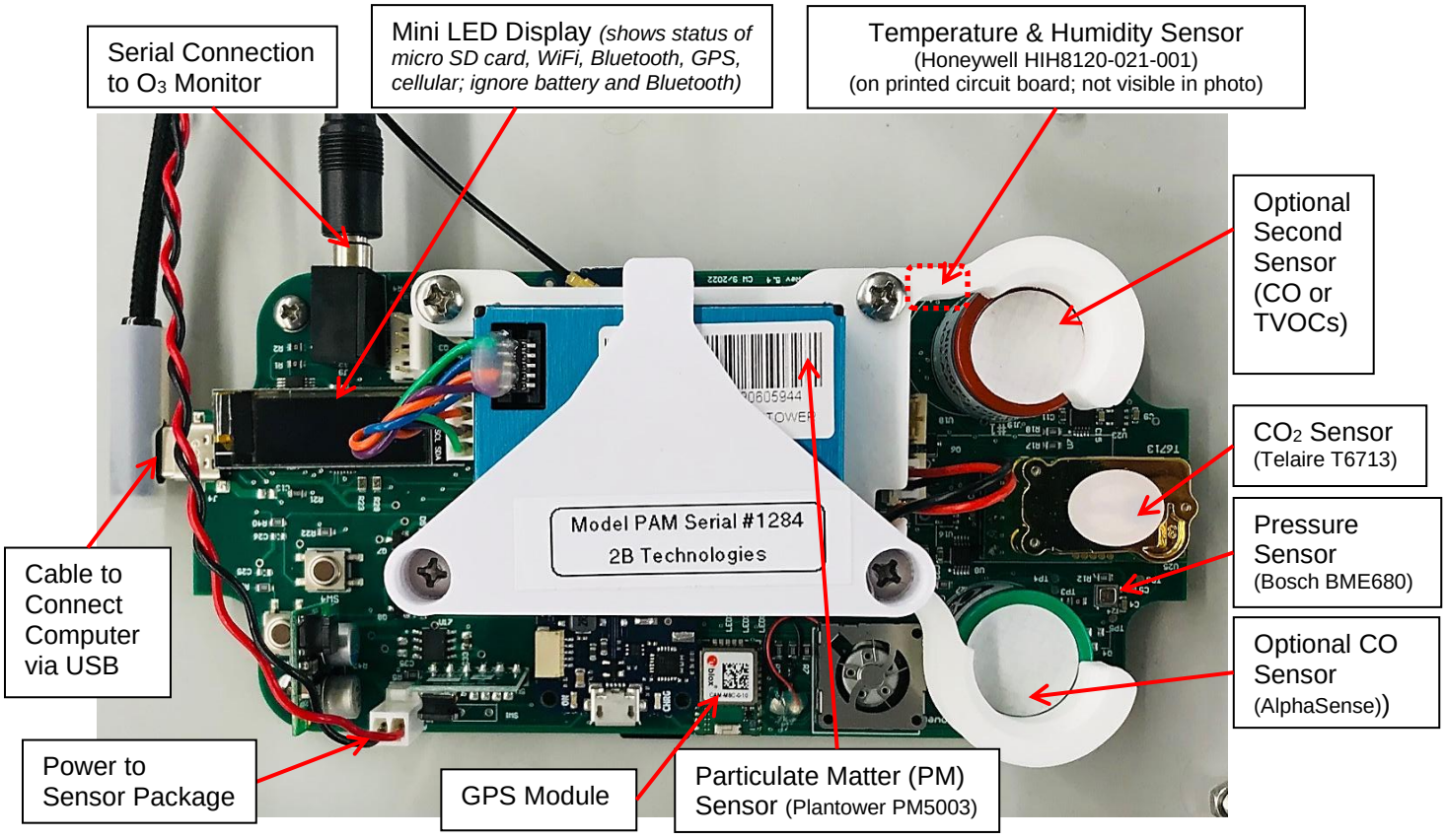


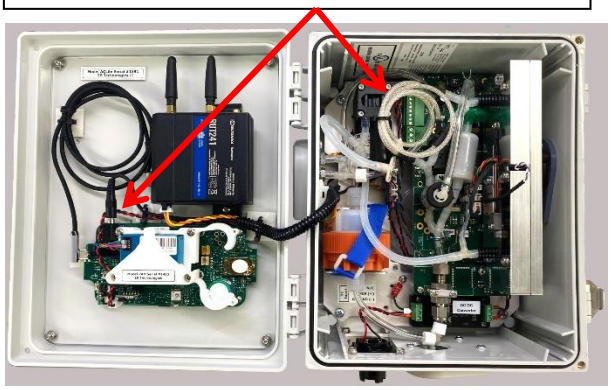
Figure A.2. AQLite-Standard sensor package

A.1.3 Viewing and Acquiring Data with the AQLite-Standard

A.1.3.1 Acquiring Integrated Sensor and Ozone Measurement Data via the Web or micro-SD Card

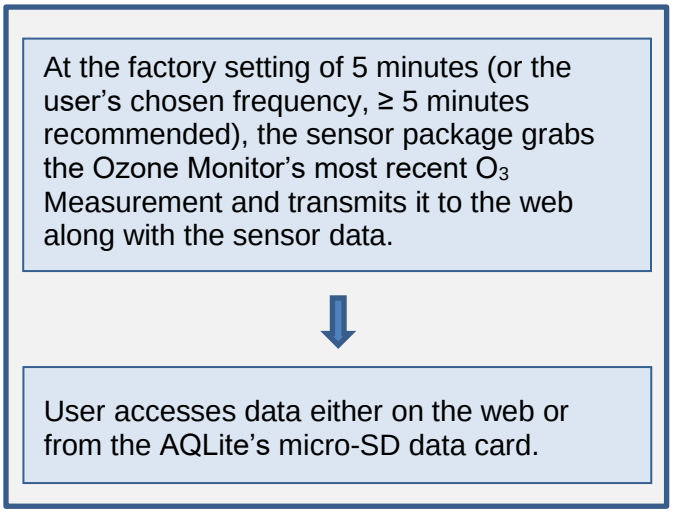
As shipped from the factory, 5-minute averaged data from the AQLite-Standard's sensor package and the Ozone Monitor data are integrated and then transmitted via cellular to the web. There, the data can be accessed for analysis using the Data Portal on top menu bar of the 2B Technologies website: https://2btech.io. *This integrated web-based data stream is the primary data acquisition mode for use of the AQLite-Standard.*

Serial connection of the sensor package to the Ozone Monitor



The averaging period and upload frequency of the measurements are set at a value of 5 minutes at the factory. Each data line contains the chemistry measurements (ozone, CO_2, PM_1, $PM_{2.5}$, PM_{10}*), location, time, and other measurements made by the sensor package (2 custom sensor choices, temperature, pressure, relative humidity within the instrument enclosure; note T and RH do not reflect ambient conditions). This data stream can be transmitted via connection to a computer for subsequent analysis.

The Ozone Monitor and the sensor package are linked via a serial connection as shown in the photo above. The ozone measurement is relayed to the sensor printed circuit board for subsequent transmission, along with the sensor data. Some of the other data acquired by the Ozone Monitor (such as cell pressure) are not transmitted in the integrated sensor+Ozone Monitor data stream.



Schematic summary of the process

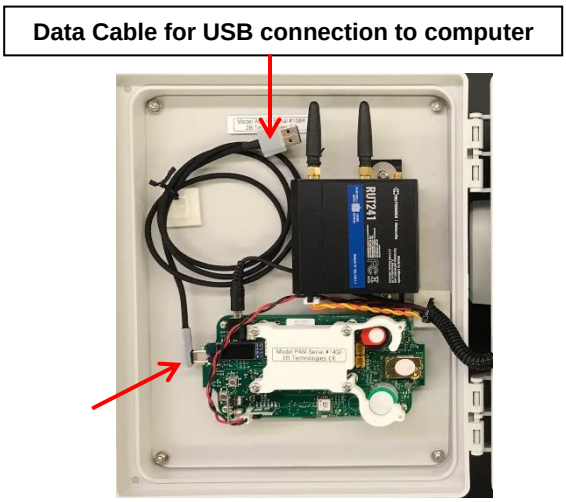
The integrated data stream is also written to a micro-SD data card installed on the bottom edge of the sensor package's printed circuit board. All previously written files are saved, and a separate new file is written each time the AQLite is turned on.

* Note that although the AQLite data stream contains data for PM_{10}, the PM_{10} data should be neglected. PM_{10} is not accurately measured by sensors because of the difficulty of sampling large particles without loss due to impaction.

A.1.3.2 Connecting a Computer to Access the SD Card, Serial Menu, and Diagnostics

The AQLite can be connected to a computer to access the data on the SD card, via the USB cable mounted on the inside of the front door. In addition, access to the serial menu of the sensor package and also the serial menu of the Ozone Monitor, is achieved via this USB connection. This enables the user to adjust various settings, and to carry out diagnostics.

The USB cable is a data cable only. Although it provides power to the sensor package on the door, it cannot be used to power the AQLite. Powering is discussed in Section B.1 of this manual.



A.1.4 General Specifications of the AQLite

Power Consumption: 12 watt after warmup; max 21 watt at startup/warmup
Dimensions: 10.12 x 8.12 x 4.38 in (25.7 x 20.6 x 11.1 cm)
Weight: 7.7 lb (3.5 kg)
Operating Temperature Range: 0 to 50 °C for ozone
Measurement Interval: 2 s
Data Outputs: Cellular Upload to Cloud, RS232, microSD data card

Please see Appendices 1 and 2 for specifications of the ozone monitor and sensors.

A.2 This User Manual

After gaining an overview of the AQLite through the description given in Section A.1 above, the user can find more detail in this manual's 5 major sections:

B. Installation and Startup of the AQLite
C. Making Measurements with the AQLite
D. Accessing the Serial Menu to Change Settings
E. Zeroing and Calibration
F. Maintaining and Troubleshooting the AQLite

Sections G through I of the manual contain labeled instrument photos, a list of spare parts, and a service log for your recordkeeping.

Users who wish to know more detail about the Ozone Monitor and the sensor package, will find information in the Appendices:

Appendix 1: The Model 108-L Ozone Monitor
Appendix 2: The AQLite-Standard Sensor Package and Options

B. Installation and Startup of the AQLite-Standard

B.1 Establish Power Connection to the AQLite

The AQLite is powered by DC, via an AC to DC converter. Plug in the connector and twist the cap to secure.

The AC to DC converter is rated IP67 for dust and water resistance.

B.2 Complete the Initial Check of the Sensor Package

After shipment, please check to make sure the sensor package is working before proceeding with your AQLite. Provide power to the AQLite. Then:

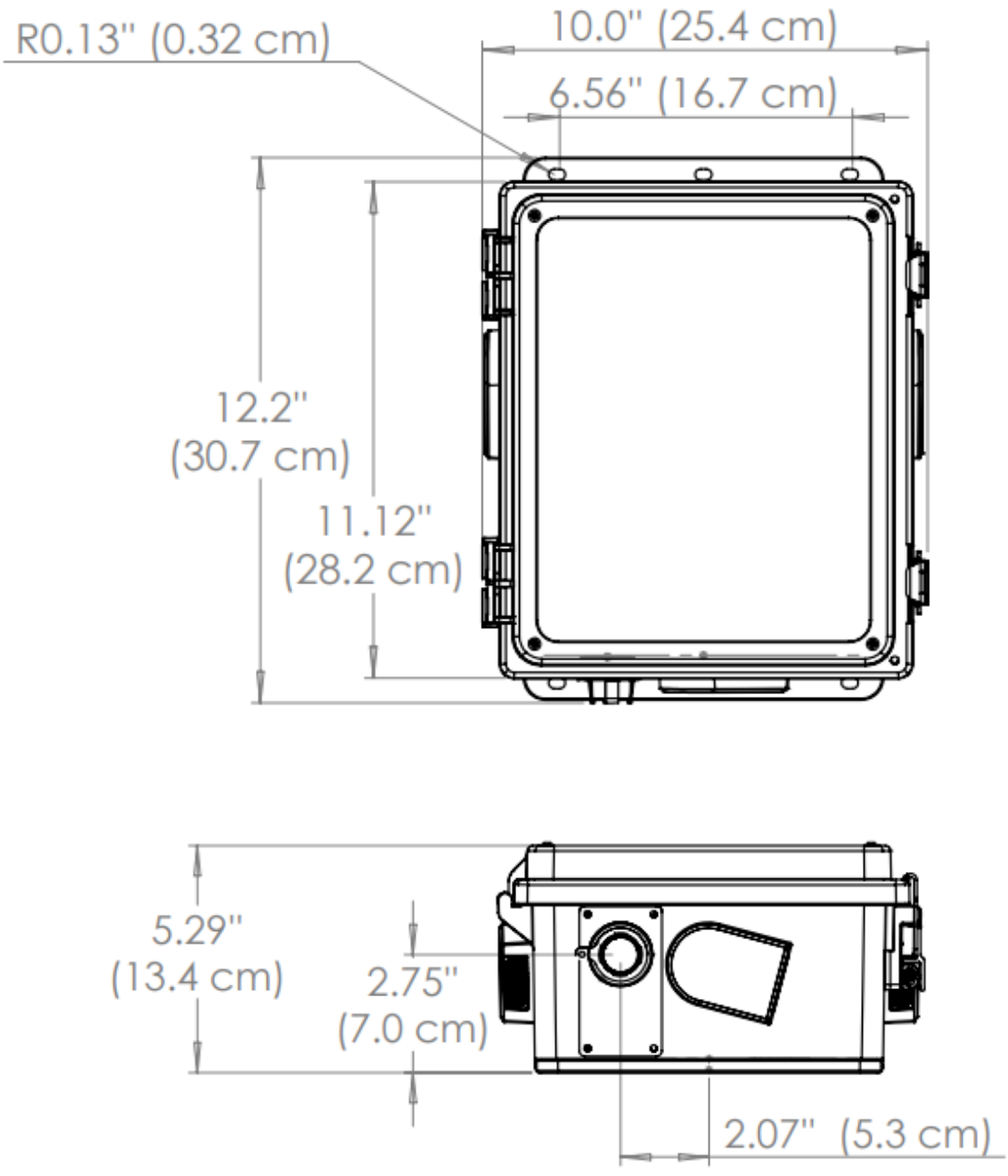
- Look for the mini-LED screen and verify that it is reading out properly. Be sure that the data connections and features you are interested in using (which can include cellular, WiFi, micro SD card, GPS) are functional. (Ignore any readings for battery, as the sensor package does not have a battery in the AQLite configuration. Also ignore Bluetooth.)

Mini LED Display *(shows status of micro SD card, WiFi, Bluetooth, GPS, cellular; ignore battery and Bluetooth)*

Successful completion of the above steps B1 and B2 indicates that the sensor package of your AQLite is working properly. Proceed with the installation step below.

B.3 Physical Installation and Dimensional Drawings

The AQLite Air Monitor is designed for outdoor environments and meets NEMA 3 specifications for environmental protection. The polyester enclosure is sealed to withstand rain and snow, and the enclosure is fitted with a weatherproof cable gland for all cable connections. We recommend that the monitor be mounted on a post, wall, or specially built stand. The back of the enclosure has three holes at the top and three holes at the bottom for mounting screws. The holes are 1/4" in diameter and should be used with stainless steel bolts and washers. The dimensional drawings are shown below.



B.4 Power Up

1. Establish the power cable connection as shown in Section B.1.
2. Provide power to the AQLite. The ozone monitor's circuit board has a LED next to the relay connector that is illuminated when power is supplied. See labeled photo in Appendix 1 Section 1.4 for location.

Once the instrument has been powered on, the first dozen readings (requiring about two minutes) will be spurious, with large positive and negative swings due to the rapid warmup of the lamp and electronics of the ozone monitor.

The ozone readings may be noisier than expected during the initial 10-20 minutes required for the lamp, photodiode, and internal temperature of the absorption cell to stabilize. The sensors require a warmup period of about an hour.

******

The steps in this Section B have ensured that your AQLite is functioning. The next section of the manual describes how to make measurements with the AQLite.

C. Making Measurements with the AQLite-Standard

When power is supplied to the AQLite-Standard, the sensor package and the Ozone Monitor begin making measurements. These measurements are integrated into a data stream that is uploaded via cellular to a 2B Technologies website and stored on a micro-SD card in the AQLite.

This Section of the manual serves as a "quick start" and describes:

- how to view/access the data; and
- how to use your computer and the AQLite's serial menu to change the instrument's factory settings if you wish to use other settings for your air sampling.

Further explanations of the specifications and operation of the Ozone Monitor and the sensor package are given in Appendix 1 and Appendix 2 of this manual.

• Complete Section B steps before proceeding.
• Each time you power up the AQLite, be sure that the data upload connections you need (which can include cellular, WiFi) are established as described in Section B.2.

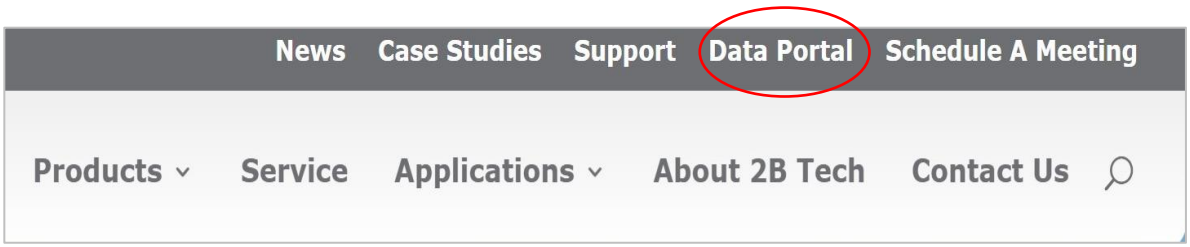
C.1 Accessing the AQLite Data via the Web

As shipped from the factory, 5-minute averaged data from the AQLite-Standard's sensor package and the Ozone Monitor are integrated and then transmitted via cellular or WiFi to the web. There, the data can be accessed for analysis using the Data Portal on the 2B Technologies website. *This integrated web-based data stream is the primary data acquisition mode for use of the AQLite-Standard.*

C.1.1 Logging into the Data Portal

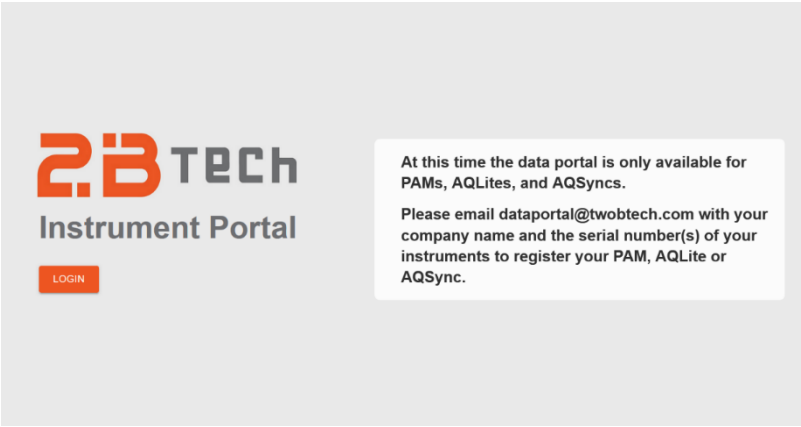
Web access is via a Data Portal on the 2B Tech website. **Contact dataportal@2btech.io to set up an account for the Data Portal**. Then:

a) Access the website https://2btech.io. Choose "Data Portal" from the top menu bar.



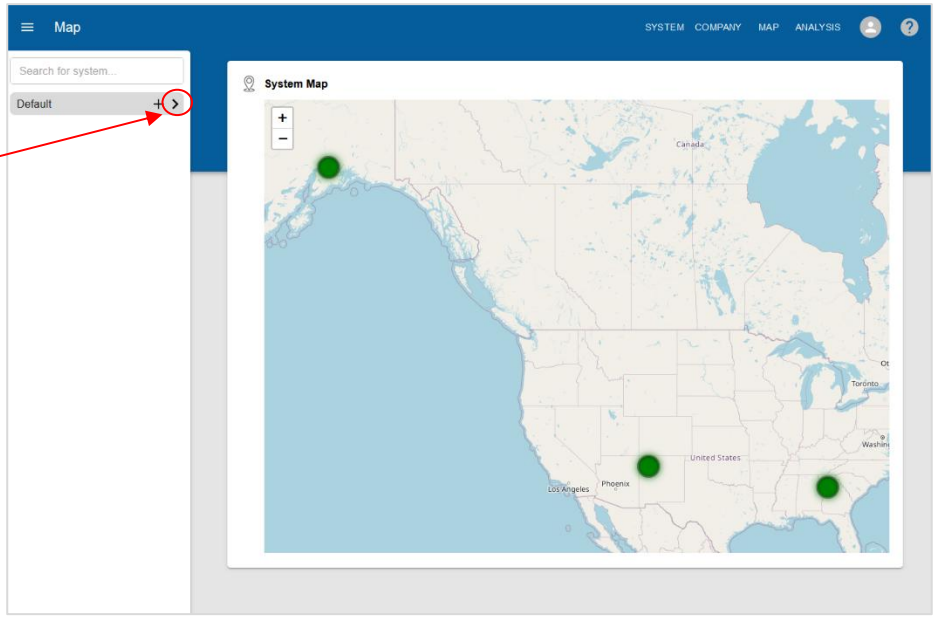
The Data Portal is used with three 2B Tech instruments: The AQLite-Standard, the AQSync, and the Personal Air Monitor (PAM).

b) Click on the orange "Login" button and use your login credentials to login:

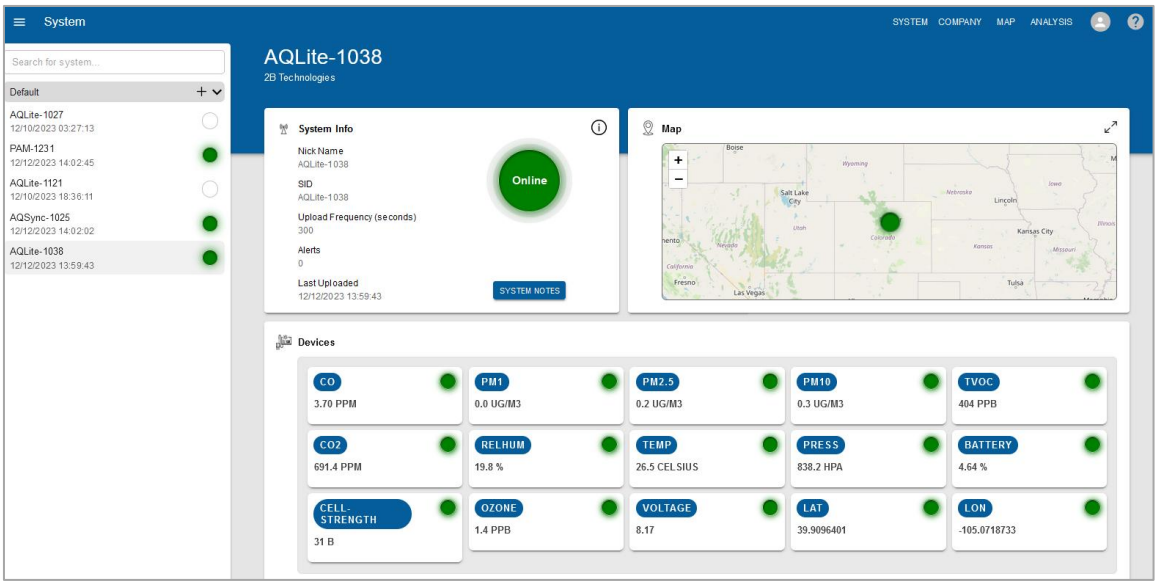


C.1.2 Viewing the Data

A few minutes after logging in, you will see the dashboard. On the left side is a Default folder containing a list of all your instruments, identified by their serial numbers. Display your instruments using the ">" pulldown on the Default tab. To the right they are displayed on a map.



Click on an instrument name/serial number to see the instrument. If the instrument is online, it is shown as a green circle in the list at the left and in the System Info box next to the map. The various measurements of that instrument are shown as a grid of boxes in the Devices section, with their status shown in a circle that is either green (functioning) or yellow. Yellow indicates there is an issue with that AQLite measurement (click on the circle to get information). The AQLite serial number is located on the back of the instrument case. (*Note that the battery readout can be ignored, as there is no battery in the AQLite's sensor package. We recommend that you neglect the readout for PM10; see Sections A.1.2 and A.1.3.1. Also ignore any other readouts for sensors that you did not include in your customizable AQLite package*.)



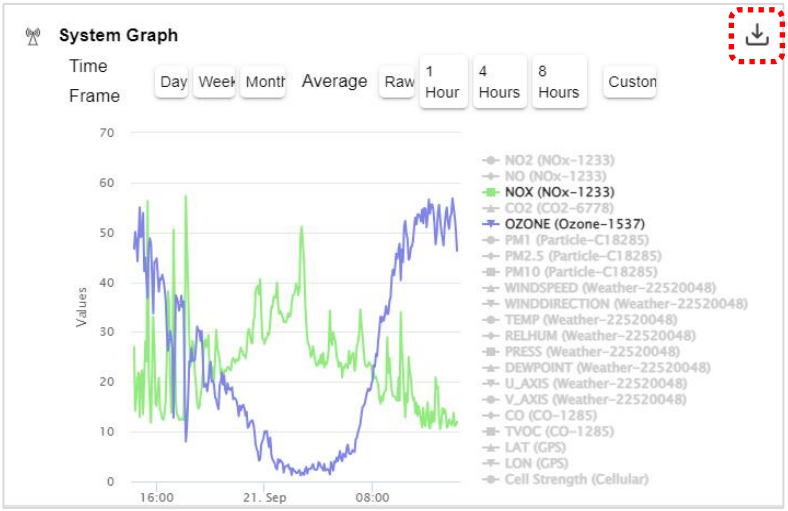
Click on the box for any of the measurements with “green” status to see a graph of its data, as in this example for ozone:

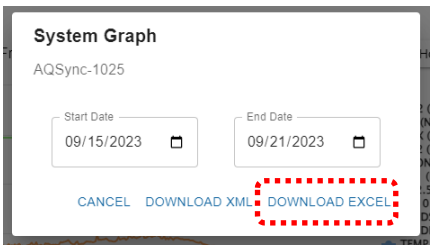
Hover over any point with the cursor to see its data value. The time frame for the data, as well as the averaging time, can be specified from the menu along the top of the graph.

Note that the “Settings” tab is currently under development. It will display instrument parameters in the future.

A graph of all the measured parameters appears at the bottom of the main screen. Use the menu buttons to choose the Time Frame and Averaging period or enter custom values for those quantities.

Click on any of the parameters to display only its data (autoscaled) on the System Graph (example shown below is for an AQSync). Multiple measurements can be displayed by clicking on them as shown below. Click again on the displayed item in the legend to return to displaying all measured parameters.





Click the icon in the upper right corner to download the displayed data. You can choose the date range for the file that will be created. The file is named "AQLite- xxxx.csv," where xxxx is the serial number of your AQLite.

The file column headings in the csv data file are largely self-explanatory. The headings contain the serial number of the PAM (sensor package) module used in measuring the parameter.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Averaged Start Date (UTC)	Averaged End Date (UTC)	PAM-1204:CO (PPM)	PAM-1204:PM1 (UG/M3)	PAM-1204:PM2.5 (UG/M3)	PAM-1204:PM10 (UG/M3)	PAM-1204:TVOC (PPB)	PAM-1204:CO2 (PPM)	PAM-1204:RELHUM (PERCENTAGE)	PAM-1204:TEMP (CELSIUS)	PAM-1204:PRESS (HPA)	PAM-1204:Battery (PERCENTAGE)	Ozone:OZONE (PPB)	Ozone: Voltage (OTHER)	GPS:LAT (LAT)	GPS:LON (LON)
2	12/12/2023 20:39	12/12/2023 20:39	5.71	0	0.2	0.2	428	646.5	21.5	25	838.3	3.45	0	8.14	39.90962	-105.072
3	12/12/2023 20:44	12/12/2023 20:44	4.61	0	0.2	0.3	411	742.6	20.7	26.1	838.3	3.79	0.9	8.14	39.90965	-105.072
4	12/12/2023 20:49	12/12/2023 20:49	4.15	0	0.1	0.1	405	781.3	20.2	26.4	838.2	4.04	0.9	8.19	39.90964	-105.072
5	12/12/2023 20:54	12/12/2023 20:54	3.77	0	0.1	0.1	404	698.1	19.9	26.5	838.1	4.3	1.7	8.19	39.90975	-105.073
6	12/12/2023 20:59	12/12/2023 20:59	3.7	0	0.2	0.3	404	691.4	19.8	26.5	838.2	4.64	1.4	8.17	39.90964	-105.072

Note that the "Download XML" choice is used for our mobile devices (the PAM Personal Air Monitor) and is not useful for the AQLite.

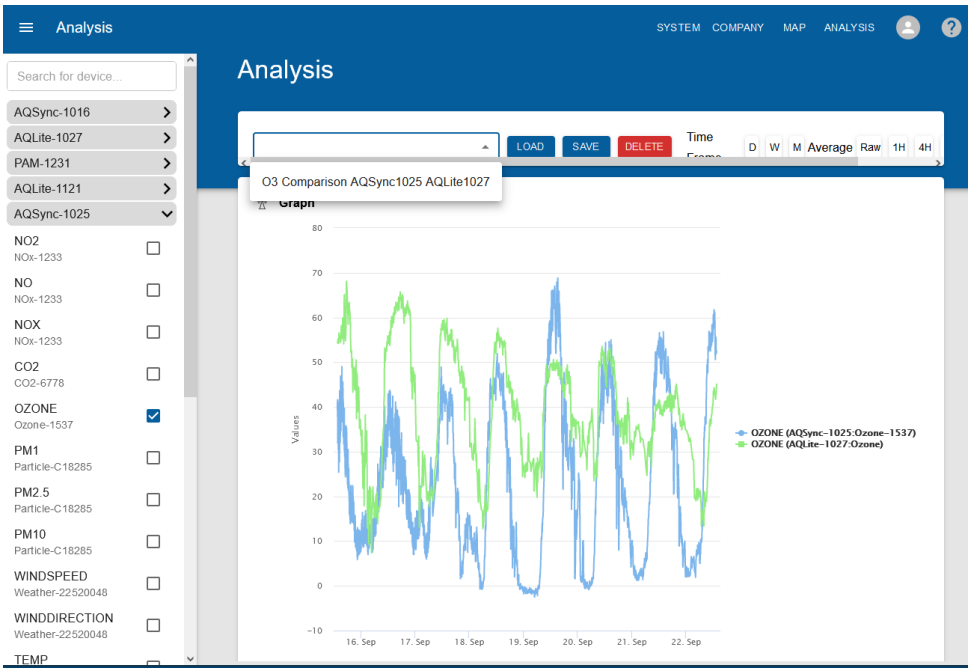
C.1.3 Organizing Your Instruments

All of your instruments are shown in the "Default" folder upon first login. Users with Admin status can create project folders (done in the "Company" tab). Click on the "+" sign of a project folder to move an instrument from the Default folder into that project folder.

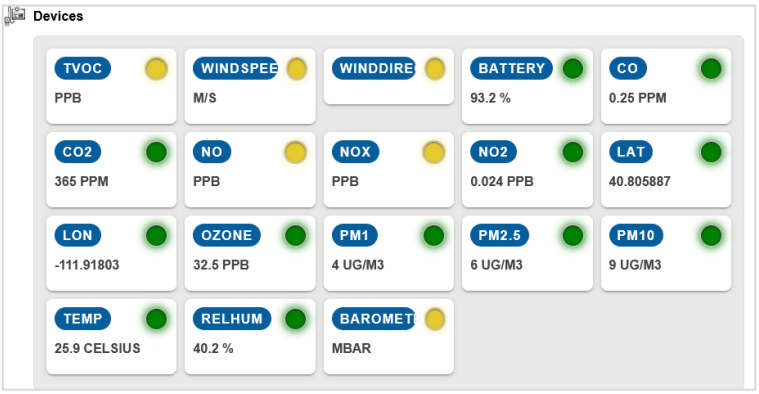
C.1.4 Viewing/Comparing Data from Different Instruments

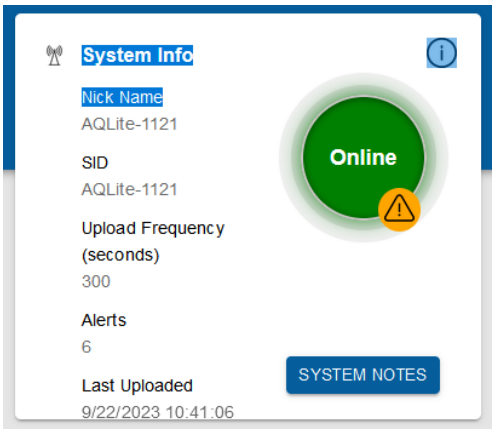
The "Analysis" tab in the upper right corner of the main screen enables you to compare data across multiple instruments.

Use the Device pulldown menus to select the items you wish to compare on the graph. Adjust the time frame and averaging as desired. If you want to frequently check the same comparison, you can “Save” it and name it. To compare it again in the future, click “Load” and select its name. Delete any named comparisons that you no longer want. The example below shows a comparison of ozone data from 2 different devices.



C.1.5 Troubleshooting





If one of your measurements has a problem, it will have a yellow circle next to it, and an orange warning triangle will appear on the system’s green circle as shown above on the right. Click on the measurement box to get information about the problem.

Click on “System Notes” to see an overview of problems with your instrument.

C.2 Accessing Data on the Micro-SD Card

1. Data are also stored on the factory-installed micro-SD card provided with your AQLite. A new file is started on the card whenever the AQLite is powered off and on again.
2. To access the data (see Section D of this manual for more detail), connect the USB cable on the inside front door of the AQLite to your computer.
3. Start up a terminal emulator such as Tera Term.
   a) Tera Term will likely identify the correct COM port and begin displaying data. The baud rate is 115200. A new data line will appear every few seconds.
   b) Put the computer's cursor in the TeraTerm window and click. Then enter "**m**" on the computer keyboard to enter the serial menu. Data acquisition will pause and the cursor will blink, indicating it is waiting for a command. (Note: Command '**?**' will output a list of all of the serial commands.)
4. Type "**p**" to see the files that are on the SD card. An example of a list of files is shown below:

```
0: 1080_20210708_163131.txt
1: 1080_20210708_163516.txt
2: 1080_20210708_171250.txt
3: 1080_20210708_184952.txt
4: 1080_20210708_185151.txt
5: 1080_20210708_185818.txt
End of files on Sd.
```

5. The file name on the SD card will be of the following format: Device#_YYYYMMDD_HourMinutesSeconds.txt. The time is in military format (see Section D.3 for information about setting the time).
6. To open a particular file, type its ID number (shown on the start of the line) and type enter.
7. Open a data file. An example is shown below:

```
File Start timestamp:
Thu Jul  13 20:06:05 2021
DEV,CO(ppm),CO2(ppm),PM1,PM2_5,PM10,T(C),Press(mBar),RH(%),O3(ppb),Batt(%),Latitude,Longitude,
Date/Time
1083,0.081,402,0,0,0,26.8,843.9,34.4,70.5,85.8,999.9999999,99.9999999,13/07/21,20:06:05
1083,0.088,407,0,0,0,26.9,843.9,34.0,72.0,85.6,999.9999999,99.9999999,13/07/21,20:06:10
```

8. The data lines in the file for the integrated sensor package + Ozone Monitor measurement will look like this, for example:

1083,3.081,402,2,2,0,26.8,843.9,34.4,70.5,12.39,85.8,999.9999999,99.9999999,13/07/23,20:06:05

where

AQLite serial number =	1083 *(labeled on your AQLite)*
CO (ppm) =	3.081
CO_2 (ppm) =	402
PM_1 (µg/m^3) =	2
$PM_{2.5}$ (µg/m^3) =	2

PM_{10} (µg/m^3) =	*[ignore number, data not valid in the AQLite]*
Temperature (C) =	26.8 (reflective of AQLite enclosure conditions, not necessarily ambient)
Pressure (mbar) =	843.9 (likely close to ambient)
Relative Humidity (%) =	34.4 (reflective of AQLite enclosure conditions, not necessarily ambient)
Ozone (ppb) =	70.5
External Voltage (V) =	12.39 *[should be ~12-12.5]*
Battery status (%) =	85.8 (ignore; this readout is invalid in the AQLite, as there is no battery)
Latitude =	999.9999999 *[default value when there's no GPS signal]*
Longitude =	99.9999999 *[default value when there's no GPS signal]*
Date =	13 July 2023 (European date format)
Time =	8:06:05 pm (military time format, UTC +/- the user's setting for GMT offset [see Section D.3])

9. Select the lines you wish to analyze, and then copy and paste them into a spreadsheet such as Excel.

Note that your data line may look slightly different than the above example, depending on the sensors you selected when you ordered your AQLite.

D. Accessing the Serial Menu to Change Settings

The AQLite comes from the factory with default settings for the averaging period (5 minutes) and the time (Mountain time UTC). These and other features of the AQLite can be changed by the user via the instrument's two serial menus that are accessible through the user's computer. While the data stream is outputting, enter the serial menu of the sensor package with the command "**m**". Alternatively, while the data stream is outputting, enter the ozone monitor serial menu with the commands "**q**" followed by "**f**".

Command "m"

Sensor package serial menu commands
- a: Go to device list to access settings
- b: Go to list of debug options
- •
- •
- •

etc. …

OR

Commands "q" > "f"

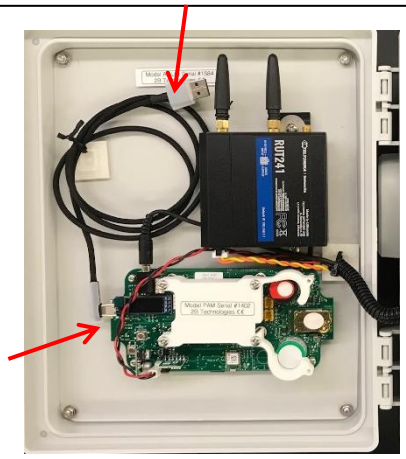
Ozone Monitor serial menu commands
- a: Averaging time
- z: Zero offset calibration setting
- •
- •
- •

etc. …

D.1 Connect Your Computer

The AQLite can be connected to a computer to access the serial menu via the USB cable mounted on the inside of the front door. This enables the user to adjust various settings, and to carry out diagnostics (but not to power the AQLite). (In addition, access to the data on the SD card is achieved via this USB connection; see Section C.2.)

Cable for USB connection to computer



1. Connect your computer using the USB cable.
2. Start up a terminal emulator such as Tera Term. Tera Term will likely identify the correct COM port and begin displaying data (baud rate 115200). A new data line will appear every few seconds.
3. Put the computer's cursor in the TeraTerm window and click.
4. Type "**m**" on the keyboard to enter the serial menu of the sensor package. Alternatively, type "**q**" and then "**f**" to enter the serial menu of the ozone monitor.
5. Data acquisition will pause and the cursor will blink, indicating it is waiting for a command.
6. Type "**?**" to see the list of available serial commands. Type "**x**" to exit the menu and resume measurements. The list of commands is shown in the next section.
7. Type "**x**" to exit the menu and resume measurements.

D.2 Serial Menus

D.2.1 Sensor Package Serial Menu and Submenus

The serial structure for the AQLite's sensor package is nested, with a Main Menu and Submenus. The Submenus (see next page) are entered using the commands "a" and "b" shown in **red** below.

Command: Description

a: Go to device list to access settings, enable/disable *(May have devices not in your AQLite's sensor package)*
b: Go to list of debug options
c: Enable status bytes for all devices *(Will change serial line to include these.) [Ignore; leave disabled unless working with 2B Tech on troubleshooting.]*
d: Enable / Disable cellular
e: Adjust frequency for uploading primary data *(in seconds)*
f: Adjust frequency for uploading diagnostic data *(in seconds)*
g: Enable / Disable WiFi
h: Change WiFi credentials *(choose network and set password)*
i: Enable / Disable CarTopper power mode. *If enabled, absence of external power will stop cellular. [Not applicable to the AQLite]*
j: Enter time zone *(adjust for shifts in local time such as daylight savings time)*
k: Output header string
l: Enable / disable SD card *[Disable/enable if removing/reinserting SD card with power on]*
n: Calibrate CO2 sensor. *After choosing this option, take outside. Calibration will start in 1 minute*.
o: Rotate OLED display
p: List files on SD card and choose which to print in serial
q: List files on SD card and choose which file to delete
r: Switch Bluetooth mode *["Beacon" or "Direct Connect"] {not applicable to newer AQLites}*
s: Set the date and time using GPS *(will not work without an active GPS signal)*
t: Set the date and time manually *(must enter in UTC)*
u: Restart ESP (have new settings be enabled) [*this is an internal power restart*]
?: Output this menu
x: Exits this menu

Submenu "a": Device Settings (not all of these may be in your AQLite)

Command: Description
a: Socket 1
b: Socket 2
c: CO2
d: Plantower-PM
e: Sensirion-PM (This will automatically turn off Plantower-PM)
f: TVOCs
g: HIH (temp, relative humidity)
h: BME (pressure)
i: Methane *(not currently available)*
?: Output this menu
x: Exits this menu

Choosing any of these brings up another submenu similar to this:
a: Disable (will not see this in effect until restart)
b: Change the slope
c: Change the zero
x: Exits this menu

Note that the population of Socket 1 and Socket 2 was customized when your AQLite was ordered.

- *Socket 1 and Socket 2 could each contain a sensor for CO.*
- *Socket 1 will be empty if a sensor for TVOCs was ordered, because the TVOCs sensor is placed in the space of Socket 1, but with different plug-in points.*

Submenu "b": Debugging Operations

These choices will print out messages pertaining to specific parts of the sensor package. For example, choosing "CO2 debug" will print out information about the CO_2 sensor after restarting the AQLite. Note that the commands listed below are meaningful only for the sensors and features present on your AQLite.

Command: Description
a: Cellular debug
b: Clock debug
c: Socket 1/2 debug
d: CO2 debug
e: PM debug
f: TVOCs debug
g: HIH (temp, relative humidity) debug
h: BME (pressure) debug
i: Methane debug *(not currently available)*
j: AQSync debug
k: Ozone debug
l: Battery debug *(not applicable for the AQLite)*
m: Bluetooth debug *(not applicable for newer AQLites)*
n: WiFi debug
o: SD card debug
p: GPS debug
?: Output this menu
x: Exits this menu

D.2.2 Ozone Monitor Serial Menu

While the data stream is outputting, enter the ozone monitor serial menu with the commands "**q**" followed by "**f**". Be sure to press **enter** after every command while in the ozone menu to confirm the change being made.

The ozone averaging time must be set to **2 seconds** for proper functioning within the AQLite-Standard.

Command:	Description
a	Averaging time: enter a number followed by carriage return (0 = 2 second (no averaging), 1 = 10 second, 2 = 1 minute, 3 = 5 minute, 4 = 1 hour). For the AQLite, this must be set to "0" for an averaging time of 2 seconds.
z	Zero (offset) calibration setting: displays current setting and waits for a setting followed by a carriage return (enter a setting [integers only] and carriage return)
s	Slope calibration setting: displays current setting and waits for a setting followed by a carriage return (enter a setting and carriage return)
h	Output serial data line header (also available during measurements).
Y	Set all configuration to default[1].
b	Adaptive filter difference (integers only; see Section 1.2 of Appendix 1).
l	Adaptive filter percent (integers only; see Section 1.2 of Appendix 1).
k	Adaptive filter long average length (integers only; Section 1.2 of Appendix 1).
m	Adaptive filter short average length (integers only; Section 1.2 of Appendix 1).
n	Output instrument serial number.
p	Perform lamp test.
g	Set the relay OFF ozone level (when ozone is greater than this, relay turns off).
j	Set the relay ON ozone level (when ozone is less than this, relay turns on).
f	Set the analog output full scale in ppb.
u	Set the ozone units (0 = ppb, 1 = pphm, 2 = ppm, 3 = $\mu g/m^3$, 4 = mg/m^3).
c	Set the temperature units (0 = K, 1 = °C, 2 = °F).
o	Set the pressure units (0 = torr, 1 = mbar, 2 = psi)
L	Set to flat temperature sensor *(do not adjust; this is a factory setting)*
T	Set to round temperature sensor *(do not adjust; this is a factory setting)*
?	Output this help menu.
x	Exit menu and return to measuring.

[1] Default settings: Avg=10 s, offset=0, slope=1, adaptive filter difference=0, adaptive filter percent=0, adaptive filter long average length=25, adaptive filter short average length=10, T in °C, P in mbar, O_3 in ppb.

D.3 To Adjust the Time Setting of the AQLite

The sensor package contains the AQLite's clock. When the sensor package connects to cellular service, the clock is automatically synced with the current UTC time.

If your AQLite is running for a long period of time without connection to cellular service, the clock time may become inaccurate and it is recommended to check the time. At this point it is recommended that you either connect to cellular service, or adjust the time via the serial menu.

If you need to change the time or set the GMT offset, follow the instructions below. Local time with the user's GMT offset is displayed in the serial output and the SD card data.

1) Outside the continental U.S., find your GMT offset online at sites such as https://greenwichmeantime.com/time-zone/definition/
2) The sensor package's time/date format is a 10-digit "epoch timestamp." Choose a reference time piece such as the clock on your cell phone. Use a free online converter such as the one found here to convert your local time to a 10-digit number: https://www.freeformatter.com/epoch-timestamp-to-date-converter.html. In the converter's "convert date to epoch timestamp" section, enter the date and a time about a minute ahead of your actual local time, and write down the epoch number. Now type the command "**t**" and enter that 10-digit number (the digits do not display in the TeraTerm window, but they are being registered by the sensor package and when the 10th digit is entered, the time is set). Hit the return key to return to the menu.

D.4 To Change the Averaging Time/Upload Frequency

In the AQLite, the data from the sensor package and the ozone measurement from the Ozone Monitor are integrated into a data line, which uploads to the web and writes to the micro-SD card located in the sensor package. The AQLite averages the most recent ozone measurements from the Ozone Monitor, combines it with its averaged sensor data, and uploads the data line at a user-specified frequency. (Small differences in the clock of the sensor package and the clock of the ozone monitor will occasionally result in a slight mismatch of the air sample represented by the sensors and the air sample represented by the ozone monitor.)

The factory setting is 5 minutes (300 seconds) for the upload frequency for the primary data of the sensor package. Upload times faster than 5 minutes are too costly (cellular data expenses). Upload times slower than 5 minutes will potentially give a larger mismatch of the air sampling from the sensor package and the ozone monitor if the timing of the two clocks is off by a few seconds.

The steps to change it are below. But again: **we strongly recommend using your AQLite at the factory settings of 5 minutes (300 seconds) for the upload frequency.**

****

We recommend consulting with 2B Technologies before making any of the changes mentioned in (a)-(f) below.

a) Connect the AQLite's USB cable to the USB of your computer and enter the serial menu of the sensor package as described previously in Section D.1 (command "**m**").

b) Type the command "**e**" to adjust the frequency for uploading (in seconds). We recommend 300 seconds or more, to save on cellular costs. The factory default value is 300. Note that the digits will not appear on the screen as you type, but they are being registered by the sensor package. Hit the return key when you have typed the number. A readout will verify what you have typed.

c) Values less than 300 are not recommended because of prohibitive cellular expense.

d) Command "f" is set to 3600 for the frequency of uploading diagnostic data, which would be used if you are working with 2B Tech to diagnose a problem. Please do not adjust this setting without talking to us.

e) Exit the serial menu with command "x" (twice).

Though many other serial commands are given in Section D.2, they will not commonly be used during normal operation. Calibration settings, for example, are only needed if the user elects to perform calibrations. Contact 2B Technologies with inquiries about any of the commands not described in this manual.

E. Zeroing and Calibration

It is recommended that the user frequently examine the data from the AQLite Air Monitor to be sure that the readings make sense and the instruments are working properly.

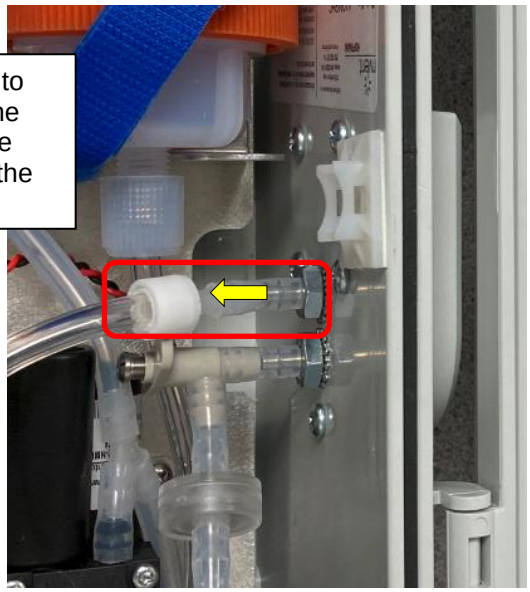
For example, on polluted days ozone readings should be higher, and other pollutants such as particulate matter might be higher (especially if fires are burning nearby, for example). Outside CO_2 readings should be around 400 ppm. If an EPA monitoring station is located nearby, the AQLite's readings could be compared to the station readings. In addition to the routine observations of the functioning of your AQLite Air Monitor, the annual calibration is recommended, and zero checks can be carried out when convenient.

E.1 Ozone Monitor

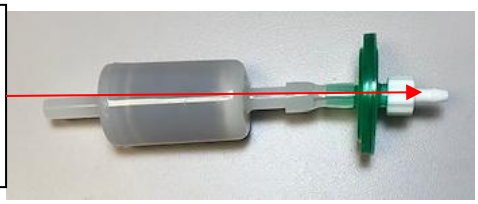
E.1.1 Zero Checks of the Ozone Monitor

The electronic zero of the Ozone Monitor may be measured by attaching an ozone destruction cartridge to the air inlet for a period of 5-10 minutes. (One was provided when you purchased your instrument.) The setup for the zero check is shown below:

1. Pull gently to remove silicone tubing from the barb fitting of the AQLite inlet



2. Attach the silicone tubing to the white barb fitting of the ozone scrubber/filter



3. Zeroing setup shown above

Once you have completed the setup as shown above, follow the steps below to zero the Ozone Monitor.

1. Power up the AQLite. For an accurate measurement, the instrument must have been turned on long enough for the internal temperature to stabilize (normally ~20 minutes).
2. While waiting for warmup, choose and set the measurement time of the Ozone Monitor (available settings are 2s, 10s, 1min, 5min, 1hr). It is recommended that the instrument be zeroed for a period of 5 to 10 minutes, so a setting of 10 seconds could be chosen, for example. To set the measurement averaging time, access the Ozone Monitor's serial menu as previously described in Section D.2.2.
3. After the instrument is warmed up, make note of the time and collect data for 5 to 10 minutes.
4. Access the data for that time interval using the web interface and compute the average.
5. The observed offset, which can amount to ± a few ppb, can be corrected for by changing the offset calibration parameter from the serial menu of the Ozone Monitor (command "**z**"; see Section D.2.2). The offset is applied in units of ppb (integer numbers only). If during your zero check the instrument reads an average of +3 ppb with the external scrubber in place, the instrument is reading too high by 3 ppb. Therefore, the value of the offset should be decreased by 3 from its present value.
6. Remove the ozone scrubber from the instrument and restore the original plumbing connections.
7. Important: Also restore the ozone instrument's averaging time to 2 s.

E.1.2 Calibration of the Ozone Monitor

It is recommended that the AQLite be returned to 2B Technologies annually for cleaning and calibration service. At that time, both the Ozone Monitor and the sensor package will be cleaned and calibrated. During calibration, the Ozone Monitor is exposed to a range of known concentrations and the calibration parameters (offset and slope) are adjusted.

Users with access to a calibration system for ozone can perform a calibration of the Ozone Monitor using the procedure described in Appendix 1.

It is recommended that the AQLite be returned to 2B Technologies annually for cleaning and calibration service.

E.2 Sensor Package

E.2.1 Zeroing and Calibration of the Sensors

The zeroing, calibration, and occasional replacement of the AQLite's sensors are done at 2B Technologies, at a frequency that depends on the environmental sampling conditions. Contact 2B Technologies to discuss recommended scheduling.

E.2.2 Recommended: Frequent Checks of the Sensor Functioning

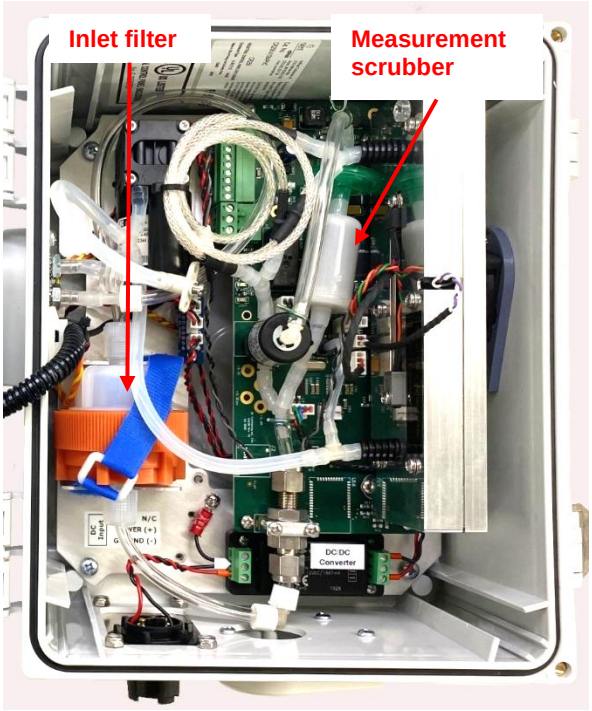
It is advisable in all cases to observe the sensor readings and assess whether they make sense for the conditions. For example, comparing the AQLite data to data from a nearby EPA monitoring site would be a good way to check the readings. Other situational checks could be made on a routine basis. For example, the CO_2 sensor should read around 400 ppm outside, and will give higher readings inside a room where people are present. Near a combustion source, CO will be higher. Smoke and dust will lead to higher PM readings. For example, the smoke from a match that is lit and then blown out provides a quick test of whether the PM sensor is functioning. If readings do not respond as expected for a given sensor, the sensor may need to be replaced at the factory.

F. Maintaining and Troubleshooting the AQLite

F.1 Maintenance

F.1.1 Ozone Monitor Maintenance

The Ozone Monitor in the AQLite is designed to be nearly maintenance free. The Ozone Monitor has an internal ozone scrubber that is used during the measurement cycle (see Appendix 1). This scrubber should be changed at least annually, or after every six months (~4,000 hours) of continuous operation. The scrubber can easily be replaced by disconnecting the tubing attached to each end and connecting a new one in its place, being sure that the "smooth" end of the scrubber is oriented as originally provided.



Also, the inlet filter should be changed if the Ozone Monitor flow rate is declining or if visible contamination is present. Frequency will depend on conditions of use.

Other ozone monitor components with a limited lifetime are the air pump (~15,000 hours), lamp (~20,000 hours) and solenoid valve (rarely fails). It is recommended that the instrument be returned to 2B Technologies if any of these components fail. Alternatively, the user may install these components at their own risk. In that case, please contact 2B Technologies for instructions.

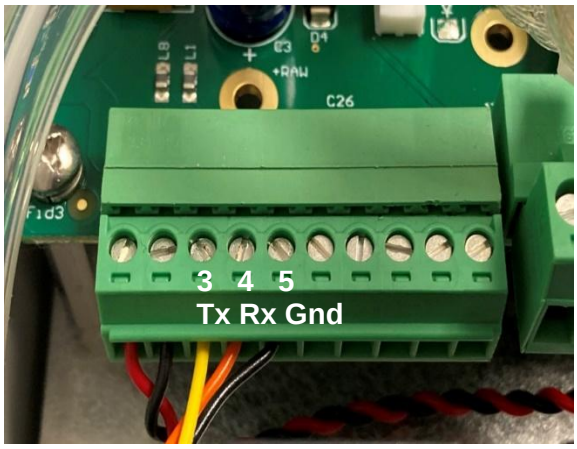
If the instrument has been sampling especially dirty air, the instrument readings could become very noisy or have a large offset. The flow path may need to be cleaned. We recommend that the AQLite be returned to 2B Technologies for this service.

Maintenance Recommendation	Frequency
Replace ozone measurement scrubber	User replace every 6 months of continuous operation (~4,000 hrs); otherwise annually
Replace inlet filter	User replace when flow rate drops or contamination is present.
Clean flow path (methanol)	Return to 2B Technologies for service if instrument has large offset and ozone readings are low, or if readings are noisy

F.1.2 Ozone Monitor Firmware Updates

A separate USB-to-serial cable is provided for your use if firmware updates are needed for the ozone monitor. It will be used to directly connect the ozone monitor to your computer.

- Note, it helps to detach the green 10-pin connector of the ozone monitor when changing the wire connections in the steps below. It helps to wiggle it gently left to right when sliding it off.
- First, detach the monitor's green 10-pin connector and remove the red, white and bare wire connections of the stereo cable of the ozone monitor (location shown in righthand picture below). Note their order in positions 3, 4, and 5 on the 10-pin.
- Connect the 3 bare wires of the separate USB-to-serial cable to the existing 10-pin terminal connector of the ozone. **Caution: Tighten firmly, and be sure there is not any insulation in the connector!!** Use positions 3 (yellow), 4 (orange), and 5 (black) in the order for Transmit, Receive, and Ground shown in the middle picture below (maintain the existing red and black power wires in positions 1 and 2).
- Reattach the green 10-pin connector and carry out the firmware update following instructions from 2B Tech (Section F.2.3).
- Remove the USB cable and restore the connections to the red/white/bare wire stereo cable when finished. Tighten firmly and be sure there is not any insulation in the connector.



USB cable connections to the 10-pin terminal of the ozone monitor.

F.1.3 Sensor Maintenance

The sensors require no routine maintenance. However, it is recommended that the sensors be checked frequently to verify that they are responding as expected, as described previously in Section E.2.

F.2 Troubleshooting

F.2.1 Ozone Monitor Troubleshooting

If the ozone monitor is experiencing communication problems with the sensor package, first check to be sure the stereo cable is firmly connected to the sensor package and to the green 10-pin terminal of the ozone monitor. Re-secure the red/white/bare-wire connections on positions 3/4/5 of the 10-pin terminal if needed (note color order). See Section F.1.2 for photo of location. If the communication problems persist, the USB-to-serial cable mentioned in Section F.1.2 above may be required for diagnosis. It will be used to directly connect the ozone monitor to your computer. Consult with our service department for instructions and further information (Section F.2.3).

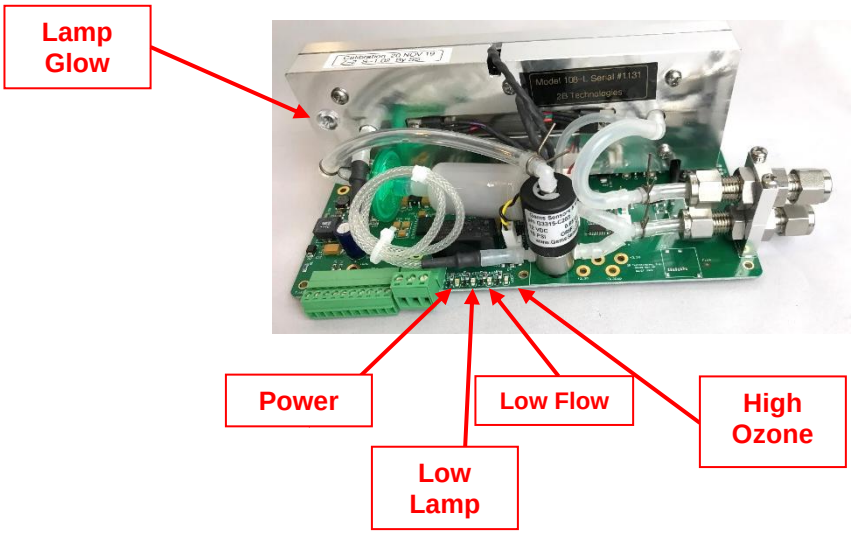
The following are indications of various instrument malfunctions for the Ozone Monitor in the AQLite. The indicator lights are labeled in the photo below (a photo of the separate Model 108 Ozone Monitor is shown below for clarity).

Air Pump Failure: The instrument will not make a humming sound. Also, the circuit breaker may prevent the instrument from powering up if the motor in the air pump develops a short. The Low Flow indicator light (third light up from the circuit board; see photo below) will activate if the flow falls below 0.4 L/min.

Lamp Failure: The ozone measurements will be erratic and the Lamp Test (serial command "**p**" in the ozone serial menu, see Section D.2.2) will show 0.0 volts for the photodiode voltage. Check the Lamp Glow indicator to see if lamp is on. The Low Lamp indicator light (second light on the circuit board; see below) will activate if the lamp voltage falls below 0.6 V.

Solenoid Valve Failure: The ozone readings will be low and average to close to zero if the solenoid valve is not switching. Partial switching of the solenoid valve will cause the instrument to read low but not zero.

Contaminated Flow Path: The instrument will typically have a large positive or negative offset and the ozone readings will be low once corrected for the measured offset.



Help with troubleshooting is provided in the following table.

Table F.1. ***Troubleshooting the Ozone Monitor for performance problems.*** *(In the photos in Section G or the photo in Section A.1.1.)*

Problem/Symptom	Likely Cause	Corrective Action
Instrument does not turn on (Power Indicator light is OFF).	Power not connected properly or circuit breaker open.	Check external power connection for reverse polarity or a short and wait a few minutes for the thermal circuit breaker to reset.
Instrument turns on then powers off.	Burned out air pump.	Turn off power and unplug the AQLite. Open AQLite enclosure cover. Follow the pump wires to connector and unplug the connector from the printed circuit board. Plug the AQLite back on and turn instrument on with the power toggle on the front door; if it remains running, then the air pump motor is burned out and shorting. Replace air pump.
Cell temperature reads low by several 10's of degrees.	Absent or loose connection of temperature probe cable to circuit board.	Power off, open AQLite as above. Reattach connector to circuit board.
Readings are noisy with standard deviations greater than 2.5 ppb.	Lamp output is weak, below 0.6 V on Lamp Test. Flow path contaminated.	Power off, open AQLite as above and check lamp connection to circuit board. Run Lamp Test from serial menu. If photodiode voltage is less than 0.6 V, replace lamp. Clean flow path with methanol (send instrument to 2B Tech).
Analog output is constant or does not track front display.	Cable not properly connected between analog output and recording device. Wrong scaling factor selected in menu.	Check continuity of your analog cable to your recording device and make sure correct connector pins are being used. Check and reset analog output scaling factor in the serial menu.
Serial output does not work.	Wrong serial cable used. Wrong baud rate or COM port specified in data acquisition program.	A "straight through" serial cable is provided. Some data collection devices require a "cross over" cable in which pins 1 and 3 are exchanged between the two ends of the cable. Use a "cross over" cable or additional connector that switches pins 1 and 3. Set baud rate to 115200 in data acquisition program. Determine correct COM port

Problem/Symptom	Likely Cause	Corrective Action
Required calibration parameters are large (>±9 ppb offset and/or >±9% slope) when calibrated using a standard ozone source or reliable ozone instrument.	Ozone measurement scrubber is contaminated.	Replace ozone measurement scrubber. Be sure to use an inlet filter to remove particulate matter.
	Flow path is contaminated.	Clean flow path with methanol (send instrument to 2B Tech or call for procedure).
	Solenoid valve is contaminated and not opening and closing properly.	Power off, open AQLite as above and, unplug pump. Turn instrument on and listen for clicking of solenoid valve every 2 seconds. If solenoid valve is clicking, remove tubing connections and test solenoid valve to confirm that air always flows through common and alternately through normally open and normally closed states. Replace solenoid valve if not working properly (requires soldering).
	Air pump is not drawing sufficient flow.	Disconnect air inlet tubing from the inlet. As a first check, hold your finger over the air inlet to determine whether air is being drawn in. If there is flow, measure the flow rate by attaching a high conductance flow meter to the air inlet. Air flow should be greater than 0.6 L/min. If flow is lower, adjust the flow using the needle valve next to the instrument inlet. If you still can't get the target flow, check for leaks. If there are no leaks, replace air pump.
Low Flow indicator light is on *(third light on the circuit board; see figure in this Section F.2.1)*	Flow has fallen below 0.4 L/min.	Check for leaks in your sampling system. If none found, check air pump as noted directly above.
Low Lamp indicator light is on *(second light on the circuit board; see Figure A.1 of main manual and Section 3.9 of Appendix 1)*	Lamp voltage has fallen below 0.6 V.	Power off, open AQLite as above and check lamp connection to circuit board. Run Lamp Test from menu. If photodiode voltage is noisy and is less than 0.6 V, replace lamp. Also check for contamination of the flow path, and clean with methanol if needed (send instrument to 2B Tech or call for procedure).
Ozone > 100 ppb indicator light is on *(fourth indicator light)*	Measured ozone is above 100 ppb.	If the ozone monitor is sampling ambient air, observe proper health precautions.

F.2.2 Sensor Troubleshooting

- If the sensor readings are noisy or do not seem to respond to changes in ambient air, be sure the fan airflow is not blocked. Keep the fan intake (bottom of the AQLite) clear.
- If a particular sensor seems to be giving faulty readings or seems nonresponsive, check to see if it has become disconnected from the printed circuit board.
- Be sure the sensor package is powered. The red light on the printed circuit board will be on when the battery in the sensor package is charging. It will go off once the battery is charged. If it is off, try reconnecting the power source and turning the AQLite off and on again to establish charging.
- Be sure the all the cable connections to the sensor package are secure.

F.2.3 Service through 2B Technologies

2B Technologies offers reasonably priced customer service for instrument repairs. The calibration service for the ozone monitor includes cleaning of the entire flow path with methanol, testing of all components for proper function, installation of a new internal ozone measurement scrubber and calibration against a NIST-traceable standard. 2B Technologies also offers calibration and service for the sensors. The best way to contact us for service is to log a customer service ticket at https://2btech.io/support/. Normally, you will hear back from us by email within a few hours. Or, call us at +1(303)273-0559.

A great deal of technical information about our instruments is posted as technical notes on the 2B Tech website at https://2btech.io/downloads/?filter=true&docs_category=tech_notes. Manuals, brochures, software, cleaning procedures and scientific papers may be downloaded at https://2btech.io/downloads/. See Section H of this manual for a list of replacement parts, which may be purchased by contacting us at sales@2btech.io or by calling us at +1(303) 273-0559.

G. Labeled Instrument Photos

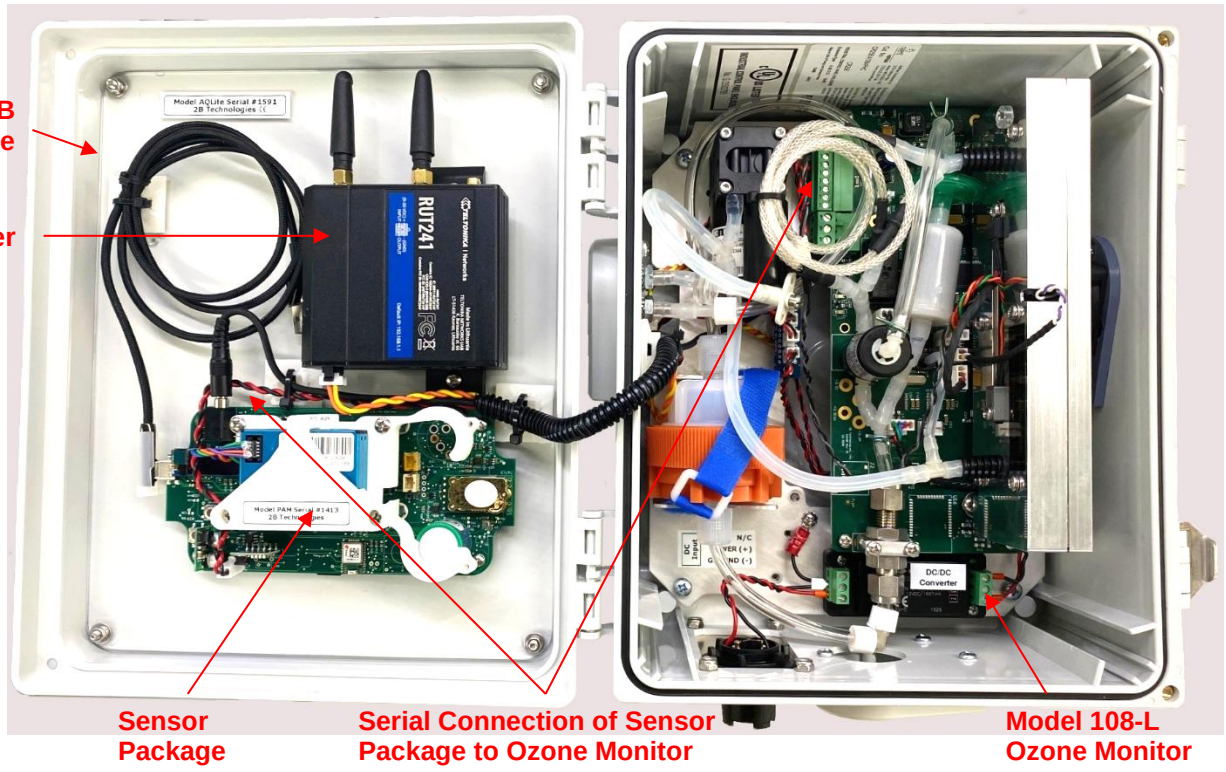


Figure G.1. Overview of the AQLite-Standard Air Monitor
(inside and outside views)

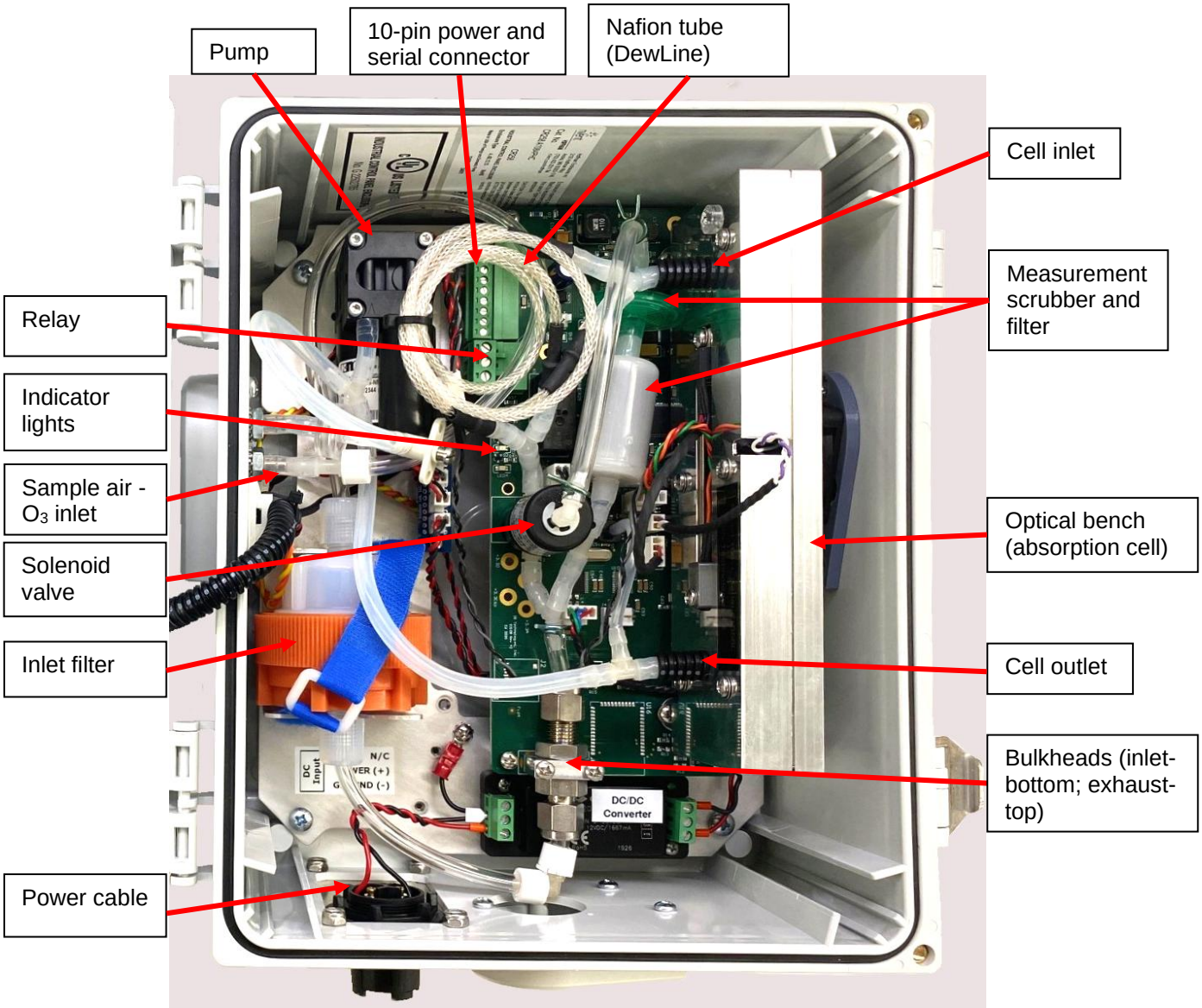


Figure G.2. The Ozone Monitor of the AQLite Air Monitor.

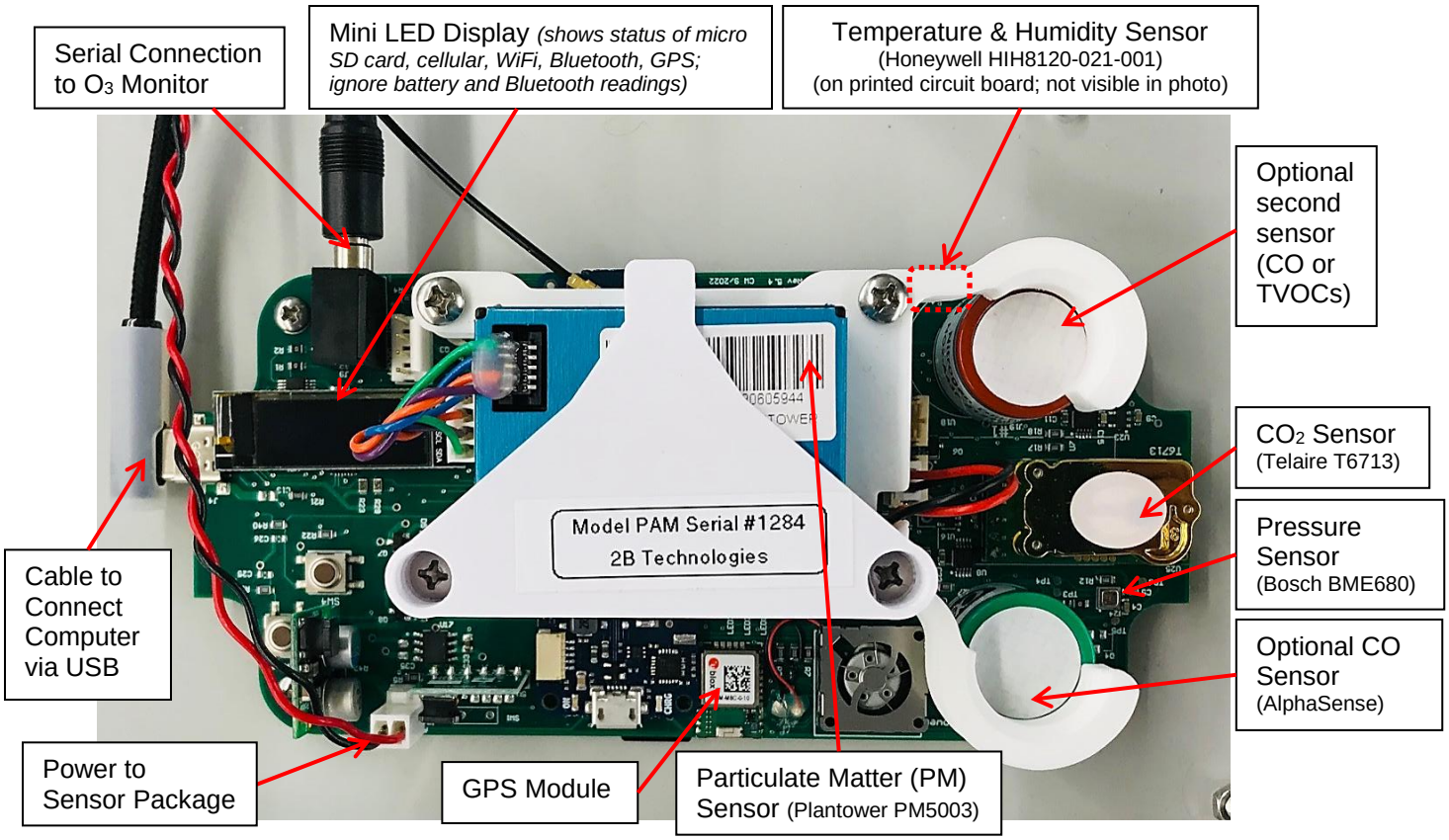


Figure G.3. The Sensor Package of the AQLite-Standard Air Monitor

H. Replacement Parts

The following list includes those parts of the AQLite-Standard Air Monitor that are user serviceable. Note that replacement of the solenoid valve requires a knowledge of soldering.

Please contact us at sales@2btech.io with questions or for any items not listed below.

Ozone Monitor

Part#	Part Name	Description
11-281	SCRBINT	Ozone measurement scrubber
10-729	SCRBEXT	Ozone zeroing scrubber (external)
11-065	OZLAMPAS108L	Lamp assembly
10-910	OZVLV108L/M	Solenoid valve
10-698	PDASSEMBLY108L	Photodiode assembly and cable
10-584	OZCELLAS108L	Absorption cell
10-669	DEW	DewLine™ (two Nafion tubes in parallel)
10-085	RELCON108	Relay connector, single
10-914	108BRKOUT	10-pin breakout connector
11-039	TEFTYG25	Teflon-lined Tygon® tubing (25 ft)
11-038	TEFTYG05	Teflon-lined Tygon® tubing (5 ft)
10-422	SILTUB05	Silicone tubing (5 ft)
11-352	CLEANLOOP108LM	Cleaning loop set

Sensor Package

Please contact 2B Technologies for parts and servicing related to the sensor package.

I. Service Log

2B Tech Model #__AQLite-Standard Air Monitor *AQLite Serial #_____*

Purchase Date:_____

Date/ Hours	**Calibrated** (note if sensors, O_3 Monitor, or both)	**Cleaned** **O_3 Monitor**	**New O_3 Scrubber**	**New Pump** **O_3 Monitor**	**New Lamp** **O_3 Monitor**	**Other**

Date/ Hours	**Calibrated** (note if sensor package, O_3 Monitor, or both)	**Cleaned** **O_3 Monitor**	**New O_3 Scrubber**	**New Pump** **O_3 Monitor**	**New Lamp** **O_3 Monitor**	**Other**

APPENDIX 1: The Model 108-L Ozone Monitor

1. INTRODUCTION - OZONE MONITOR

The 2B Technologies Model 108-L Ozone Monitor inside your AQLite is designed to enable accurate measurements of ozone in air over a wide dynamic range extending from a few parts-per-billion by volume (ppb) to 1 part-per-million (ppm) based on the well-established technique of absorption of ultraviolet light at 254 nm. Note that throughout this manual and in the instrument output, “ppb” (identical to “ppbv”) refers to parts-per-billion by volume (not weight).

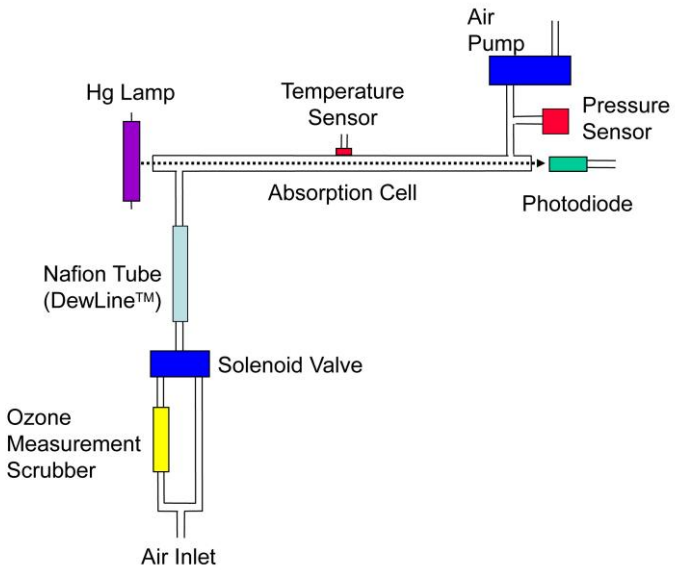
1.1 Theory of Operation

Absorption of UV light has long been used for measurements of atmospheric ozone with high precision and accuracy. The ozone molecule has an absorption maximum at 254 nm, coincident with the principal emission wavelength of a low-pressure mercury lamp. Fortunately, few molecules found at significant concentrations in the atmosphere absorb at this wavelength. However, interferences, such as organic compounds containing aromatic rings, can occur in highly polluted air.

Figure 1.1 is a schematic diagram of the Ozone Monitor. Ozone is measured based on the attenuation of light passing through a 14-cm absorption cell fitted with quartz windows. A low-pressure mercury lamp is located on one side of the absorption cell, and a photodiode is located on the opposite side of the absorption cell. The photodiode has a built-in interference filter centered on 254 nm, the principal wavelength of light emitted by the mercury lamp. An air pump draws sample air into the instrument at a flow rate of approximately 1 L/min. A solenoid valve switches so as to alternately send this air directly into the absorption cell or through an ozone scrubber and then into the absorption cell. The intensity of light at the photodiode is measured in air that has passed through the ozone measurement scrubber (I_o) and air that has not passed through the scrubber (I). Ozone concentration is calculated from the measurements of I_o and I according to the Beer-Lambert Law:

$$C_{O_3} = \frac{1}{\sigma l} \ln\left(\frac{I_o}{I}\right) \tag{1}$$

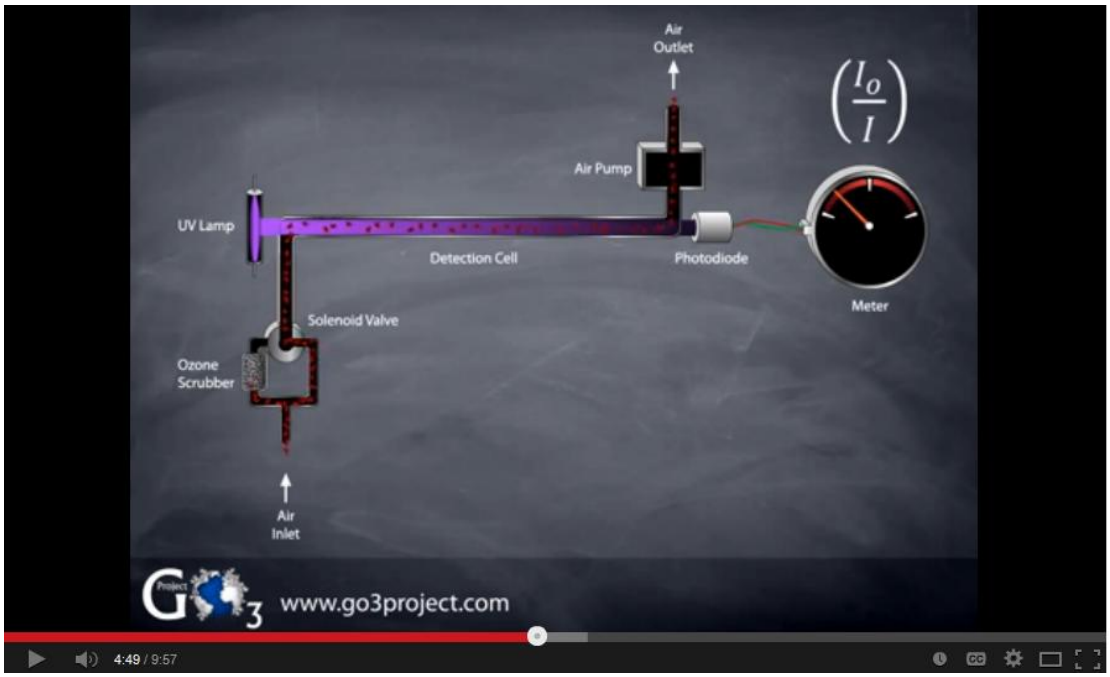
where l is the path length (14 cm) and σ is the absorption cross section for ozone at 254 nm (1.13×10^{-17} cm^2 molecule^{-1} or 304 atm^{-1} cm^{-1}), which is known with an accuracy of approximately 0.3%. The 2B Technologies instrument uses the same absorption cross section (extinction coefficient) as used in other commercial instruments.



Appendix 1 / Figure 1.1. Schematic Diagram of the Ozone Monitor.

The pressure and temperature within the absorption cell are measured so that the ozone concentration can be expressed as a mixing ratio in parts-per-billion by volume (ppbv).

The following animated video developed by 2B Technologies provides a detailed explanation of how this and other UV-based ozone monitors measure ozone. Click on the link https://www.youtube.com/watch?v=3qBdl5qSYm4 or the image below:



In principle, the measurement of ozone by UV absorption requires no external calibration; it is an absolute method. However, non-linearity of the photodiode response and electronics can result in a small measurement error. Therefore, each instrument is

compared with a NIST-traceable standard ozone spectrophotometer in the laboratory over a wide range of ozone mixing ratios. These results are used to calibrate the Ozone Monitor with respect to an offset and slope (gain or sensitivity). The corrections for offset and slope are recorded in the instrument Birth Certificate. These calibration parameters are entered into the microprocessor prior to shipment. The user may change the calibration parameters from the serial menu if desired. It is recommended that the instrument be recalibrated at least once every year and preferably more frequently. The offset may drift due to temperature change or chemical contamination of the absorption cell. An accurate offset correction can be measured from time to time using an external ozone scrubber.

Shown on Fig. 1.1 is the DewLine™, which serves to make the humidity entering the detection cell identical during I and I_o measurements. Please see our website for a technical discussion of the DewLine™ and its importance to ozone measurements: https://2btech.io/dewline/. Briefly, water vapor adsorbed to the inner wall of the detection cell changes the reflectivity of the cell. If humidity is not the same during I and I_o measurements, an offset in the ozone measurement will occur and can be up to several tens of ppb for sudden changes in ambient humidity. The offset will change with time as the internal ozone scrubber equilibrates with water vapor. Even for fixed-site ozone monitors, an offset measurement error will occur if the instrument is zeroed with dry tank air and then used to measure ozone in humid air. The DewLine™ solution to this often-ignored problem is unique to 2B Tech instruments.

1.2 Adaptive Filter

The Model 108-L firmware has the capability to sample the ozone concentration data through a built-in adaptive filter. By default, this filter is turned off. The user can choose to activate this filter via the serial menu, which smooths the data via an averaging algorithm described below. The filter is particularly helpful during periods of high measurement noise or when concentration is expected to jump to a significantly higher or lower level because of changing ambient conditions.

During operation of the adaptive filter, the firmware will automatically switch between two different filter lengths based on the conditions at hand, as determined by settings specified by the user. 2B Technologies recommends the following settings for the adaptive filter:

adaptive filter change difference: 15 (ppb)
adaptive filter change percent: 5 (%)
adaptive filter change Long average: 25 (number of points)
adaptive filter change Short average: 10 (number of points)

During the measurement of stable concentrations, the firmware, with the above settings, computes an average of the last 25 raw two-second measurements, or 50 seconds of measurements. This provides smooth and stable readings by averaging out a considerable amount of random noise to improve the precision. If the filter detects rapid changes in concentration, the filter reduces the averaging to only 10 samples or 20 seconds, to allow the analyzer to respond more quickly. Two conditions must be simultaneously met to switch to the short filter. First, the instantaneous concentration

must differ from the average in the long filter by at least 15 ppb. Second, the instantaneous concentration must differ from the average in the long filter by at least 5% of the average in the long filter. The lengths of the long and short filter can be changed as well as the minimum difference and percent difference. This can be done via the serial connection as outlined in the Serial Menu section in this manual (Section D of main part of this manual).

The default settings of the adaptive filter as shipped are: adaptive filter difference=0, adaptive filter percent=0, adaptive filter long average length=25, adaptive filter short average length=10.

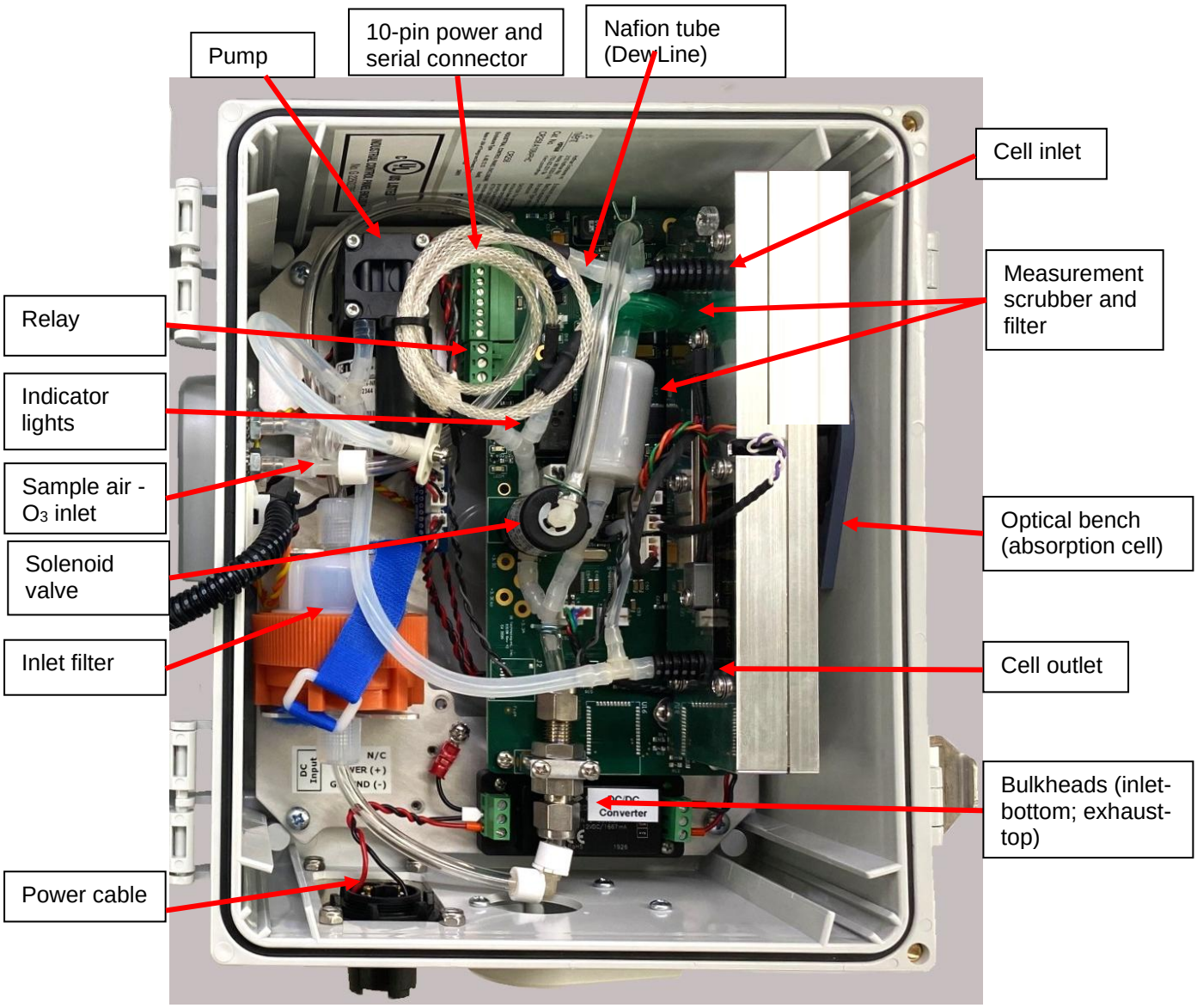
To disable the adaptive filter, set the short average length to 1, the difference to 0, and the percent to 0.

1.3 Instrument Default Settings

When shipped, the instrument has the following default settings: Avg=10 s, offset=0, slope=1, adaptive filter difference=0, adaptive filter percent=0, adaptive filter long average length=25, adaptive filter short average length=10, T in °C, P in mbar, O_3 in ppb.

1.4 Labeled Photo of the Ozone Monitor in the AQLite

On the next page is a labeled photo of the Ozone Monitor showing most of the components given in the previous schematic (Appendix 1 / Section 1.1 / Figure 1.1).



Appendix 1 / Figure 1.2. The Ozone Monitor in the AQLite.
Compare to the schematic in Appendix 1 / Figure 1.1.

2. SPECIFICATIONS: Model 108-L Ozone Monitor in the AQLite

Measurement Principle	UV Absorption at 254 nm, single beam
Federal Equivalent Method	Yes, 0-0.5 ppm (modification of FEM EQOA-0914-218)
Linear Dynamic Range	0-1 ppm (1,000 ppb)
Resolution	0.1 ppb
Measurement Frequency	2 s, 0.5 Hz
Data Averaging Options	10 s, 1 min, 5 min, 1 hr (must use 2 s in AQLite)
Response Time, 100% of Step Change	For 2-s output: 4 s, 2 data points For 10-s output: 20 s, 2 data points
Precision (1σ) for 10-s output (rms noise)	Greater of 1.5 ppb or 2% of measurement
Limit of Detection (2σ)	3 ppb for 10-s averaging
Accuracy	Greater of 1.5 ppb or 2% of measurement
Calibration	NIST traceable, annual calibration recommended
Flow Rate Limits	Minimum required: 0.6 Liter/min (volumetric); Nominal: 1 Liter/min; Maximum: 1.5 Liter/min
Ozone Units	ppb, pphm, ppm, µg m^{-3}, mg m^{-3}
Pressure Units	torr, mbar, psi
Temperature Units	°C, °F, K
Temperature and Pressure Corrected	Yes
Temperature Range	0 – 50 °C (20 – 30 °C for FEM)
Data Outputs	RS232, 0-2.5 V, 4-20 mA
Output Ranges	User-defined scaling factor in serial menu
Adaptive Filter	Available; user-defined parameters
Relay with Two Set Points	Relay responds based on ozone set points (user-defined in serial menu)

3. OPERATION - OZONE MONITOR

3.1 Overview

To operate the Ozone Monitor, connect the AQLite to an external power source. The instrument requires a 12 V DC source, which can be supplied by a 100-240 V AC power adapter provided when you purchased the AQLite. See Section B.1 of the main section of this manual for information about installing the 12V power supply cable through the cable gland on the bottom of the AQLite enclosure, and for other DC and direct AC options for powering the AQLite and its Ozone Monitor.

Alternatively, we are investigating options for using a solar panel and/or batteries to power the AQLite's Ozone Monitor and sensor package. Contact 2B Technologies to inquire about the status of that research.

Once turned on, the first dozen readings (requiring about two minutes) will be spurious, with large positive and negative swings due to the rapid warmup of the lamp and electronics. Also, ozone readings may be inaccurate during the 10-20 minutes required for the lamp, photodiode, and internal temperature of the absorption cell to stabilize. Four LEDs on the left side of the printed circuit board indicate whether the instrument is powered on (top LED), if flow and lamp voltage are adequate (middle two LEDs), and if measured ozone exceeds 100 ppb (bottom LED).

A pump draws air into the Ozone Monitor though the inlet on the left side of the enclosure. The air sample passes through a Teflon filter (inside the orange and white housing) to prevent internal contamination of the tubing and absorption cell of the Ozone Monitor by particulate matter. The filter should be replaced when contamination is evident (visually or by a reduced flow rate).

3.2 Operating Recommendations

The following table gives a summary of the operating recommendations mentioned in this Appendix 1.

Operating Recommendation	**Frequency**	**Appendix 1 Section Reference**
Allow ~20 minutes for instrument warmup	Each startup	3.1
Use a Teflon or PVDF inlet filter (provided with AQLite; monitor it for contamination	Each use	3.1
Check the zero offset; do a span check	Occasionally when convenient	3.4, 6
Perform multipoint calibration	• Annually • Any time major disassembly of components is performed	5

	• Any time the zero or span checks give results outside of the acceptable limits	
Use adaptive filter if rapidly changing ozone concentrations are occurring or are anticipated	User-defined	1.2

3.3 Accessing the Ozone Monitor's Serial Menu

The serial menu of the Ozone Monitor is accessed through the Admin menu of the AQLite. Please refer to Section D of the main manual.

3.4 Span and Zero Checks

The electronic zero of the instrument may be measured by attaching an ozone destruction cartridge to the air inlet for a period of 5-10 minutes. For an accurate measurement, the instrument must have been turned on long enough for the internal temperature to stabilize (normally ~20 minutes). The observed offset, which can amount to ± a few ppb, can be corrected for by changing the offset calibration parameter (Z) from the serial menu. Consult Section E.1.1 of the main part of this manual for carrying out the zero check of the Ozone Monitor in the AQLite. Section D of the main manual describes the serial menu access.

A span check can be performed by supplying a known quantity of ozone to the instrument, for example by using an ozone calibration source such as the 2B Tech Model 306. See Section 6 of this Appendix.

3.5 To Set the Ozone Calibration Parameters

The Ozone Monitor is calibrated at the factory, where slope (S) and offset (Z) parameters are entered into the instrument's memory. These preset calibration parameters are given in the Ozone Monitor's Birth Certificate and recorded on the calibration sticker on the top of the absorption cell of the instrument.

However, the calibration parameters may be changed by the user. For example, it may be desirable to provide a positive offset by a known amount (e.g., 10 ppb) if the analog output is being used for external data logging, because the analog voltage output does not go negative below zero ppb, and the current output does not go below 4 mA. Because of noise and/or an inherent offset, some measured values will be below zero at very low ozone mixing ratios or while zeroing the instrument with an external scrubber. Also, the instrument zero may drift by a few ppb over time. For this reason, frequent zeroing of the instrument using an external ozone scrubber to determine the offset is recommended (see previous Section 3.4 of this Appendix 1).

Any change in the slope (gain) of the instrument is likely due to a serious problem such as contamination, an air leak, obstruction of air flow, or loss of catalytic activity by the internal ozone scrubber, but it also can be adjusted. Once the zero of the instrument is corrected, the slope may be adjusted so that the instrument readout agrees with a standard ozone source (such as the 2B Technologies Model 306 Ozone Calibration Source™) or with the readout from another instrument whose calibration is considered

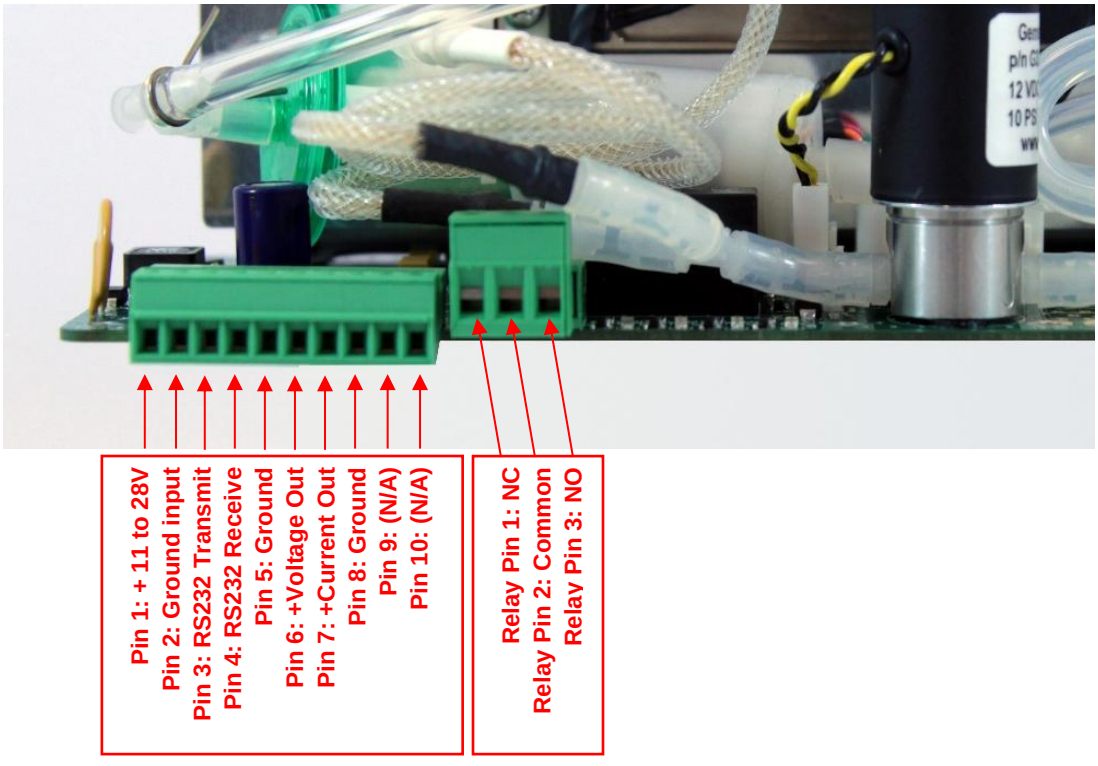
to be accurate. See Section 5 of this Appendix 1 for information on how to do a full calibration.

Once a calibration is completed, the calibration parameters Z and S may be adjusted in the serial menu of the Ozone Monitor (refer to Section D of the main manual). Here Z is the offset applied in units of ppb and S is the slope applied. The value of Z is added to the measured ozone value, and the value of S is then multiplied by the measured ozone value. During factory calibration, Z is set to 0 and S set to 1.00; if your instrument reads an average of 3 ppb with the external scrubber in place, for example, the value of Z should be set to –3. If after correction for the zero, the instrument consistently reads 2% low, for example, the value of S should be set to 1.02.

For more details about calibrating the ozone monitor against another instrument or calibrated ozone source, see the "Calibration" section (Section 5) of this Appendix 1, or refer to Tech Note No. 15.

3.6 Collecting Data from the Analog Output of the Ozone Monitor

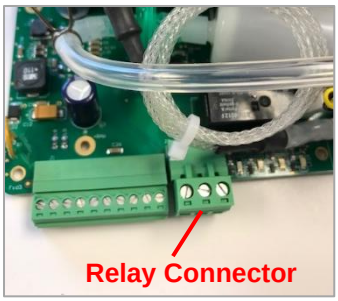
The data may be logged in real time using a data logger attached to the 10-pin connector on the left side of the printed circuit board using either a voltage or current recorder or data logger. The 0-2.5 V voltage output is measured across pins #6 (+) and #5 or #8 (ground). The 4-20 mA current output is measured across pins #7 (+) and #5 or #8 (ground).



To change the analog output voltage scaling factor, send the character 'f' in the Ozone Monitor's serial menu and enter a number between 1 and 99999. For example, if you

entered the number 2000, then 2.5 volt (full scale) = 2000 ppb; i.e., 1 volt = 800 ppb. Also, the current output will be scaled such that the full scale of 20 mA corresponds to 2000 ppb. A reading of zero ozone concentration will be output as 0 V and as 4 mA. Thus, the instrument is not limited to a fixed number of "ranges" common to most ozone monitors. Instead, any range can be defined.

3.7 Using and Setting the Relay Limits



The Ozone Monitor may be used to control other devices, such as an ozone generator, using the 12-amp relay located on the side of the printed circuit board. The relay connector is the smaller green 3-pin connector. See our Tech Note 45 for applications of relays in ozone measurements.

To set the On and Off limits of a relay, use the instructions in Section D of this manual to enter the Ozone Monitor's serial menu and press commands "g" and "j" to access the high and low limits for the relay settings. Enter a number between 1 and 99999 for each of the desired settings. For example, with units set to ppb, "ON" ozone level = 01000, and "OFF" ozone level = 00900, the relay will close (pass current) until the ozone concentration exceeds 1000 ppb. Above this concentration, the switch relay will open. The relay will not close again until the ozone concentration drops below 900 ppb. In this way, for example, the ozone concentration from an ozone generator could be controlled in the range 900 to 1000 ppb.

Physical connection to the relay is made by means of a supplied screw connector for attaching wires to your device. The center terminal is common. When viewing the connector from the side of the instrument (see photos in Section G of this manual), the terminal on the right is in normally open (i.e., it closes when the ozone concentration is below the first set point). This is the connection you would ordinarily use. The screw connector on the left is normally closed; i.e., it behaves in the opposite manner as the right screw terminal.

3.8 Lamp Test

If the instrument is excessively noisy (standard deviation greater than 2 ppb) or always reads near zero even in the presence of ozone, it is useful to perform the lamp test to make sure that the lamp is turning on and does not fluctuate too rapidly. Before performing the lamp test, allow the instrument to warm up for at least twenty minutes.

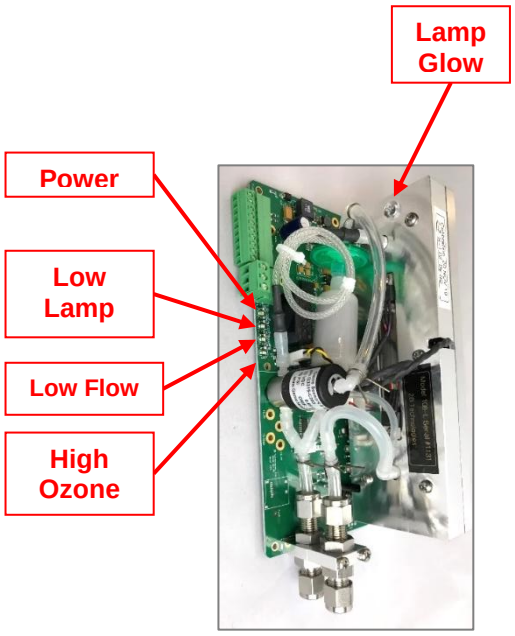
Access the serial menu of the Ozone Monitor using the instructions in Section D of this manual. Type command "p" to execute the Lamp Test. The pump will go off. The photodiode voltage will then be displayed, and after a few lamp measurements have been made, the electronic offset and then a little later the standard deviation also will be displayed as, for example:

PDV= 0.89801 V
1.2+/-1.85

The photodiode voltage (PDV) is a measure of the lamp intensity and should be in the range 0.6-2.2 volts. Since absorbance is a ratio measurement, the absolute value of the voltage is not particularly important. However, above 2.5 volts, which could occur if the instrument is allowed to become too hot, the photodiode is saturated and the calculated ozone concentration will be zero. A photodiode voltage less than 0.6 volts is indicative of either a weak lamp or a dirty detection cell and may result in a noisy measurement. The photodiode voltage will typically increase as the instrument warms up. Lamp drift is continuously monitored and corrected for in the firmware and thus has very little effect on the measured ozone concentration. Once the instrument is warmed up, fluctuations in photodiode voltage should be limited primarily to the last digit displayed. The lamp test also calculates an electronic offset and standard deviation of the measurement itself, displayed in the above example as 1.2 ppb for the electronic offset and +/-1.85 ppb for the standard deviation. The standard deviation is a quantitative measure of the lamp and associated electronic noise. Electronic offsets should normally be -5 to 5 ppb equivalent. After running the lamp test for a few minutes, values above 2.50 for the standard deviation usually indicate an excessively noisy lamp. Lamps seldom “burn out” but may become noisy with time and need to be replaced. Some lamps become noisy after only a short period, while others will be extremely stable for years. If your lamp fails the lamp test during the first year of operation, contact us for a new lamp under the instrument warranty. Contamination of the detection cell may also cause a high standard deviation, in which case the flow path should be cleaned with methanol and the internal ozone measurement scrubber replaced.

3.9 LED Indicator Lights

Four indicator lights are on the left side of the circuit board. Going from the top to the bottom, those lights are:



- The top light is a power indicator. It is always on during normal operation.
- The Low Lamp indicator comes on if the lamp voltage drops below 0.6 volts, indicating that a lamp test should be conducted (Section 3.8) and that the lamp may need replacement and/or the flow path may need cleaning.
- The Low Flow indicator comes on if the flow rate is less than 0.4 L/min. This indicates that there could be leaks, or that the air pump needs replacing. See the Maintenance / Troubleshooting Section 4 of this Appendix 1.
- The bottom light indicates the ozone level is above 100 ppb. If the Monitor is sampling ambient air, personnel in the vicinity should take precautions to avoid breathing unsafe levels of ozone.

4. MAINTENANCE/TROUBLESHOOTING – OZONE MONITOR

4.1 Overview

The Ozone Monitor in the AQLite is designed to be nearly maintenance free. The Ozone Monitor has an internal ozone scrubber (in this Appendix 1, see Figure 1.2 of Section 1.4). The ozone measurement scrubber should be changed at least annually, or after every six months (~4,000 hours) of continuous operation. The scrubber can easily be replaced by disconnecting the tubing attached to each end and connecting a new one in its place, being sure that the larger "smooth" end of the scrubber is oriented as originally provided.

Also, the inlet filter (inside the orange and white filter housing) should be changed if the Ozone Monitor flow rate is declining or if visible contamination is present. Frequency will depend on conditions of use.

Other components with a limited lifetime are the air pump (~15,000 hours), lamp (~20,000 hours) and solenoid valve (rarely fails). It is recommended that the instrument be returned to 2B Technologies if any of these components fail. Alternatively, the user may install these components at their own risk. In that case, please contact 2B Technologies for instructions.

The instrument flow path will become contaminated over time during use. The recommended annual service of the AQLite includes cleaning of the flow path.

The following are indications of various instrument malfunctions.

Air Pump Failure: The instrument will not make a humming sound. Also, the circuit breaker may prevent the instrument from powering up if the motor in the air pump develops a short. The Low Flow indicator light (see Section 3.9 of this Appendix) will activate if the flow falls below 0.4 L/min.

Lamp Failure: The ozone measurements will be erratic and the Lamp Test will show 0.0 volts for the photodiode voltage. The Low Lamp indicator light (see Section 3.9 of this Appendix) will activate if the lamp voltage falls below 0.6 V.

Solenoid Valve Failure: The ozone readings will be low and average to close to zero if the solenoid valve is not switching. Partial switching of the solenoid valve will cause the instrument to read low but not zero.

Contaminated Flow Path: The instrument will typically have a large positive or negative offset and the ozone readings will be low once corrected for the measured offset.

4.2 Maintenance Recommendations

The following is a summary of recommended maintenance procedures mentioned in this Appendix 1.

Maintenance Recommendation	Frequency	Appendix 1 Section Reference
Recalibrate instrument and clean flow path	At least once per year	3.5, 5.1-5.5 of Appendix 1
Replace ozone measurement scrubber	every 6 months of continuous operation (~4,000 hrs); otherwise annually	4.1-4.2 of Appendix 1
Replace inlet filter	User replace when flow rate drops or contamination is present.	4.1-4.2 of Appendix 1
Clean flow path (methanol)	As needed if instrument has large offset and ozone readings are low, or if readings are noisy	4.1 of Appendix 1; send instrument to 2B Tech

4.3 Troubleshooting

Please refer to Section F.2.1 of the main part of this manual for troubleshooting information.

5. CALIBRATION – OZONE MONITOR

5.1 Overview

Every analytical instrument is subject to some drift and variation in response, making it necessary to periodically check the calibration. Dynamic calibration is a multipoint check where gas samples of known concentrations are sampled by the instrument in order to determine a calibration relationship. For more information on calibration of ozone monitors refer to the Code of Federal Regulations (Title 40, Part 50, Appendix D) and the EPA's Technical Assistance Document for the Calibration of Ambient Ozone Monitors.

Calibration is the process of adjusting the gain and offset of the Ozone Monitor against some recognized standard. The reliability of the data collected from any analytical instrument depends on the accuracy of the calibration, which is largely dependent upon its analytical traceability to a reference material or reference instrument calibration. This calibration may be performed by the user with the guidelines provided in this section. Alternatively, the ozone monitor may be returned to 2B Technologies for calibration service. 2B Tech's calibration service includes cleaning of the entire flow path with methanol, testing of all components for proper function, installation of a new internal ozone scrubber and calibration against a NIST-traceable standard. The best way to contact us for service is to log a customer service ticket via our website: https://2btech.io/support/. Normally, you will hear back from us by email within a few hours. Or, call us at +1(303)273-0559.

Because of the instability of ozone, the certification of ozone concentrations in a compressed gas cylinder is impossible due to loss of ozone over time. When ozone concentration standards are required, the ozone must be generated and certified on site. The following information is based on EPA requirements for calibrations of ozone monitors for monitoring in compliance with the U.S. Clean Air Act. Similar procedures are recommended for other applications as well.

Ozone standards can be classified into two basic types:

1. A **Primary Ozone Standard** is the combination of an ozone generator and an ozone monitor based on UV absorbance (a UV photometer) that has been set up in accordance with the procedures prescribed by the U.S. Environmental Protection Agency (EPA) under Title 40 of the Code of Federal Regulations, Part 50, Appendix D (40 CFR Part 50).

2. An **Ozone Transfer Standard** is a system (a portable ozone monitor and/or a portable ozone generator) that can produce accurate ozone concentration standards that are quantitatively related to a primary ozone standard. An example of an ozone transfer standard is the 2B Technologies Model 306 Ozone Calibration Source. Ozone transfer standards must be certified before use in accordance with the procedures prescribed by the U.S. Environmental Protection Agency (EPA) under Title 40 of the Code of Federal Regulations, Part 50, Appendix D (40 CFR Part 50).

5.2 Equipment Required for Calibration

The equipment that is needed to carry out the calibration is commercially available, or it can be assembled by the user. Calibration using a primary ozone standard involves the generation of ozone concentrations that are simultaneously measured by a primary ozone standard and the instrument undergoing calibration. This procedure requires the following equipment:

1. Zero air source
2. Ozone generator
3. Sampling manifold (inert material such as PTFE or FEP only)
4. Sampling lines (inert material such as PTFE or FEP only)
5. UV Photometer

Use of a certified transfer standard for calibration involves the generation of ozone concentrations, using the calibrated ozone generator, that are measured by the instrument undergoing calibration. This procedure requires the following equipment:

1. Zero air source
2. Certified Transfer Standard
3. Sampling manifold (inert material such as PTFE or FEP only)
4. Sampling lines (inert material such as PTFE or FEP only)

Zero air can be generated either from compressed cylinders or from scrubbed ambient air. If ambient air is used, contaminants such as ozone and nitric oxide must be removed. Detailed procedures for generating zero air are in the EPA's Technical Assistance Document for the Calibration of Ambient Ozone Monitors.

5.3 Instrument Preparation

Prior to calibration, follow the steps below:

1. Turn on the Ozone Monitor and allow it to stabilize for a minimum of one hour.
2. Connect the instrument to the manifold on the ozone calibration setup. We recommend that the calibration manifold be connected to the sampling tubing inside the AQLite after disconnecting it from the bulkhead fitting on the enclosure wall. If a particle filter will be used in normal operation, the calibration must be performed through the filter. The manifold must be vented to atmosphere so that pressure does not build up in the calibration setup. Connection of the Ozone Monitor directly to a pressurized output of any device can damage the ozone monitor.
3. Verify that the flow rate into the manifold is greater than the total flow required by the ozone monitor and any other flow demand drawing from the manifold.

5.4 Calibration Setup Preparation

As indicated in the EPA Technical Assistance Document, there are several tests that should be performed prior to calibration to ensure the accuracy of the measurements. These tests include:

- Setup check
- Ozone loss test
- Linearity check
- Intercomparison test

5.4.1 Setup Check

A visual inspection of the calibration setup should be performed before calibration to verify that the setup is in proper order. All plumbing connections should be checked and verified to follow the manufacturer's instructions. Any obvious leaks should be fixed and the manifold and sampling lines should be checked for general cleanliness. For more information, refer to the manufacturer's User Manual for the primary ozone standard or ozone transfer standard.

5.4.2 Ozone Loss Test

Some ozone may be lost in the calibration setup due to reaction with the walls of the manifold and sampling lines. Any significant loss of ozone must be measured and be subsequently applied to correct the calibration measurements. For more information, refer to the manufacturer's User Manual for the primary ozone standard or ozone transfer standard.

5.4.3 Linearity Check

Since the Model 108-L is inherently linear over several orders of magnitude, a linearity check provides a test that the instrument is operating properly. Instrument linearity can be checked by comparison to an ozone standard (see Calibration Procedure – Calibration Curve, Section 5.5.4) or by dilution of an ozone measurement. To check the instrument linearity by dilution of an ozone measurement, generate and measure a concentration of ozone near the upper range of ozone monitor (80% of full scale is recommended). Additional ozone concentrations should be generated by accurately diluting the ozone flow with zero air and each concentration should be measured once the instrument reaches a stable response. The accuracy of the linearity test relies on the accuracy of the flow meters used to perform the dilution. The percent of non-linearity is calculated from the formula:

$$R = \frac{F_o}{F_o + F_d} \tag{2}$$

$$E = \frac{C_1 + \frac{C_2}{R}}{C_1} x100\% \tag{3}$$

where R = Dilution ratio
F_o = Ozone generator flow
F_d = Diluent zero air flow
E = Linearity error, in percent
C_1 = Measured concentration of original concentration
C_2 = Measured concentration of diluted concentration

The linearity error should not be greater than 5%. If the error is greater than 5%, the accuracy of the flow dilution should be checked before assuming that the ozone monitor is not linear. Note that the inherent linearity of the Model 108-L is better than the error calculated in this linearity check due to the uncertainty introduced by the flow measurements.

5.4.4 Intercomparison Test

Comparison of the calibration setup with other ozone standards is a good check of the overall accuracy of the setup. If measurements from another ozone standard are found to deviate from the calibration setup greater than the instrument specifications, one of the calibration setups is not accurate.

5.5 Calibration Procedure

A multipoint calibration should be performed annually, any time major disassembly of components is performed, or any time the zero or span checks give results outside of the acceptable limits.

5.5.1 Instrument Preparation

1. Turn on the Model 108-L Ozone Monitor and allow it to stabilize for a minimum of one hour.
2. Enter the calibration commands via the serial menu and set the zero (Z) value to 0 and the slope (S) value to 1.00.
3. Connect the ozone monitor to the manifold on the ozone calibration setup. If a particle filter will be used in normal operation, the calibration must be performed through the filter. The manifold must be vented to atmosphere so that pressure does not build up in the calibration setup. Connection of the Model 108-L directly to a pressurized output of any device can damage the ozone monitor.
4. Verify that the flow rate into the manifold is greater than the total flow required by the ozone monitor plus any other flow demand drawing from the manifold such as a UV photometer or ozone transfer standard.

5.5.2 Measurement of Zero Air

1. Verify that the zero air supply is on and the ozone generator is off. The same zero air supply used in the ozone generator must be used in the zero air measurement.
2. Allow the Model 108-L to sample zero air until the response is stable.
3. Record the average zero air response.

5.5.3 Measurement of Ozone Standards

1. Generate an ozone concentration slightly less than the concentration range of interest and allow the ozone generator to warm up for at least 5 minutes. The same zero air supply used for making zero air measurements must be used in the ozone generator.

2. Allow the Model 108-L Ozone Monitor to sample the ozone concentration standard until a stable response is measured.
3. Record the average response of the ozone monitor as well as either the average response of the UV photometer or the transfer standard.
4. Generate several other ozone concentration standards. At least 5 ozone concentration standards are recommended over the range of interest.
5. For each ozone concentration standard, record the response of the ozone monitor as well as either the response of the UV photometer or the transfer standard.

5.5.4 Calibration Curve

1. Plot the Model 108-L Monitor responses (y-axis) versus the corresponding standard ozone concentrations (x-axis).
2. Fit the data to a straight line (y = mx + b) using the linear regression technique to determine the calibration relationships, where m=slope and b=intercept.
3. Determine if any points deviate significantly from the line, which is an indication of an error in determining the calibration curve. The error may be due to the calibration setup or the ozone monitor being calibrated. The most likely problems in the ozone monitor are leaks, a malfunctioning ozone measurement scrubber, a contaminated valve, or contamination in the optical setup. See the "Troubleshooting" section of this manual (Section F.2.1 of the main manual).
4. The inverse of the slope of the line (1/m) is the gain factor (S) and the negative of the intercept (-b) is the offset (Z, <u>in units of ppb</u>, integers only) that need to be applied to the ozone monitor response to calibrate it to the primary ozone standard. If the intercept is outside of the range from -10 to 10 ppb or the slope is outside of the range from 0.90 to 1.10, this is an indication of a problem in the calibration setup or the ozone monitor being calibrated. The most likely problems in the ozone monitor are leaks, a malfunctioning ozone measurement scrubber, a contaminated valve, or contamination in the optical setup. See the "Troubleshooting" section of this manual, Section F.2.1 of the main manual.
5. Enter the calibration commands via the serial menu and set the calibration parameters Z and S as determined above. If the calibration has been done in units other than ppb, the offset (Z) value must be converted to ppb for entry into the instrument software.

6. ZERO AND SPAN CHECKS – OZONE MONITOR

To ensure the quality of the ozone monitor data, zero and span checks can be performed when convenient by following the steps below:

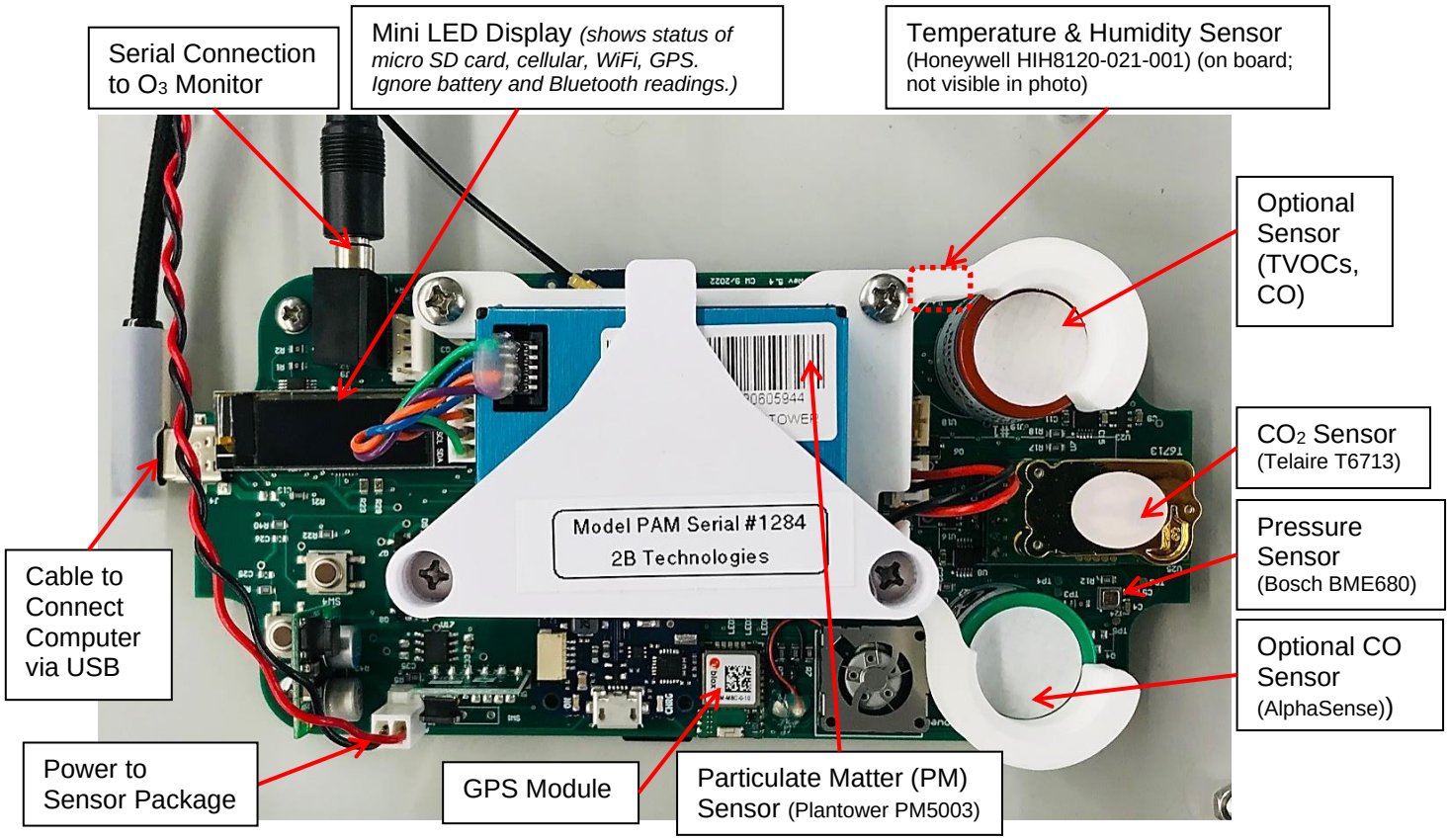
1. A zero check is performed by sampling zero air with the Model 108-L as described in Section 5.5.2 above, “Measurement of Zero Air.”
2. A span check is performed by sampling an ozone concentration at the high end of the concentration range of interest as described in Section 5.5.3 above, “Measurement of Ozone Standards.”
3. Average measurements from the zero check or span check should be within the instrument specifications. If the measurements are not within specifications, this is an indication of problem in the calibration setup or the ozone monitor being checked. The most likely problems in the ozone monitor are leaks, a malfunctioning ozone measurement scrubber, a contaminated valve, or contamination in the optical setup. See the “Troubleshooting” section of this manual (Section F.2.1 of the main manual).

APPENDIX 2: The Sensor Package of the AQLite

A. OVERVIEW

The AQLite's sensor package contains sensors for the measurement of several air pollutants, along with pressure, temperature and relative humidity. In the AQLite, the sensor package works in conjunction with the Ozone Monitor to provide a comprehensive measurement of ambient air pollution.

The AQLite-Standard's sensor package is shown in the photo:



The AQLite-Standard comes with the sensors such as shown in the photo above. In the customizable options, the sensor package can be populated with user's choice of any 2 of the following 2 sensors: CO, TVOCs.

Ignore battery readout on the mini LED display; in the AQLite, the "PAM" sensor package does not have a battery.

B. SENSOR PACKAGE TECHNICAL INFORMATION

B.1 Sensor Specifications

Sensor Specifications (per manufacturer)	
Carbon Dioxide (CO_2) **Sensor:** Telaire T6713 (NDIR) **Measurement Range:** 0-5000 ppm **Accuracy:** 400-5000 ppm: ± 30 ppm, ± 3% of reading **Response Time:** < 3 min for 90% step change	**Particulate Matter (PM_1, $PM_{2.5}$)** **Sensor:** Plantower PMS7003 (Laser Scattering) **Particle Size Range:** 0.3-10 µm **Mass Concentration Range:** 0-999 µg/m^3 **Count Accuracy:** 50% @ 0.3 µm, 98% @ ≥ 0.5µm **Response Time:** < 10 s
Carbon Monoxide (CO) **Sensor:** Alphasense CO-A4 (Electrochemical) **Response Time:** < 30 s for a 10-ppm step change **Precision:** contact 2B Tech for information **Measurement Range:** 0-500 ppm	**Total VOCs** **Sensor:** ION Science Mini-PID2 HS (Photoionization) **Measurement Range:** 0 to 3 ppm **Minimum Detection Limit:** 0.5 ppb **Response Time:** < 12 s **Sensitivity:** > 600 mV per ppm
Pressure **Sensor:** Bosch BME680 **Measurement Range:** 300 to 1100 hPa **Accuracy:** ±1.0 hPa **Resolution:** 0.18 Pa **Long-Term Stability:** ±1.0 hPa per year	**Enclosure Temperature and Relative Humidity** **Sensor:** Honeywell HIH8120 (Platinum RTD/Capacitive) **Measurement Range:** 0-65 °C / 0 to 100 %RH **Accuracy:** ± 0.5 °C from 5 °C to 50 °C / ± 2 %RH **Response Time (RH):** 8 s

B.2 Printed Circuit Board

The sensor package is built on a customized printed circuit board.

B.3 GPS Module

The GPS module is a U-Blox CAM-M8.