Ozone Calibration Source

2B Technologies, Inc.

OPERATION MANUAL

Model 306

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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 306 Ozone Calibration Source™. The Model 306 is a portable source of ozone that can be used to provide ozone in the range of 0 to 1000 parts per billion by volume (ppbv) for the calibration of ozone analyzers and other applications where a precise and accurate supply of ozone is required. 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 ..... December 2006

Revision B ..... April 2011

Revision C ..... November 2014

Revision D ..... June 2015

Revision E (serial no. 307 and above) ..... November 2016
Revision E-2 (serial no. 307 and above) ..... August 2017
[Clarifications on the scheduler feature, serial connection, 3-way valve, Vout, photo labels, and Figure 1-1 schematic. Expanded information in the introduction, startup operation, specifications, calibration sections, and instrument photos. Reorganized major Sections, and added the Parts section. Corrected external battery requirements specified in Section 3.2 and midnight hour setting in Section 4.2.3.]

TRADEMARKS & PATENTS

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www.twobtech.com/techsupport

This way all technical staff at 2B Tech will be alerted of your problem and 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 though 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.

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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 the Ozone Calibration Source™ manual. Usage of maintenance materials purchased from suppliers other than 2B Technologies will void this warranty.

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SAFETY WARNINGS

The Model 306 Ozone Calibration Source is designed specifically to produce ozone. Ozone is a toxic gas and should be handled with caution. The same kind of care should be taken in handling the output of the Ozone Cal Source™ as for any other toxic gas that, for example, may come from a compressed gas cylinder. Under normal operating conditions, the instrument will produce ozone in air at concentrations up to 1 to 2 ppm. The main danger is from inhalation of such high concentrations of ozone. As a safety measure, a cap is provided for the ozone outlet. When the cap is properly secured all of the ozonated air is diverted through an ozone scrubber inside the instrument. When attached to an ozone monitor, the ozone may be exhausted to the ambient environment by the ozone monitor, depending on the ozone monitor design. Thus, when calibrating ozone monitors, one should know in advance how the ozone exhaust is handled. It may be necessary to attach an ozone scrubber either prior to or after the ozone monitor air pump. Alternatively, one can perform the calibration inside a chemical hood. 2B Technologies provides inexpensive, high conductance ozone scrubbers that can be used to scrub the exhaust of ozone monitors.

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*

The Model 306 Ozone Calibration Source™ (OCS™) is a portable source of ozone that allows one to calibrate any ozone monitor, or to supply a calibrated source of ozone for experiments such as exposure studies. Major features of the Model 306 are:

- The instrument scrubs ozone from ambient air and produces either zero air or air having a mixing ratio of ozone in the range 30-1,000 parts-per-billion by volume (ppbv). The desired ozone concentration is chosen from the easy-to-use LCD menu using a rotary select switch, or from a serial connection.
- The instrument can be programmed to output up to 10 individual ozone step concentrations over a chosen time interval, for uses such as calibrating ozone monitors.
- The instrument has a scheduler feature for once-daily automated execution of the step program, at the user-specified hour.
- The total output volumetric flow rate is 3.0 L/min.
- The ozone mixing ratio is controlled so as to be independent of ambient temperature, pressure, and humidity.
- A three-way valve in the Model 306 OCS™ allows the user to switch their ozone monitor easily from air sampling mode to calibration mode.

The Ozone Cal Source™ output may be connected directly to the inlet of any ozone monitor (provided that the ozone monitor's sampling rate is less than 3.0 L/min); the excess flow is vented through an ozone scrubber internal to the OCS™. Besides portability, an important advantage of the Model 306 OCS™ is that it provides a known concentration of ozone in ambient air containing the same level of humidity as the air sample to be measured.

The Ozone Cal Source™ is factory calibrated against a NIST-traceable ozone standard. However, the calibration parameters may be changed in the menu in case the user wants to recalibrate the OCS™ against a separately maintained standard; i.e., the Ozone Cal Source™ can be used as a transfer standard. The OCS™ may be used, for example, for maintaining the calibration of a large number of ozone monitors in the field relative to a highly stable laboratory instrument. In this case, a huge advantage of the OCS™ is its portability.

Besides its use as a calibrator of ozone monitors, the Ozone Cal Source™ may be used as a calibrated ozone source for studies of the effects of ozone on materials (rubber, plastics, paints, etc.) and on biological organisms such as plants.

1.1 Theory of Operation

The portable Ozone Calibration Source makes use of a low-pressure mercury lamp to photolyze oxygen and produce ozone. The vacuum UV lines near 185 nm are

absorbed by O_2 to produce oxygen atoms. The oxygen atoms attach to O_2 to form ozone, O_3. The well-known mechanism, which is responsible for the presence of Earth's protective ozone layer, is as follows:

$$O_2 + h\nu \rightarrow O + O \quad (1)$$

$$2\,[O + O_2 + M \rightarrow O_3 + M] \quad (2)$$

$$\text{Net: } 3\,O_2 + h\nu \rightarrow 2\,O_3 \quad (3)$$

where $h\nu$ symbolizes a photon of light and M is any molecule (e.g., N_2, O_2, Ar). Absorption of one photon of light by O_2 results in the formation of two ozone molecules. The concentration of ozone produced in a flowing stream of air depends on the intensity of the photolysis lamp, the concentration of oxygen (determined by pressure and temperature), and the residence time in the photolysis cell (determined by volumetric flow rate and cell volume). By holding these parameters constant, it is possible to produce a flow of air containing a constant concentration of ozone, and the concentration of ozone produced can be varied most conveniently by varying the lamp intensity. Figure 1-1 is a schematic diagram of the Ozone Calibration Source™.

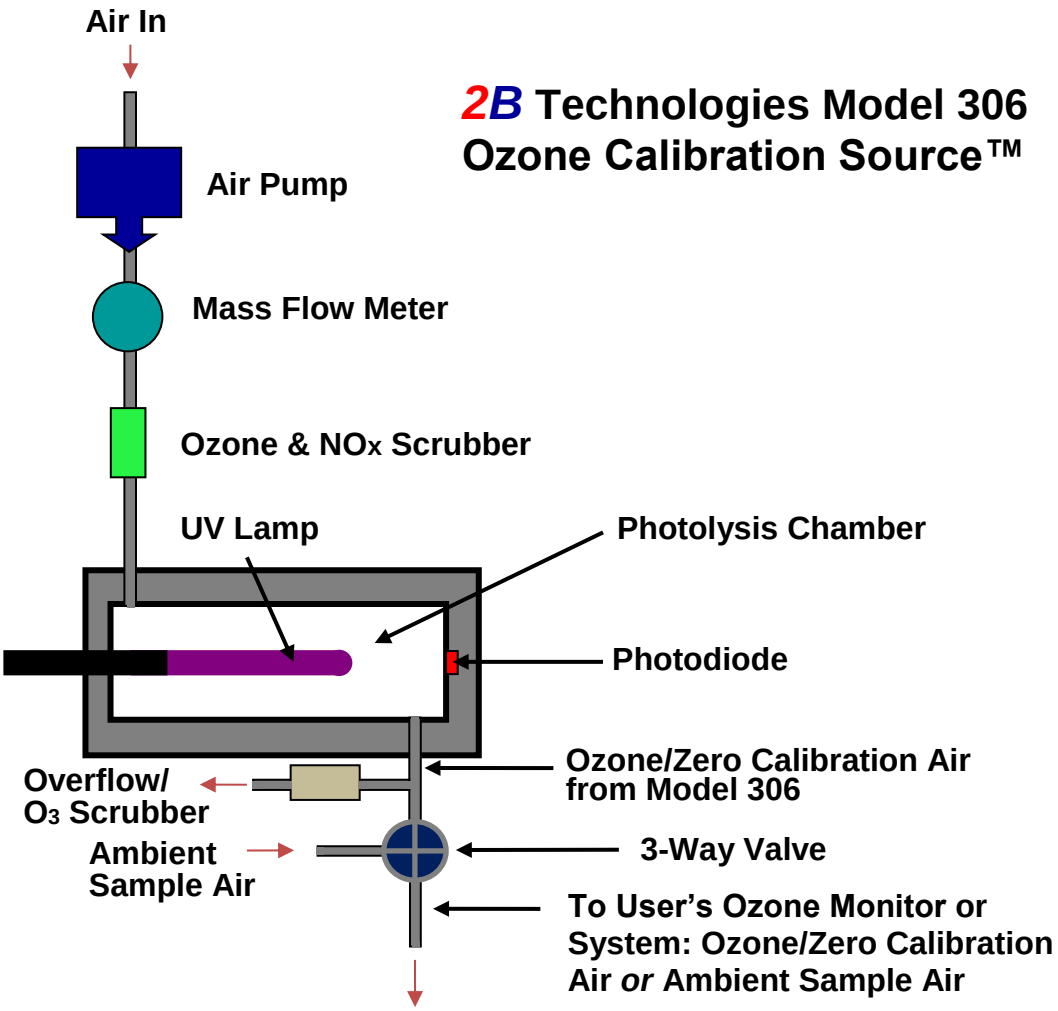


Figure 1-1. Schematic diagram of the Model 306 Ozone Calibration Source™.

1.2 Summary of Schematic Diagram

An air pump pushes air through a particle filter, then through a mass flow meter. The microprocessor controls the flow rate at a value of 3.0 L/min volumetric by means of pulse-width modulation of the power to the pump. Before entering the photolysis chamber, the air passes through an ozone/NO_X scrubber to remove any ambient ozone and NO_X. The air passes through another particle filter, and then passes through the photolysis chamber containing a low-pressure mercury lamp where absorption of atomic lines near 185 nm produces oxygen atoms from molecular oxygen, and the oxygen atoms react with molecular oxygen to form ozone (reactions 1, 2, and 3 above). The lamp intensity is monitored by a photodiode and controlled by the microprocessor. The photodiode voltage is calibrated against the output ozone concentration. Pressure within the gas stream is measured but not controlled. Instead, the lamp intensity is varied to compensate for changes in pressure using a proprietary algorithm. Air containing ozone exits the photolysis cell through an overflow tee, where excess air not sampled by the ozone monitor being calibrated is exhausted through an internal ozone scrubber. If it is desired to have the full 3.0 L/min of air/ozone exit the instrument, the internal ozone scrubber may be capped. The other end of the overflow tee goes to a valve which selects either the ambient sample air or the calibration air to exit through the output of the 306.

2. SPECIFICATIONS: MODEL 306 OZONE CALIBRATION SOURCE

Method of Ozone Production	UV photolysis of molecular oxygen (O_2) at 185 nm
Ozone Concentration Range	0 ppbv and 30 ppbv to 1,000 ppbv *
Output Flow Rate	3.0 L/min volumetric
Precision and Accuracy	Greater of 2.0 ppbv or 2.0% of ozone concentration
Response Time for Change in Ozone Output Concentration	< 30 s to reach 95% of selected concentration
Dimensions	3.5 × 6.3 × 11.6 inches (9 × 21 × 29 cm)
Weight	5.6 lb (2.6 kg)
Power Requirements	12 V DC or 120/240 V AC, 18 watt
Analog Output	Yes; voltage output tracks ozone output and provides system error codes
Serial Connection	Yes; for remote operation and for system diagnostics
Programmable Output	Yes, user-specified ozone output for up to 10 steps from 0 to 1,000 ppbv; stored in internal memory
Scheduler	Yes; once-daily execution of the step program at user-specified hour
Baud Rate	4800

* Even though the instrument is capable of producing greater than 1,000 ppbv of ozone, the upper limit to the concentration that can be accurately controlled should be assumed to be 1,000 ppbv.

3. STARTUP OPERATION

Please read all the following information before attempting to install the Ozone Calibration Source™. For assistance, please call 2B Technologies at (303)273-0559 or email us at techsupport@twobtech.com.

NOTE:
Save the shipping carton and packing materials that came with the Ozone Calibration Source™. If the Ozone Calibration Source™ 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.

3.1 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.

3.2 Startup of the Ozone Calibration Source™

To operate the Ozone Calibration Source™, connect it to an external power source and turn the instrument on by flipping the front panel switch. The instrument requires a 12 V DC source which can be supplied by: 1) the 110-220 V AC power adapter (2.5 amp or higher), 2) a cigarette lighter adapter plugged into a 12 V DC source such as found in an automobile or many light aircraft, or 3) a 12 V battery. The source must be very close to 12 V because of the power requirements of the instrument's pump. When using a battery, be certain to attach the positive (red) and negative (black) wires correctly. 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.

Once turned on, the instrument will briefly display the version number of the software installed on the microprocessor. The instrument will then display

Warming up …
delT = -xx.xx

where **delT** is the deviation of the temperature of the photolysis chamber from the set point of 315 K (42°C). As the chamber warms up, the temperature deviation will be continuously displayed. During the warmup period, the photolysis lamp and the pump are turned off and the internal 3-way valve is set to divert sample air to the output of the Model 306.

Warmup will take approximately 15-20 minutes. Once **delT** is within 1°C of the set point, the display will read: **Temperature Set**
Press Select

Press in and hold the black Select switch on the front of the instrument to bring up the LCD Menu. See the next section for a description of how to operate the instrument using this menu.

The user's ozone monitor, or other experimental system, can be attached to the Model 306 OCS^{TM} to receive air containing calibrated amounts of ozone. Alternatively, a 3-way valve inside the Model 306 OCS^{TM} can be set so that air from a sampling inlet on the back of the instrument bypasses the Model 306 and is routed to the user's ozone monitor or system. When the Model 306 OCS^{TM} is turned off, or in hibernation mode (discussed in Section 5.3), the valve is set so that air is routed from the sampling inlet. This permits the user to leave the Model 306 OCS^{TM} plumbed in-line with their ozone monitor or other system when the Model 306 is not in use.

4. OPERATION VIA THE LCD MENU

4.1 Menu Overview

Any time after powering the instrument on, you may enter the main menu by holding in the rotary select switch until the menu appears. Once the menu appears, release the select switch. (Note: You may enter the menu without waiting for the warm up to be complete; however, the ozone concentration selected will not be accurately output until the set point temperature is reached.)

The following diagram summarizes the complete LCD menu.

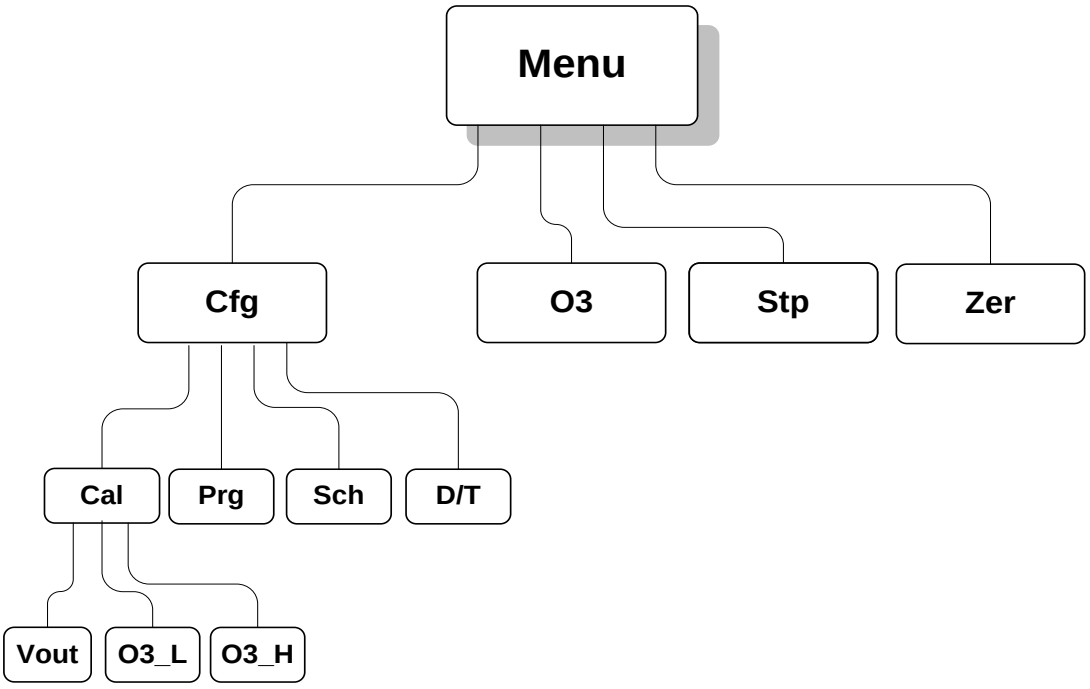


Figure 4-1. The LCD Menu of the Model 306 Ozone Calibration Source™.

After pressing the select switch the main menu will then be displayed as:

Menu
Cfg O3 Stp Zer

Rotating the select switch will move the blinking cursor to highlight the first character of each of the four submenus, **Cfg**, **O3**, **Stp** and **Zer**. One can enter any one of these submenus by rotating the select switch to move the cursor over the first letter of the submenu, and then momentarily pressing ("clicking") the select switch.

4.2 Configuration Menu (Cfg)

Selecting the **Cfg** submenu will produce the following display:

Cfg Menu
Cal Prg Sch D/T ←

where **Cal** is a submenu for entering the calibration menu; **Prg** is a submenu for defining a programmed series of step ozone concentrations; **Sch** is a submenu that allows the user to set the Model 306 to run an ozone step function once per day at a chosen time; and **D/T** is a submenu for setting the date and time. The purpose of the return symbol (←) is to return to the previous menu; i.e., depressing the select switch when ← is highlighted allows one to move one level up in the menu. The function of each submenu is described below.

4.2.1 Calibration Submenu

Choosing the **Cal** submenu results in the following submenu:

Cal Menu
Vout O3_L O3_H ←

where **Vout** is a submenu for setting the voltage offset value and **O3_L** and **O3_H** are submenus for setting the calibration factors for Ozone output.

Choosing **Vout** results in the following submenu:

Vout Offset Menu
Offset= xx mV ←

There is an inherent electronic offset in the analog output of the ozone level being produced. The **Vout offset** can be adjusted so that zero ozone will provide a measurable positive voltage. It is adjustable from -99 millivolts to 99 millivolts, and this setting is used to adjust the voltage output downward to 0.05 V for zero ozone output. **Vout** itself can be used measure ozone concentrations, as well as to provide error messages for diagnostic uses. More details are provided below in Section 6, “Using the Voltage Output.”

In order to account for the small curvature in the plot of ozone concentration versus lamp intensity, calibration parameters are entered into the instrument in two concentration ranges: low (300 ppbv and below) and high (301-1000 ppbv). Choosing **O3_L** results in the following submenu for setting the zero offset and slope for ozone output in the ranges of 0 and 30-300 ppb, for example:

O3L Cal Menu
Z= 2 S= 1.05 ←

Choosing **O3_H** results in the following submenu for setting the slope and offset for ozone output in the range of 301-1000 ppbv, for example:

O3H Cal Menu
Z= 1 S= 1.03 ←

Both of the offset values, **Z_L** and **Z_H**, are in units of ppb. The Ozone Cal Source™ is shipped with a NIST-traceable calibration. The calibration factors, **Z_L**, **S_L**, **Z_H**, and **S_H** are set in the instrument and recorded in the instrument's calibration document and birth certificate. However, you may choose to change the calibration factors so that the instrument output agrees with your own ozone standard. You can always return the instrument to its factory calibration if desired. To change the calibration factor, place the cursor over the **Z_L**, **S_L**, **Z_H**, or **S_H** and hold in the select switch until the cursor blinks. You may now change the value of the calibration factors by rotating the select switch. Increasing the slope (**S_L**) calibration factor increases the ozone output concentration linearly for ozone values equal or less than 300 ppbv; i.e., for S=1.10, the ozone concentration produced will be 10% higher than for S=1.00, and for S=0.95 it will be 5% lower. Likewise increasing the slope (**S_H**) calibration factor increases the ozone output concentration linearly for ozone values above 300ppbv. Once the desired value of **S_L** or **S_H** is selected, momentarily press the select switch such that the cursor no longer blinks. The low and high offsets, **Z_L** and **Z_H,** are set in a similar fashion (in units of ppb). You may now exit the **Cal** submenu by selecting and clicking on ←. See Section 8 for information on calibrating your Model 306 Ozone Cal Source™.

4.2.2 Program Submenu

Choosing the **Prg** submenu from the **Cfg** menu, allows one to define a program of steps in ozone concentration. Choosing **Prg** results in the following submenu:

Prg Menu
Num Steps= x ←

Upon placing the cursor under the currently set value x and clicking, a blinking cursor will appear. You may now rotate the select switch to obtain the number of steps, up to 10, you wish to have in your program. Clicking again will turn off the blinking cursor and you may return the cursor to ← to continue defining the program. After choosing the number of steps, the following submenu will appear:

Prg Menu
Time/Step= x ←

You may now move the cursor to the currently set time/step value x, click to obtain a blinking cursor and rotate the select switch to choose a step time in the range 1 to 60 minutes. To select the value, click to remove the blinking cursor, then use ← to begin defining the target concentrations of each of the steps. The following submenu will now appear:

Select O3 Step
Step[1]= xxxx ←

where xxxx is the target ozone concentration in ppbv that is currently being used for the first step of the program. You may now change the ozone concentration for the first concentration step in the same way that the Time/step was changed. Executing ← will bring up the following submenu and allow you to set the target concentration for the next step:

Select O3 Step
Step[2]= xxxx ←

This process is repeated until the target concentrations are set for all of the steps in your program. These steps may span the full range of the instrument, from 0 to 1000 ppbv, if desired.

This program resides in memory until the next time you choose to change it.

4.2.3 Scheduler Submenu

Choosing the **Sch** submenu from the **Cfg** menu, allows one to schedule a once-daily execution of the step program defined in Section 4.2.2. This could be used, for example, to carry out a daily autocalibration of an ozone monitor. Choosing **Sch** results in the following submenu:

Sch Menu
Auto Cal Hr = x ←

where x is the time (hour) to commence the step program, in military units (24 = midnight). To turn off the scheduler function, use the select switch to scroll to "OFF."

Important: After setting the scheduler hour, the user needs to power cycle the Model 306 off and back on, and leave it in the warm-up menu (it reads "temp set press select" when the photolysis chamber is at temperature). If not left in this state, the scheduled step program will not run.

4.2.4 Date/Time Submenu

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

D/T: 14:32:21 ←
17/10/2016

meaning that it is 21 seconds after 2:32 p.m. on October 17, 2016 (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 ←.

4.3 Ozone Menu (O3)

You may choose to output a constant ozone concentration by choosing **O3** from the main menu. Upon clicking on **O3**, the following submenu will appear:

Select Amount
O3= xxxx ←

You may change the desired target ozone concentration by selecting xxxx and rotating the select switch to choose a value. To start producing that concentration of

ozone, click on ←. The instrument will now output the selected concentration of ozone from the stainless steel outlet on the back of the instrument (Figure 10-1 or 10-2) until you enter menu again and change the target concentration. As an example, the display will read as follows

Target= 200 ppb
delT=-0.1 ▌▌▌▌▌▌

if you have chosen 200 ppb as the target concentration. The deviation of the photolysis chamber temperature from the target temperature is displayed in addition to a series of six solid or open bars. When all bars are solid, the lamp intensity is within range to produce the target concentration.

The selected target ozone concentration will remain in memory until the next time you change it. Bear in mind that the instrument will output up to 1,000 ppbv of ozone reliably. Higher concentrations may be chosen, but the instrument may not be capable of delivering the concentration chosen. For higher target concentrations, you will need to independently measure the maximum concentration of ozone that the instrument can output and regulate.

While generating ozone in the target amount, the flow rate may be checked by rotating the select switch. It should be in the range of 3 L/min.

To cease generating ozone, push in the select switch until the main menu appears.

4.4 Start Step Menu (Stp)

Choosing **Stp** executes the program of concentration steps you have stored in memory (under **Cfg/Prg**). The target concentrations are displayed as the instruments steps through the program. For example, the first display might read

Step[1]=100 ppb
delT=0.2 ▌▌▌▌▌▌

if you have chosen 100 ppb as the target concentration for your first step and the photolysis chamber is higher than the target value by 0.2°C. The six solid bars indicate that the cell temperature and lamp intensity are within range for accurate output of the selected ozone concentration. The flow rate may be checked by rotating the select switch (should be ~3 L/min). To advance through the steps you have programmed, push in the select switch. To cease generating ozone, push in the select switch until the main menu appears.

4.5 Zero Menu (Zer)

This submenu provides a rapid way to produce air containing 0 ppbv of ozone. In this mode, the photolysis lamp is turned off. While producing 0 ppbv of ozone, the flow rate may be checked by rotating the select switch. To exit, push in the select switch until the main menu appears.

5. USING THE SERIAL INTERFACE

5.1 Collecting Diagnostic Data over the Serial Port in Real Time via the LCD

Collecting serial data for a few minutes can be extremely useful in diagnosing a problem with the Ozone Calibration Source™. To transmit diagnostic data to a computer over the serial port in real time, connect the Ozone Calibration Source™ to the serial port of the computer using the 9-pin cable provided. If your computer does not have a serial port, you can use a serial-to-USB adapter, available at most computer stores or at our online store (see Section 11). Activate your data acquisition software; e.g., HyperTerminal (a program provided with earlier versions of Windows) or Tera Term. The latter software is preferred since Hyperterminal has a 500-line buffer limit, but the user may set the maximum buffer size for Tera Term to 10,000 lines. Both programs allow you to log data to a computer file with no limit on number of data lines. Using these terminal emulation programs, data may be saved to a text file and then opened in Microsoft Excel (or other spread sheet program) where it may be converted to formatted data in columns by defining delimiters (such as commas and carriage returns) for data manipulation and graphing.

For data transfer the correct settings are: Baud rate = 4800, data bits = 8, parity = none, stop bits = 1, flow control = note or hardware.

Connect the serial cable to the computer as noted above. From the LCD screen, use the Select switch to begin operation of the Model 306 to generate ozone or zero air from the **O3**, **Stp**, or **Zer** menu. (Alternatively, the terminal emulator may be used to initiate a data stream; see Section 5.2 below.) Serial data lines containing diagnostic data are output approximately once every second. A typical data line might read:

21,311.6,705.8,3.273,1.43,100,90,1.0001,1

where

21 = Intensity:	This value corresponds to the lamp intensity corrected for changes in volumetric flow. It will remain steady when outputting a set value of ozone.
311.6 = T(K):	Temperature in Kelvin of the ozone generator chamber.
705.8 = P(Torr):	Pressure in Torr of the ozone generator chamber.
3.273 = F(L/min):	Flow rate in liters per minute through the generator chamber. This is the max flow that the connected instrument can possibly pull.
1.43 = LampDuty:	Duty cycle of the UV lamp creating the ozone (%).
100 = HeatDuty:	Duty cycle of the heater heating the generator chamber (%).
90 = PumpDuty:	Duty cycle of the pump pushing air through the generator (%).
1.0001 = ErrorFrac:	Intensity divided by the target intensity. This value should be between 0.99 and 1.01 for stable operation.
1 = ValveState	Status of Calibration Valve (0 = sample air, 1 = calibration air)

To stop data collection, press and hold in the Select switch on the Model 306 (alternatively, type **n** from the terminal emulator; see Section 5.2 below).

If you have a problem with your instrument, please collect a data file and email it to 2B Technologies at techsupport@twobtech.com along with a description of the problem.

5.2 Operating the Instrument Remotely via the Serial Menu

The serial menu and serial commands can be used to control the functionality of the Model 306 remotely. Establish the serial connections as noted in Section 5.1 above. Start your terminal emulator (e.g., Tera Term or Hyperterminal) and when the instrument temperature is set, you will be prompted to press "**Enter**" to access the serial menu. (If your instrument is already generating a serial data stream, enter "**n**" and then "**Enter**" from the keyboard to access the serial menu.)

The following list describes the commands available through the serial menu interface:

run step	Starts the stored step program
output ozone	Continuous output of ozone selected (prompts user to enter desired ozone concentration)
n	Skips to next concentration while running step, *or* Exits continuous output of ozone and enters hibernation mode
set lslope	Prompts user to enter new low slope (≤ 300 ppb) in format x.xx
set hslope	Prompts user to enter new high slope (>300 ppb) in format x.xx
set lzero	Prompts user to enter new low zero *(in units of ppbv)*
set hzero	Prompts user to enter new high zero *(in units of ppbv)*
set steps	Prompts user to enter step program (# of steps, time/step, concentration in ppbv for each step)
set hr	Prompts user to enter the hour that the step program will start each day *(military time format, 24 = midnight; 0 to disable). Must set instrument to hibernate (or power cycle the instrument) to execute the step program at the new hour.*
set time	Prompts user to enter time of day *(military format)*
set date	Prompts user to enter date *(European format)*
hibernate	Pump off, lamp off, maintains temperature control with heater on, valve open to sample air (waits for wakeup through serial port or select switch)
hibernate -nt	Pump off, lamp off, heater off, valve open to sample air (waits for wakeup through serial port or select switch)
v	Adjusts the valve to allow calibration air from Model 306 into stream.
c	Adjusts the valve to allow sample air from sample inlet into stream.
l	Turns LCD backlight ON
o	Turns LCD backlight OFF
header	Describes the values in the serial data output
?	Displays this menu
x	Exits the serial menu.

As noted in the table above, the instrument must be put in **hibernate** mode (or power cycled) after changing the scheduler hour with the **set hr** command. Otherwise, the step program will not execute at the new scheduled hour.

If you are acquiring serial data, you can end the data collection from either the LCD menu of the Model 306 (by pressing in the Select switch) or from the keyboard of your computer (using the **n** command). If you wish to continue operation from the LCD menu, you must end data collection from the LCD menu. Likewise, if you wish to continue operation from the computer keyboard, you must end data collection from the keyboard. (Otherwise, it may be necessary to power cycle the Model 306 if you wish to resume operation in your preferred mode.)

5.3 Hibernate Feature

Most remote applications require low power consumption. The Model 306 has the ability to enter a "hibernation" mode where the firmware powers only the essentials to consume less power while waiting to output ozone for a calibration or other experiment. During hibernation, the valve is open to air from the sample inlet of the Model 306.

- **hibernate** Entering this command turns the pump and lamp off while maintaining the set temperature of the photolysis chamber and awaits a character through the serial port (any character) or select switch press to wake out of hibernation. This is feature is useful for on-demand calibrations in cold weather applications. Also, this feature must be activated whenever the scheduler hour is reset from the serial menu, as noted in Section 5.2.
- **hibernate –nt** Entering this command turns the pump, lamp, and heater off and awaits a character through the serial port or select switch press to wake out of hibernation. This feature is useful where power is highly limited.

6. USING THE VOLTAGE OUTPUT (Vout)

6.1 Using the Voltage Output to Measure Ozone Output Concentration

Using the BNC connector on the back of the Model 306, the user can monitor a voltage signal that is proportionally scaled to the ozone output setting. When set to output zero ozone, the voltage output will be 0.05 Volts. The voltage output ranges from 0.05 V to 1.05 V for ozone output. The scaling factor is 1mV/ppb. For example, if set to output 200 ppb of ozone, the voltage output should be 0.250 Volts (0.05 + 0.001*Ozone).

If the zero-ozone setting is greater than 0.05 V, the user should make an adjustment from the **Cfg** / **Cal** / **Vout** menu to subtract the voltage offset above 0.05 V (see Section 4.2.1).

6.2 Using the Voltage Output for Error Diagnostics

Error messages are displayed as voltages in the range 1.55 V to 2.00 V, as described below. An output signal below 0.05 V indicates that the 3-way valve is set so that the output air is coming from the sample inlet.

TEMPERATURE LOW ERROR: 1.55 V
TEMPERATURE HIGH ERROR: 1.60 V
FLOW LOW ERROR: 1.65 V
FLOW HIGH ERROR: 1.70 V
INTENSITY LOW ERROR: 1.75 V
INTENSITY HIGH ERROR: 1.80 V
FLOW and TEMPERATURE ERROR: 1.85 V
FLOW and INTENSITY ERROR: 1.90 V
TEMPERATURE and INTENSITY ERROR: 1.95 V
FLOW, TEMPERATURE, and INTENSITY ERROR: 2.00 V

7. USING THE MODEL 306 TO CALIBRATE AN OZONE MONITOR

7.1 Flow Requirement

The flow requirement of your ozone monitor must be less than the output capacity of the Model 306 Ozone Cal Source™, which is about 3 L/min.

7.2 Attaching the Ozone Cal Source™ to an Ozone Monitor

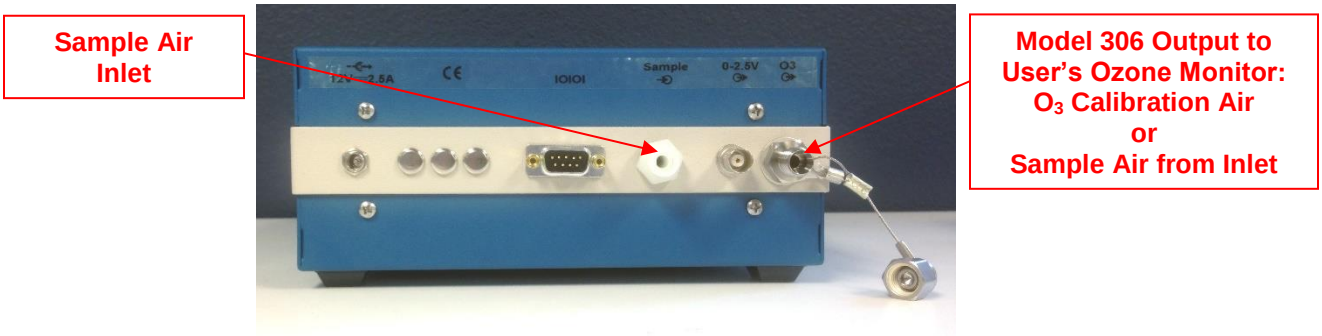
7.2.1 Overview

For calibration of an ozone monitor, tubing may be attached from the ¼-inch stainless steel Swagelok outlet fitting on the back of the Model 306 Ozone Cal Source™, to the inlet of the ozone monitor. The tubing should be made of PTFE (Teflon®), PFA, 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 (not more than a few feet) to minimize ozone destruction. Tygon®, polypropylene (which may look like Teflon®), and metal tubing should not be used. Teflon-lined Tygon® tubing, which is supplied with the instrument and is available from our online store (http://twobtech.com/parts-online.html), provides the flexibility of Tygon® and the inertness of Teflon®.

The Model 306 Ozone Cal Source™ may be attached directly to the ozone monitor; excess ozone flow will be diverted through an ozone scrubber internal to the Model 306, and any perturbation in total flow rate will be automatically adjusted by the microprocessor using feedback from the mass flow meter of the Model 306.

7.2.2 Installation of the Model 306 on a Sampling Line

A 3-way valve inside the Model 306 OCS™ can be set so that air from a sampling inlet on the back of the instrument bypasses the Model 306 and is routed to the user's ozone monitor or system. When the Model 306 OCS™ is turned off, or in hibernation mode (discussed in Section 5.3), the valve is set so that air is routed from the sampling inlet. This permits the user to leave the Model 306 OCS™ plumbed in-line with their ozone monitor or other system when the Model 306 is not in use.



7.3 Running a Calibration of an Ozone Monitor

Once the connections are established between the Model 306 outlet and the inlet of your ozone monitor, the calibration may be performed. The ozone output of the Model 306 may be changed manually from the LCD **O3** menu or from the serial menu.

Alternatively, the Model 306 can run a preprogrammed step calibration using a user-prescribed series of up to 10 different ozone output steps, executed either in the LCD menu (**Stp** menu) or in the serial menu (**run step** command). See Sections 4.4 and 5.2 for information on these options. The series of steps are defined by the user, using either the LCD menu (**Cfg** / **Prg**) or the serial menu. See Sections 4.2.2 and Section 5.2 for information on defining the step program.

The preprogrammed step calibration can be scheduled to run automatically once per day at a user-defined time. See Section 4.2.3 for information about setting this scheduler feature from the LCD menu (**Cfg** / **Sch** menu, followed by power cycling the instrument), and Section 5.2 for setting it remotely from the serial menu (**set hr** command, followed by **hibernate**).

8. CALIBRATING THE MODEL 306 OZONE CALIBRATION SOURCE

The absorption of 185-nm light by oxygen is very weak ($\sigma \sim 2 \times 10^{-22}$ cm^2/molec). As a result, the absorbance within the photolysis chamber is optically thin, meaning that only a very small fraction of the emitted light is absorbed by oxygen to produce ozone. Thus, for a constant flow residence time within the photolysis chamber (constant flow rate), we expect the concentration of ozone produced to be linear with lamp intensity. In practice, however, a slight curvature in the calibration plot is observed when the calibration plot is extended to 1,000 ppb. This could be due to a number of factors, one of which is a lack of a constant ratio of the intensities of the emission lines at 185 nm and 254 nm as the lamp duty cycle is varied. Since 185 nm falls in the vacuum UV where light intensity is difficult to measure, the output of the Ozone Calibration Source is actually calibrated against the measured intensity of the 254-nm emission line. In order to remove the small curvature observed in the plot of ozone concentration produced and lamp intensity at 254 nm, four parameters are used to calibrate the instrument, consisting of two offsets Z_L and Z_H, and two slopes S_L and S_H. The offset Z_L and slope S_L are determined for the range of output ozone concentrations of 0 and 30-300 ppb. The offset Z_H and slope S_H are used to produce the most accurate ozone concentration in the range 301-1,000 ppbv.

We recommend returning the Ozone Calibration Source to us annually for a new calibration. Alternatively, you can calibrate the instrument against your own reference ozone monitor by plotting the observed ozone concentration against the setpoint ozone concentration and obtaining the linear regression slope m and intercept b. For example, for the low range of ozone outputs (0, 30-300 ppbv):

$$[O_3]_{L\_measured} = m[O_3]_{L\_setpoint} + b$$

The calibration parameters that should be entered into the instrument are S_L = 1/m and Z_L= -b (in units of ppbv).

If you want to extend the calibration to higher concentrations, plot measured ozone vs setpoint ozone in the range 301-1,000 ppbv and obtain the linear regression slope m and b as above:

$$[O_3]_{H\_measured} = m[O_3]_{H\_setpoint} + b$$

Then, S_H = 1/m and Z_H = -b (in units of ppbv). Use of two sets of slope/intercept calibration factors allows expansion of the calibration range while maintaining the accuracy within the specifications of 2 ppb or 2% of the ozone setpoint.

If you don't plan to output concentrations higher than 300 ppbv, simply set S_H = S_L and Z_H = Z_L.

9. MAINTENANCE/TROUBLESHOOTING

The Ozone Calibration Source™ is designed to be nearly maintenance free. The only components that require routine maintenance are the two particle filters and the two scrubbers (the ozone/NOx scrubber and the ozone scrubber; see Figure 10-1), which should be changed at least annually, or more often under heavy use of the instrument. Other user-serviceable components include the lamp, air pump, and 3-way solenoid valve, all of which are easily replaced should they fail. Parts are available at our online store, http://twobtech.com/parts-online.html (see Section 11 for parts list).

If the instrument fails to operate correctly, common problems can be identified and corrected using Table 8-1. If the problem cannot be easily corrected, please contact Customer Service at 2B Tech via our web ticketing software at:

www.twobtech.com/techsupport

Alternatively, you can email us at techsupport@twobtech.com or call us at +1(303)273-0559. If we mutually determine that the instrument cannot be repaired onsite, we will provide you with a Return Authorization number and a short form to be filled out and returned to our Service Department along with the instrument.

The figures in Section 10 provide a "guided tour" of the instrument so that critical components and connectors may be easily identified. Section 11 gives a parts list.

Table 9-1. *Troubleshooting the Ozone Cal Source™ 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.
	Power cable not connected to circuit board.	Remove top cover and disconnect and reconnect power cable to circuit board.
Instrument turns on then powers off.	Burned out air pump.	Remove top cover 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 top cover and reconnect display to circuit board. Check solder connections to display.
Target temperature is never reached.	Absent or loose connection of temperature probe cable to circuit board. Heater is burned out.	Remove top cover and reattach connector to circuit board. Replace cartridge heater.
Instrument does not output ozone.	Photolysis lamp is burned out. Cable not properly connected between lamp and circuit board.	Replace lamp and recalibrate instrument. Remove top cover and reconnect lamp cable to circuit board.
Select switch does not work.	Cable not properly connected between select switch and circuit board.	Remove top cover and reconnect select switch cable to circuit board.
Serial port does not work.	Cable not properly connected between serial port 9-pin connector and circuit board. Wrong serial cable used. Wrong baud rate selected. Wrong com port assigned.	Remove top cover and reconnect serial port cable to circuit board. 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. Make sure that the baud rate is set to 4800. Make sure that the com port assigned by your computer matches the com port setting in your terminal emulator (e.g., Tera Term or Hyperterminal).

10. LABELED INSTRUMENT PHOTOS

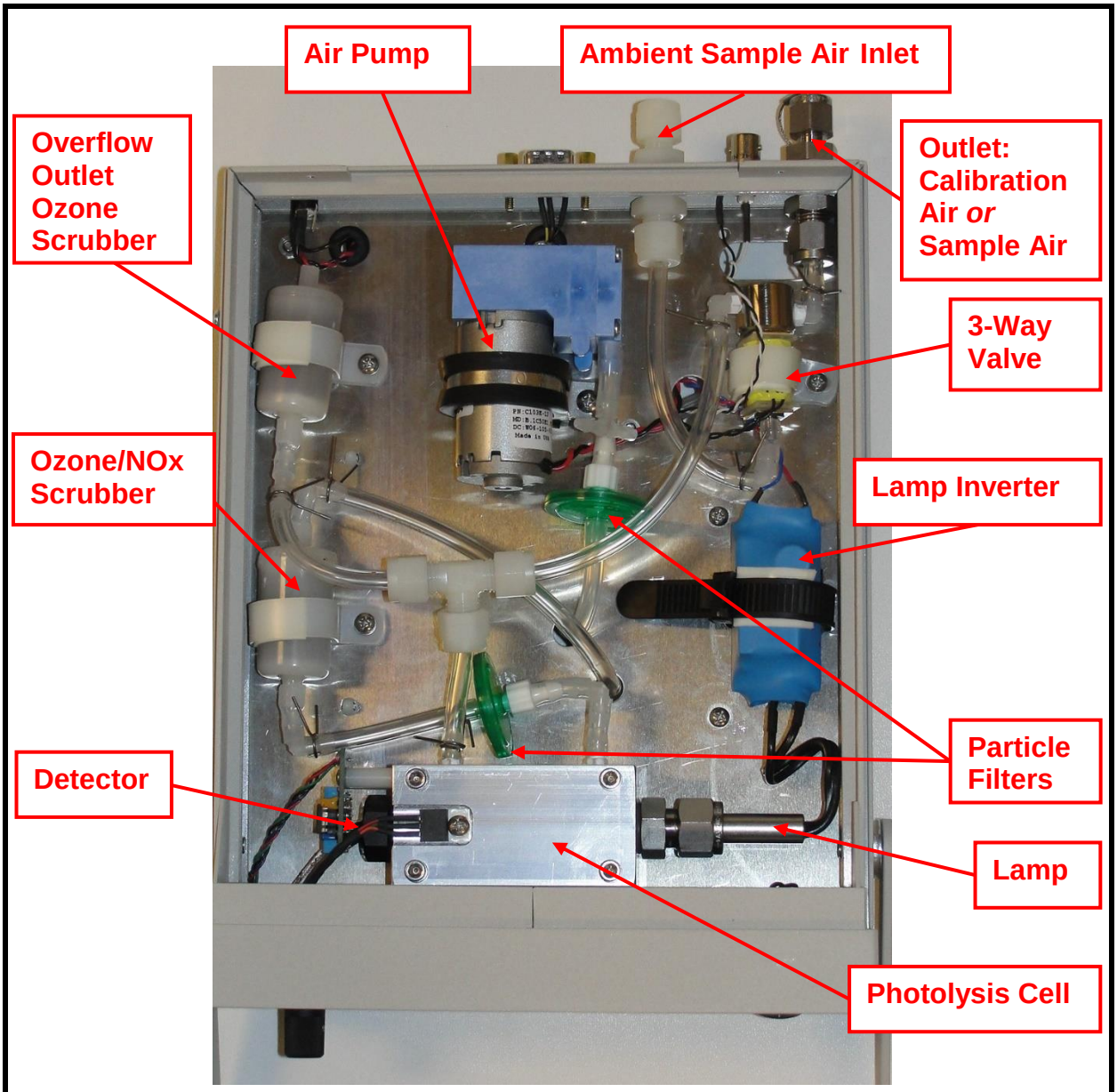


FIGURE 10-1: ***Bottom view of Ozone Cal Source™ with cover removed.***
Refer to schematic in Figure 1-1.

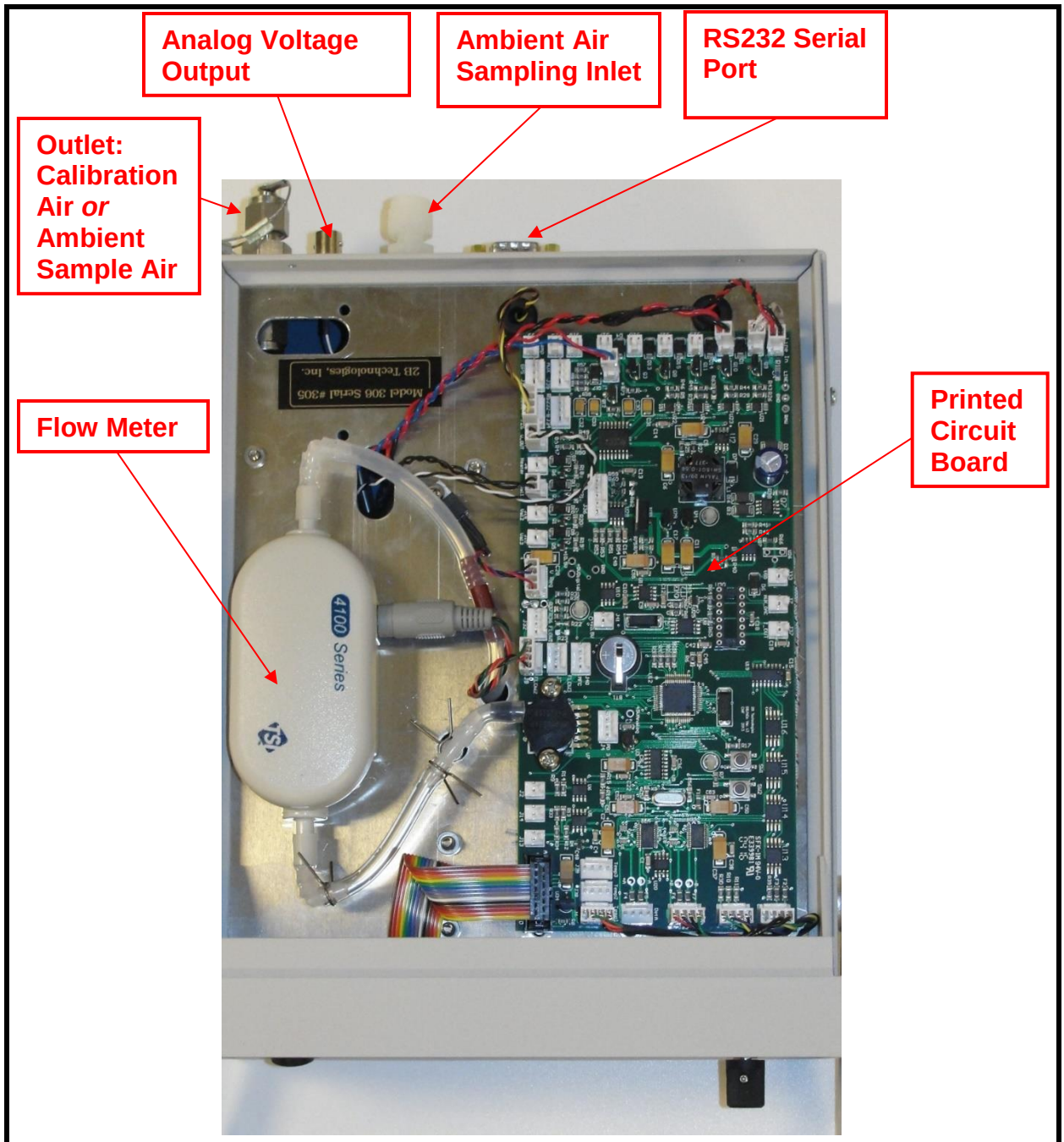


FIGURE 10-2: ***Top view of Ozone Cal Source™ with cover removed***

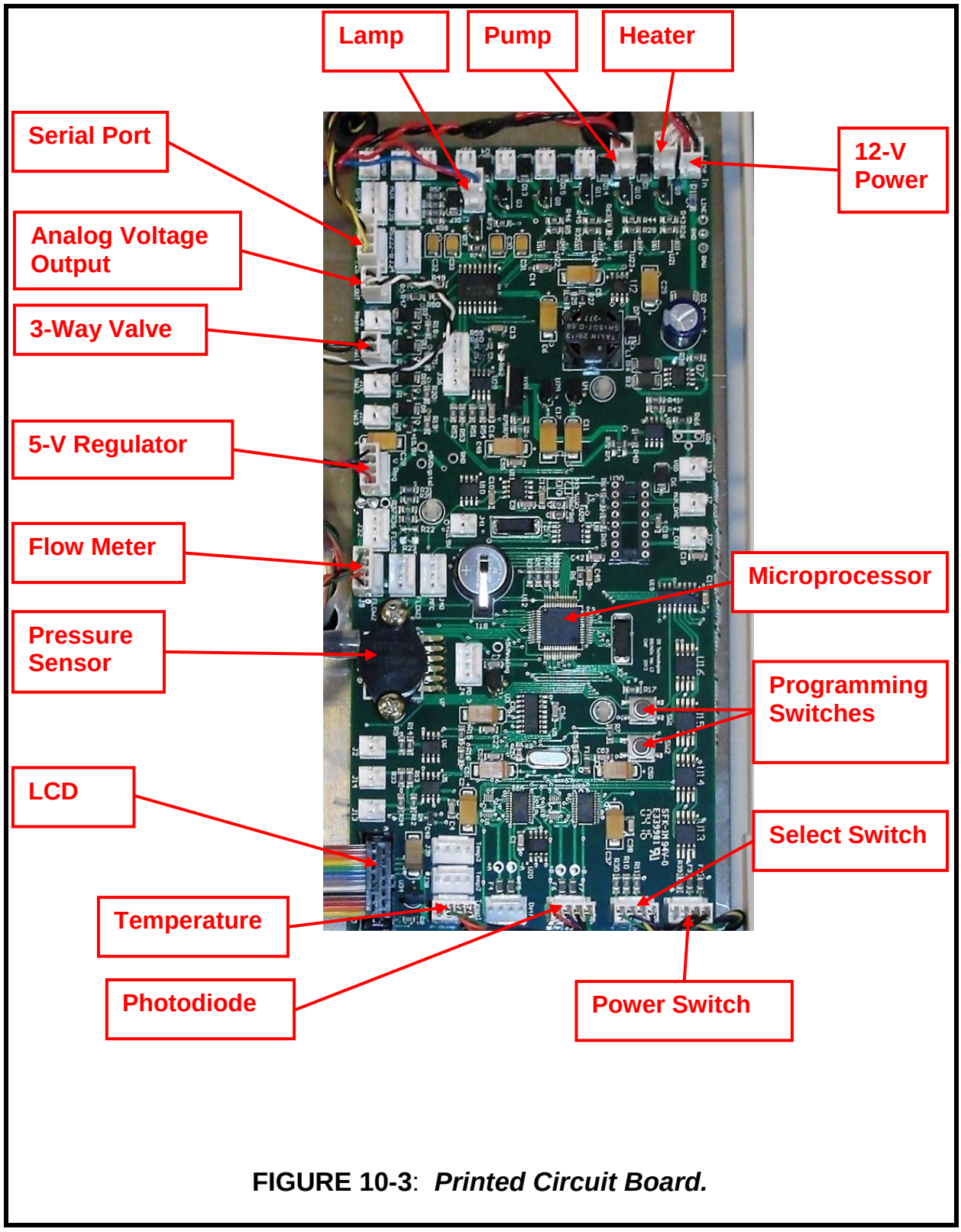


FIGURE 10-3: ***Printed Circuit Board.***

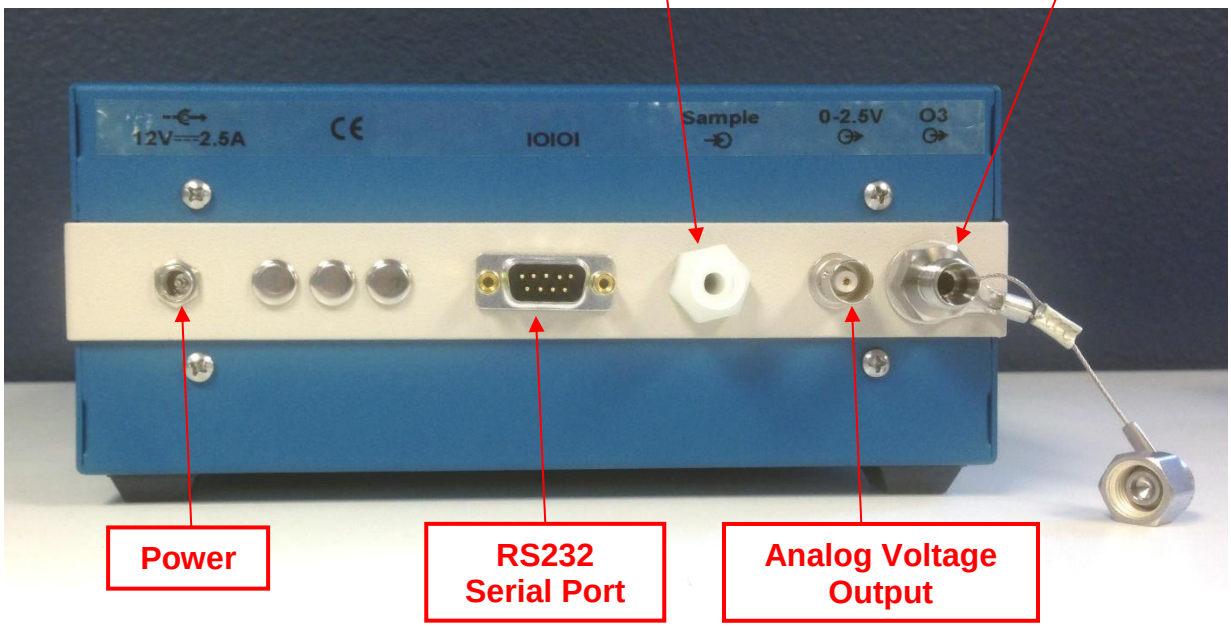


FIGURE 10-4: ***Back panel of Ozone Cal Source™.***

11. PARTS LIST

The following list includes those parts of the Model 306 Ozone Calibration Source™ that are user serviceable.

Please see the 2B Technologies website for a full and updated list of parts and pricing: http://twobtech.com/parts-online.html

Part Number	Description
OZPUMP306	Air pump (5,000 hr), Hargraves, for Models 306 and 408
PDASSEMBLY306	Photodiode assembly for Model 306
FLOWMETER306	TSI flow meter assembly for Model 306
SELECTSWITCH	Select switch for Models 202, 205, 306, and 408
OZVLV306	Solenoid valve and cable for Model 306
PWRASSY	Internal power jack and cable for Models 202, 205, 306, 400, 410
PWRPK-2.5 A	2.5 amp power pack
SERUSB	Serial-to-USB adapter
SERCABL	Serial cable for connecting instrument to computer (straight-through, female-female, 9-pin)
SCRBINT306OZ	Internal ozone scrubber for Model 306
SCRBINT306NOX	Internal O_3/NOx scrubber for Model 306

12. SERVICE LOG

2B Technologies, Inc. Model 306 Ozone Calibration Source™

Purchase Date: _____ Serial No._____

Date	Calibrated	Cleaned	New O_3/NO_x or Outlet Scrubber	New Pump	New Lamp	Other

Date	Calibrated	Cleaned	New O_3/NO_x or Outlet Scrubber	New Pump	New Lamp	Other