Ozone Monitor

OPERATION MANUAL

Model 108-MH

Technical Support:
https://2btech.io/support/
techsupport@2btech.io
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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 Model 108-MH Ozone Monitor used for measurement of Medium-High ozone concentrations in air over a wide dynamic range extending from 0.10 parts-per-million by volume (ppm) to an upper limit of 10,000 ppm. 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-10 ..... February 2025
Revision A-20 ..... April 2025
Correction to baud rate information in Specifications table of Section 1.3. Added information about the DewLine in Section 1.1

TRADEMARKS & PATENTS

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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.

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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.

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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 Ozone 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 Ozone 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。

1 OZONE MONITOR INTRODUCTION

The 2B Technologies Model 108-MH Ozone Monitor is designed to enable accurate measurements of Medium-High concentrations of ozone in air over a wide dynamic range extending from 0.1 parts-per-million by volume (ppm) to an upper limit of 10,000 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, "ppm" (identical to "ppmv") refers to parts-per-billion by volume (not weight). The Model 108-MH is designed for integration in the user's ozone system and makes use of the ozone system's pump to supply the air sample. The Model 108-MH Ozone Monitor is lightweight (1.7 lb, 0.77 kg) has a low power consumption (~3 watt) relative to conventional instruments, and is therefore well suited for applications such as:

- Long-term monitoring at remote locations where power is highly limited.
- Monitoring and control of ozone in industrial settings.
- Off-gas analysis in water treatment plants before ozone destruction.

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 6-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 external air pump (user-supplied) 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 (6 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.

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-million by volume (ppm). The instrument displays and records the cell temperature and pressure in addition to the ozone

mixing ratio. The cell pressure is displayed and logged in units of mbar or torr and the cell temperature in units of either °C or K).

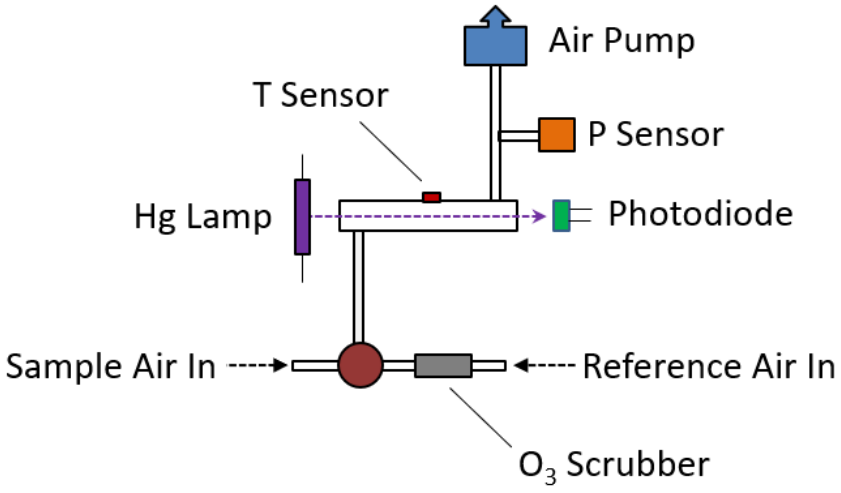


Figure 1.1. Schematic Diagram of the Ozone Monitor. *The air pump is a user-supplied external pump required for instrument operation. The pump must be configured to pull (not push) air through the system.*

Not shown on Figure 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 Calibration Overview

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 user may perform the calibration (see Section 4), or return the instrument to 2B Technologies for calibration servicing.

The offset may drift due to temperature change or chemical contamination of the absorption cell. As discussed in Section 4 below, an accurate offset correction can be measured from time to time using the external ozone scrubber supplied with the instrument.

1.3 Specifications: Model 108-MH Ozone Monitor

Measurement Principle	UV Absorption at 254 nm
Measurement Interval	2 s
Linear Dynamic Range	0-10,000 ppm
Resolution	0.1 ppm
Precision (1σ for 10-s average; aka rms noise)	Greater of 0.05 ppm or 2% of reading
Limit of Detection (10-s average, 2σ)	0.1 ppm
Accuracy	Greater of 0.05 ppm or 2% of reading
Baseline Drift	< 0.1 ppm/day, < 0.3 ppm/year
Sensitivity Drift	< 1%/day, < 3%/year
Calibration	NIST Traceable; annual calibration recommended
Measurement Time and 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
Data Transfer Baud Rates	2400
Ozone Units	ppm, mg m^{-3}
Temperature Units	°C, K, °F
Pressure Units	mbar, torr, psi
T and P Corrected	Yes
DewLine™ for Humidity Control	Yes
Operating Temperature Range	0 to 50°C
Flow Rate	Minimum: 0.6 L/min; Nominal: 1 L/min; Maximum: 1.5 L/min
Power Requirements	11-28 V DC, nominally 250 mA at 12 V DC, 3 watt
Digital Data Output	RS232
Analog Data Outputs	0-2.5 V Analog, 4-20 mA; user-scalable in menu
Relay with 2 Setpoints	Relay responds according to user's ozone or temperature set points depending on user's selection.
Size	8.7 × 4.0 × 3.0 inches (22 × 10 × 7.6 cm) (l × w × h)
Weight	1.7 lb (0.77 kg)
Options	Enclosure

2 OPERATION

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

NOTE:

Save the shipping carton and packing materials that came with the Ozone Monitor. If the Ozone 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.

2.1 Shipping Box Contents

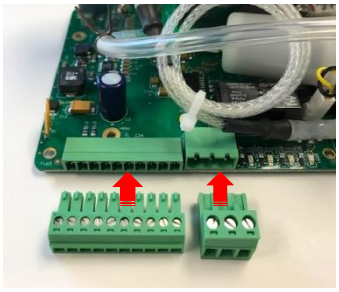
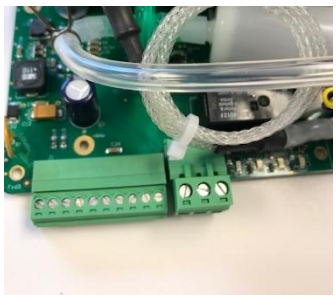
Open the shipping box and verify that it contains all of the items on the shipping list. If anything is missing or obviously damaged, contact 2B Technologies immediately.

2.2 Operation of the Ozone Monitor

Please see the **Quick Start Manual** for streamlined instructions on getting started with your Model 108 Ozone Monitor. The manual applies to both the Model 108-L and the Model 108-MH. A pdf may be downloaded from our website using this link: https://2btech.io/docs/docs_108/108/

2.2.1 Overview of Installation and Startup

Install the 10-pin connector and relay connector on your Model 108-MH Ozone Monitor (click into place).

To operate the Ozone Monitor, connect it to an external 12V DC power source using pins #1 (12V in) and #2 (ground) of the 10-pin connector (see Section 2.9 and Figure 5.1 in Section 5 of this manual). A power connector and power plug are provided with the instrument upon purchase.

If using a different power source in your setup, note that the source can be in the range 11-28 V DC without any detrimental effects on the measurement. A circuit breaker and diode are installed on the circuit board in case of an electrical short or incorrect battery attachment. If activated, the breaker will reset itself after a few minutes.

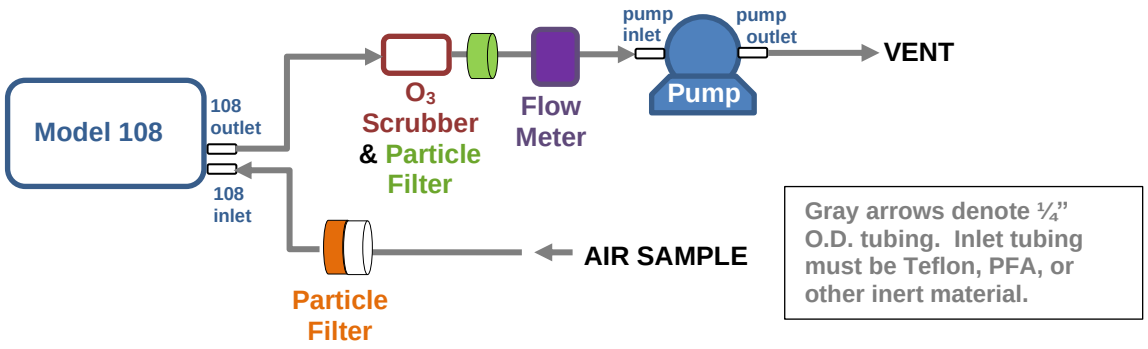
The air sample is supplied to the Ozone Monitor by an external pump, located in the user's ozone system. The pump should be installed on the ¼-inch nylon Swagelok outlet fitting of the Model 108-MH, so that it pulls the sample through the instrument. (The instrument cannot be used in a "push" configuration.) It is recommended that an ozone scrubber and filter be installed between the Model 108-MH outlet and the pump, to protect the pump from ozone damage. The pump can be powered using pins #1 and #2 of the 10-pin connector if desired (see Quick Start Guide for details).

Inlet tubing may be attached to the ¼-inch nylon Swagelok fitting on the instrument. The inlet tubing should be made of PTFE (Teflon®), PFA, FEP, PVDF or some other inert material that does not destroy ozone and that does not desorb plasticizers and other organics that can contaminate the flow path. The length of tubing should be kept as short as possible (preferably not more than a few feet) to minimize ozone destruction within the inlet tubing. Tygon®, polypropylene (which may look like Teflon) and metal tubing should not be used. FEP-lined Tygon tubing, which is used inside the instrument, provides the flexibility of Tygon with the inertness of FEP. A Teflon or PVDF inlet filter is highly recommended to prevent internal contamination of the tubing and absorption cell by particulate matter. The filter should be tested for ozone loss by measuring ambient ozone with and without the filter attached. Filters and filter holders are available through 2B Technologies.

The Model 108-MH Ozone Monitor should be operated within flow limits (0.6 to 1.5 L/min) of the instrument. The user should configure a flow meter in the system so that the flow rate can be measured and adjusted if needed to meet these requirements. Diaphragm pumps capable of delivering this flow rate are available through 2B Technologies (see Section 6). Please contact Customer Service for advice on selecting an external pump for a particular application/sampling setup if necessary.

The diagram below summarizes the configuration recommended of the Model 108-MH.

Note: The sample must be PULLED through the Model 108-MH. "Push" configurations will not work.



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. 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.

Caution: Do not pressurize the inlet of the instrument. It will damage the instrument. Use a tee to vent at the inlet if you are providing a flow to the instrument.

Although the instrument compensates for temperature drift, if strong temperature fluctuations are expected, the instrument should be placed in a thermally insulated box.

When using downstream of an ozone generator, use dry oxygen (not air) as the feed gas for the ozone generator.

2.2.2 Operating Recommendations

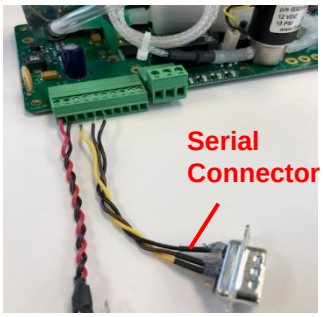
The following table gives a summary of the operating recommendations mentioned in this manual.

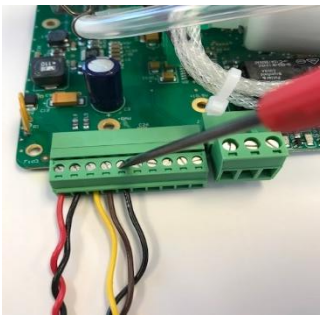
Operating Recommendation	**Frequency**	**Section Reference**
Allow ~20 minutes for instrument warmup before taking data	Each startup	2.2.1
Install a pump to pull (not push) the sample through the instrument	Each use	2.2.1
Inlet tubing should be made of inert materials, such as PTFE, PFA, FED, PVDF (do not use Tygon®, polypropylene, or metal tubing)	Each use	2.2.1
Maintain flow rate within operating limits (0.6 to 1.5 L/min)	Each use	2.2.1
Use a Teflon or PVDF inlet filter; test it for ozone loss	Each use	2.2.1
Use an ozone scrubber on the outlet to protect the pump from ozone damage	Each use	2.2.1
Check the zero offset	Occasionally	4.6
Replace the ozone measurement scrubber, exhaust scrubbers (2), and exhaust filter	Every 6 months of continuous operation (~4,000 hours); otherwise annually	3.1
Perform multipoint calibration	• Annually • Any time major disassembly of components is performed • Any time the zero or span checks give results outside of the acceptable limits	4
If strong temperature fluctuations are expected, place the instrument in a thermally insulated box	User-defined	2.2.1
When using downstream of an ozone generator, use dry oxygen as the feed gas for the ozone generator.	When using downstream of an ozone generator	

2.3 Collecting Data over the Serial Port in Real Time

To transmit data to a computer over the serial port in real time, connect the Ozone Monitor to the serial port of the computer using the 9-pin cable provided when you purchased your instrument. Note that this is a “straight-through” female-female serial cable. A “cross-over” cable will not work.

For the serial port connection, use the serial connector provided with your instrument and pins 3, 4, and 5 of the 10-pin connector (see Section 2.9 and Figure 5.5, Section 5 of this manual). The RS232 protocol is 2400 baud; 8 bits; no parity; 1 stop bit. The digital pinout for the RS232 is standard and as follows: Pin 3 = transmit (yellow), Pin 4 = receive (brown), Pin 5 = ground (black). Note the proper wiring of the serial connector:





2.3.1 Data Acquisition Software

Start your data acquisition software, terminal emulation software such as HyperTerminal (a program provided with earlier versions of Windows) or Tera Term.

2.3.2 Determine the Connection Port and Set the Baud Rate

When setting up your software or terminal emulator, choose the correct COM port listed in the Device Manager. If using Windows, go to the control panel and select System and Security > System > Device Manager. Select “Ports” to see the assigned serial COM port number.

For the serial port, the baud rate setting in the data acquisition software must match the baud rate setting of the Model 108-MH (2400 baud). Adjust the baud rate setting in the software’s setup menu to 2400.

2.3.3 Data Output

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:

0.1,30.5,842.2,1.1974
where:

Ozone = 0.1 ppm

Cell temperature = 30.5 ºC

Cell pressure = 842.2 mBar (1 atm = 1013.25 mBar)

Photodiode Voltage = 1.1974 volts

See Section 2.4 (next) for how to access the serial menu.

2.4 Accessing the Serial Menu

Measurements and logging tasks can be accessed via the serial port using a terminal emulator such as Tera Term or HyperTerminal running on an attached computer. Commands can be sent using the terminal emulator set with the properties listed in the section of this manual entitled “Collecting Data over the Serial Port in Real Time” (Section 2.3). Listed below are the lower-case letters that are commands for performing certain operations while the instrument continues to measure:

h Output serial data line header
m Serial menu

If the letter **m** is sent as a command, **menu>** will be displayed in the terminal emulator window. When the serial menu is accessed, the instrument is no longer making measurements; it is waiting for the next command to be entered. The following is the list of serial menu items accessible from this point:

Menu Commands: Serial Port

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].
n Output instrument serial number.
p Perform lamp test.
e Set the relay to function based on ozone.
d Set the relay function based on temperature.
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).
l Set the relay OFF temperature level (when temperature in Celsius is greater than this, the relay turns off).
q Set the relay ON temperature level (when temperature in Celsius is less than this, the relay turns on).
f Set the analog output full scale in ppm.
u Set the ozone units (ppm, mg/m3).
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)*
P Enable PID (admin only).
Q Disable PID (admin only).
F Print the firmware version.
? Output the help menu.
x Exit menu and return to measuring.

[1] Default settings: Avg=10 s, offset=0, slope=1, T in °C, P in mbar, O_3 in ppm.

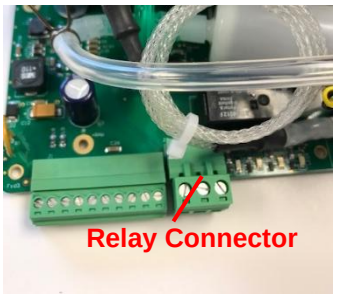
2.5 Collecting Data from the Analog Output

The data may be logged in real time using a data logger attached to the 10-pin connector on the 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). See Section 2.9 and Section 5 of this manual for the labeled instrument photos and pin connections.

To change the analog output voltage scaling factor, send the character 'f' in the serial menu and enter a number between 1 and 99999.

For example, if you entered the number 100, then 2.5 volt (full scale) = 100 ppm; i.e., 1 volt = 40 ppm. Also, the current output will be scaled such that the full scale of 20 mA corresponds to 100 ppm. 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.

2.6 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.

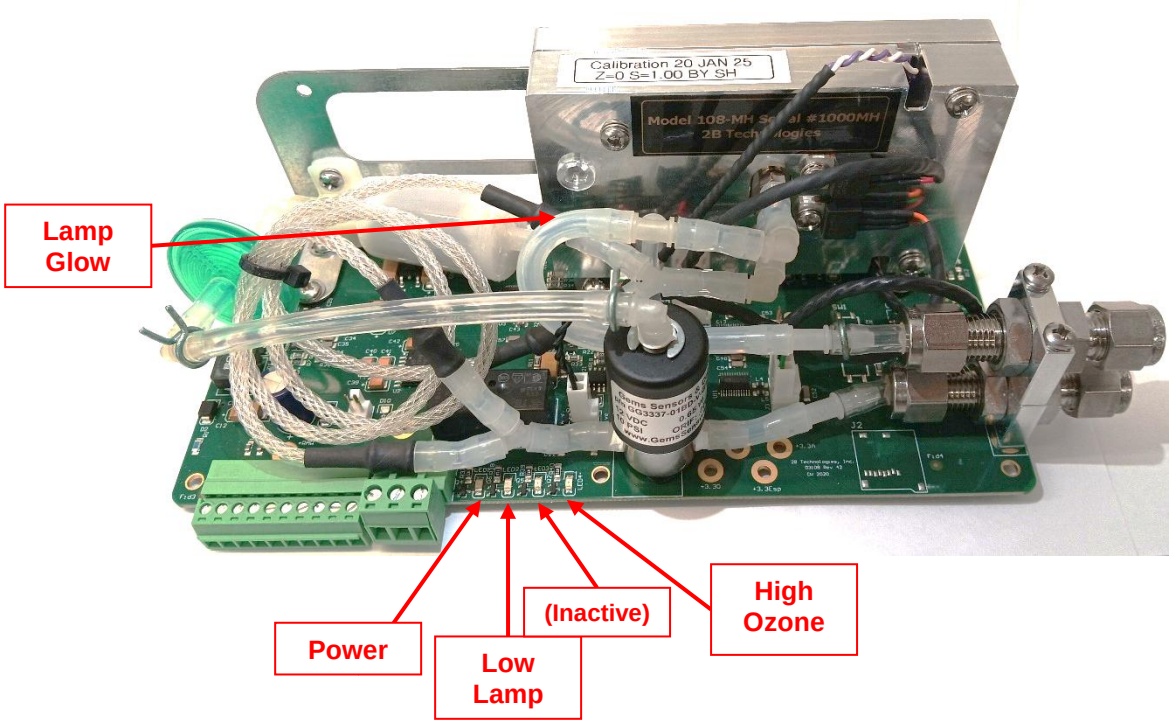
To set the On and Off limits of a relay, enter the serial menu and press 'g' and "j" to access the high and low ozone limits for the relay settings. Enter a number between 1 and 99999 for each of the desired settings. For example, with units set to ppm, "ON" ozone level = 000100, and "OFF" ozone level = 000090, the relay will close (pass current) until the ozone concentration exceeds 100 ppm. Above this concentration, the switch relay will open. The relay will not close again until the ozone concentration drops below 90 ppm. In this way, for example, the ozone concentration from an ozone generator could be controlled in the range 90 to 100 ppm.

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 5 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.

2.7 LED Indicator Lights and Lamp Glow Indicator

The Model 108-MH has four LED lights on the side of the instrument to indicate any system issues that may require troubleshooting:

- **Power On:** The far-left LED is a Power On indicator. It indicates that there is power to the instrument and that the main circuit board is working properly. The normal state is ON.
- **Low Lamp:** Second from left is the Low Lamp indicator. This indicator comes on if the lamp voltage drops below 0.6 volts, indicating that a lamp test should be conducted (Section 2.8) and that the lamp may need replacement and/or the flow path may need cleaning. The normal state is OFF.
- **Low Flow:** LED 3 is the Low Flow indicator. This LED should remain off at all times. The Model 108-MH does not have a flow meter and this LED currently has no function.
- **High Ozone:** LED 4 is the High Ozone indicator. This turns on when 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.



The instrument also has a **Lamp Glow** indicator on the inside of the optical bench (see above). It should be illuminated when the instrument is on and functioning properly. If it is off, the lamp may have become disconnected, or the lamp is broken.

2.8 Performing a Lamp Test

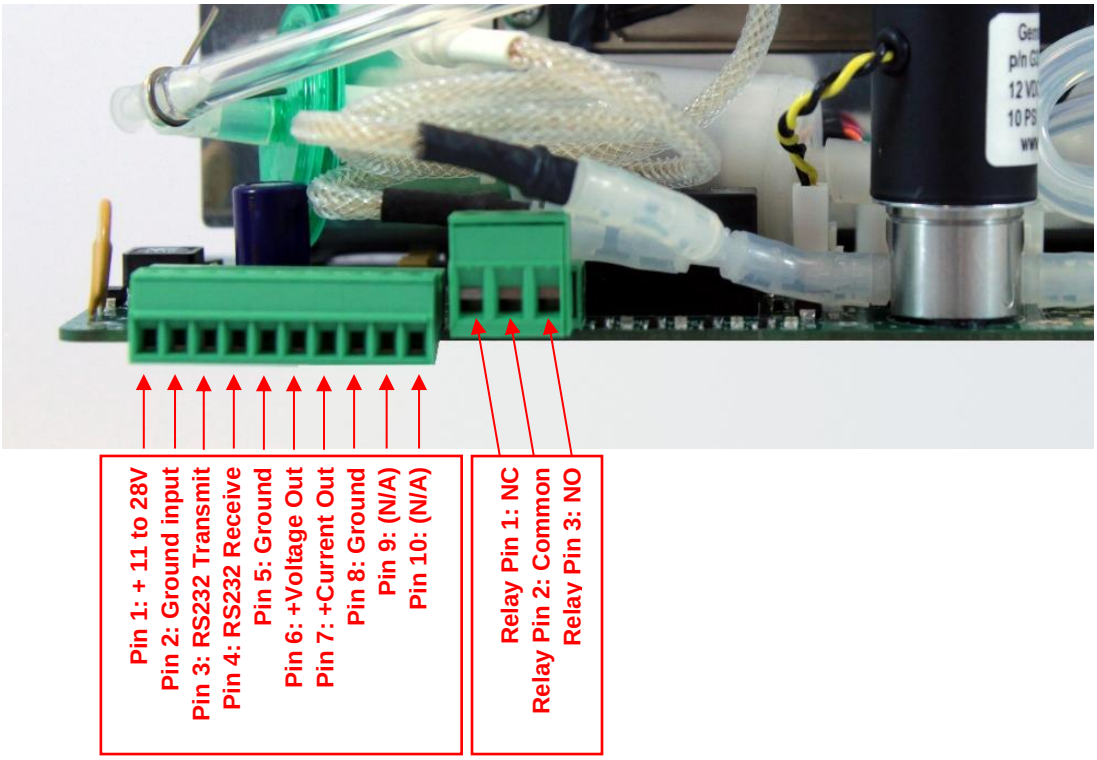
If the instrument always reads near zero in the presence of ozone or if the Low Lamp indicator light is turned on (Section 2.7), it is useful to perform the lamp test to make sure that the lamp is turning on. Before performing the lamp test, allow the instrument to warm up for at least twenty minutes.

A lamp test is performed from the serial menu, using command “p.” After a few moments, the serial output will give the results of the test. The photodiode voltage will then be displayed, for example:

1.24578

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. Photodiode voltages less than 0.6 volts without any ozone in the cell are 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. If your lamp fails the lamp test during the first year of operation, contact us for a new lamp under the instrument warranty.

2.9 Summary of Pin Connections



3 MAINTENANCE/TROUBLESHOOTING

3.1 Overview

The Model 108-MH Ozone Monitor is designed to be nearly maintenance free. The only component that requires routine maintenance is the internal ozone scrubber (see Figure 5.1 of Section 5 and Figure 1.1 in Section 1.1), which is used for the ozone measurement. The ozone measurement scrubber is connected to the top of the solenoid valve. It should be replaced every six months (~4,000 hours) of continuous operation; otherwise, annual replacement is recommended. The internal ozone measurement scrubber can easily be replaced by disconnecting the tubing attached to the end and connecting a new one in its place.

Other components with a limited lifetime are the 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.

It is recommended that the user install and replace as needed an ozone scrubber and filter on the exhaust line, to protect the user's pump. Also, the inlet filter (user supplied) should be changed as recommended by the filter manufacturer.

The following are indications of various instrument malfunctions.

Lamp Failure: The ozone measurements will be erratic and the Lamp Test will show 0.0 volts for the photodiode voltage. The Lamp Indicator light will go on when the lamp voltage drops below 0.6 volts. The Lamp Glow indicator will also be unlit. See Section 2.7.

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.

See Section 2.7 for information about the LED indicator lights on the Model 108-MH Ozone Monitor and see Section 3.3 below for Troubleshooting tips.

3.2 Maintenance Recommendations

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

Maintenance Recommendation	Frequency	Reference
Recalibrate instrument and clean flow path	At least once per year	2.2.2, 4.1-4.6
Replace ozone measurement scrubber	every 6 months of continuous operation (~4,000 hrs); otherwise annually	3.1
Clean flow path (methanol)	As needed if instrument has large offset and ozone readings are low, or if readings are noisy	3.1; send instrument to 2B Tech, or call 2B Tech for cleaning procedures

3.3 Troubleshooting

Help with troubleshooting is provided in the following table.

Table 3.1. ***Troubleshooting the Model 108-MH Ozone Monitor for performance problems.*** *(Refer to Figures 5.1-5.5 in Section 5.)*

Problem/Symptom	Likely Cause	Corrective Action
Instrument does not turn on (Power On 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.
Lamp Low LED is ON.	The lamp intensity is low.	If the photodiode voltage is near 0.6 volts, the instrument may still function properly, but the lamp should be replaced when possible.
Cell temperature reads low by several 10's of degrees.	Absent or loose connection of temperature probe cable to circuit board.	Reattach connector to circuit board.
Readings are noisy with standard deviations greater than 0.2 ppm.	Lamp output is weak, below 0.6 V on Lamp Test. Flow path contaminated.	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, or call 2B Tech for cleaning procedures).

Problem/Symptom	Likely Cause	Corrective Action
Analog output is constant or does not track serial readings.	Cable not properly connected between analog output and recording device.	Check continuity of your analog cable to your recording device and make sure correct connector pins are being used.
	Wrong scaling factor selected in menu.	Check and reset analog output scaling factor in the serial menu.
Serial port does not work.	Wrong baud rate or COM port specified in data acquisition program.	Set baud rate to 2400 in data acquisition program. Determine correct COM port (Section 2.3.2).
	Wrong serial cable used.	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.
Required calibration parameters are large (>±1 ppm 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 to 2B Tech or call for procedure.
	Solenoid valve is contaminated and not opening and closing properly.	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).

2B Technologies offers reasonably priced customer service for instrument repairs. The calibration service 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. 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 on our website. Technical notes, manuals, brochures, software, cleaning procedures and scientific papers may be downloaded from our website at https://2btech.io/downloads/. See Section 6 of this manual for a list of replacement parts, which may be purchased by calling us at +1(303) 273-0559.

4 CALIBRATION AND SPAN CHECKS

4.1 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.

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).

4.2 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. For calibration of the Model 108-MH Ozone Monitor, 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. Sampling pump
6. 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)
5. Sampling pump

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.

4.3 Instrument Preparation

Prior to calibration, follow the steps below:

1. Connect your pump to the outlet of the Model 108-MH Ozone Monitor (see Section 5 photos).
2. Turn on the Model 108-MH Ozone Monitor and allow it to stabilize for a minimum of one hour.
3. Connect the instrument to the manifold of your 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-MH 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 and any other flow demand drawing from the manifold.

4.4 Calibration Setup Preparation

As indicated in the EPA Technical Assistance Document, several tests 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

4.4.1 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.

4.4.2 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 ozone loss 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.

4.4.3 Linearity Check

Since the Model 108-MH 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 4.5.4) 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-MH is better than the error calculated in this linearity check due to the uncertainty introduced by the flow measurements.

4.4.4 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.

4.5 Calibration Procedure

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

4.5.1 Instrument Preparation

1. Turn on the Model 108-MH Ozone Monitor and allow it to stabilize for a minimum of one hour.
2. Enter the serial menu (press ‘m’ to enter serial menu) and set the zero (Z, command ‘z’) value to 0 and the slope (S, command ‘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-MH 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.

4.5.2 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 ozone calibration.
2. Allow the Model 108-MH to sample zero air until the response is stable.
3. Record the average zero air response.

4.5.3 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-MH 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.

4.5.4 Calibration Curve

1. Plot the Model 108-MH 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 3.3).
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) 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 -20 to 20 ppm 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 3.3.
5. Enter the serial menu and set the calibration parameters Z and S as determined above.

4.6 Periodic Zero and Span Checks

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

1. A zero check is performed by sampling zero air with the Model 108-MH as described in Section 4.5.2 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 4.5.3 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.

5 LABELED INSTRUMENT PHOTOS

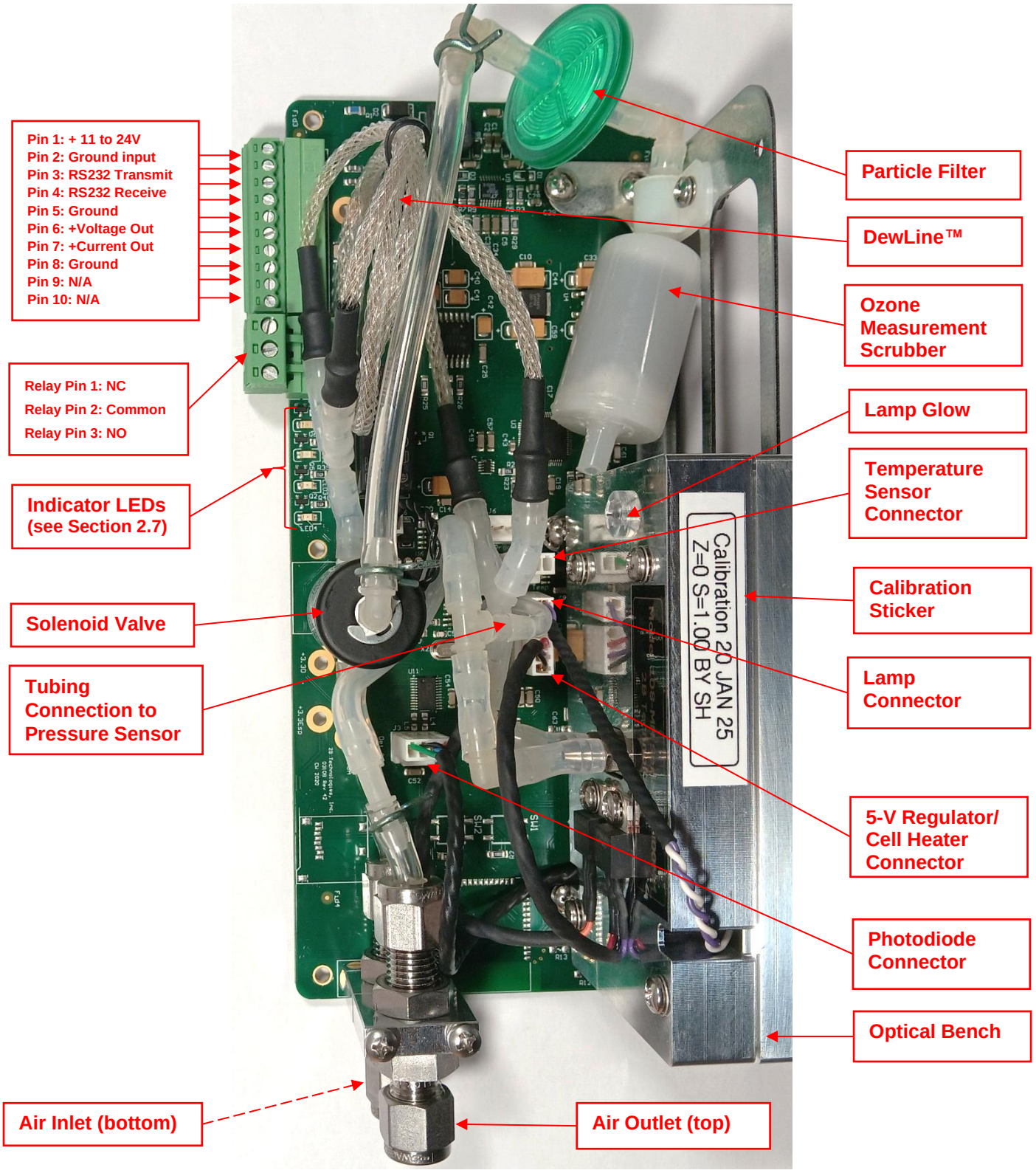


Figure 5.1. Top View of the Model 108-MH.

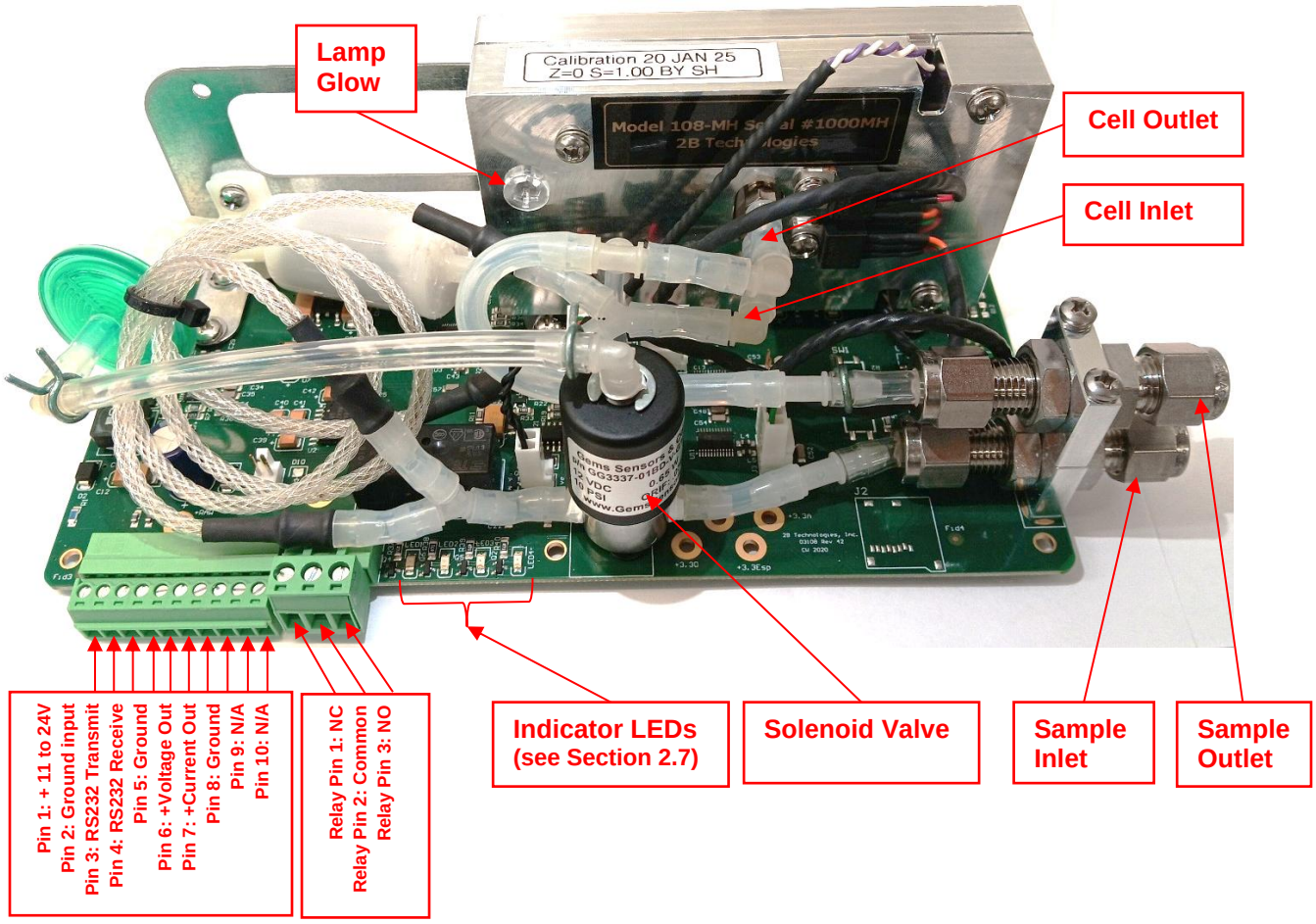


Figure 5.2. Side View of the Model 108-MH.

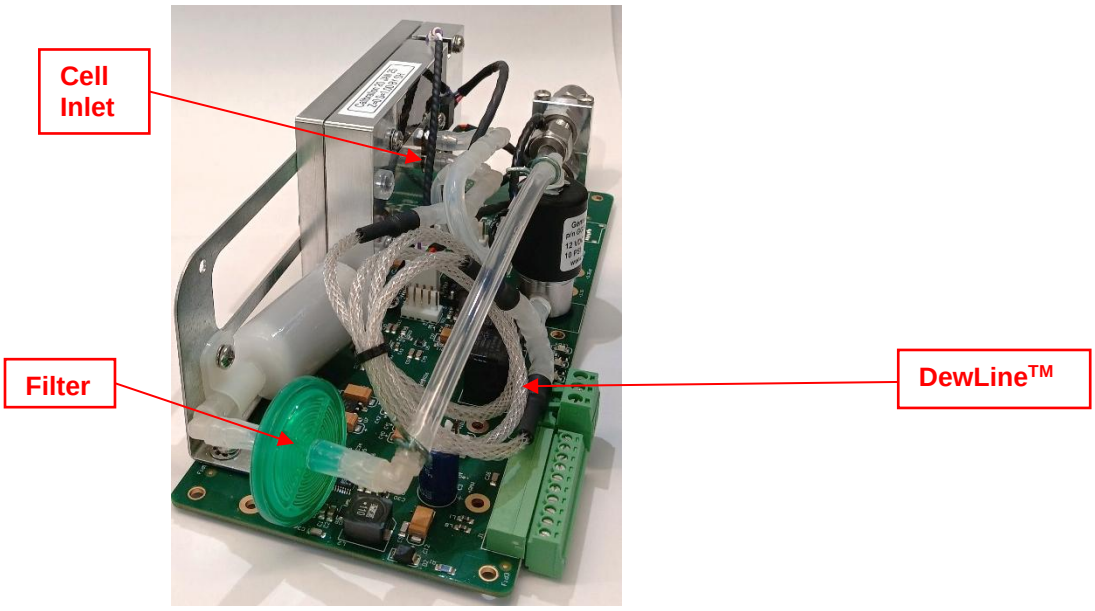


Figure 5.3. Front View of the Model 108-MH.

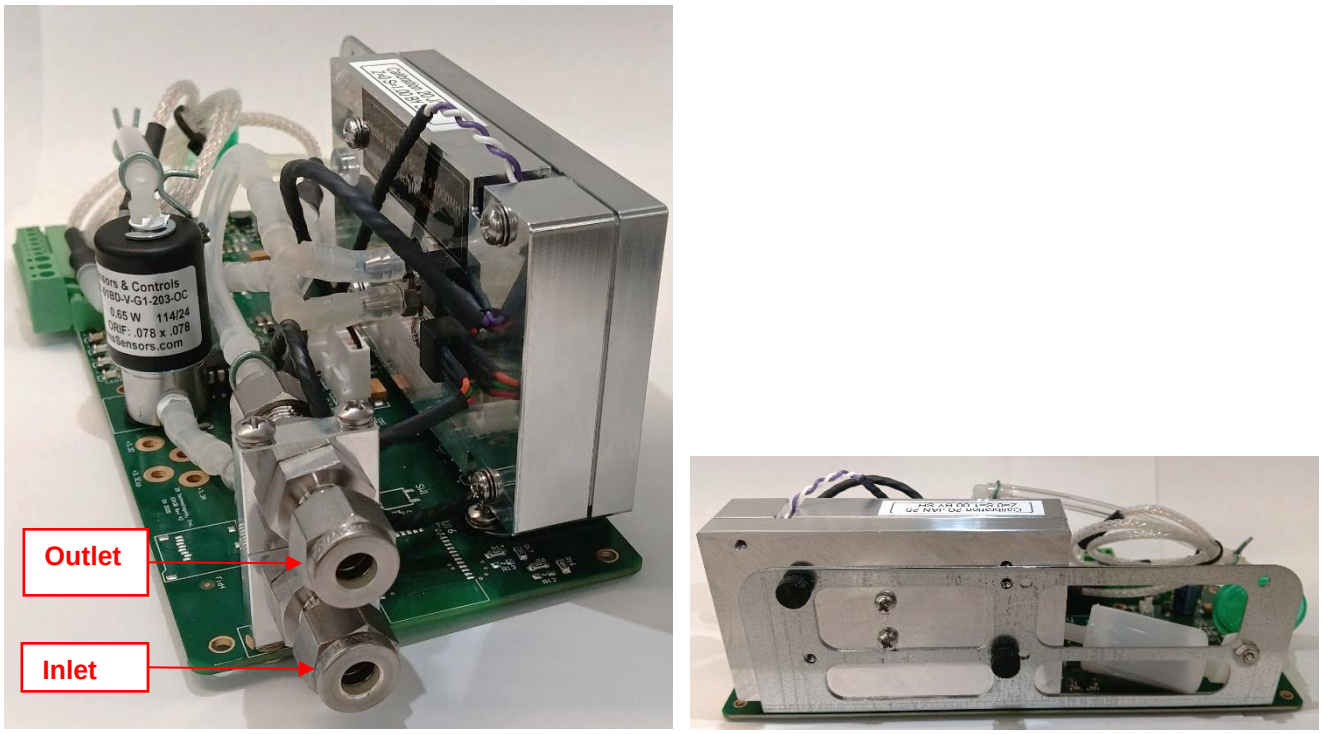


Figure 5.4. Back and Side Views of the Model 108-MH.

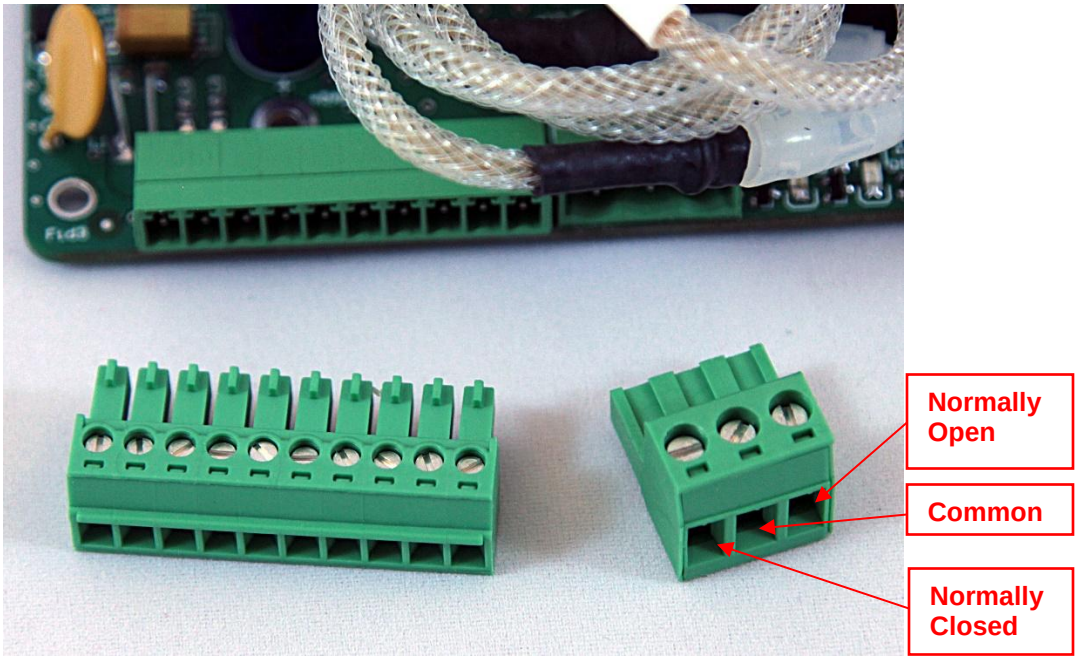


Figure 5.5. Detail of the 10-Pin and Relay Connectors of the Model 108-MH.

6 REPLACEMENT PARTS

The following list includes those parts that are user serviceable. Replacement of the solenoid valve requires a knowledge of soldering.

Please contact us for pricing.

Part Number	Description
11-281	Ozone measurement scrubber
10-729	Ozone zeroing scrubber (external)
11-065	Lamp assembly for Model 108
10-910	Solenoid valve for Model 108
10-698	Photodiode assembly and cable for Model 108
10-669	DewLine™ (two Nafion tubes in parallel)
10-025	Serial port cable (to computer)
10-547	Power wire harness for Model 108
10-548	Serial wire harness for Model 108
10-422	Silicone tubing (5 ft)
11-352	Cleaning kit for Models 106, 108, 202, 205

Recommended External Air Pumps

10-295 (modified)	Air pump used for Model 106L, M
10-300 (modified)	Air pump, quiet, used for Model 205

7 SERVICE LOG

2B Tech Instrument: *Model 108-MH* ***Serial #:***_____ ***Purchase date:***_____

Date/ Hours	Calibrated	Cleaned	New O_3 Scrubber	New Lamp	Other

Date/ Hours	Calibrated	Cleaned	New O_3 Scrubber	New Lamp	Other