Aqueous Ozone Monitor

2B Technologies, Inc.

OPERATION MANUAL

Model UV-106-W

Technical Support:
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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 UV-106-W Aqueous Ozone Monitor, which uses our patented MicroSparge™ technology to measure dissolved ozone in water over the range of 0.50 to 100 parts per million by weight (ppm) with high precision and accuracy. Unlike most dissolved ozone sensors, the instrument does not make use of a membrane that will foul over time. Instead, dissolved ozone is measured by nearly complete sparging of ~2 mL of water with ozone-scrubbed ambient air and integrating the gas-phase concentration of ozone stripped from solution. Because ozone is measured in the gas phase, interferences from particles and dissolved inorganic and organic compounds are removed, making the instrument applicable to both ultrapure water and "dirty" water, such as drinking water, which can contain a wide variety of dissolved inorganic and organic impurities and suspended particles.

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. In Revision C, a description of the optional Cleaning System was added to the manual as an appendix. Other corrections, updates, and reorganizations were incorporated.

Revision B ....January 2016
Revision C ....October 2017

TRADEMARKS AND PATENTS

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WARRANTY STATEMENT

2B Technologies, Inc. warrants its products against defects in materials and workmanship. 2B Technologies will, at its option, repair or replace products which 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 Periods

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, Inc.

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:

www.twobtech.com/techsupport

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@twobtech.com 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 trouble-shooting 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. You also may download this form from our website at http://twobtech.com/RMA.pdf.

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 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, Inc. 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, Inc., 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, Inc., 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, Inc., 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, Inc. 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, Inc., 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. INTRODUCTION: MODEL UV-106-W AQUEOUS OZONE MONITOR

The Model UV-106-W Aqueous Ozone Monitor™ uses our patented MicroSparge™ technology to measure dissolved ozone in water with high precision and accuracy. Unlike most dissolved ozone sensors, the instrument does not make use of a membrane that will foul over time. Instead, dissolved ozone is measured by nearly complete sparging (bubbling) of ~2 mL of water with ozone-scrubbed ambient air and integrating the gas-phase concentration of ozone stripped from solution. A small correction, based on the temporal profile of ozone removed from solution, is made to account for any ozone remaining in solution. Because ozone is measured in the gas phase, interferences from particles and other dissolved inorganic and organic compounds is removed, making the instrument applicable to both ultrapure water and "dirty" water, such as drinking water, which can contain a wide variety of dissolved inorganic and organic impurities and suspended particles.

1.1. Theory of Operation

Absorption of UV light has long been used for measurements of gas-phase ozone and of ozone dissolved in pure solvents 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, making UV absorbance the most accurate method for measuring ozone in ambient air and in the output streams of ozone generators. There are commercial instruments available for the direct measurement of ozone in ultra-high-purity water and other solvents, but those instruments cannot be used for drinking water and other "dirty" water because of the presence of UV-absorbing compounds and particles that absorb and scatter UV radiation as well. In addition, the concentrations of those species change upon exposure to ozone, further complicating direct UV absorbance measurements of dissolved ozone.

Sparging (bubbling) of ozone from solution followed by measurement of ozone in the gas phase has the advantage of measuring the ozone in the absence of UV-absorbing interferences that remain in the water. However, instruments designed around this principle in the past have incorporated very large and cumbersome sparging chambers and rely on a fixed value of the Henry's Law constant, which is strongly temperature dependent, that partitions ozone between the liquid and gas phases.

In our patented MicroSparge™ technology, the total quantity of ozone in a small volume of ~2 mL is sparged from solution over a period of ~5 s using ozone-scrubbed ambient air, and the ozone concentration vs time profile is measured in the gas phase. During the sparging period nearly all of the ozone is removed from solution. Integration under the ozone-time profile provides the total number of molecules of ozone in the ~2 mL sample. A small correction is made for the ozone that remains in solution based on the measured rate of exponential decay in the tail of the ozone-time profile.

Figure 1.1 is a schematic diagram of the Aqueous Ozone Monitor. Four 2-way valves and one 1-way valve direct the flow of air and water through the apparatus. The process of measuring dissolved ozone consists of two steps. In the first step (left panel of Fig. 1.1), the sample loop is overfilled with a flow of pressurized water from the water source to be analyzed, and an internal air pump pressurizes the impinger to empty ozone-depleted water from the previous sample. In the second step, valve states are changed so that ozone-free air from the air pump/scrubber both forces the ~2 mL water sample into the impinger and sparges the sample, with the ozone-enriched air passing through the optical bench where ozone is measured. Each step requires approximately 5 seconds, and a new ozone measurement is reported every 10 seconds.

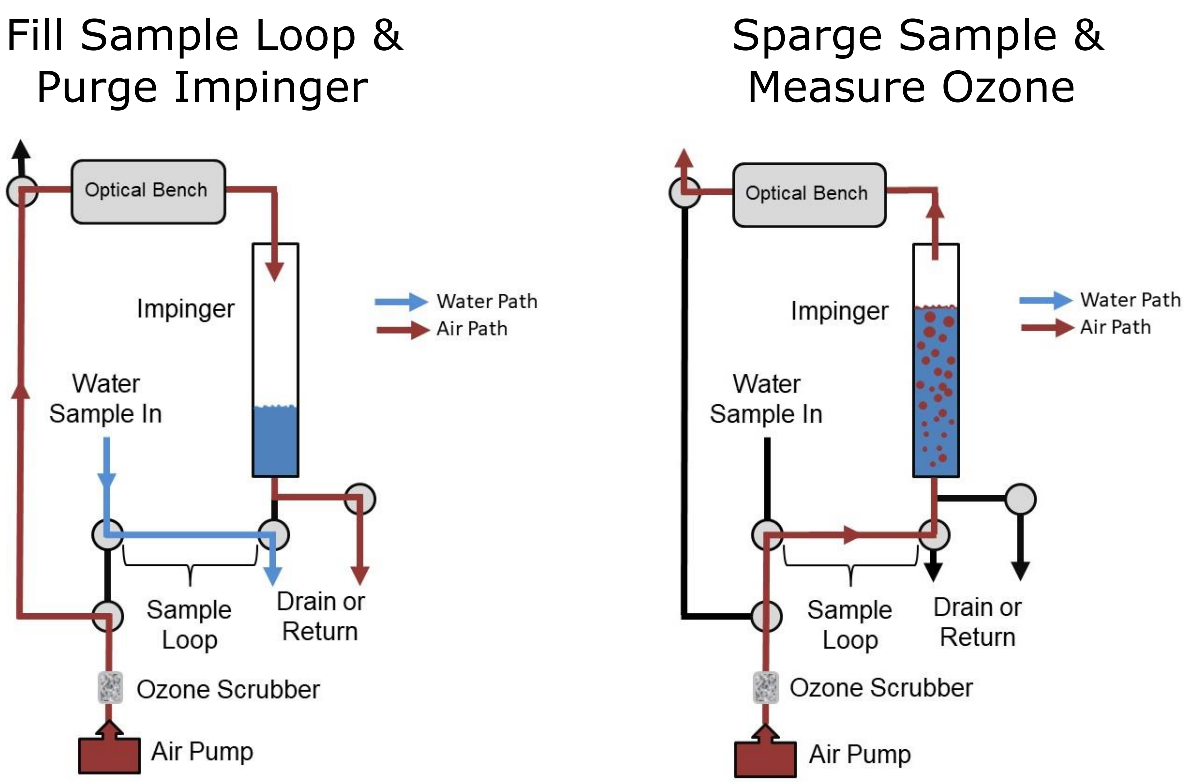


Figure 1.1. Schematic diagram of the air and water flow paths in the Aqueous Ozone Monitor. See more detailed schematic in Section 8.

The optical bench is identical to that of our Model 106-M Ozone Monitor for gas-phase ozone monitoring. Ozone is measured based on the attenuation of UV 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. Light intensity is continuously measured at a rate of 20 Hz, i.e., once every 0.05 seconds. At the beginning of the Sparge cycle (right panel of Fig. 1.1), ozone-free air remaining from the Fill and Purge cycle (left panel of Fig. 1.1) passes through the absorption cell, and the light intensity in the absence of ozone (I_o) is obtained as an average of 3 data points. The light intensity then begins to fall as ozone sparged from solution begins to pass through the detection cell.

More than 100 measurements of the light intensity (I) are made over the period of ~5 seconds required to remove >80% of the ozone from solution, and the concentration of ozone molecules is calculated for each measurement to create an ozone concentration vs. time profile using the Beer-Lambert Law,

$$C_{O_3}(molec/cm^3) = 10^9 \frac{1}{\sigma l} \ln\left(\frac{I_o}{I}\right) \quad (1)$$

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}).

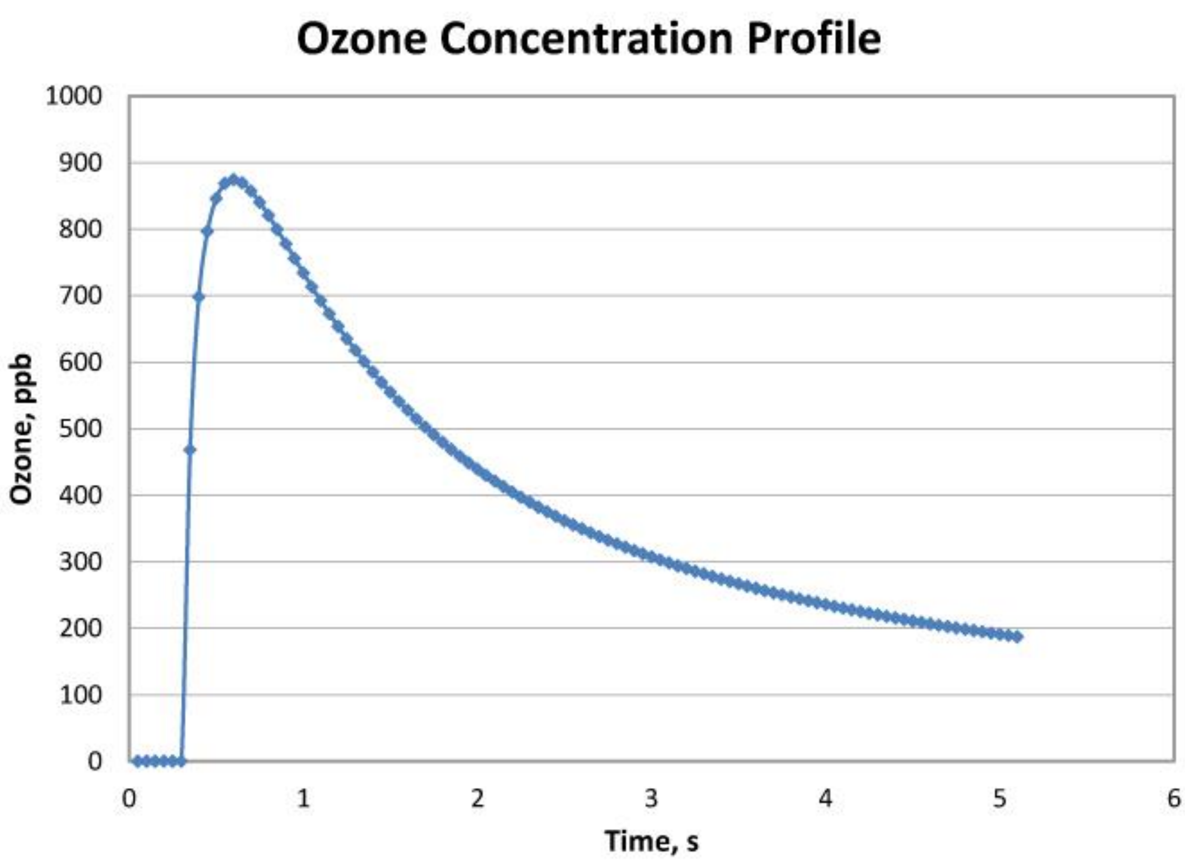


Figure 1.2. Ozone concentration vs. time profile for sparging of 2 mL of water with air. For convenience, the ozone units are converted to a gas-phase mixing ratio in parts-per-billion.

We can obtain the total number of ozone molecules in the original ~2 mL sample of water by integrating under the ozone profile curve and multiply by the volumetric flow rate, F(cm^3/s),

$$N_{O_3} = F \int_0^{\infty t} C_{O_3}\, dt \quad (2)$$

but we can only measure ozone out to some finite time t, which is about 5 s, so we can separate the integral into two parts,

$$N_{O_3} = F\int_0^t C_{O_3}\,dt + F\int_t^\infty C_{O_3}\,dt \tag{3a}$$

or

$$N_{O_3} = N_{O_3}(profile) + N_{O_3}(tail) \tag{3b}$$

Here, the integral is separated into two terms. The first term is the integral under the measured profile of Fig. 1.2 out to a time t of ~5 s. In theory, it takes an infinite time to purge all of the ozone from solution; thus, the second term is calculated based on exponential removal of ozone from solution. The exponential decay constant, k, is calculated from a fit to the last one second of measured data, and the second term, or "tail" of the ozone profile is calculated as,

$$N_{O_3}(tail) = F(C_{O_3})_t \int_0^\infty e^{-kt}dt = \frac{F}{k}(C_{O_3})_t \tag{4}$$

where $(C_{O_3})_t$ is the concentration of ozone at time t (end of measurement period) and k is the exponential decay constant (units of s^{-1}) for removal of ozone from solution. The total number of molecules of ozone in the sparged sample is given by the sum of ozone molecules measured under the ozone profile and ozone molecules calculated to be in the tail of the decay curve. Once we know the total number of molecules in the sample loop volume V, we can calculate the dissolved ozone concentration,

$$C_{O_3,aqueous}(ppm) = \frac{N_{O_3}(total)}{N_A}\frac{48}{V\,\rho_{H_2O}}\;x\;10^6 \tag{5}$$

where N_A is Avagadro's number (6.022×10^{23} molec/mol), 48 is the molecular weight of ozone in g/mol, V is the volume of the sample loop in mL (~2 mL), and ρ_{H_2O} is the density of water (1 g/mL).

Note that dissolved ozone is expressed on a weight-weight basis and that:

1 ppm = 1 μg/mL = 1 mg/L = 1 g/m^3

1 ppm = 1000 ppb

In principle, this measurement of ozone is absolute and requires no external calibration. However, non-linearity of the photodiode response and electronics and other factors can result in a small measurement error of up to a few percent. Therefore, each UV-106-W instrument is calibrated against a reference dissolved ozone monitor that itself has been calibrated using the indigo trisulfonate (blue indigo dye) method, thus providing 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 of the instrument prior to shipment. The user may change the calibration parameters from the front panel 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. As discussed below, an accurate offset correction can be measured from time to time by sampling ozone-free water.

1.2. Specifications of the Model UV-106-W

Measurement Principle (Absolute Method)	Integrated UV Absorbance of Ozone Completely Sparged from ~2 mL of Water Sample
Applications	Ozone in Clean or "Dirty" Water
Ozone Concentration Range	0-100 ppm (g/m^3, µg/mL)
Precision	Greater of 0.05 ppm or 1% of Reading
Accuracy	Greater of 0.05 ppm or 1% of Reading
Zero Drift	< 0.05 ppm per month
Measurement Frequency	10 s
Response Time	20 s
Averaging Times	10 s, 1 min, 5 min, 1 hr
Ozone Units Displayed	ppm, mg/L, g/m^3, µg/L, ppb
Temperature Units	°C, K
Pressure Units	mbar, torr
Power Requirements	11-14 V DC, 1.7 A at 12 V, 20.4 watts (1.75 A, 21 watts with Cleaning System)
Sample Water Flow Rate	Nominal: 250-300 mL/min; Range: 50-1000 mL/min
Pressure Range	0-50 psi (>100 psi Burst Pressure)
Housing	NEMA
Relays (2 in Optional Breakout Box)	0.1 ppm Resolution, 2-Level, SPDT Dry Contacts
Analog Outputs	4-20 mA, 0-2.5 V (2 point scalable)
Digital Outputs	LCD, RS232, USB
Baud Rates	4800, 9600, 38400
Logging	Internal Data Logger, 16,383 lines (10 s avg. = 1.9 days; 5 min avg = 57 days)
LED Alarms	Low Lamp, Low Flow, Invalid Measurement
Dimensions (without mounting bracket)	13.3 h × 12.0 w × 7.3 d in (33.8 × 30.5 × 18.5 cm)
Weight	15.1 lb (6.8 kg)

2. INSTALLATION

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

Save the shipping carton and packing materials that came with the Aqueous 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, please contact 2B Technologies immediately.

2.2. When to Use the Optional Cleaning System

If ozone is being measured in water that does not have a lot of precipitating solids (primarily those containing manganese and iron), the standard (i.e., "stand-alone") configuration of the Model UV-106-W Aqueous Ozone Monitor may be used.

If analyzing water that is "dirty" (i.e., contains manganese and/or iron that precipitates in the presence of ozone), it is recommended that the unit be operated with the Model UV-106-W Cleaning System. In this configuration, the Cleaning System and the Aqueous Ozone Monitor are installed and operated side by side. During operation of the Aqueous Ozone Monitor, the Cleaning System adds citrate to the sample flow at regular intervals to remove scaling and buildup of deposits.

The Model UV-106-W Cleaning System is available for separate purchase from 2B Technologies. It should be used whenever the Aqueous Ozone Monitor is sampling "dirty" water (i.e., water that will precipitate solids in the presence of ozone).

If you have any questions about whether the Cleaning System is advisable for your application, please contact us for further discussion (reach us at 303-273-0559 or support@twobtech.com).

<u>The main body of this manual describes operation of the standard configuration of the Model UV-106-W Aqueous Ozone Monitor</u>, without the Cleaning System. The installation and operation of the Cleaning System are described in Appendix A of this manual.

2.3. Setup: Stand-Alone Configuration of the Aqueous Ozone Monitor

2.3.1. Upright Mounting

The instrument must be operated in an upright position. The internal components will be damaged if the instrument is turned on while laying down on its back. If you have the wall-mount configuration of the instrument, use the holes on the NEMA enclosure to attach the instrument to your system. Alternatively, 2B Technologies offers a sturdy metal stand for purchase (Figure 2.1). The instrument can also be ordered as a free-standing configuration with legs built into the NEMA enclosure.

Figure 2.1. Optional metal stand for upright installation of the Model UV-106-W Aqueous Ozone Monitor.

2.3.1. Flow and Pressure Requirements

The Aqueous Ozone Monitor requires a slightly pressurized source of the water to be analyzed. The inlet pressure should be adjusted to produce a flow rate through the injection loop of at least 50 mL/min. This requires a differential pressure across the **Inlet** and **Return** connectors of at least ~0.3 psi, corresponding to ~8 inches of water. For safety reasons and to prevent leaks, the pressure at the **Inlet** should not exceed 50 psi. The **Inlet** pressure can be adjusted using a needle valve or other pressure regulator to achieve the desired flow rate. If your system has a sample line pressure at or greater than 50 psi, use the Pressure Reduction Needle Valve Assembly provided with your Aqueous Ozone Monitor. See Section 7, "*Optional Accessories,"* for more details. The flow rate into or out of the instrument should be in the range 50-1000 mL/min, with 250-300 mL/min being the optimal flow rate.

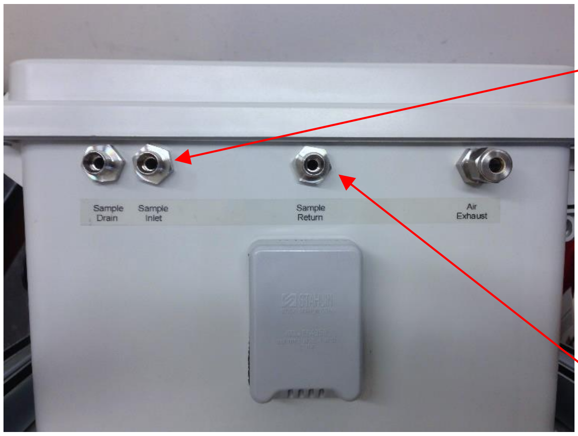


Figure 2.2. External Plumbing Connections located on the bottom of the NEMA enclosure.

2.3.2. Plumbing Connections

Sample Inlet: This port is for your sample line coming from your main water system. Attach the water source to be sampled to the **Sample Inlet** connector located at the lower left bottom of the instrument. Use ozone-compatible tubing (see below) of a length as short as possible to minimize ozone losses and reduce response time.

Sample Return: Attach a return line to the **Sample Return** connector. If you are returning this water to your system, use ozone-compatible tubing (see below) and make sure to connect to a point in your system that has a lower pressure than where your Sample Inlet line is attached. The Sample Return can be connected to the ozonized water source at a lower pressure point; i.e. downstream in a flowing system, or at a higher level (~1-5 feet higher) in a static tank. Alternatively, the Sample Return can be plumbed to a waste stream. Note that water exiting the **Sample Return** will contain dissolved ozone and pose a health hazard due to off gassing of ozone if not disposed of safely.

With no dissolved ozone present, the flow rate into or out of the instrument can be measured using a rotameter or other water flow meter in-line, and adjusted to be in the range 50-1000 mL/min, with 250-300 mL/min being the optimal flow rate.

Sample Drain: Next, connect tubing to the **Sample Drain** connector (far left connection in Figure 2.2). Both air and partially ozone-stripped water exit the drain at a pressure of a few psi. The Sample Drain can be plumbed to return to the ozone/water source if the source is not pressurized. Otherwise, the Sample Drain fluent must be disposed of through a system designed to remove ozone. Note that water exiting the **Sample Drain** will contain both air and water containing ozone and pose a health hazard due to off gassing of ozone if not disposed of safely.

Air Exhaust: If the instrument is being used in a wet/hose-down environment, attach tubing to the **Air Exhaust** port (far right in Figure 2.2) and run the tubing to an area that will not be exposed to water. Otherwise, do not attach tubing to this port.

Tubing: All connectors are ¼ inch stainless steel Swagelok fittings. The Sample Inlet tubing (and Sample Return tubing, if connected back to your water system) should be made of PTFE (Teflon®), PFA, FEP, PVDF, or some other inert material that does not destroy ozone. The length of tubing should be kept as short as possible (preferably not more than a few feet) to minimize ozone destruction within the residence time within the tubing. Tygon® or polypropylene (which may look like Teflon) should not be used. FEP-lined Tygon is recommended; it provides the flexibility of Tygon with the inertness of FEP.

2.3.3. Electrical Connections

Figure 2.3 shows the wiring harness for the UV-106-W Aqueous Ozone Monitor. On one end, a single black 8-pin female connector attaches to the 8-pin male connector on the lower left side of the Aqueous Ozone Monitor (align the notches of the connectors).

The other end of the wiring harness provides 3 connection choices:

Power Connection: The round connector at the end of the red and black wires attaches to the power connector of the 12 VDC/5 A power pack provided with the instrument. This power pack can be connected to any 120 or 240 VAC source as 50 or 60 Hz. Other DC sources in the range 11-14 V such as batteries or other power supplies also may be used, provided that they can supply up to 2.5 amp of current.

Serial Connection: A 9-pin male connector is provided to attach to the provided “straight through” serial cable using blue, brown, and yellow wires.

Analog Output Connections: Bare wires are provided for the analog outputs with white (ground), purple (4-20 mA) and orange (2.5 V).

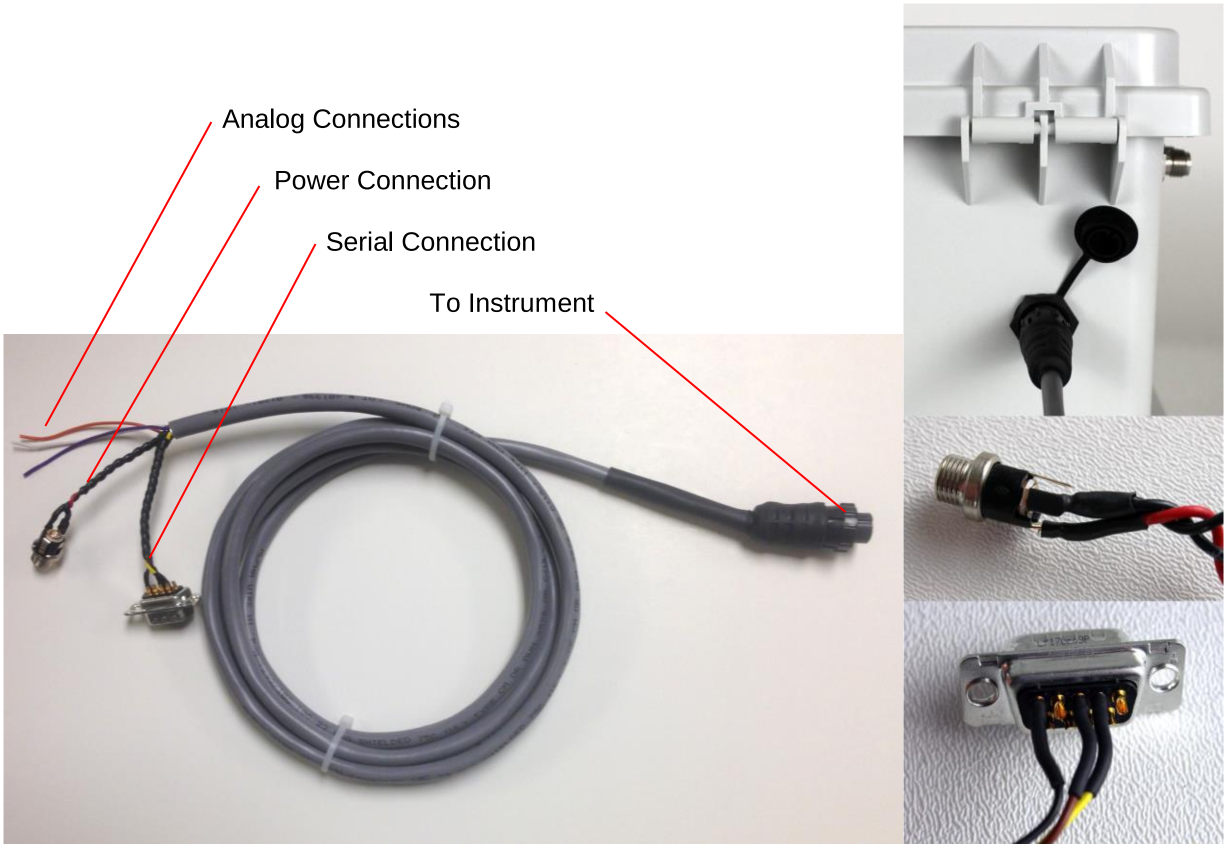


Figure 2.3. Wiring harness for Model UV-106-W.

2.4 Pre-Operation System Checks

i. **No Leaking Water:** Turn the instrument on and make sure there is no water leaking from the tubing connections or from within the instrument. If you see any leaks coming from your tubing connections: first try tightening the connections and if tightening doesn't work add plumbers tape to the threads of the ports. If there is water leaking from within the instrument there is a problem with your instrument and you should turn it off immediately and contact 2B Technologies.

ii. **Warmup the Instrument:** Allow the instrument to warmup for a minimum of 20 minutes before taking ozone measurements.

iii. **No LED Warning Lights Are Illuminated:** After the 20-minute warmup period, make sure none of the LED warning lights are illuminated on the front panel of the instrument (Low Lamp, Low Flow, and Invalid). If any of these LEDs are illuminated (other than the Power LED), there is a problem with your instrument and you should contact 2B Technologies. See Section 3.19 for additional information.

3. OPERATION

Establish the electrical and plumbing connections described above in Section 2.3, and carry out the pre-operation system checks described in Section 2.4.

3.1. Power On and Warm-Up

Power on the instrument using the Power Switch on the front panel of the instrument (see photo below). The instrument will display the version number of the software installed on the microprocessor. After a few seconds, the instrument will start displaying readings for ozone. The first dozen readings (requiring about two minutes) will be spurious, with large positive and negative swings due to the rapid warm up of the lamp and electronics. Also, dissolved ozone measurements may be inaccurate during the ~20 minutes required for the lamp, photodiode, and internal temperature of the absorption cell to stabilize.

3.2. Beginning Measurements

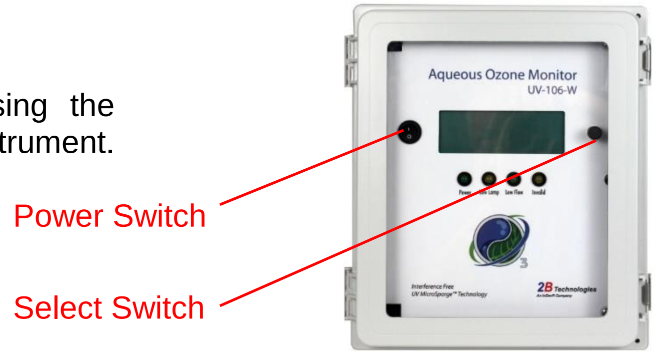
The instrument displays readings for ozone, time, and date. When first turned on, the instrument will start making measurements at a rate of once every 10 s (unless a different averaging time was previously chosen; see Section 3.5 below). Data may be viewed in real time on the LCD display of the instrument. In addition, real-time data may be output to a computer via a serial connection, and/or to a data logger via the analog current or voltage connection.

The data may be logged in the internal data logger (Section 3.6). Up to 16,383 data lines containing log number, ozone measurement, internal cell temperature, internal cell pressure, volumetric air flow rate, photodiode voltages (I_o and I; see Section 1.1), % ozone in tail, ozone decay constant, date, and time may be stored in internal memory, corresponding to an operational time of 1.9 days for 10-s measurements. Averaging times of 1 min, 5 min and 1 hr also may be selected from the menu, thereby allowing the instrument to operate for 11 days, 57 days, and 1.87 years, respectively, before filling the memory. Data from the internal logger may be output to a computer via the serial connection.

The instrument may be operated from the LCD menu as described below. Operation from the serial menu is described in Section 4 of this manual.

3.3. Accessing the Main Menu

The instrument menu is accessed using the Select switch on the front panel of the instrument.



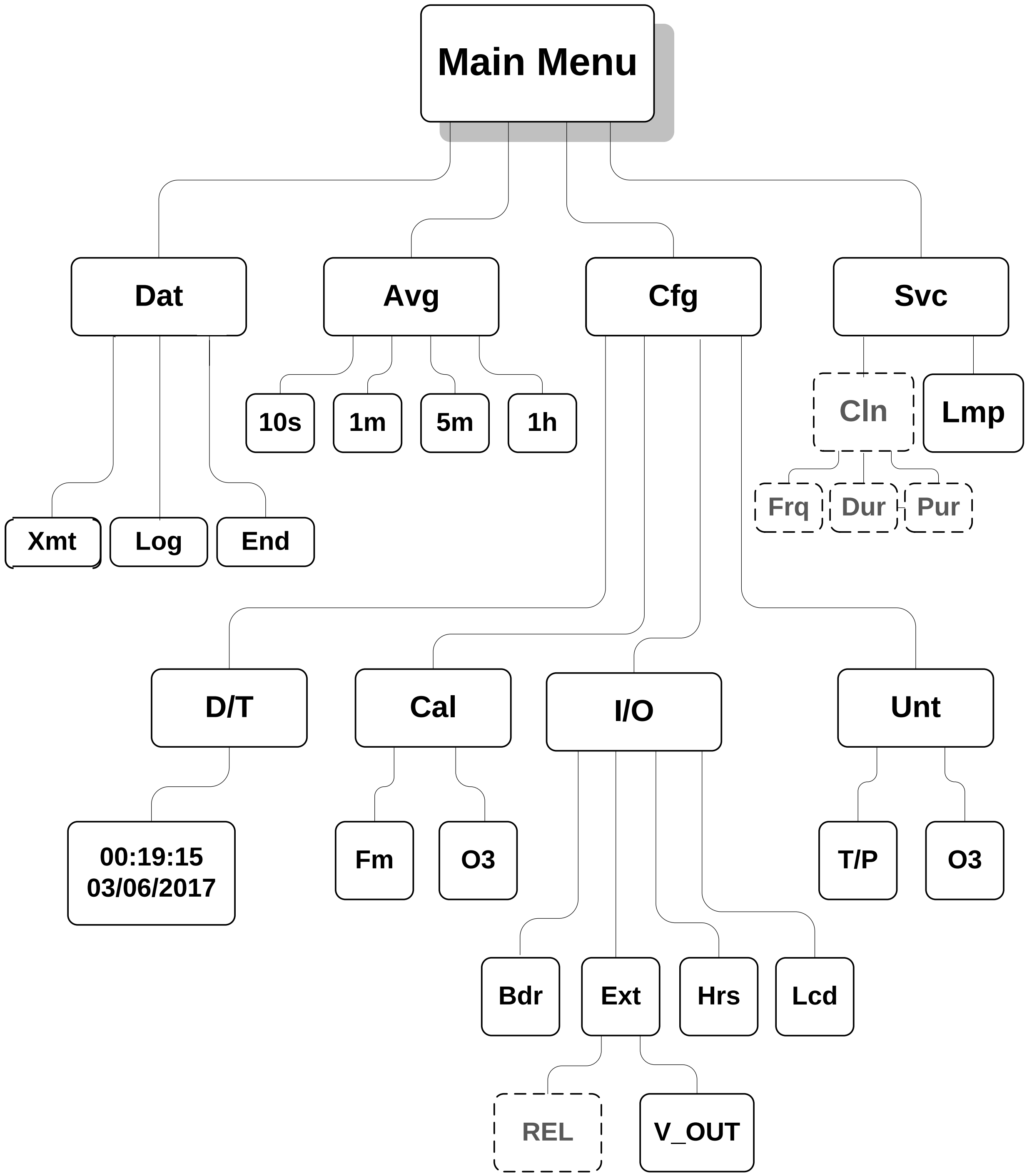
To reach the **Main Menu**, press and hold in (for up to 5 seconds) the Select switch until the display shows: **Menu**. Then release the switch. After a brief period, the panel will next display:

Menu
Dat   Avg   Cfg   Svc ←

where **Dat**, **Avg**, **Cfg**, and **Svc** are submenus that may be selected. A blinking cursor will show across the **D** of the **Dat** submenu. The Select switch may be rotated clockwise or counterclockwise to move the cursor under the first letter of one of the other submenus. To select a particular submenu, move the cursor under the first letter of a submenu and click (press in) the Select switch. To exit the Main Menu and begin making measurements again, select and click on the left arrow (←).

3.4. LCD Menu

The following diagram summarizes the complete instrument Menu that is accessible from the LCD screen.



Items shown in dashed lines are only active if the instrument has been purchased with the corresponding option.

3.5. Selecting the Averaging Time

Hold down the Select button to obtain the **Menu**. Select and click on **Avg** to obtain the **Avg** menu:

Avg Menu
10s 1m 5m 1h ←

Use single clicks to move the cursor to **10s**, **1m**, **5m** or **1h** for averaging times of 10 s (no averaging), 1 min, 5 min, or 1 hr averaging, respectively. Then click on the averaging time you want to use. You will be returned to the main **Menu.** To exit the menu and start acquiring data, click on ← again.

The Ozone Monitor will then begin displaying the most recent 10-s measurement and the current average value. For example, if 10 second averaging (no averaging) is selected, the display might read

O3= 3.211 ppm

13:05 02/05/17

where the current 10-s measurement is 3.211 ppm the time is 1:05 pm (24 hr clock), and the date is 2 May 2017 (European date format). If any other averaging time has been selected, the above display will be replaced by

O3= 3.211 ppm
Avg O3= 3.257 ppm

13:05 02/05/14

for example, where the most recent average value of ozone computed is 3.257 ppm. Though ppm is used in this example, the user can specify other units for the ozone value; see Section 3.15 below.

Note that entering the menu will interrupt the averaging interval that is in progress, and the averaging interval will start over when the menu is exited and measuring is resumed.

3.6. To Log Data

Select the **Dat** submenu from the Main Menu using the Select button. The display will now show:

Dat Menu
Xmt Log End ←

To start logging data, rotate the Select switch to move the cursor to **Log** and click to select the logging mode. You will then receive the prompt:

Logging Menu
Resume   Restart ←

Select and click on **Restart** to begin a new data log or select **Resume** to add data to a current data log. If you chose Restart, you will receive the following warning and choice of whether to overwrite all data in the logger:

This will overwrite
all existing data.
Are you sure?
No   Yes ←

Warning: If you choose Yes, all data previously stored in the logger will be irretrievably lost. **If you have data in the logger that you want to keep, be sure to download it (see below) before starting logging.**

Click on **Yes** if you are sure you want to erase all stored data start a new data log.

If data are being logged and averaged, alternate screens show the log number and the number of new measurements made for the next average (minus 1) in place of the date and time; e.g.,

O3= 3.211 ppm
Avg O3= 3.257 ppm

Log= 193:4

where **Avg O3** is the average ozone value most recently written to the logger, and the current log number is 193. The "4" in 193:4 refers to the number of 10-s data points that have been measured so far for inclusion in the next average to be displayed and logged. If 1-min averaging is used, this number will increment from 0 to 5 (displaying every other number because of the alternate date/time display); for 5-min averaging, the number will increment from 0 to 29; and for 1-hr averaging, it will increment from 0 to 359. This number is displayed so that the user will know how many more 10-s measurements need to be made before a new average is displayed and logged.

Note that entering the menu will interrupt the averaging interval that is in progress, and the averaging interval will start over when the menu is exited and measuring is resumed.

If there is a power failure while the instrument is in the logging mode, logging will resume after power is restored. A note of

Data Interrupt

will be written to the logger prior to writing the first new data line. In the case of a power failure, 2 data lines may be lost because the microprocessor writes to the logger memory in groups of 2 lines. All data residing only in the volatile memory of the microprocessor are lost when power is interrupted.

The instrument can accommodate multiple data interruptions due to power failures. For example, one can purposely switch the instrument off, move to another location and restart logging simply by turning the instrument back on. Data sets will be separated by the data interrupt message.

3.7. To Stop Logging Data

Hold in the Select button to obtain the **Menu**. Go to the **Dat** submenu by clicking on **Dat**. Choose and click on the **End** function. This will end data logging. You may now return to the **Dat** menu to transmit the data to a computer by clicking on **Xmt** (see Section 3.8 below). The stored data will reside in memory (even when new measurements are being made whether the instrument is logging or not) and can be transmitted using the **Xmt** function as often as you like.

You can append the logged data with additional data by choosing **Resume** in the Log submenu. As discussed above, all stored data are lost once logging is started again using the **Restart** function. Thus, you should always transmit your data to a computer before restarting logging.

If you fail to **End** logging prior to transmitting the data using the **Xmt** function, the instrument will automatically execute the **End** function for you prior to transmitting the data.

3.8. To Transmit Logged Data to a Computer via Serial Connection

Connect the serial port of the instrument's wiring harness (Section 2.3.3, Figure 2.3) to your computer using the supplied 9-pin cable (and serial-to-USB converter if needed). Note that this is a "straight-through" female-female serial cable. A "cross-over" cable will not work. Enable a data acquisition program on the computer such as HyperTerminal (available on earlier Windows® platforms, usually in Start/All Programs/Accessories/Communications/Hyper Terminal) or Tera Term, which can be downloaded at:

http://logmett.com/index.php?/download/tera-term-483-freeware.html

The correct settings for receiving data are: chosen baud rate (4800, 19200 or 38400); 8 bits; no parity; 1 stop bit. The baud rate for data transmission is set by the user in the **Cfg** / **I/O** / **Bdr** menu as described below. (New instruments are shipped with the default baud rate of 38400.)

Click and hold the Select button to obtain the **Main Menu**. Go to the **Dat** submenu by clicking on **Dat**. Next, click on **Xmt**. The message "Transmitting logged data" will be written to the serial port, followed by a carriage return and all of the lines of logged data. After all data are transmitted, the message "End Logged Data" and a carriage return are written. After transmission is complete, you can return to any position in the menu or resume ozone measurements. The logged data continues to be available for transmission until a new data log is started.

The output serial data line is comma-delimited ASCII text consisting of the log number, dissolved ozone concentration, detection cell temperature, cell pressure, air flow rate, light intensity I_o, average light intensity I, calculated percent of ozone in the tail of the ozone profile, ozone decay constant k, date, and time. Time is provided in 24-hour (military) format, and the date is given in European style (day/month/year).

A typical data line would read:

2893,5.606,30.8,857.9,1937.68,1.4409,1.3965,18.04,0.27,19,3448,20/07/17,20:19:37

where:

Log number = 2893
Ozone = 5.606 ppm (units as selected)
Cell temperature = 30.8°C (units as selected)
Cell pressure = 857.9 mbar (units as selected)
Air Flow rate = 1937.68 cc/min (volumetric)
Photodiode Voltage (I_o) = 1.4409 volts
Average Photodiode Voltage (I) =1.3965 volts
%Ozone in Tail = 18.04
Ozone Decay Constant (k) = 0.27
Number of 10-s data points to next cleaning cycle = 19 (ignore if not using Cleaning System)
Conductivity = 3448 microsiemens (ignore if not using cleaning system)
Date = July 20, 2017
Time = 8:19:37 pm

In addition to data lines, messages are written to the serial port when logging is begun or ended, when transmission of data from the logger is begun and ended, when data collection is interrupted (e.g., due to a power failure) and when the averaging time is changed.

3.9. To Set the Calibration Parameters

The instrument 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 instrument’s Birth Certificate and recorded on the calibration sticker on the instrument case. However, the calibration parameters may be changed by the user. For example, the instrument may develop a slight positive or negative offset due to temperature change or contamination. This offset may be removed by changing the offset (**Z**) calibration parameter. Any significant change in the slope (sensitivity, gain) calibration parameter (**S**) of the instrument is likely due to a serious problem such as contamination, an air leak or obstruction of air flow, but it also can be adjusted. Once the zero of the instrument is corrected by sampling ozone-free water and adjusting the **Z** parameter, the slope may be adjusted so that the instrument readout agrees with the readout from another instrument whose calibration is considered to be accurate. See Section 5 for information on performing zero and span checks.

To change the calibration parameters, choose the **Cfg** submenu from the main **Menu** and click on **Cal** to obtain the display

Cal Menu
Fm   O3 ←

Click on the **Fm** submenu to display the calibration factor for the air flow meter:

Fm Cal Menu
Fm= 0.92 ←

This is a multiplicative factor that will increase the indicated flow rate if you increase the value. Adjust this value to correct the measured flow rate when comparing it to a calibrated volumetric flow meter connected to the air outlet of the instrument.. When the **Fm Menu** first appears, the first digit of Fm will be underlined with a cursor. A single click will activate a blinking cursor. Change the value of Fm by rotating the Select switch to the left or right. After choosing the desired value, a click turns off the blinking cursor and allows you to scroll to ← to exit the submenu.

Click on the **O3** calibration submenu to obtain the calibration factors for ozone, for example:

Cal Menu
Z= -0.015   S= 1.01

Here Z is the offset applied (units of ppm; in this case -0.015 ppm) and S is the slope applied (in this case 1.01). 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 calibration Z is set to 0 and S set to 1.00. If the instrument reads an average of 0.018 ppm while sampling ozone-free water, the value of Z should be set to –0.018. If after correction for the zero, the instrument consistently reads 2% low, the value of S should be set to 1.02.

When the **O3 Menu** first appears, the **Z** will be underlined with a cursor. You may rotate the Select switch to choose the calibration parameter **S** or **Z**. A single click on **S** or **Z** will select that parameter for change and activate a blinking cursor. Once **S** or **Z** is selected, its value can be changed by rotating the Select switch to the left or right. After choosing the desired value, a click turns off the blinking cursor and allows you to scroll to the other parameter or to ← to exit the submenu. Once the values of **Z** and **S** are set, clicking on ← will return the display to the **Cal** menu.

The calibration parameters reside in non-volatile memory and are not affected by power failures.

3.10. To Set the Time and Date (Cfg Submenu)

From the **Main Menu**, select the **Cfg** submenu. Next, select the **D/T** submenu. The display will read, for example:

D/T: 14:32:21 ←
17/09/2017

meaning that it is 21 seconds after 2:32 p.m. on September 17, 2017 (military time and European date). To change a number in the date and time, rotate the Select switch to underline the numeral you want to change. A single click then causes a blinking cursor to cover that numeral. The number can then be changed by rotating the Select switch. Once the number is correct, click on the Select switch to turn off the blinking cursor. You may now rotate the Select switch to choose another numeral to change. Once the time and date is correct, clicking on ← will set the internal clock to that time and return the display to the **Cfg** menu. As in setting a digital watch, the seconds should be set in advance of the real time since the clock starts to run again only when the set time is entered; in this case by clicking on ←.

3.11. To Change the Baud Rate

The baud rate for transmission of data to a computer via the serial connection may be changed by going to **Menu/Cfg/I/O/Bdr** to obtain:

Baud Menu
4800 9600 38400 ←

Choosing a baud rate will automatically return you to the **I/O** submenu.

3.12. To Read the Number of Hours of Ozone Monitor Use

The instrument keeps track of the total number of hours of use. This is helpful for determining when the instrument should be serviced, a pump replaced, etc. To read the number of hours of operation choose **Menu/Cfg/I/O/Hrs**. Click the back arrow ← to exit.

3.13. Collecting Data from the Analog Output

The data may be read or logged in real time using a data logger attached to bare wires provided for voltage output (0-2.5 V; white = ground, orange = positive voltage) and current output (4-20 mA; white = ground, purple = positive current).

To change the analog output voltage scaling factor, go to **Menu/Cfg/I/O/Ext/V_OUT**. The display will read for example:

2.5V=00050 ppm
20mA=00020 ppm ←

Here, the output scaling factor is set as 2.5 Volt (full scale) = 50 ppm; i.e. 1 Volt = 20 ppm. Also, the current output will be scaled such that the full scale of 20 mA corresponds to 20 ppm. A reading of zero ozone concentration will be output as 0 V and as 4 mA. You can use the Select switch to change the scaling factor to the value of your choice by selecting and changing the individual digits in the scaling factor of either the voltage or current.

Thus, the instrument is not limited to a fixed number of “ranges” common to most ozone monitors. Instead, any range can be defined.

3.14. Optional Relays

If the instrument has been purchased with the optional relays, their settings are accessed from the **Cfg** / **I/O** / **Ext** / **REL** menu.

With the optional relays, the Aqueous Ozone Monitor may be used to control other devices, such as ozone generators. **Relay 1** may be used for ozone set points, for example to set limits for high levels of ozone. **Relay 2** may be used for a second set of ozone set points (for example, in the low ozone range), or instead could be used for diagnostics such as temperature, pressure, flow rate, or lamp voltage.

To set the On and Off limits of a relay, choose **REL** from the **Cfg / I/O / Ext** submenu. The menu will show, for example:

Relay 1
On =0090.00 ppm
Off=0100.00 ←

With these settings, 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. You may now move the cursor using the Select switch to choose the digits in the On and Off relay settings: choose a digit to change by depressing the Select switch, and rotate the Select switch to change those settings. To choose another digit to change, depress the Select switch again to remove the blinking cursor. Click the arrow to access Relay 2. When finished setting Relay 2, click the arrow to exit.

3.15. To Change the Ozone, Temperature, and Pressure Measurement Units

From the **Cfg** submenu, choose the **Unt** submenu:

Unt Menu
T/P O3 ←

Choose O3 to change the ozone units:

O3 Units Menu
Ozone: ppm ←

Select **ppm**, depress the Select switch to obtain a blinking cursor and rotate the Select switch to choose between units of ppm, g/m^3, mg/L, μg/L, and ppb. Note that ppm, g/m^3, and mg/L are the same numerically, so you are only changing the text displayed. Similarly, ppb and μg/L are the same numerically. Press the Select switch again to remove the blinking cursor, and return to the **Unt** menu using the left arrow. Ozone concentrations will now be calculated and reported in the chosen units.

Temperature and pressure a measured within the detection cell to correct the measured mass flow rate to volumetric flow rate. Select T/P from the **Unt** submenu to change the units reported for temperature and pressure:

T/P Units Menu
T:C P:mbar ←

You may now select units of degrees C or K for temperature and mbar or torr for pressure using the same procedure used to set the units for ozone concentration.

3.16. Lamp Test

If the instrument is excessively noisy (standard deviation greater than 2 ppb) or always reads near zero 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 20 minutes.

Choose **Lmp** from the **Svc** (Service) menu. The display will momentarily read "**Lamp Test**". The photodiode voltage will then be displayed, and after a few lamp measurements have been made, the electronic offset and standard deviation also will be displayed as, for example:

Va= 1.29801 V
A=1.2+/-1.85 ←

The photodiode voltage (Va) 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 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 (in ppb) of the measurement itself, displayed in the above example as 1.2 ppb for the electronic offset and +/-1.85 for the standard deviation. The standard deviation is a quantitative measure of the lamp and associated electronic noise. Electronic offsets should normally be -10 to 10 ppb equivalent. After running the lamp test for a few minutes, values above 5.00 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 scrubber replaced. Please contact us for detailed procedures if you want to perform these operations on site.

To exit the Lamp test, press/hold in the Select switch and then release it.

3.17. Settings for Optional Cleaning System

As mentioned in Section 2.2, the Aqueous Ozone Monitor may be purchased with an optional Cleaning System, which prevents buildup of precipitating solids when analyzing water that is "dirty" (i.e., contains manganese and/or iron that precipitates in the presence of ozone). The Cleaning System injects small amounts of citrate into the Aqueous Ozone Monitor at regular intervals, as defined by settings accessible from the **Svc** / **Cln** menu. The default cleaning frequency is every 30 minutes. At that frequency, the citrate valve will open momentarily to add citrate to the sample flow for a short duration. If any discoloration is seen in the lines to or from the Aqueous Ozone Monitor or the internal sparging chamber, the frequency of the cleaning should be increased. To change the cleaning parameters for frequency and duration, access the **Svc** / **Cln** menu.

See Appendix A for more details on the installation and operation of the Cleaning System.

3.18. To View the Flow Rate, Lamp Voltage, and % Ozone in Tail on the LCD

Additional diagnostic information may be viewed during normal operation of the Aqueous Ozone Monitor. Rotate the Select switch in either direction to view this information on the LCD:

O3= 3.211 ppm
Avg O3= 3.257 ppm
Flow = 1985 cc/min
Lamp = 1.4 V   Tail = 17.573

Here, the LCD shows the current air flow rate (expected range: 600-2000 cc/min, typically ~1500-2000 cc/min), lamp intensity (expected range: 0.6-2.2 volts), and the most recent measurement of the percent of ozone in the tail (typically ~15-20%).

3.19. Instrument Warning Lights

Three warning lights are provided on the front panel of the Aqueous Ozone Monitor. If any of these lights are illuminated during operation, there is a problem with your Monitor:

Low Lamp: This light will illuminate if the voltage of the photodiode drops below 0.4 volts. Perform a Lamp Test (Section 3.16) to investigate the problem further. The lamp may need to be replace.

Low Flow: This indicates that the air flow rate to the instrument is too low. Air flow to the instrument must be at least 1800 mL/min. First try adjusting the bleed valve that is attached to the ozone pump to bring the flow rate up above 1800 mL/min. If that fails to solve the problem, the pump may need replacement.

Invalid: This light will illuminate if the ozone reading is greater than 20,000 or less than -2,000 (regardless of the units chosen for ozone). Readings this high or low could be an indicator that water has entered the optical bench of the instrument. This could happen if the instrument is operated on its back, rather than in the required upright position (see Section 2.3.1).

4. OPERATION VIA THE SERIAL CONNECTION

4.1. Setting Up for Serial Operation

Connect the serial port of the instrument's wiring harness (Section 2.3.3, Figure 2.3) to your computer using the supplied 9-pin cable (and serial-to-USB converter if needed). Note that this is a "straight-through" female-female serial cable. A "cross-over" cable will not work. Enable a data acquisition program on the computer such as HyperTerminal (available on earlier Windows® platforms, usually in Start/All Programs/Accessories/ Communications/Hyper Terminal) or Tera Term, which can be downloaded at:

http://logmett.com/index.php?/download/tera-term-483-freeware.html

The correct settings for receiving data are: chosen baud rate (4800, 19200 or 38400); 8 bits; no parity; 1 stop bit. The baud rate for data transmission is set by the user in the **Cfg** / **I/O** / **Bdr** menu as described below. (New instruments are shipped with the default baud rate of 38400.)

4.2. Collecting Data over the Serial Port in Real Time

To transmit data to a computer over the serial port in real time, establish the serial connection and enable your data acquisition program as noted above.

The dissolved ozone concentration, detection cell temperature, cell pressure, air flow rate, light intensity I_o, average light intensity I, calculated percent of ozone in the tail of the ozone profile, ozone decay constant k, time until next cleaning cycle, conductivity, date, and time are sent as comma-delimited ASCII text to the serial port of the instrument (4800, 9600 or 38400 baud as selected in menu; 8 bits; no parity; 1 stop bit) every ten seconds, 1 minute, 5 minutes, or 1 hour, depending on the averaging time selected from the instrument menu. Time is provided in 24-hour (military) format, and the date is given in European style (day/month/year).

A typical data line would read:

5.606,30.8,857.94,1937.68,1.440997,1.396549,18.04,0.27,19,3448,20/07/17,20:19:37

where:

Ozone = 5.606 ppm (units as selected)
Cell temperature = 30.8°C (units as selected)
Cell pressure = 857.94 mbar (units as selected)
Air Flow rate = 1937.68 cc/min (volumetric)
Photodiode Voltage (I_o) = 1.44097 volts
Average Photodiode Voltage (I) =1.396549 volts
%Ozone in Tail = 18.04
Ozone Decay Constant (k) = 0.27
Number of 10-s data points to next cleaning cycle = 19 (ignore if not using Cleaning System)
Conductivity = 3448 microsiemens (ignore if not using Cleaning System)
Date = July 20, 2017
Time = 8:19:37 pm

If outputting logged data, the output serial data line will be preceded by the log number:

2893,5.606,30.8,857.94,1937.68,1.440997,1.396549,18.04,0.27,19,3448,20/07/17, 21:19:37

where 2893 is the log number.

In addition to data lines, messages are written to the serial port when logging is begun or ended, when transmission of data from the logger is begun and ended, when data collection is interrupted (e.g., due to a power failure) and when the averaging time is changed.

4.3. 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 above in Section 4.1 of this manual. Listed below are the lower-case letters that are commands for performing certain operations while the instrument continues to measure:

l	Start logging
b	Resume logging
t	End logging and transmit data
e	End logging
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 menu items accessible from this point:

Serial Menu Commands

l	Start logging (also available during measurements).
b	Resume logging (also available during measurements).
t	End logging and transmit data (also available during measurements).
e	End logging (also available during measurements).
a	Set average and output frequency.
z	Set the zero offset calibration factor.
s	Set the slope calibration factor.
f	Set the flow calibration factor.
c	Set the time and date (enter “n” if no change).
d	Turns the LCD backlight on.
g	Turns the LCD backlight off.
p	Performs lamp test.
h	Output the serial header (also available during measurements).
w	Runs 100 samples to calibrate sample loop size.
o	Toggle output of photodiode measurements.
?	Print help menu
x	Exit menu

5. PERIODIC ZERO AND SPAN MEASUREMENTS

The instrument 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 instrument's Birth Certificate and recorded on the calibration sticker on the instrument case. However, the calibration parameters should be periodically checked and if needed, may be changed by the user. For example, the instrument may develop a slight positive or negative offset due to temperature change or contamination.

Step 1. To perform these checks, first set the S and Z values to 1.00 and 0.000, respectively. This may be done from the front panel (as described in Section 3.9) or from the serial menu using the **s** and **z** commands (Section 4.3).

Step 2. The zero offset calibration parameter (Z) is checked by sampling water containing no dissolved ozone such as tap water. For an accurate measurement, the instrument must have been turned on long enough for the internal temperature to stabilize, which at room temperature is usually about 20 minutes. The observed offset, which is usually less than ± 0.02 ppm, can be corrected for by changing the offset calibration parameter (Z) from the front panel, as described in Section 3.9, or from the serial menu using the **z** command, as described in Section 4.3. For example, if the instrument reads 0.007 when sampling ozone-free water, the Z parameter should be set to -0.007.

Step 3. If possible, it is desirable to also check and adjust the slope parameter (S) periodically by performing a span measurement. This is done by sampling water with a known dissolved ozone concentration, and adjusting the S calibration parameter based on whether the instrument is reading higher or lower than the known ozone value. For example, if after correction for the zero offset the instrument reads 2% lower than the known concentration, the S parameter should be set to 1.02.

It is recommended that the Aqueous Ozone Monitor be returned to 2B Technologies at least annually for a full calibration.

6. MAINTENANCE/TROUBLESHOOTING

The UV-106-W Aqueous Ozone Monitor™ is designed to be nearly maintenance free. The only components that require routine maintenance are the internal ozone scrubber and the internal sparging chamber, which should both be changed at least once annually. We recommend replacement of the sparging chamber when the interior of the chamber and the Teflon beads are entirely coated with a dark brownish residue. The amount of time until the sparging chamber needs to be replaced is dependent on how “dirty” the water is that you are sampling and how long the instrument has been sampling (in some extreme cases with particularly “dirty” water we recommend replacement of the sparging chamber every few months).

To change the ozone scrubber, remove the two screws that hold the interior door closed and open the door to expose the instrument’s internal components. The ozone scrubber consists of two ozone scrubbing cartridges in series. The ozone scrubber can easily be replaced by disconnecting the silicone attached to each end and connecting a new one in its place.

To change the sparging chamber, remove the two screws that hold the interior door closed and open the door to expose the instrument’s internal components. The sparging chamber is the tube on the right side of the instrument containing many small Teflon beads. To remove the sparging chamber, first unscrew the top bulkhead nut. Next, remove the chamber via the quick release fitting at the bottom. Install the new chamber in its place.

Other components with a limited lifetime are the air pump (~15,000 hours), lamp (~20,000 hours), and solenoid valves (rarely fail). 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 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.

Lamp Failure: The ozone measurements will be erratic and the Lamp Test will show 0.0 volts for the photodiode voltage.

Solenoid Valve Failure: The ozone readings will be low and possibly highly erratic if one or more of the solenoid valves are failing to open and close properly.

Contaminated Air Flow Path: The instrument will typically have a large positive or negative offset.

Three warning lights are provided on the front panel of the Aqueous Ozone Monitor. If any of these lights are illuminated during operation, there is a problem with your Monitor:

Low Lamp: This light will illuminate if the voltage of the photodiode drops below 0.4 volts. Perform a Lamp Test (Section 3.16) to investigate the problem further. The lamp may need to be replaced.

Low Flow: This indicates that the air flow rate to the instrument is too low. Air flow to the instrument must be at least 1800 mL/min. First try adjusting the bleed valve that is attached to the ozone pump to bring the flow rate up above 1800 mL/min. If that fails to solve the problem, the pump may need to be replaced.

Invalid: This light will illuminate if the ozone reading is greater than 20,000 or less than -2,000 (regardless of the units chosen for ozone). Readings this high or low could be an indicator that water has entered the optical bench of the instrument. This could happen if the instrument is operated on its back, rather than in the required upright position (see Section 2.3.1).

Help with trouble shooting is provided in the following table:

Table 6.1. Troubleshooting the Aqueous Ozone Monitor for performance problems.

Problem/symptom	Likely cause	Corrective action
Instrument does not turn on.	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.	Remove cover to circuit board chamber and unplug air pump. Turn instrument on; if it remains running, then the air pump motor is burned out and shorting. Replace air pump.
Display is blank or nonsense.	Bad connection of display to circuit board.	Remove cover to circuit board chamber and reconnect display to circuit board. Check solder connections to display. A new LCD may be required.

Cell temperature reads low by several 10's of degrees.	Absent or loose connection of temperature probe cable to circuit board.	Remove cover to circuit board chamber and reattach connector to circuit board.
Readings are noisy with standard deviations greater than 0.05 ppm.	Lamp output is weak, below 0.4 V on Lamp Test. Flow path contaminated.	Remove covert to circuit board chamber and check lamp connection to circuit board. Run Lamp Test from menu. If photodiode voltage is less than 0.4 V, replace lamp. Clean flow path of optical bench with methanol (call 2B Tech).
Analog output is constant or does not track front display.	Cable not properly connected between analog output and recording device. Wrong scaling factor selected in menu.	Check continuity of your analog cable to your recording device and make sure correct connector pins are being used. Check and reset analog output scaling factor in the Menu.
Select switch does not work.	Bad solder joint to circuit board or damaged Select switch.	Open internal door by removing the two screws and check solder connection to Select switch. It may be necessary to replace the Select switch.
Serial port does not work.	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.

	Wrong baud rate selected. Wrong computer com port chosen.	Make sure that the baud rate chosen in the menu matches the baud rate setting of your data acquisition program. Try choosing other com ports in the data display software.
Required calibration parameters are large (>±0.2 ppm offset and/or >±10% slope) when calibrated against a known aqueous ozone concentration.	Air flow path is contaminated. One or more solenoid valves are contaminated and not opening and closing properly. Air pump is not providing sufficient flow. Sparging chamber contains dark brownish residue which is destroying some of the ozone.	Clean flow path with methanol (contact 2B Tech). Make sure that both water and air are exiting the instrument. Replace any solenoid valve that is not working properly. As a first check, hold your finger over the air outlet to determine whether air is flowing. Also, rotate Select switch one click to obtain a display of the air flow rate. Air flow should be greater than 1800 cc/min. If the flow rate is lower, try adjusting the bleed valve. Next check for leaks. If there are no leaks, replace air pump. Replace the sparging chamber.

2B Technologies strongly recommends sending the UV-106-W back to the factory for annual service and calibration. In the annual service: we will replace the internal ozone scrubber, sparging chamber, clean the entire flow path of the instrument, and test all of the components for proper function. 2B Technologies offers reasonably priced customer service for instrument repairs. The best way to contact us for service is to log a customer service ticket at www.twobtech.com/techsupport. Normally, you will hear back from us by email within a few hours. Or, call us at +1(303)273-0559.

There is a great deal of technical information about our instruments posted as technical notes at www.twobtech.com/tech_notes.htm. Manuals, brochures, software, cleaning procedures and scientific papers may be downloaded from our website at www.twobtech.com/downloads.htm.

7. OPTIONAL ACCESSORIES

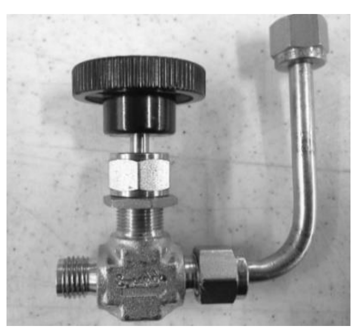
In addition to the Cleaning System described in Appendix A, 2B Technologies offers various optional accessories to make the UV-106-W work for your specific application. For more information and pricing details on any of the following accessories contact 2B Technologies Customer Service Department.

7.1. Metal Stand

2B Technologies offers a sturdy metal stand to hold up the UV-106-W for applications without somewhere to mount the instrument.

7.2. Pressure Reduction Needle Valve Assembly

The acceptable water pressure range for the UV-106-W is 0-50 psi. If the water system you are measuring from has a sample line pressure greater than 50 psi, our Pressure Reduction Needle Valve Assembly will be required to reduce your sample line water pressure to the acceptable range. The Pressure Reduction Needle Valve Assembly contains a stainless steel “Integral Bonnet Needle Valve” which is rated to handle a system pressure up to 5000 psig @ 100ºF. One is included with every instrument when purchased.



8. INSTRUMENTS PHOTOS

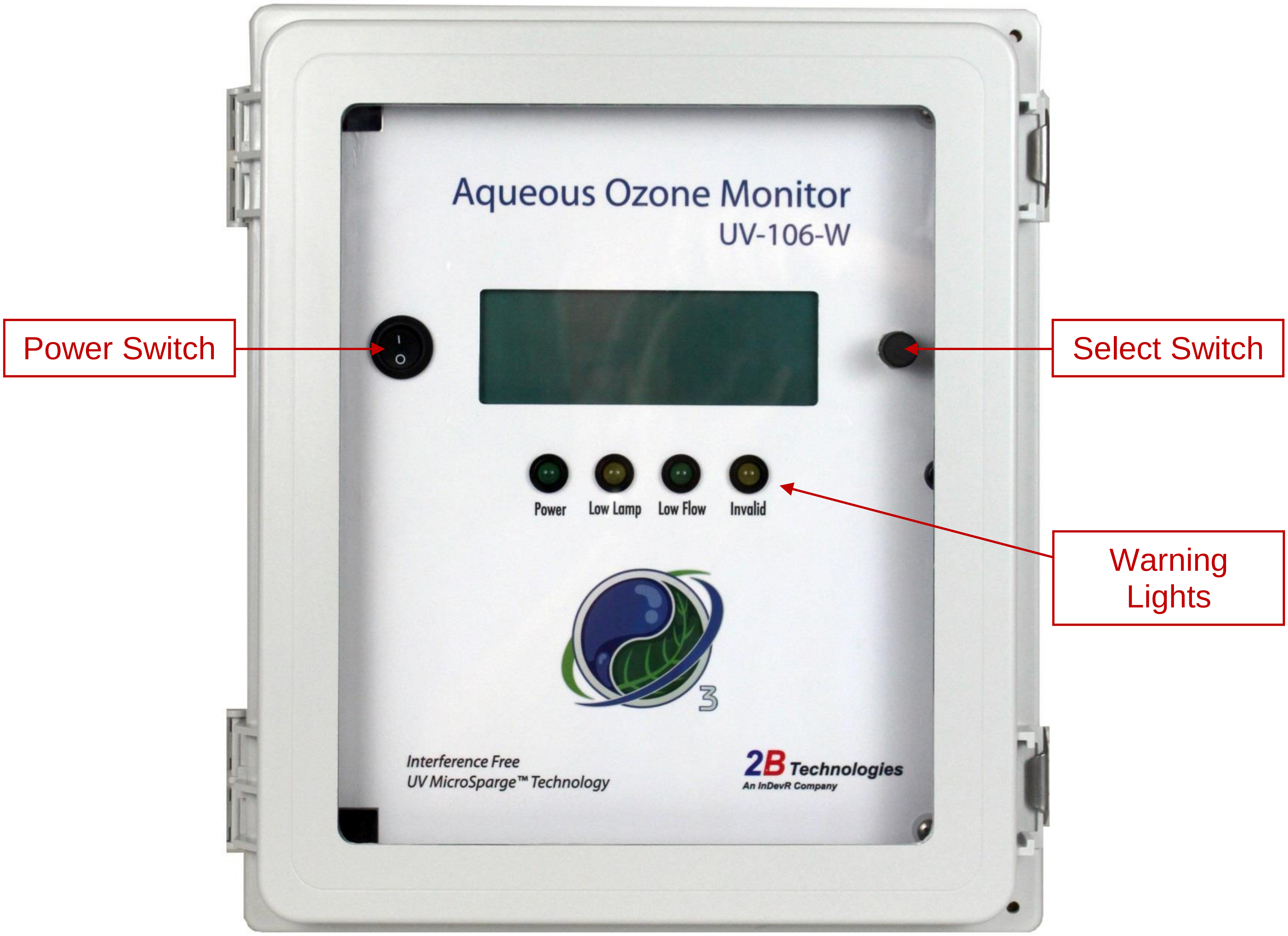


Figure 8.1. Front View of Model UV-106-W.

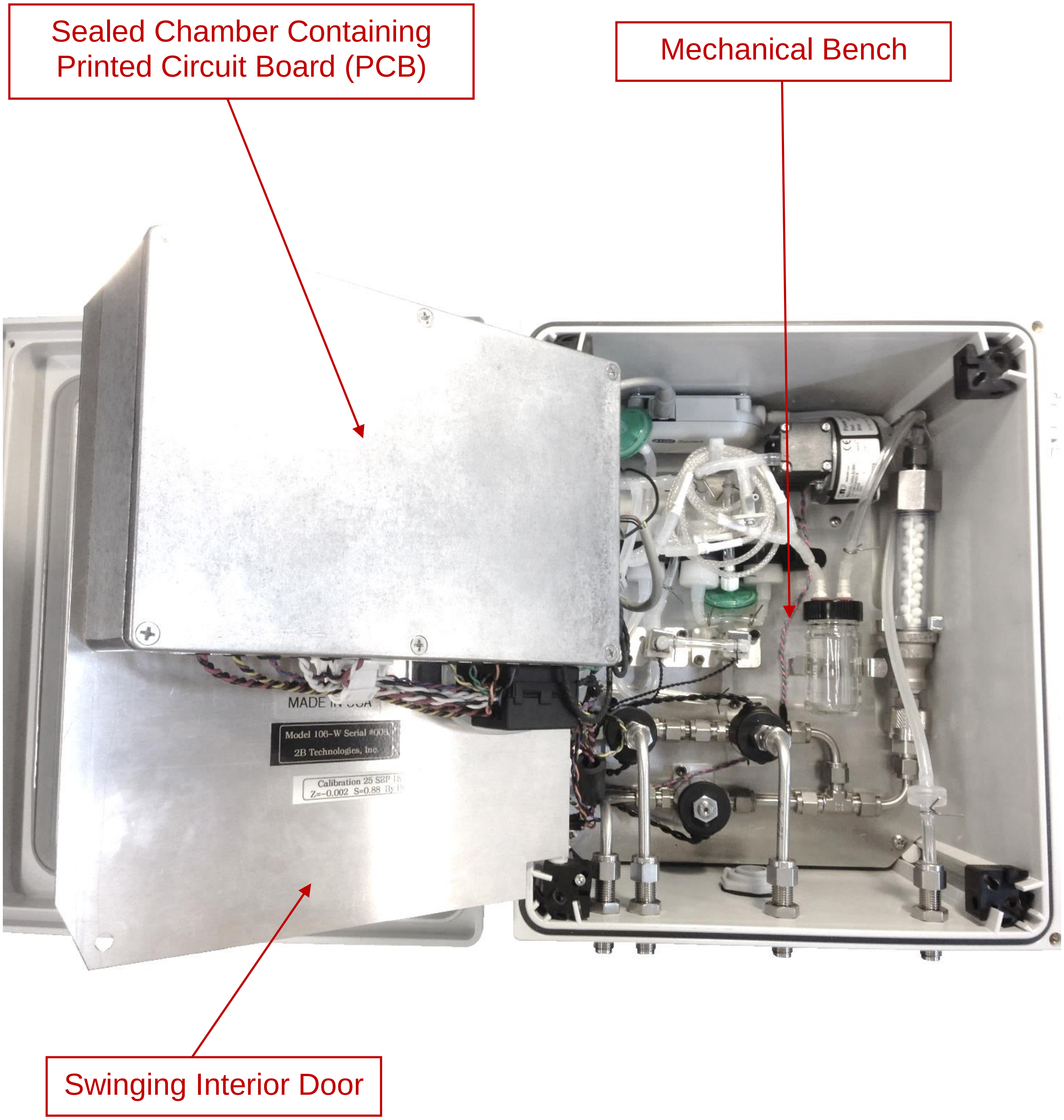


Figure 8.2. Inside View of Model UV-106-W.

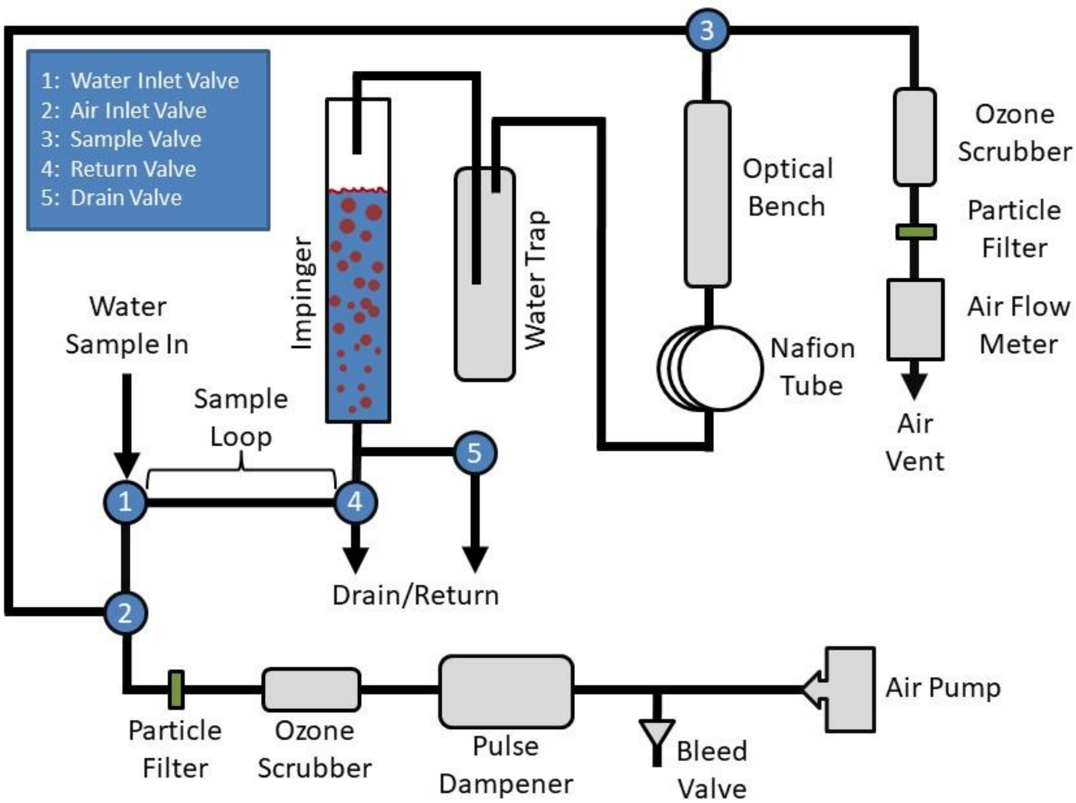


Figure 8.3. Schematic Diagram of Model UV-106-W Aqueous Ozone Monitor.

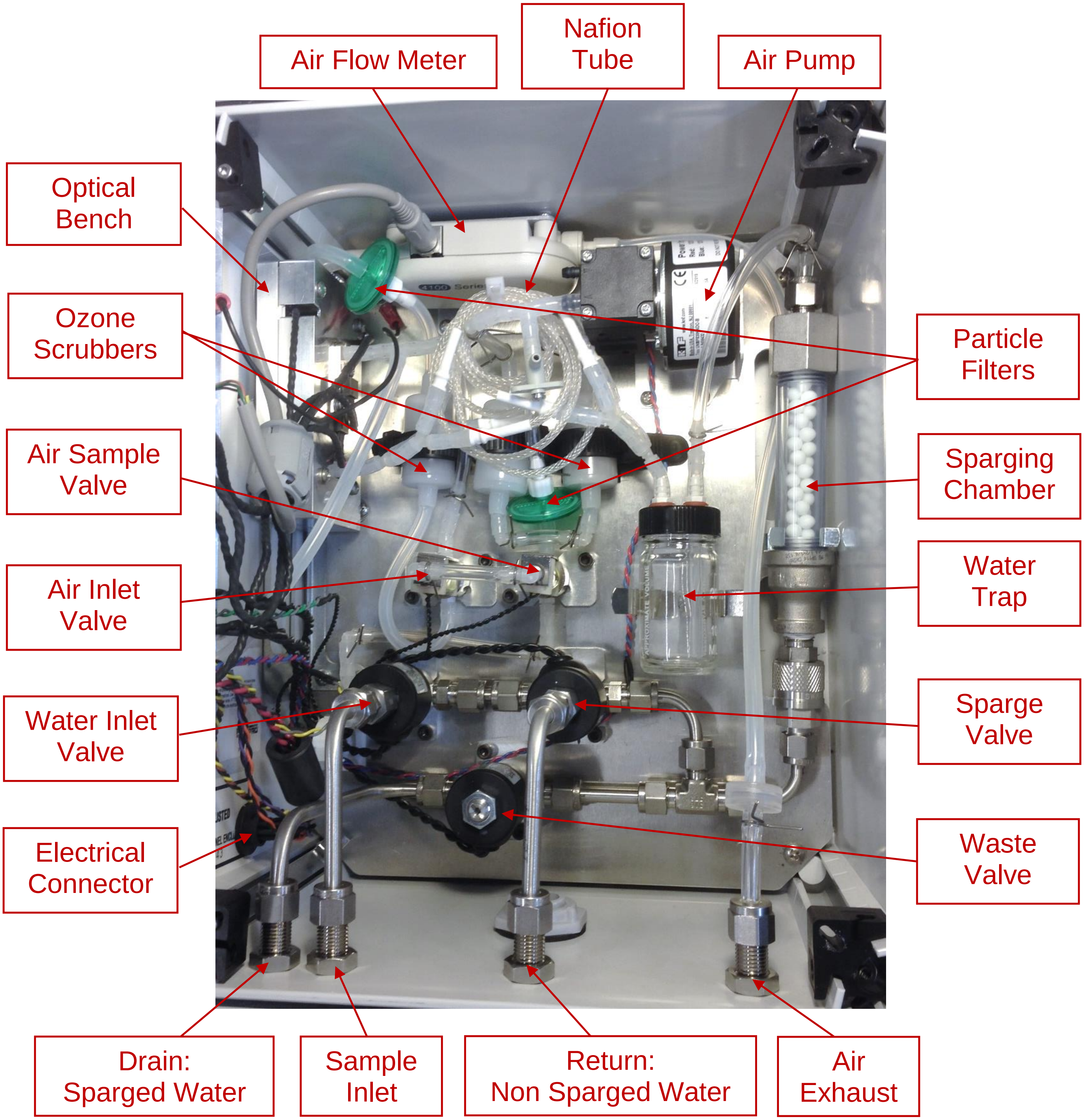


Figure 8.4. View of Mechanical Bench. Compare to previous figure.

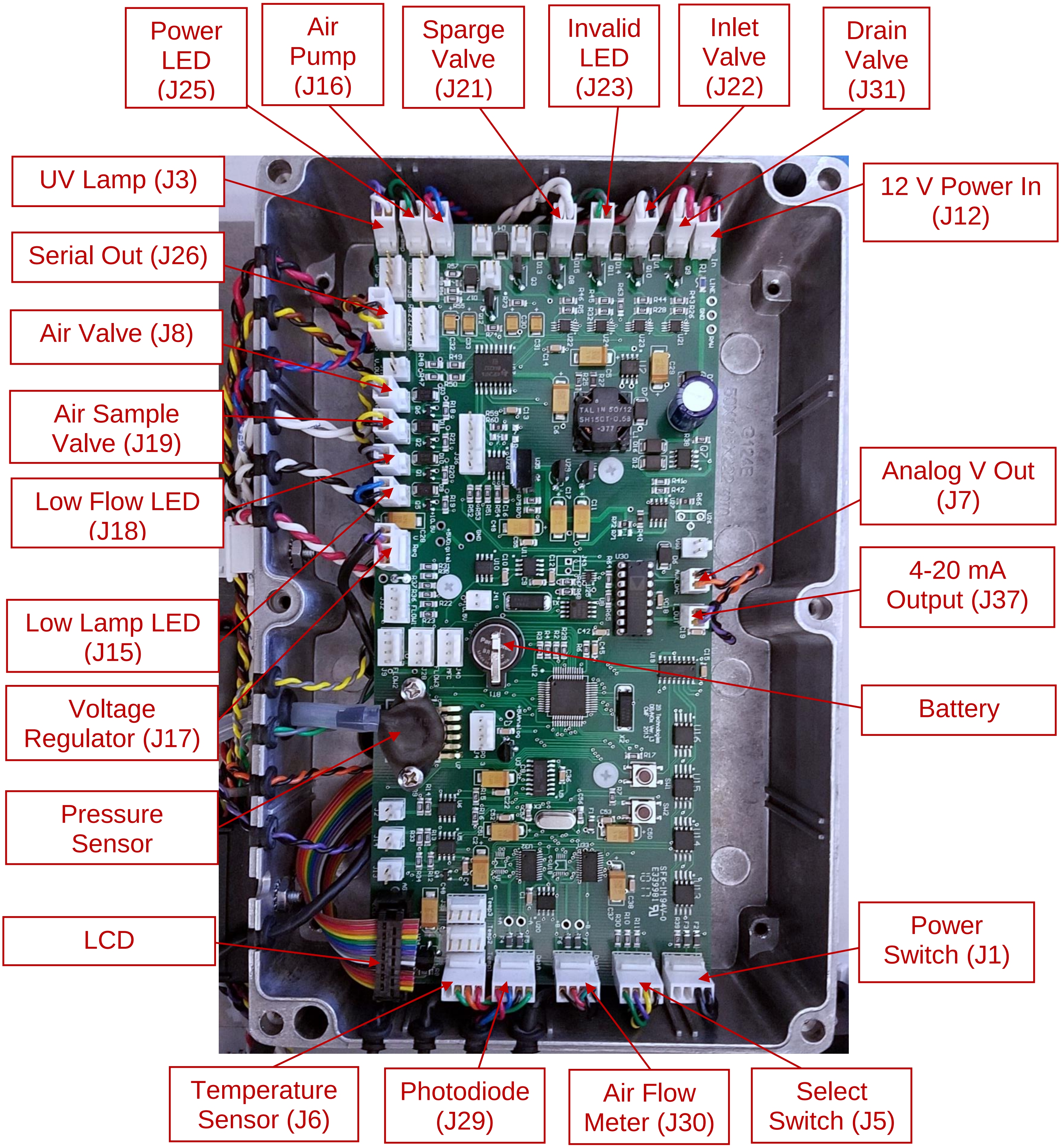


Figure 8.5. Printed Circuit Board.

9. PARTS LIST

The following list includes those parts that are user serviceable. Please contact us for information and pricing (303 273 0559, sales@twobtech.com).

Part Number	Description
SCRBINT106W	Ozone scrubber
SPARGECHAM106W	Sparging chamber
OZLAMP106W	Lamp and inverter
OZVLV106W(AIR)	Air solenoid valve
OZVLV106W(3WAY)	Water solenoid valve, 3-way for 106-W
OZVLV106W(2WAY)	Water solenoid valve, 2-way for 106-W
OZDSP106W	LCD display and cable
OZPUMP106W	Air pump
PDASSEMBLY106W	Photodiode assembly and cable
OZCELLAS106W	Absorption cell
PRESSREDVLV106W	Pressure reduction needle valve assembly
CLNSYS106W	Cleaning System
SERCABL	Serial port cable (to computer)
TEFTYG05	Teflon-lined Tygon® tubing (5 ft)
TEFTYG25	Teflon-lined Tygon® tubing (25 ft)
SILTUB05	Silicone tubing (5 ft)

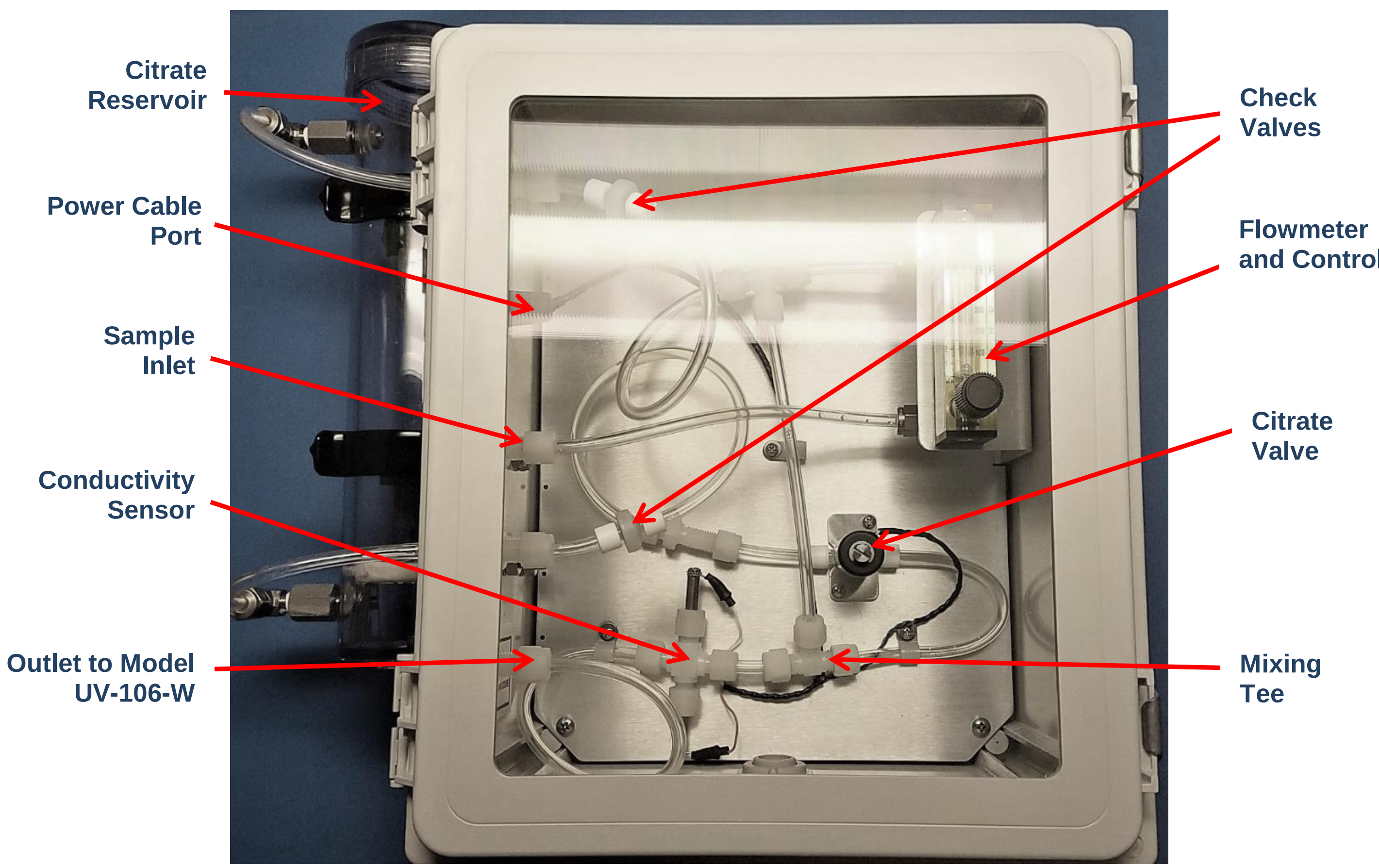
10. SERVICE LOG

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

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

Appendix A: Installing and Operating the Optional Cleaning System

The Cleaning System adds citrate to the sample flow at regular intervals to remove scaling and buildup of deposits in the Model UV-106-W Aqueous Ozone Monitor™. Citrate is added to the sample flow from a reservoir using an automated valve system. A full reservoir provides enough citrate for at least a month and the reservoir has a large screw cap that can be removed for easy filling. A conductivity sensor is installed after the mixing tee to provide diagnostic data on the system and verify that the citrate valve is operating properly. Conductivity data is output via the serial data stream of the Model UV-106-W.



1. **Installation**

   A. Freestanding System: Simply push on the legs on either side of the Cleaning System where it says "push". This will unlock the legs and allow them to extend down to hold the Cleaning System upright.

   Wall Mounted System: Use the provided bolts, nuts, and lock washers to mount your Cleaning System to your wall or rack. The six slotted-holes on the top and bottom of the Cleaning System brackets are the mounting holes.

   B. Verify that flow is prevented through the system by turning the knob on the flow meter all the way clockwise until it stops and the flow meter reads 0 cc/min.

   C. Connect the sample line coming from your water system to the "Inlet" fitting on the side of the Cleaning System. We recommend that all Swagelok nuts be tightened ¼ turn past finger-tight to ensure a leak-free connection. In order to provide the most accurate ozone measurements, it is important that you make both the inlet and outlet lines (with ozone compatible tubing) as short as possible and without kinks.

   D. Install a water line coming from the fitting labeled "Outlet" on the Cleaning System to the fitting labeled "Inlet" on your Model UV-106-W.

   E. Remove the lid of the citrate reservoir.

   F. Add clean water (tap water will suffice) into the citrate reservoir to bring the liquid level to quarter of the way full.

   G. Fill the reservoir with citric acid powder, being careful not to spill as citric acid will leave a sticky residue and can cause skin irritation. Food-grade citric acid is readily available and is a non-toxic cleaning reagent. Consult the citric acid manufacturer's Material Safety Data Sheet for further information on safety and handling.

   H. If the liquid level is not above the top port on the side of the citrate reservoir, slowly add more clean water to the reservoir. Fill the reservoir until water is above the top port on the side of the reservoir.

   I. Make sure the lip around the top of the citrate reservoir is clean as well as the O-ring on the reservoir lid before installing the lid. Any citric acid powder on the rim of the reservoir or O-ring can prevent a water tight seal and may result in leaks.

J. Install the lid hand-tight. It is important not to overtighten the lid as this will make it extremely difficult to remove when refilling the citrate reservoir.

K. Verify that all connections, including the lid of the citrate reservoir, are tight and the plumbing is secure.

L. Securely connect one side of the "Cleaning System Power Cable" into the black 4-pin power cable port on the left side of the Cleaning System (location shown in the first photo). In order to achieve a proper connection, pay attention to the notch on the cable and the corresponding notch on the power cable port. Next, plug the other end of the "Cleaning System Power Cable" into the correct port on the Model UV-106-W (labeled "CLEANING SYSTEM").

2. Start Up

A. Verify that flow is prevented through the system by turning the knob on the flowmeter all the way clockwise until it stops and the flowmeter reads 0 cc/min.

B. Make sure the Model UV-106-W and the Cleaning System are plumbed properly: The "Inlet" and "Outlet" ports should be connected as described in steps C and D of the "Installation" section above. An example of a completed installation is shown below.

C. Turn on your Model UV-106-W Aqueous Ozone Monitor™.

D. Start flow through the Cleaning System by rotating the knob on the flow meter counterclockwise until the flow reads ~300 mL/min.

E. Purge the Cleaning System as outlined in the Operation section of this Appendix (below).

F. After the purge step, the citrate reservoir should be full of liquid and your Cleaning System will be fully installed.

3. Operation

A. The Cleaning System adds citrate to your instrument to clean it at regular intervals. The default cleaning frequency is every 30 minutes. At that frequency, the citrate valve will open momentarily to add citrate to the sample flow for a short duration. If any scaling or discoloration is seen in the lines to or from the Model UV-106-W or on the internal sparging chamber, the frequency of the cleaning should be increased.

B. To change the cleaning parameters, access the cleaning menu in the Model UV-106-W using the Select button on the front panel of the instrument. To reach the menu hold in the Select button (for up to 5 seconds) until

Menu

is displayed, then release the Select button. After a brief period the main menu will appear:

Menu
Dat Avg Cfg SVC ←

where **Dat**, **Avg**, **Cfg**, and **SVC** are submenus. Select and click on **SVC** to access the Service menu:

SVC Menu
Lmp Cln ←

Select and click on **Cln** to access the Cleaning menu:

Clean Menu
Frq Dur Pur ←

C. To set the cleaning frequency, select and click on **Frq** to access the **Frequency** menu:

Clean Frequency Menu
Frequency: 30 mins ←

Select and click on the frequency value to change it. Scroll through options including: OFF, 10 minutes, 30 minutes, 1 hour, 6 hours, 12 hours, and 1 day.

Selecting OFF will turn the cleaning function off completely. Once the frequency is set, clicking on ← will return the display to the **Cln** menu. The default frequency is 30 minutes.

D. To set the cleaning duration, select and click on **Dur** to access the Duration menu:

Clean Duration Menu
T= 0.50 Seconds ←

Select and click on duration value to change it. Scroll the value to change it from 0 to 30 seconds. Once the duration is set, clicking on ← will return the display to the **Cln** menu. The default duration is 0.50 seconds.

E. To activate the purge function, select and click on **Pur**:

This will purge
clean for 1 minute.
Are you sure?
No Yes ←

Click on **Yes** if you would like to purge the Cleaning System which opens the citrate valve for 1 minute allowing flow through the citrate reservoir. This function is necessary when starting the Cleaning System after initial installation or after refilling the citrate reservoir. Once the purge function is set, clicking on ← will return the display to the **Cln** menu. The time remaining for the purge function will be displayed on the LCD along with the electrical conductivity of the sample + citrate mixture. To verify the citric acid is being injected into the system make sure the displayed conductivity value reads 2000 or more. If you want to stop the purge function, click the select switch to stop the purge and return to the **Cln** menu. After the initial installation or after refilling the reservoir you may need to use the purge function multiple times in order to resume the flow of acid and receive the large conductivity values which signify the Cleaning System is functioning again.

4. Refilling The Citrate Reservoir

A. Stop flow through the system by turning the knob on the flowmeter all the way clockwise until it stops and the flowmeter reads 0 cc/min.

B. Remove the Swagelok nut on the bottom of the citrate reservoir by turning it counterclockwise. Remove this nut slowly and carefully as the system will still be under pressure and the water inside will want to spray out. It helps to have a drain pan ready to catch the water remaining in the reservoir.

C. Remove the lid from the citrate reservoir.

D. Replace the Swagelok nut on the bottom of the citrate reservoir by tightening it ¼ turn past hand-tight.

E. Fill the reservoir to a quarter of the way full with clean water (tap water will suffice).

F. Fill the reservoir to the top with citric acid powder. Be careful not to spill the citric acid as it will leave a sticky residue and can cause skin irritation. Food-grade citric acid is readily available and is a non-toxic cleaning reagent. Consult the citric acid manufacturer's Material Safety Data Sheet for further information on safety and handling.

G. If the liquid level is not above the top port on the side of the citrate reservoir, slowly add clean water (tap water is OK) in the reservoir. Fill the reservoir until water is above the top port on the side of the reservoir.

H. Make sure the lip around the top of the citrate reservoir is clean as well as the O-ring on the reservoir lid before installing the lid. Any citric acid powder on the rim of the reservoir or O-ring can prevent a water tight seal and may result in leaks.

I. Install the lid hand-tight. It is important not to overtighten the lid as this will make it extremely difficult to remove when refilling the citrate reservoir.

J. Verify that all connections are tight and the plumbing is secure.

K. Now that the citrate reservoir has been refilled, follow the directions outlined in the "Start Up" section of this Appendix to resume proper function of your Model UV-106-W Cleaning System.