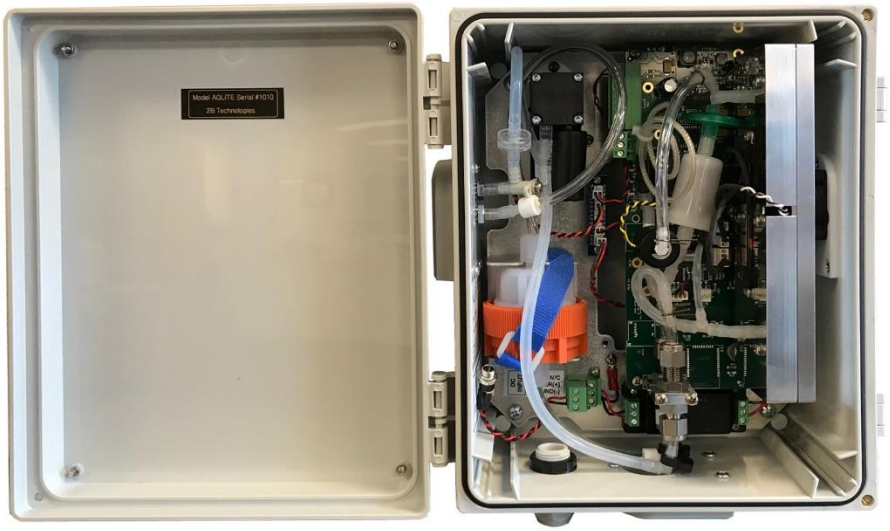
AQLite Air Monitor:
AQLite-Basic



OPERATION MANUAL

Model AQLite-Basic

Technical Support:
https://2btech.io/support/
techsupport@2btech.io
+1(303)273-0559

Contents

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-Basic Air Monitor used for measurement of ambient levels of ozone (O_3), 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 .....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.
Revision A-3 .....December 2023
Updated hyperlinks.
Revision A-4 .....December 2023
Updated maintenance Section E.1 to include information about USB-to-serial cable.
Revision A-5 .....October 2024
Corrected AC wiring shown in bullet 3 of Section B.1.2, step 9 (page 7).

TRADEMARKS & PATENTS

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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-Basic Air Monitor

The AQLite-Basic Air Monitor is a compact and versatile package containing an Environmental Protection Agency (EPA)-Federal Equivalent Method (FEM) instrument for measuring ambient levels of ozone housed in a rugged, weatherproof 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 parts-per-million (ppm) levels 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.

On the next page 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, and more details.

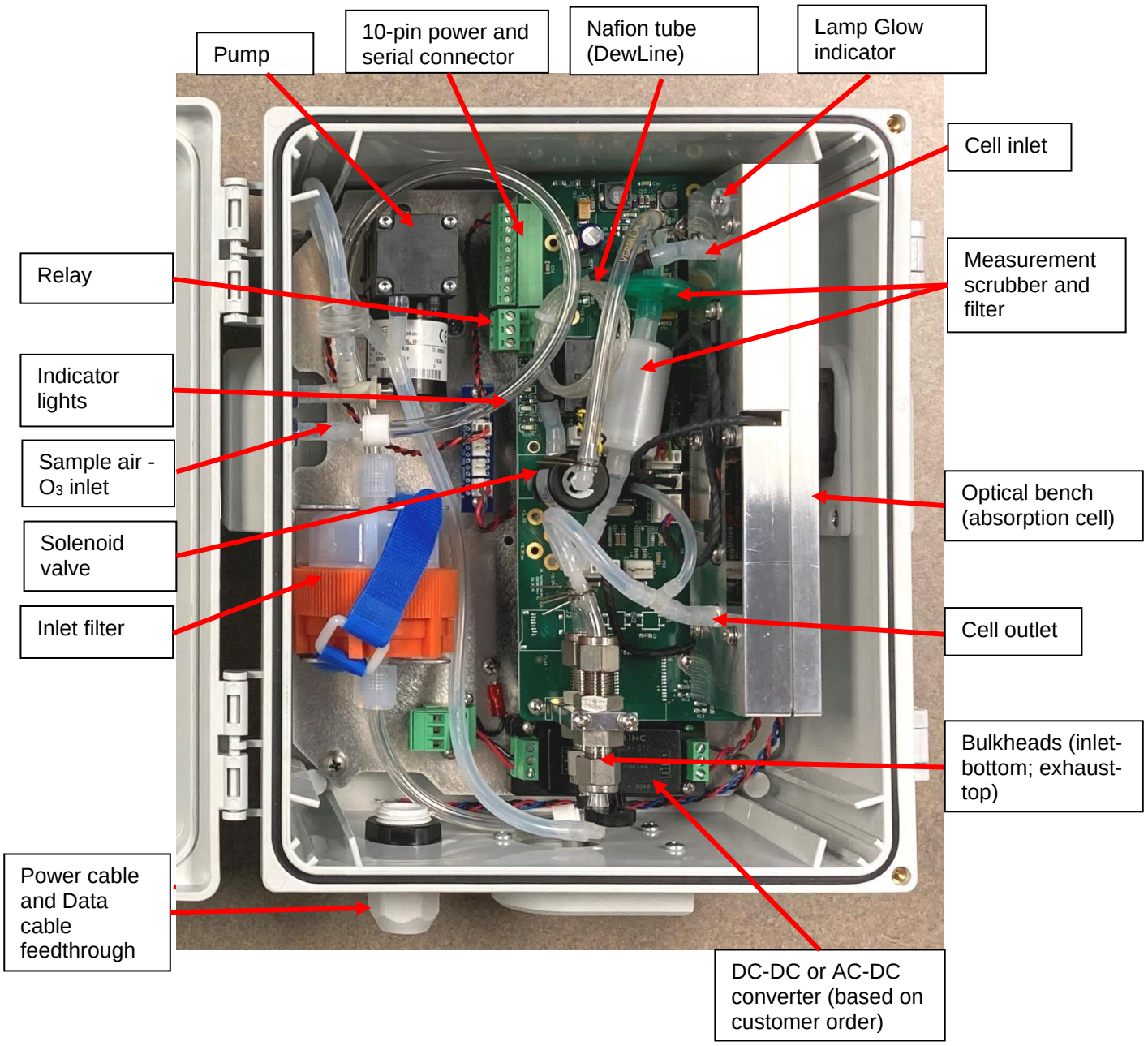
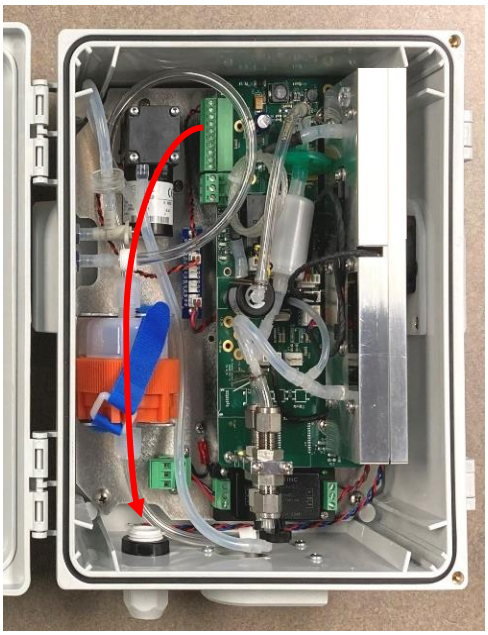


Figure A.1. Model 108-L Ozone Monitor in the AQLite

A.1.2 Viewing and Acquiring Data with the AQLite-Basic

The AQLite can be connected to a computer, data logger, or other data interface to access the data on the logged by the ozone instrument. A USB cable is routed through the bottom of the AQLite enclosure, along with the power cord for the instrument.

This connection also enables the user to adjust various settings, and to carry out diagnostics.



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. Acquiring Data and Operating the AQLite
D. Zeroing and Calibration
E. Maintaining and Troubleshooting the AQLite

Sections F through H 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 will find information in the Appendix:

Appendix 1: The Model 108-L Ozone Monitor

B. Installation and Startup of the AQLite-Basic

B.1 Establish Power Connection to the AQLite

B.1.1 Powering Method

The AQLite can be powered by DC or AC.

DC options are:

- a 2B Tech 12V power supply purchased with the instrument;
- the user's conventional 12V battery; or
- the user's solar panel.

12V power supply option for powering the AQLite

DC power to the AQLite should be provided via connection to a removable terminal mounted on the baseplate. The DC power supply is run through a DC-DC converter that accepts input voltage of 9 to 36 volts DC.

The AQLite can also be purchased in a configuration that has a 100-250 volt AC-DC converter to allow for direct AC inlet power.

The choice among these methods must be specified when the AQLite is ordered so that the proper converter is installed (DC to DC, or AC to DC). If you later wish to change the configuration of your AQLite, please contact 2B Technologies.

B.1.2 Power Cable and Data Cable Feedthrough

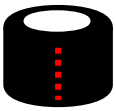
To keep the AQLite weather resistant, you must properly seal the hole where the DC or AC power cable and the USB data cable enter the enclosure. This can be accomplished using the threaded cable-gland following these steps:

1. Locate the external 12V power supply for the AQLite (picture above) or your chosen DC or AC power cable. Also locate the USB/RS232 data cable sent with the AQLite (or other data cable you wish to use).
2. Locate the cable-gland parts and separate them (threaded fitting with ring nut, rubber sleeve with slit, nut).

Inside of nut, showing the rubber sleeve with slit

(feedthrough)

3. *If the rubber sleeve does not have a vertical slit through it, carefully use an Exacto blade to make one.*



Vertical slit so sleeve can be opened and placed around power cable

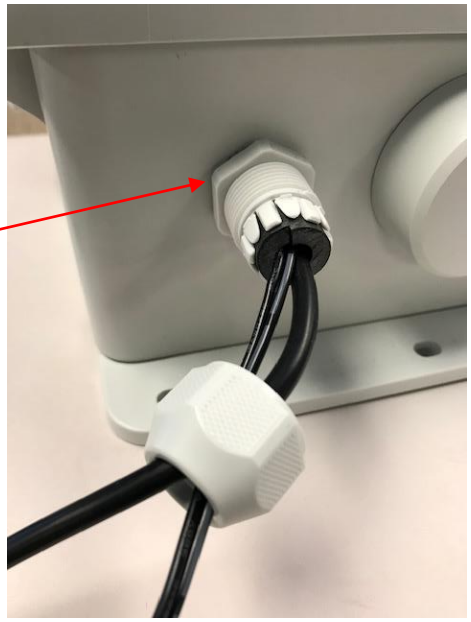
4. Insert the barrel connector from the DC power supply for the AQLite through the nut. (Alternatively, if using other powering source, place your power cable through the nut.) This should be done on the outside of the AQLite enclosure. Also insert the USB/RS232 cable through the nut. Place the rubber sleeve with slit around the two cables.

5. From the outside of the enclosure, feed the cables through the threaded fitting.

Note orientation of threaded fitting

6. Push threaded fitting through the hole in the enclosure from the outside of the enclosure, so the bulkhead of the threaded fitting is against the outside enclosure wall.

Bulkhead of threaded fitting



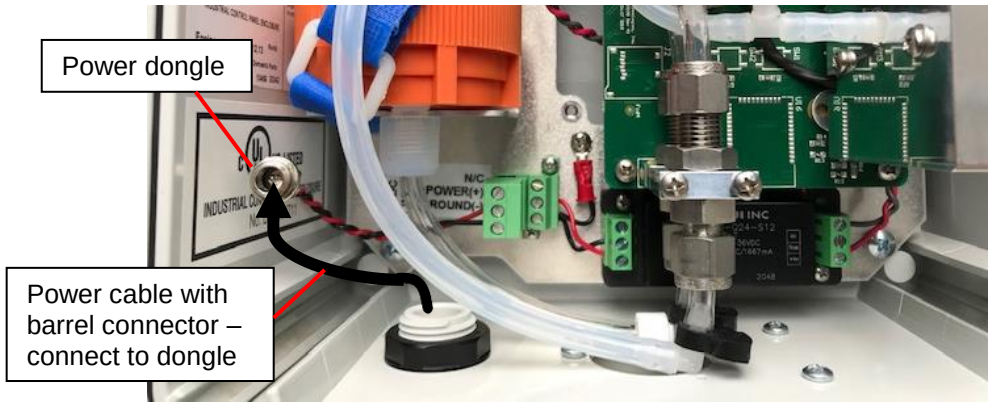
7. On the inside of the enclosure, tighten the black ring nut so that the threaded fitting is securely mounted to the enclosure. (We suggest using two wrenches, with one on the inside to hold the black ring nut and one on the outside of the enclosure to tighten the bulkhead; see two red arrows.)

8. On the outside of the enclosure, be sure that the split rubber sleeve is around the cable. Gently push the sleeve into the fluted end of the fitting.

Push the black rubber sleeve into the fitting

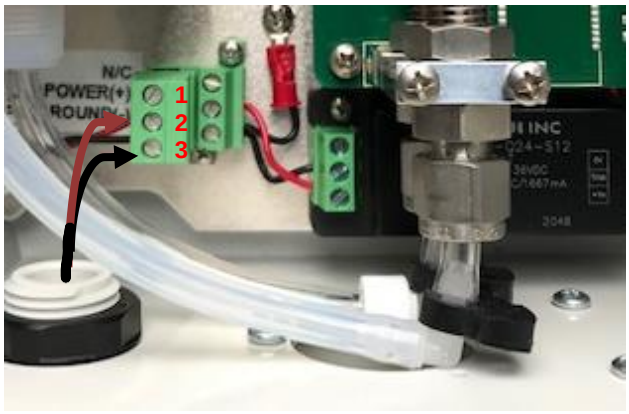
9. Pull power cable through to the length needed to make the connection to the AQLite's Model 108-L Ozone Monitor power inlet (green 3-pin terminal).

   - If using the 12V DC power supply pictured in Section B.1.1, plug the barrel connector into the dongle that comes installed on the 3-pin terminal of your instrument:



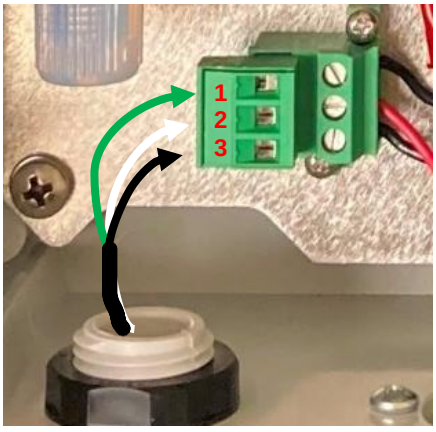
   - If a user-supplied 12V battery or solar panel/battery combination is being used, the power cable should be installed on the power input terminal as shown below.

Position 2: POWER (+)
Position 3: GROUND (-)

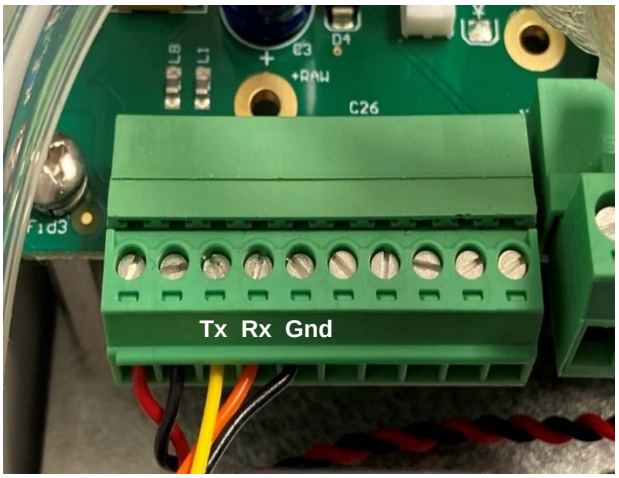


   - If the direct AC configuration is being used, your instrument must have been ordered with an AC-DC converter rather than a DC-DC converter. Install the wiring as shown:

Position 1: CASE GROUND
Position 2: NEUTRAL
Position 3: LINE



10. Pull the end of the USB/RS-232 cable inside the instrument so it reaches to the 10-pin terminal strip (near the top of the instrument). Insert the 3 leads of this wire into the terminal connector as shown in the photo.
    #3 position: Tx – Transmit (yellow in 2B Tech-provided cable)
    #4 position: Rx – Receive (orange in 2B Tech-provided cable)
    #5 position: Gnd – Ground (black in 2B Tech-provided cable)



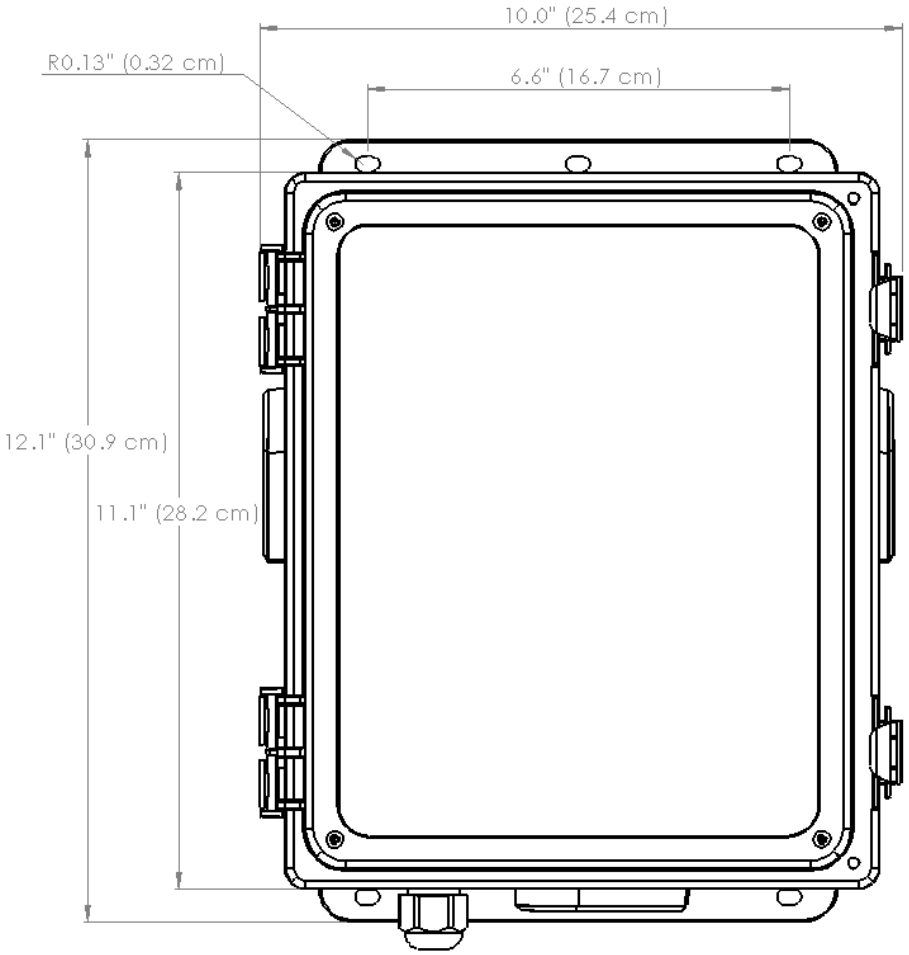
Wiring shown for the USB-to-RS232 cable provided by 2B Technologies. If using your own cable, be sure to follow the Tx/Rx/Gnd locations as noted.

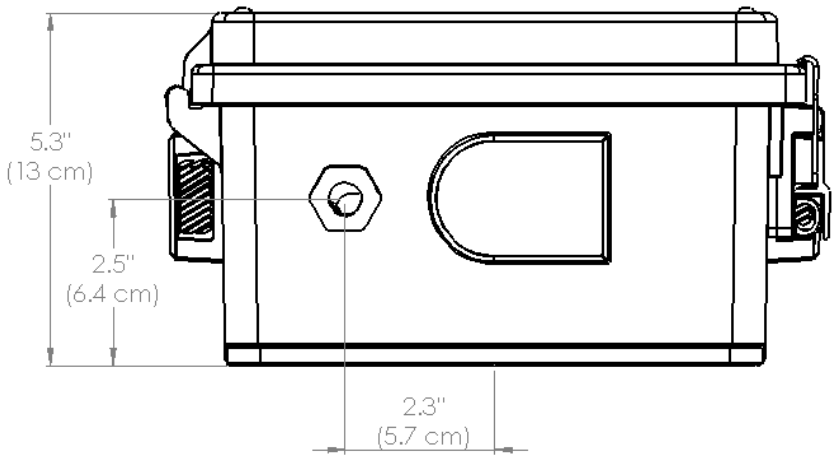
11. Tighten the nut onto the fitting, which should seal the rubber sleeve around the wires.

B.2 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 drawing is shown on the next page.





B.3 Power Up

1. Establish the power cable connection as shown in Step 9 of Section B.1.2.
2. Provide power to the AQLite. The circuit board has a LED next to the relay connector that is illuminated when power is supplied.

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. Acquiring Data and Operating the AQLite-Basic

When power is supplied to the AQLite-Basic, the Ozone Monitor begins making measurements.

This Section of the manual describes:

- how to view/access the data; and
- how to use 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 are given in Appendix 1 of this manual.

• Complete Section B steps before proceeding.

C.1 Accessing the AQLite Data via the Serial Connection

As shipped from the factory, 10-second averaged data from the AQLite-Basic's Ozone Monitor are transmitted via the serial connection.

1. To access the data, connect the USB cable (which you routed through the cable gland in Section B.1.2) to your computer, data logger, or other data communication device you wish to use.
2. Start up a terminal emulator such as Tera Term. The baud rate of the data acquisition software must match the baud rate setting of the Ozone Monitor (2400 baud).
   a) TeraTerm will likely identify the correct COM port and begin displaying data. A new data line will appear every few seconds.
   b) The ozone mixing ratio, internal cell temperature, cell pressure, and photodiode voltage are sent as comma-delimited ASCII text to the serial port every 2 seconds, 10 seconds, 1 minute, 5 minutes, or 1 hour, depending on the averaging time selected using the serial menu. A typical data line would read:

      3.2,309.4,759.3,1.212

      where:
      Ozone = 3.2 ppb
      Cell temperature = 309.4 K
      Cell pressure = 759.3 torr (1 atm = 760 torr)
      Photodiode Voltage = 1.212 volts

C.2 Accessing the AQLite Serial Menu to Change Settings

The serial menu can be used to change the factory settings for the instrument, such as units used for ozone/cell pressure/cell temperature and the adaptive filter. The menu can also be helpful for diagnostics and troubleshooting.

1. With the AQLite powered on and your terminal emulator running as described in the above Section C.1, put the computer's cursor in the TeraTerm window and click.
2. 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.
3. Command '**?**' will output a list of all of the serial commands. They are:

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)
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; see Section 3.7 of Appendix 1).
j	Set the relay ON ozone level (when ozone is less than this, relay turns on; see Section 3.7 of Appendix 1).
f	Set the analog output full scale in ppb (see Section 3.6 of Appendix 1).
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. Zeroing and Calibration

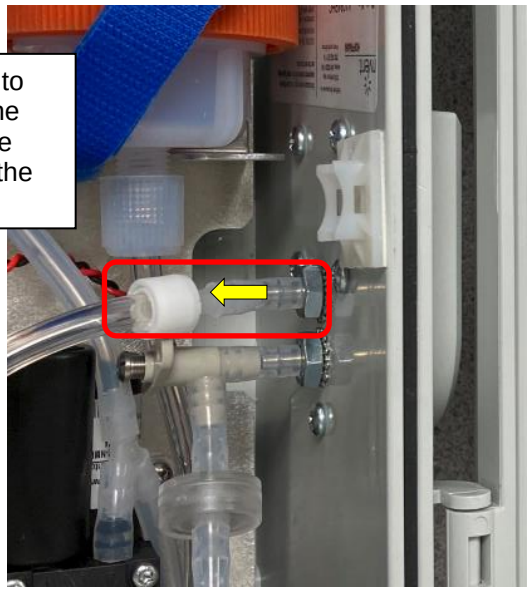
It is recommended that the user frequently examine the data from the AQLite Air Monitor to be sure that the readings make sense and the instrument is working properly.

For example, on polluted days ozone readings should be higher. 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.

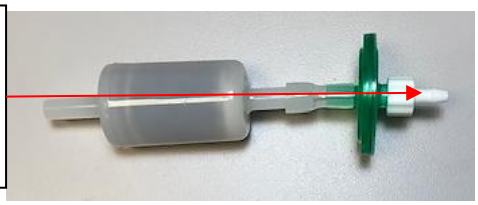
D.1 Zero Checks of the Ozone Monitor

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 commands in Section C.2 as previously described. Command "**a**" adjusts the averaging time.
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 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 C.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: Restore the measurement time of the instrument to 5 minutes.

D.2 Calibration of the Ozone Monitor

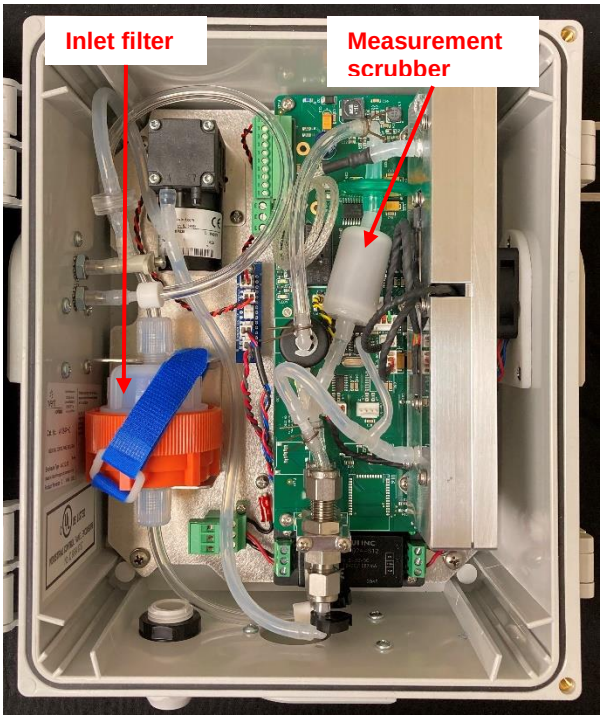
It is recommended that the AQLite be returned to 2B Technologies annually for cleaning and calibration service. At that time, the Ozone Monitor will be calibrated. During calibration, the Ozone Monitor is exposed to a range of known concentrations and the calibration parameters (offset and slope) are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

E.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.

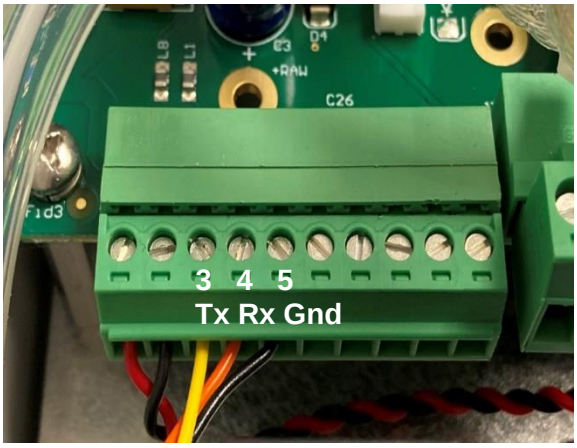
Also, the inlet filter should be changed if the Ozone Monitor flow rate is declining or if visible contamination is present. Frequency will depend on conditions of use.

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

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. Connect the 3 bare wires of the cable to the existing 10-pin terminal connector of the ozone monitor (location shown in righthand picture below). **Caution: Tighten firmly, and be sure there is not any insulation in the connector!!** Use positions 3, 4, and 5 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). Carry out the firmware update following instructions from 2B Tech (Section F.2.3).



E.2 Ozone Monitor Troubleshooting

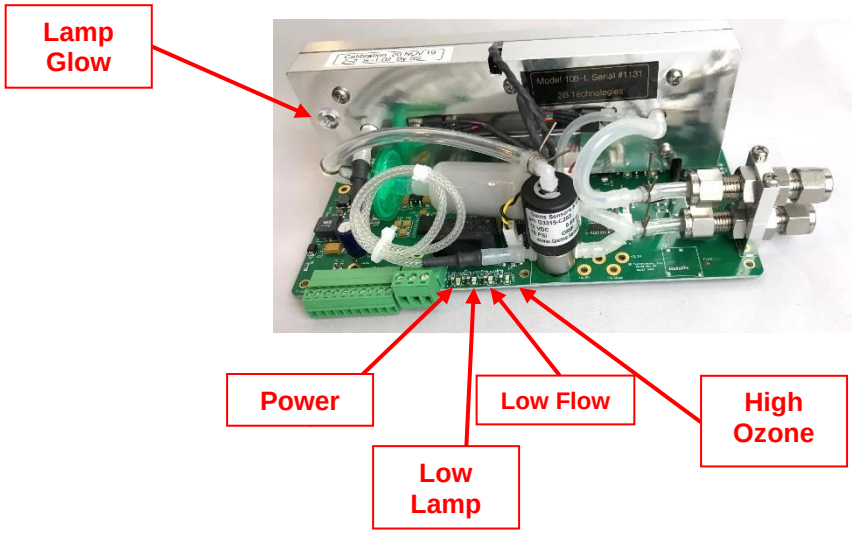
The following are indications of various instrument malfunctions for the Ozone Monitor in the AQLite. The indicator lights are labeled in the photo below (a photo of the separate Model 108 Ozone Monitor is shown below for clarity).

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 C.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 E.1. ***Troubleshooting the Ozone Monitor for performance problems.***
(Refer to the photos in Section F 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 red and blue 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.

Problem/Symptom	Likely Cause	Corrective Action
Readings are noisy with standard deviations greater than 2.5 ppb.	Lamp output is weak, below 0.6 V on Lamp Test.	Power off, open AQLite as above and check lamp connection to circuit board. Run Lamp Test from menu. If photodiode voltage is less than 0.6 V, replace lamp.
	Flow path contaminated.	Clean flow path with methanol (send instrument to 2B Tech).
Serial output does not work.	Wrong serial cable wiring.	Check that wiring has been done as described in Section B.1.2.
	Wrong baud rate or COM port specified in data acquisition program.	Set baud rate to 2400 in data acquisition program. Determine correct COM port
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.

Problem/Symptom	Likely Cause	Corrective Action
Low Flow indicator light is on *(third light on the circuit board; see figure in this manual Section E.2)*	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 in this manual Section E.2)*	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.

E.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. Manuals, brochures, software, cleaning procedures and scientific papers may be downloaded at https://2btech.io/downloads/. See Section G of this manual for a list of replacement parts, which may be purchased by emailing sales@2btech.io or by calling us at +1(303) 273-0559.

F. Labeled Instrument Photos

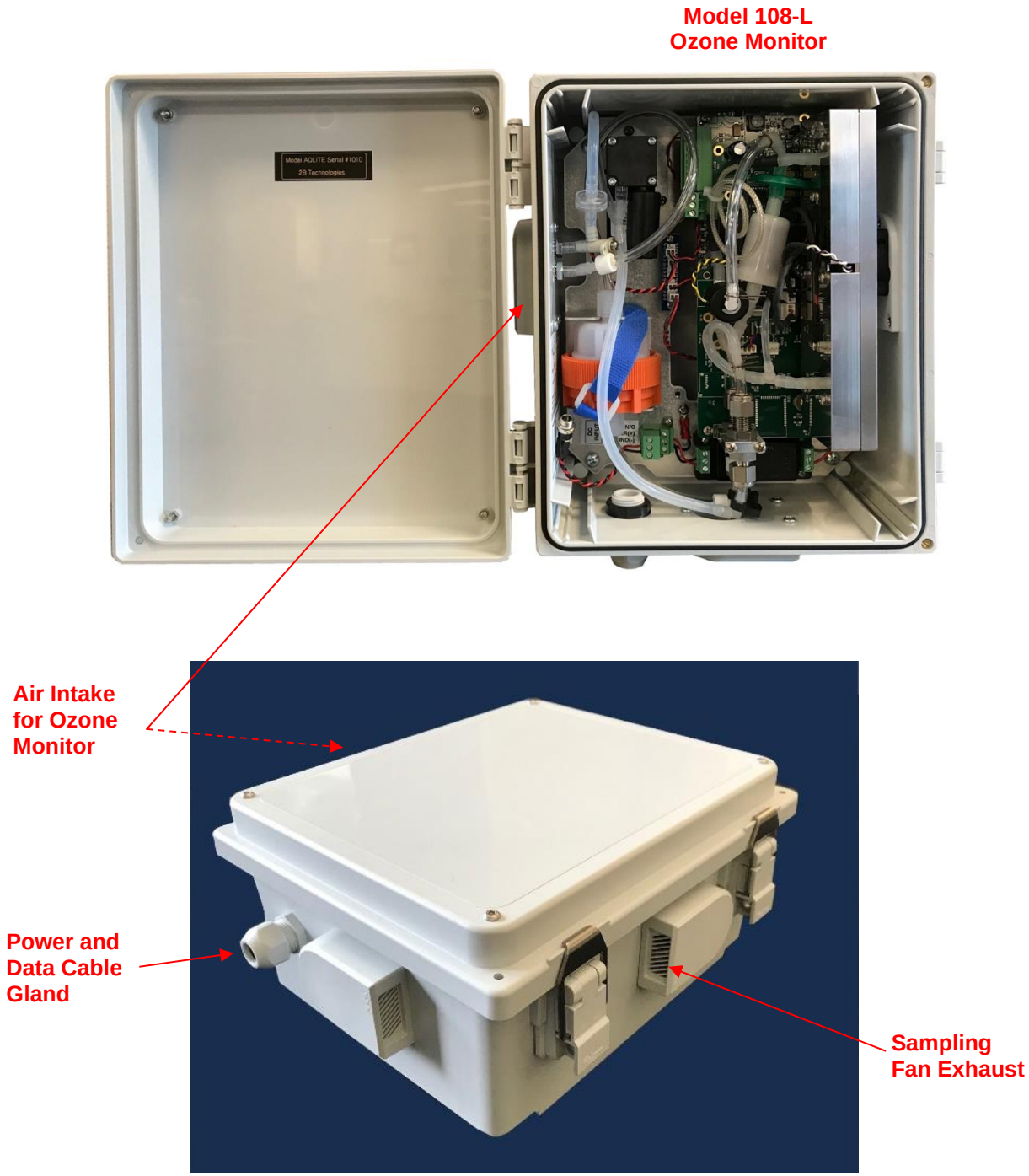


Figure F.1. Overview of the AQLite-Basic Air Monitor
(inside and outside views)

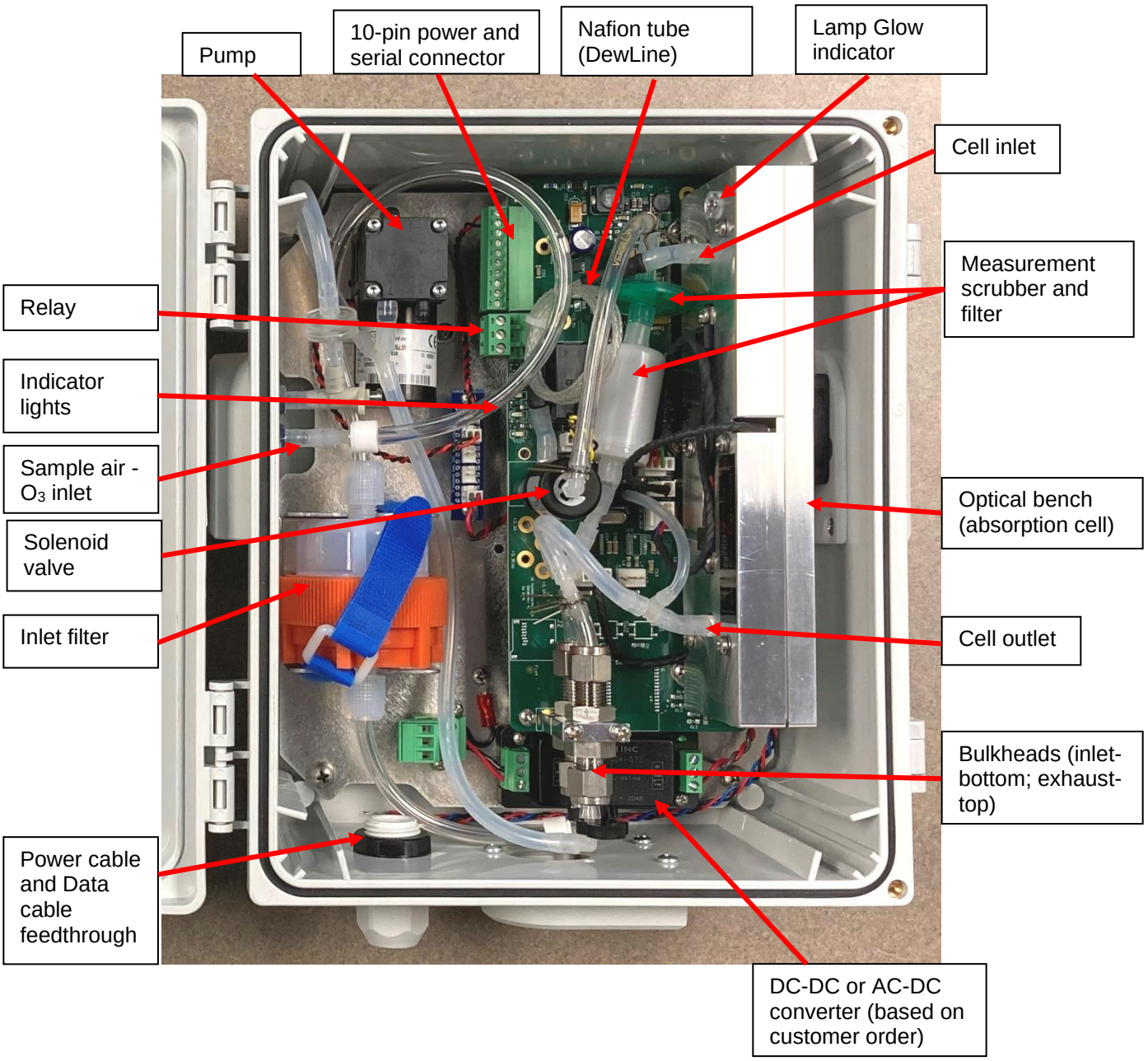


Figure F.2. The Ozone Monitor of the AQLite-Basic Air Monitor.

G. Replacement Parts

The following list includes those parts of the AQLite-Basic 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.

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

H. Service Log

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

Date/ Hours	Calibrated	Cleaned O_3 Monitor	New O_3 Scrubber	New Pump O_3 Monitor	New Lamp O_3 Monitor	Other

Date/ Hours	Calibrated (	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 parts-per-million (ppm) levels based on the well-established technique of absorption of ultraviolet light at 254 nm. The Model 108-L is designated by the U.S. EPA as a Federal Equivalent Method (modification of FEM EQOA-0914-218). Note that throughout this manual and in the instrument output, "ppb" (identical to "ppbv") refers to parts-per-billion by volume (not weight).

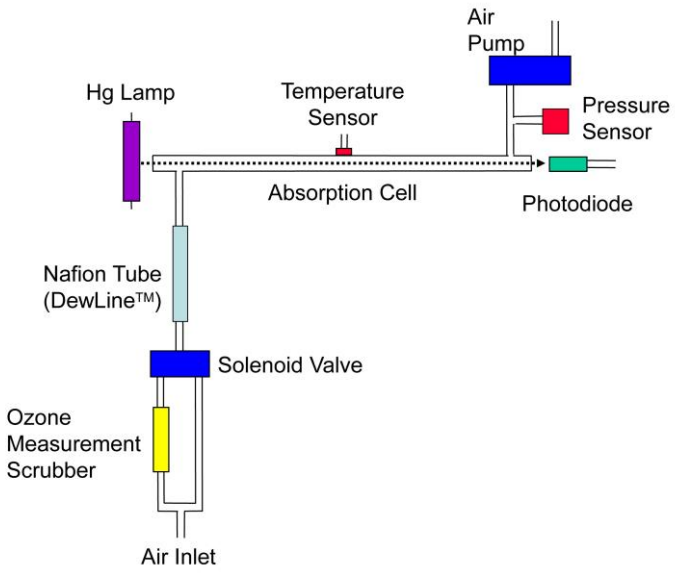
1.1 Theory of Operation

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:

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

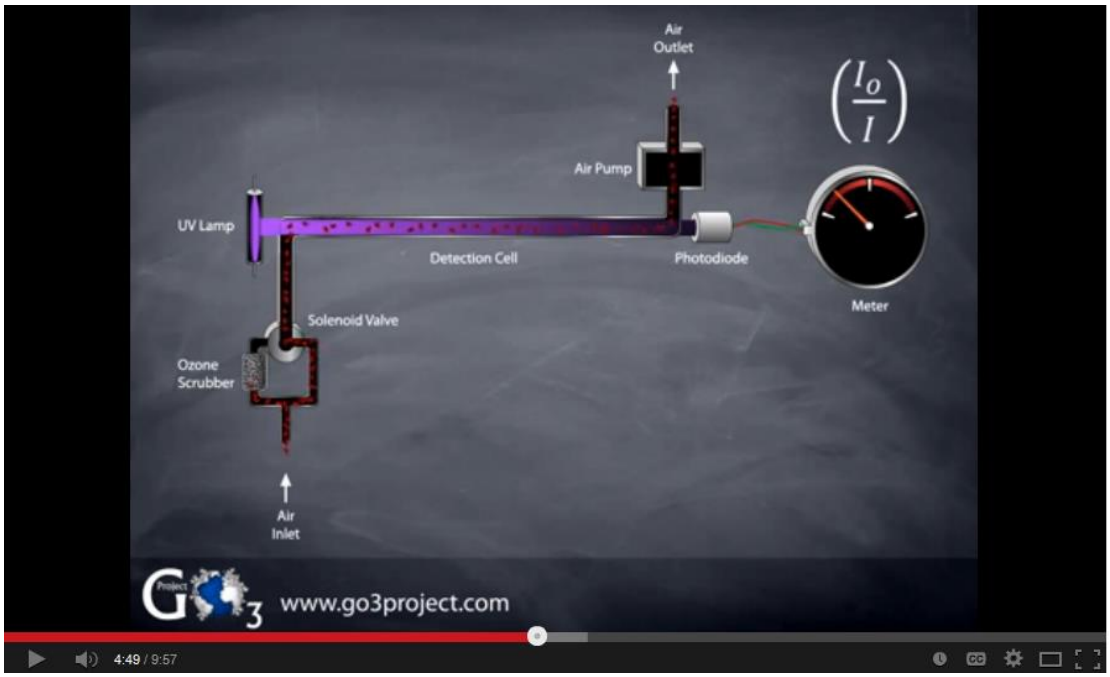
where l is the path length (14 cm) and σ is the absorption cross section for ozone at 254 nm (1.15×10^{-17} cm^2 molecule^{-1} or 308 atm^{-1} cm^{-1}), which is known with an accuracy of approximately 1%. The 2B Technologies instrument uses the same absorption cross section (extinction coefficient) 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 C of main part of this manual).

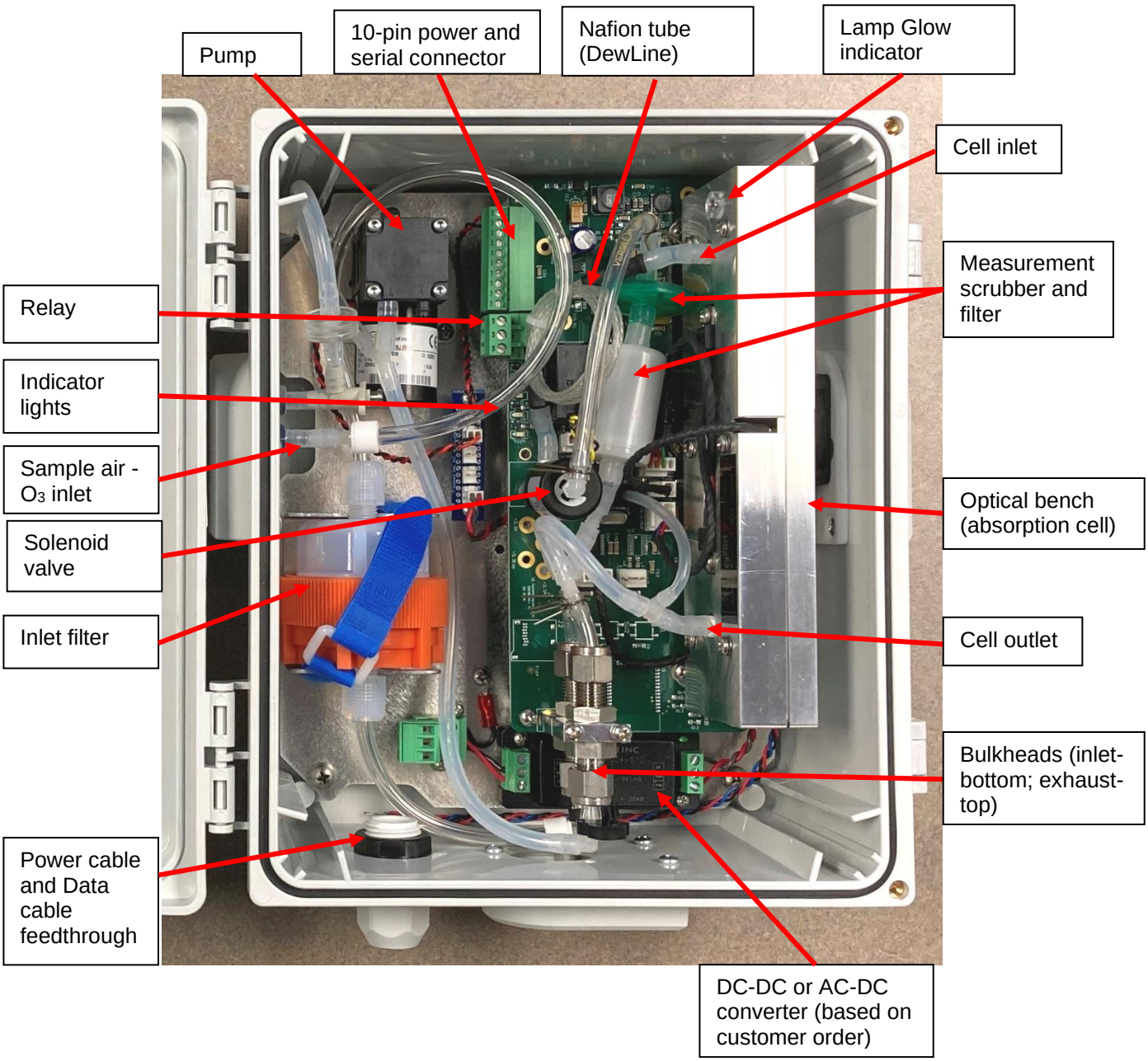
To disable the adaptive filter, set the difference to 0 and the percent to 0 (these are the default settings in the instrument as shipped).

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 (modification of Federal Equivalent Method (FEM): EQOA-0914-218).
Linear Dynamic Range	0-100 ppm (100,000 ppb); 0-0.5 ppm for FEM
Resolution	0.1 ppb
Measurement Frequency	2 s, 0.5 Hz
Data Averaging Options	10 s, 1 min, 5 min, 1 hr
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
Data Transfer Baud Rate	2400
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 a RS-232 data cable attached to the 10-pin terminal block of the instrument. 2B Tech provides a USB-to-RS232 cable for this purpose, but your own cable may be used. See Section C.1 of the main part of this user 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 D.1 of the main part of this manual for carrying out the zero check of the Ozone Monitor in the AQLite. Section C 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

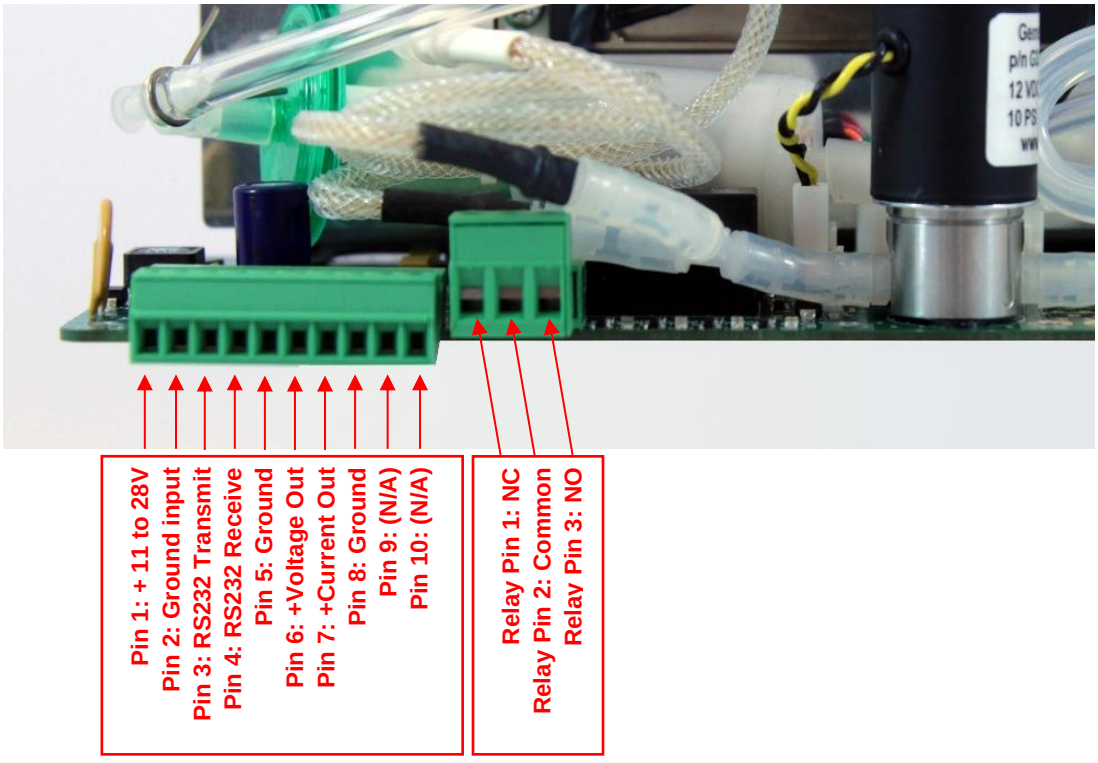
internal ozone scrubber, but it also can be adjusted. Once the zero of the instrument is corrected, the slope may be adjusted so that the instrument readout agrees with a standard ozone source (such as the 2B Technologies Model 306 Ozone Calibration Source™) or with the readout from another instrument 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 C.2 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.

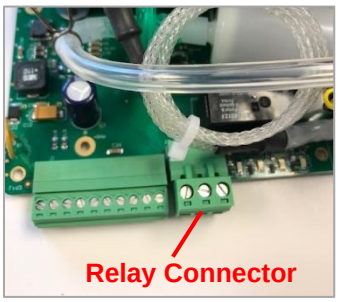
3.6 Collecting Data from the Analog Output of the Ozone Monitor

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 C of the main part 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 F 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.

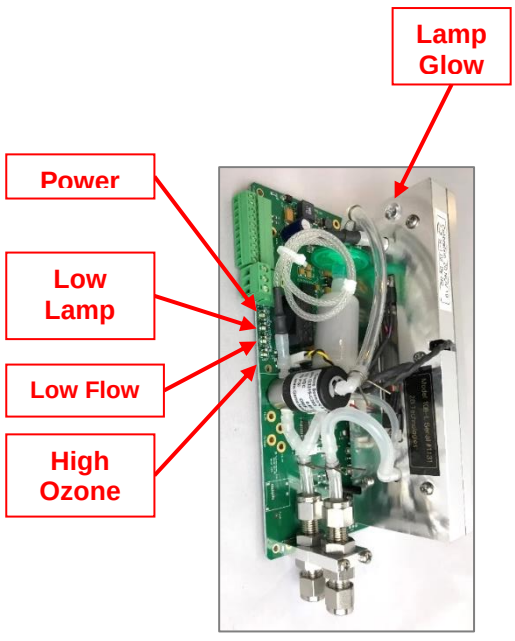
Access the serial menu of the Ozone Monitor using the instructions in Section C of this manual. Type command "**p**" to execute the Lamp Test. The pump will go off. The photodiode voltage will then be displayed, and after a few lamp measurements have

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:

- Power, 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.
- Ozone level is above 100 ppb. Personnel should take safety precautions.

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, 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 E.2 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 E.2 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 E.2 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 E.2 of the main manual).