

# Ozone Monitor

## Scrubberless Dual Beam

**2B Technologies, Inc.**



## OPERATION MANUAL

### Model 211

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## ***IDENTIFICATION RECORDS***

Record the following information for future reference:

Unit serial number: \_\_\_\_\_

Warranty start date: \_\_\_\_\_  
(date of receipt)

## PRINTING HISTORY

This manual covers the Model 211 Scrubberless Ozone Monitor used for accurate measurements of atmospheric ozone over a dynamic range extending from a limit of detection of 1.0 part-per-billion by volume (ppb) to an upper limit of 2.0 parts-per-million by volume (ppm). The Model 211 ozone monitor combines the stability of our proven dual beam ozone monitors with our selective scrubber technology to greatly reduce potential interferences from particulates, VOCs, and mercury, thereby providing accurate ozone measurements even in the most polluted air.

New editions of this manual are complete revisions that reflect updates to the instrument itself, as well as clarifications, additions, and other modifications of the text. In this revision, the instrument was modified to include an SD card data logger.

Revision A .....	July 2012
Revision B .....	September 2012
Revision C .....	January 2013
Revision D .....	September 2013
Revision E .....	January 2014
Revision F .....	May 2014
Revision G-1 (serial no. 24 and above) .....	3 August 2017
Revision G-2 (serial no. 24 and above) .....	14 August 2017
<i>(Correction to Equation 4 on page 3; updated page numbering.)</i>	
Revision G-3 (serial no. 24 and above) .....	4 December 2017
<i>(Clarification regarding 8 g and 16 g N<sub>2</sub>O cartridges; addition of scrubber info to specification table; Appendix B updates.)</i>	

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## **WARRANTY STATEMENT**

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### **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](http://www.twobtech.com/techsupport)

This way all technical staff at 2B Tech will be alerted to 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](mailto: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.

### **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 the Ozone Monitor 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.

## Safety Warning

The Model 211 Scrubberless Ozone Monitor is designed to use an internal generator of nitric oxide (NO) that makes use of an external source of nitrous oxide (N<sub>2</sub>O) gas. Nitric oxide is a toxic gas and should be handled with caution. Under normal operating conditions, the instrument will produce ~5 ppm NO in air. The instrument is equipped with an internal NO and NO<sub>2</sub> scrubber to remove these compounds before venting the sample. However, the scrubber has a lifetime of approximately 2 months of continuous use and when used up could result in the release of NO through the outlet. For this reason, it is recommended to properly vent the output of the instrument to protect against any unscrubbed NO. The outlet should not be vented near the inlet of any NO<sub>x</sub> or ozone monitor inlets to avoid false measurements.

The NIOSH exposure limit for nitric oxide is 25 ppm (8-hour time weighted average).

The NO generator uses nitrous oxide (N<sub>2</sub>O) to produce NO by photolysis. The nitrous oxide is supplied by an external cylinder or lecture bottle. Nitrous oxide or “laughing gas” is commonly used as a general anesthetic at concentrations up to 50% and is thus well tolerated by humans. There are no known toxicological effects of N<sub>2</sub>O other than asphyxiation at extremely highly concentrations due to exclusion of oxygen. N<sub>2</sub>O is not itself combustible, but it strongly supports combustion of organic materials and reducing agents.

The Material Safety Data Sheet (MSDS) for N<sub>2</sub>O may be found here:

<https://www.airgas.com/msds/001042.pdf>

The MSDS for NO may be found here:

<https://www.airgas.com/msds/001039.pdf>

# 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 choc qui pourrait être dangereux, déconnectez 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, daß 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 handling 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：**

任何需要触及设备内部的操作可能造成人身伤害。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の指定でなければ、機器の保護が損なえます。



## 1. OZONE MONITOR INTRODUCTION

The 2B Technologies Scrubberless Ozone Monitor™ is designed to enable accurate measurements of atmospheric ozone over a dynamic range extending from a limit of detection of 1.0 part-per-billion by volume (ppb) to an upper limit of 2.0 parts-per-million by volume (ppm) based on the well-established technique of absorption of ultraviolet light at 254 nm.

The Scrubberless Ozone Monitor uses the proven ultraviolet (UV) absorption method with a patented ([US Patent no. 8,395,776 B2](#)) gas-phase scrubber technology to measure ozone virtually free from interferences. In the reference measurement step, the instrument uses the reaction between ozone and nitric oxide (NO) to selectively remove ozone from the sample. The reaction of NO with O<sub>3</sub> is orders of magnitude faster than with any other ambient gas, resulting in the removal of only ozone but not other potentially interfering compounds that absorb UV light. The instrument is ideally suited for measurements of ozone in heavily polluted air where interference is likely from particulates, mercury, or VOCs. The ozone monitor combines the stability of our proven dual beam ozone monitors with our selective scrubber technology to provide accurate ozone measurements in the most polluted air.

### 1.1 Theory of Operation

Absorption of UV light has long been used for measurements of atmospheric ozone with high precision and accuracy. The ozone molecule has an absorption maximum at 254 nm, coincident with the principal emission wavelength of a low-pressure mercury lamp. Few molecules found at significant concentrations in the atmosphere absorb at this wavelength. However, UV-absorbing organic compounds containing aromatic rings (benzene, toluene, xylene, etc.), can occur in highly polluted air and provide an interference of up to several ppb. Indoor air can contain a wide variety of UV-absorbing compounds due to outgassing of polymeric materials such as carpet, furniture, and insulation. Mercury vapor can be a significant interference inside buildings where mercury spills have occurred in the past and in the vicinity of certain mining operations. Because ozone monitors use a Hg vapor lamp as an excitation source, mercury is detected with about 1,000 times more sensitivity than is ozone. In other words, 1 part-per-trillion of Hg can produce a signal equivalent to about 1 ppb of ozone. UV-absorbing compounds are present in many industrial settings as well. Because of these potential interferences, 2B Technologies developed the scrubberless ozone monitor to provide a very high degree of selectivity against all UV-absorbing compounds other than ozone. The term “scrubberless” means that the instrument does not contain a conventional solid-phase ozone scrubber. Instead, nitric oxide is used in the gas phase to remove or “scrub” ozone.

The interference problem in conventional ozone monitors can be traced to the ozone scrubber. UV absorbing compounds that adsorb on the solid-phase scrubber and are removed from the sample air in the “reference” measurement are erroneously measured as ozone. The Model 211 Scrubberless Ozone Monitor uses a gas-phase

scrubber technology that quantitatively removes ozone from the sample and does not remove UV-absorbing compounds. Since the potentially interfering compounds are present at the same concentrations in the “reference” and “sample” measurement steps, their contribution to the measured light absorption is cancelled out and they are not measured as ozone.

The gas-phase scrubber technology is based on the quantitative reaction of nitric oxide (NO) with ozone (O<sub>3</sub>):



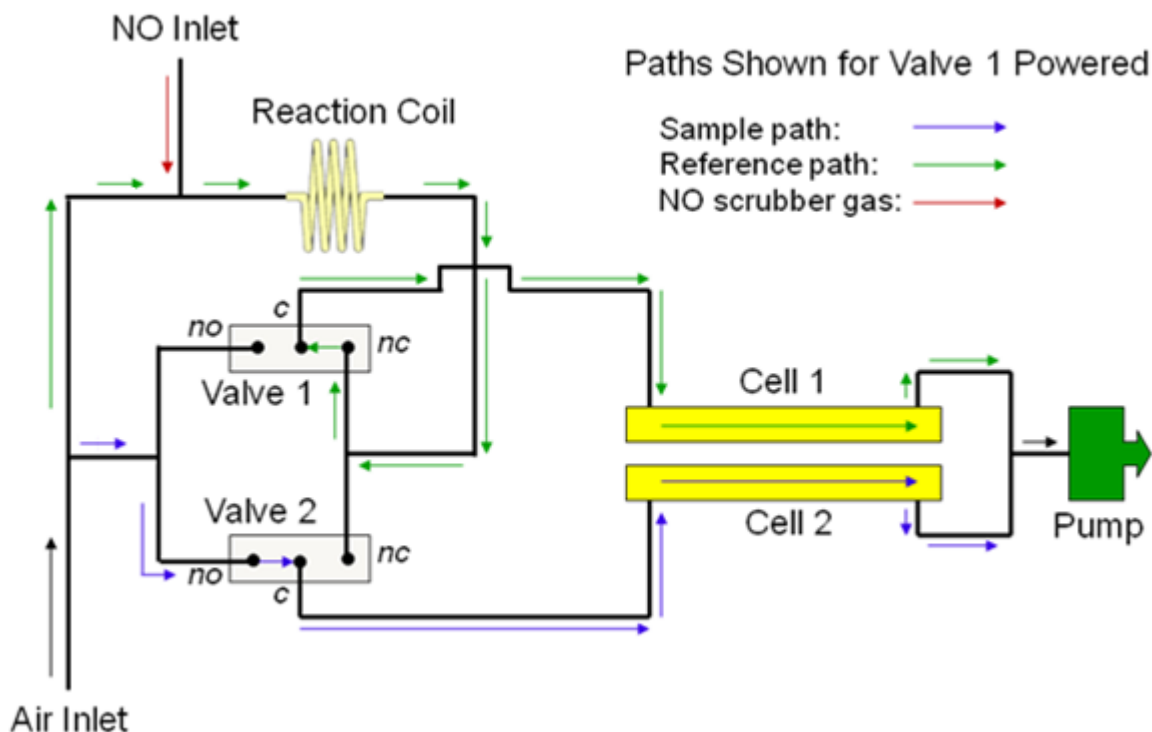
This reaction has long been used as a gas-phase titration for the measurement of either NO or O<sub>3</sub> in laboratory kinetics experiments, and the reaction is stoichiometric; i.e., one O<sub>3</sub> molecule is consumed for every NO molecule oxidized to NO<sub>2</sub> in the reaction. This reaction is orders of magnitude faster than with any other ambient gas, resulting in the removal of only ozone and not other potentially interfering compounds that absorb UV light. In the Model 211 Scrubberless Ozone Monitor, rather than direct the gas flow through a solid-phase ozone scrubber to obtain a reference light intensity, a small concentration of NO (~5 ppm) is periodically added to the gas sample stream to destroy ozone in the gas phase.

Because of the dilution effect of the added NO, the contributions to absorbance by interfering compounds will be slightly different during reference (*I*<sub>o</sub>) and sample (*I*) measurements. The absorbance by an interference will be reduced by the factor *R* as follows:

$$R = \frac{F_{\text{Sample}} + F_{\text{Reagent}}}{F_{\text{Reagent}}} \quad (2)$$

In other words, if the NO flow makes up 1% of the total flow, the absorbance from interferences is reduced by a factor of 100.

Figure 1.1 is a schematic diagram of the dual beam ozone monitor. Ozone is measured based on the attenuation of light passing through two separate 30-cm long absorption cells fitted with quartz windows. A single low-pressure mercury lamp is located on one side of the absorption cells, and photodiodes are located on the opposite sides of the absorption cells. The photodiodes have built-in interference filters centered at 254 nm, the principal wavelength of light emitted by the mercury lamp. An air pump draws sample air into the instrument at a flow rate of approximately 2.0 L/min. The flow is split, and nitric oxide is added to one flow path to remove ozone from the sample as it passes through the reaction coil. A pair of solenoid valves switch in unison so as to alternately send ozone-scrubbed air and unscrubbed air through the two absorption cells. Thus, the intensity of light passing through ozone-scrubbed air (*I*<sub>o</sub>) is measured in Cell 1 while the intensity of light pass through unscrubbed air (*I*) is measured in Cell 2. Every 2 seconds, the solenoid valves switch, changing which cell receives ozone-scrubbed air and which cell receives unscrubbed air.



**Fig. 1.1.** Schematic diagram of the Model 211 Scrubberless Ozone Monitor. Flow paths are shown for Valve 1 powered and Valve 2 unpowered.

Ozone concentration,  $[O_3]$ , in units of molecules/cm<sup>3</sup> is calculated for each cell from the measurements of  $I_o$  and  $I$  according to the Beer-Lambert Law:

$$[O_3] = \frac{1}{\sigma l} \ln \left( \frac{I_o}{I} \right) \quad (3)$$

where  $l$  is the path length (30 cm) and  $\sigma$  is the absorption cross section for ozone at 254 nm ( $1.15 \times 10^{-17}$  cm<sup>2</sup> molecule<sup>-1</sup> or 308 atm<sup>-1</sup> cm<sup>-1</sup>), which is known with an accuracy of approximately 1%. The 2B Technologies instrument uses the same absorption cross section (extinction coefficient) as used in other commercial instruments.

In order to convert this concentration to a mixing ratio (fraction of total air molecules that are ozone), we also measure the cell temperature and pressure, which determines the total concentration of air molecules. From the temperature and pressure we use the ideal gas law to calculate the concentration of molecules,  $M$ , in the detection cell. Ozone in units of ppb is then given by:

$$[O_3]_{ppb} = 10^9 \frac{[O_3]}{[Air]} = 10^9 \frac{RT}{N_A P l \sigma} \ln \left( \frac{I_o}{I} \right) \quad (4)$$

where  $N_A$  is Avogadro's number ( $6.02214129 \times 10^{23}$  molec/mol),  $R$  is the gas constant ( $82.05746$  cm<sup>3</sup> atm K<sup>-1</sup> mol<sup>-1</sup>),  $T$  is the absolute temperature in K, and  $P$  is the cell pressure in atmospheres.

The instrument displays and records the cell temperature and pressure in addition to the ozone mixing ratio. The cell pressure is displayed and logged in units of either Torr or mbar, and the cell temperature in units of either °C or K.

## 1.2 Calibration and Zeroing Overview

In principle, the measurement of ozone by UV absorbance requires no external calibration; it is an absolute method. However, non-linearity of the photodiode response and electronics can result in a small measurement error. Therefore, each instrument is compared with a NIST-traceable standard ozone spectrophotometer in the laboratory over a wide range of ozone mixing ratios (typically 0-300 ppb for atmospheric applications). These results are used to calibrate the Ozone Monitor with respect to an offset and slope (gain or sensitivity). The corrections for offset and slope are recorded in the instrument Birth Certificate and on a calibration sticker that can be viewed by removing the top cover of the instrument. These calibration parameters are entered into the microprocessor memory prior to shipment. The user may change the calibration parameters from the front panel if desired. It is recommended that the Ozone Monitor be recalibrated at least once annually and preferably more frequently. This calibration may be performed by the user (see Section 7 of this manual), or the ozone monitor may be returned to 2B Technologies for calibration service.

The offset may drift due to temperature change or chemical contamination of the absorption cell. As discussed in Section 8 below, an accurate offset correction can be measured from time to time using the external ozone scrubber supplied with the instrument. The user may change the slope and offset calibration parameters by entering the LCD menu (see Section 4.11) or the serial menu (Section 5).

## 1.3 Nitric Oxide Scrubber Gas

As discussed in Section 1.1, the instrument uses nitric oxide (NO) as a gas-phase scrubber, rather than a solid-phase scrubber. This patented process has the advantage of reducing interferences in the ozone measurement. Two different approaches can be used for supplying the NO scrubber gas:

- (1) *Indirect: N<sub>2</sub>O Gas Photolysis.* Compressed gas cylinders are commonly used for supplying nitric oxide, but have the limitation of being expensive and requiring expensive, corrosion-resistant pressure regulators. The internal NO generator supplied with the Model 211 Ozone Monitor makes use of a low-pressure mercury lamp to photolyze nitrous oxide (N<sub>2</sub>O), an inexpensive, non-corrosive and low toxicity gas, to produce NO. The vacuum UV emission lines of mercury near 185 nm are absorbed by N<sub>2</sub>O to produce electronically excited oxygen atoms, O(<sup>1</sup>D<sub>2</sub>). A large fraction of these highly energetic oxygen atoms react with N<sub>2</sub>O to form NO:



where  $h\nu$  symbolizes a photon of light. The concentration of NO produced in a flowing stream of air depends on the intensity of the photolysis lamp, the

concentration of N<sub>2</sub>O (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, a flow of air containing a constant concentration of NO can be produced and the concentration of NO produced can be varied by varying the lamp intensity. This same technology is used in the 2B Technologies Model 408 Nitric Oxide Calibration Source. The N<sub>2</sub>O gas can be supplied using either a compressed-gas cylinder of N<sub>2</sub>O, or for greater portability we have designed the Model 211 to enable use of inexpensive 8-gram or 16-gram liquid N<sub>2</sub>O cartridges that are commercially available. These cartridges provide 4 hours or 8 hours of continuous operation, respectively.

- (2) *Direct: NO Gas Cylinder.* Nitric oxide may be directly supplied to the Model 211 using a compressed-gas cylinder of 400 ppm of NO in N<sub>2</sub>.

Please see Section 3.4.2 for further details on working with the gas-phase scrubber.

#### **1.4 Federal Equivalent Method (FEM) Designation**

Designation of the Model 211 Ozone Monitor as a Federal Equivalent Method (FEM) was published in the [Federal Register](#) on June 18, 2014 (EQOA-0514-215).

## 2. SPECIFICATIONS: MODEL 211 OZONE MONITOR

<b>Measurement Principle</b>	UV Absorbance at 254 nm; Dual Beam
<b>Federal Equivalent Method (FEM)</b>	Yes, EQOA–0514–215
<b>Ozone Scrubber Technology</b>	Gas-phase scrubber using NO, provided directly or by photolysis of N <sub>2</sub> O (supplied by either compressed-gas cylinder or portable liquid cartridge)
<b>Linear Dynamic Range</b>	0-2,000 ppb (0-2 ppm)
<b>Resolution</b>	0.1 ppb
<b>Precision (1<math>\sigma</math>; rms noise)</b>	Greater of 0.5 ppb or 1% of reading for 10-s average
<b>Accuracy</b>	Greater of 1.0 ppb or 2% of reading
<b>Limit of Detection (2<math>\sigma</math>)</b>	1.0 ppb for 10-s average
<b>NIST-Traceable Calibration</b>	Yes
<b>Flow Rate (nominal)</b>	~2 Liter/min
<b>Flow Rate Requirement</b>	>1.2 L/min
<b>Baseline Drift</b>	<1 ppb/day <3 ppb/year
<b>Sensitivity Drift</b>	<0.5%/day <3%/year
<b>Response Time, 100% of Step Change</b>	20 s for 10-s averaging; 4 s for 2-s measurement mode
<b>Measurement and Averaging Times</b>	2 s, 10 s, 1 min, 5 min, 1 hr
<b>Internal Data Logger Capacity</b>	16,383 lines (10-s avg = 1.9 days; 1-min avg = 11 days; 5-min avg = 1.9 mo; 1-hr avg = 1.9 yr)
<b>SD Card Logger Capacity</b>	Minimum 2 GB (> 5-year capacity for 10-s measurement mode)
<b>Ozone Units</b>	ppb, pphm, ppm, $\mu\text{g m}^{-3}$ , $\text{mg m}^{-3}$
<b>Pressure Units</b>	mbar, torr

<b>Temperature Units</b>	°C, K
<b>T and P Corrected</b>	Yes
<b>Operating Temperature Range</b>	10 to 50 °C
<b>Operating Altitude Range</b>	~0-13.5 km (150-1,013 mbar) standard; ~0-25 km (30-1,013 mbar) with upgraded pressure sensor
<b>Power Requirement; Supplied by Battery or 110/220 VAC Power Pack</b>	11-14 V DC or 120/240 V AC, nominally 1 A at 12 V, 12 watt
<b>Size</b>	Rackmount: 17" w × 14.5" d × 5.5" h (43 × 37 × 14 cm)
<b>Weight</b>	14.7 lb (6.7 kg)
<b>Data Outputs</b>	USB, RS232, 0-2.5 V Analog, Optional 4-20 mA Analog
<b>Data Transfer Baud Rates</b>	2400, 4800, 19200
<b>Output Ranges</b>	User-Defined Scaling Factor in Menu
<b>DewLine™</b>	Yes
<b>Long-Life Pump</b>	Yes, 20,000 hr
<b>Flow Meter</b>	Yes
<b>Options</b>	Battery, External Particle Filter, Lamp Heater, Bluetooth, 4-20 mA Analog Current Output, External USB Adapter, High-Altitude Upgrade (pressure sensor)

### 3. INSTALLATION AND START-UP

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

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

#### 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 Pre-Operation Flow Settings of the Ozone Monitor

The Model 211 Scrubberless Ozone Monitor has two flow rates that need to be verified and adjusted before operating the instrument. These are the volumetric flow rates through cell A and B. The flow rates are adjusted to be in the correct range at the factory. However, due to changes in altitude and thus pressure, the flow rates need to be verified and adjusted to be within the specified ranges if necessary. To do this, turn the instrument on and read the volumetric flow rates reported as Fa and Fb in units of  $\text{cm}^3/\text{min}$  on the front display. These flow rates must be in the range 900-1300  $\text{cm}^3/\text{min}$ . The flows are pulled through the cells by a single pump and can be adjusted by the needle valve located on the back panel labeled "Sample Flow". Once these flows have been verified and adjusted they should not need to be readjusted unless the instrument's location changes in altitude.

#### 3.3 Powering and Startup of the Ozone Monitor

To operate the Ozone Monitor, connect it to an external power source and power the instrument on using the front panel power switch. The instrument requires a 12 V DC source, which can be supplied by the 110-220 V AC power adapter provided or an external battery. The power source should be capable of supplying at least 2.5 amperes of current at 12 V (30 watts). The source can be in the range 11-14 V DC without any detrimental effects on the measurement.

Once turned on, the instrument will display the version number of the firmware installed on the microprocessor followed by a display of the time and date. After a few seconds, the instrument will start displaying readings for ozone, and alternates in displaying readings for temperature and pressure of the absorption cell, flow rates, time/date, and instrument settings for the scrubber source gas and logging function. During the first two minutes the readings will be spurious, with large positive and negative swings, due to the rapid warm up of the lamp and electronics. Also, ozone



readings may be inaccurate during the 10-20 minutes required for the lamp, photodiode, and internal temperature of the absorption cell to stabilize.

### 3.4 Connections and Setup

#### 3.4.1 Exhaust Vent

Vent the EXHAUST port (see Fig. 3-4) to atmospheric pressure and out of the room. The ozone monitor has an internal scrubber that removes nitric oxide from the sample before exiting the instrument through the EXHAUST port. However, it is recommended that the pump exhaust be vented to a well-ventilated area outside the room in case the scrubber fails.

#### 3.4.2 Gas-Phase Scrubber Source Gas

As mentioned in Section 1.3, the user may choose to employ either  $N_2O$  or NO gas for the gas-phase scrubber. **NOTE: Be sure to specify the scrubber gas you are using before operation;** see Section 4.4. Three configurations are possible:

$N_2O$  cylinder: A compressed cylinder of nitrous oxide ( $N_2O$ ) may be used with the Nitric Oxide Generator inside the ozone monitor to generate the required NO reagent gas. The purity of the nitrous oxide must be 95% or higher. Connect the cylinder to the 1/4" compression fitting on the back of the instrument labeled "Reagent Gas" (see Section 10, Figure 10.4) using tubing made from high purity materials, such as Kynar, FEP, or PTFE. Open the cylinder and adjust the pressure regulator to deliver a pressure of 15 to 20 psig. Do not adjust the pressure higher than 20 psig. The instrument has a pressure relief device that opens at 25 psig and will exhaust the contents of the cylinder if over-pressurized. When using  $N_2O$  as the scrubber gas, choose **N2O** in the **Cfg/Gas** menu.

$N_2O$  cartridge: The Model 211 Ozone Monitor comes with a cracker for use with 8-gram or 16-gram  $N_2O$  cartridges (see Section 10, Figure 10.5), which provide 4 hours or 8 hours of continuous operation, respectively.  $N_2O$  cartridges of sufficient purity are commonly available commercially for food and restaurant applications. This configuration gives greater portability and avoids the use of compressed-gas cylinders, but does require more frequent attention to replace the spent  $N_2O$  cartridges. Set the **Cfg/Gas** menu to  $N_2O$  as the source gas. See Appendix B of this manual for more information about working with the  $N_2O$  cartridge cracker.

NO cylinder: A compressed cylinder of nitric oxide can be used to supply NO reagent gas to the Model 211. For the instrument to operate correctly, the cylinder should be 400 ppm +/-5% nitric oxide in nitrogen. Connect the cylinder to the 1/4" compression fitting on the back of the instrument labeled "Reagent Gas" using tubing made from high purity materials, such as Kynar, FEP, or PTFE. Open the cylinder and adjust the pressure regulator to deliver a pressure of 15 to 20 psig. Do not adjust the pressure higher than 20 psig. The instrument has a pressure relief device that opens at 25 psig and will exhaust the contents of the cylinder if over-pressurized. When using NO/ $N_2$  as the scrubber gas, choose **NO** in the **Cfg/Gas** menu.

### **3.4.3 Sample Inlet Line**

Attach the sample inlet line to the SAMPLE inlet port see Figure 3-4). The pressure of the sample gas at the inlet port should be at ambient pressure and constant. The inlet 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 to minimize ozone destruction. Tygon®, polypropylene (which may look like Teflon®) and metal tubing should not be used. Teflon®-lined Tygon® tubing, which is used inside the instrument provides the flexibility of Tygon with the inertness of Teflon®. A Teflon® inlet filter is highly recommended to prevent internal contamination of the tubing and absorption cell by particulate matter. The filter should be tested for ozone loss by measuring ambient ozone with and without the filter attached. Filters and filter holders are available through 2B Technologies. See our website: [www.twobtech.com/shop](http://www.twobtech.com/shop).

If the instrument is being flown on an aircraft, tethered balloon, kite, etc., the inlet should not point into the wind, because the resulting pressure fluctuations will cause a noisy signal. Although the instrument compensates for temperature drift, if strong temperature fluctuations are expected, as in vertical profiling applications using balloons, the instrument should be placed in a thermally insulated box in order to slow the rate of temperature change.

### **3.5 Checking the Zero Offset**

Check the zero measurement occasionally, or if the instrument has not been used recently. The electronic zero of the instrument may be measured by attaching an external ozone scrubber to the air inlet for a period of 5-10 minutes. For an accurate measurement, the instrument must have been turned on long enough for the internal temperature to stabilize (~20 minutes). The observed offset, which can amount to a few ppb, can be corrected by changing this calibration Zero parameter from the front panel, as described below (Section 4.11 “Setting the Ozone Measurement Calibration Parameters”), or by correcting the data at a later time. See Section 8 for further information about checking the zero offset.

An external ozone scrubber is supplied with the Model 211 Ozone Monitor at purchase. Replacement scrubbers are available as part SCRBEXT on our online store at <http://twobtech.com/shop/html> or by contacting us at [sales@twobtech.com](mailto:sales@twobtech.com).

A summary of start-up and operating recommendations is given on the next page.

### 3.6 Summary of Start-Up and Operating Recommendations

Recommendation	Frequency	Manual Section
Allow ~20 minutes for instrument warmup before taking data	Each startup	3.3
Specify the scrubber gas (N <sub>2</sub> O or NO) from the LCD menu	Each startup	4.4
Check flow rates to be sure they are in the range 900-1300 cm <sup>3</sup> /min	Initial use of instrument, and whenever the instrument is moved to a new location	3.2
Vent the exhaust port to a fume hood or outside of room	Each use	3.4.1
If using a compressed-gas cylinder of N <sub>2</sub> O or NO for the scrubber gas, keep pressure below 20 psig (15-20 psig recommended)	Each use	3.4.2
Inlet tubing should be made of PTFE (Teflon), PFA, or some other inert material (do not use Tygon, polypropylene, or metal)	Each use	3.4.3
Recharge or replace internal NO scrubber and filter	Every 2 months of continuous operation	6; p. vii
Check the zero offset	Occasionally or if not used recently	3.5, 8
Perform multipoint calibration	<ul style="list-style-type: none"> <li>• Annually</li> <li>• Any time major disassembly of components is performed</li> <li>• Any time the zero or span checks give results outside of the acceptable limits</li> </ul>	1.2, 7
If strong temperature fluctuations are expected, place the instrument in a thermally insulated box	User-defined	3.4.3

## 4. OPERATION

### 4.1 Beginning Measurements

As noted in Section 3.4.2 above, the scrubber gas must be specified as either N<sub>2</sub>O or NO in the menu at startup. The following sections describe how to access the menu; see Section 4.4 for specific instructions on setting the scrubber gas.

The instrument displays readings for ozone, and alternates in displaying readings for temperature and pressure of the absorption cell, flow rates, time/date, and instrument settings for the scrubber source gas and logging function. When first turned on, the instrument will start making measurements at a rate of once every 2 s (unless a different averaging time was previously chosen; see Section 4.6 below). The data may be logged in the internal data logger (Section 4.7). Up to 16,383 data lines containing log number, ozone mixing ratio, internal cell temperature, internal cell pressure, volumetric flow rates, date, and time may be stored in internal memory, corresponding to an operational time of 9.1 hours with no averaging. Averaging times of 10 s, 1 min, 5 min and 1 hr also may be selected from the menu, thereby allowing the instrument to operate for 1.9 days, 1.6 weeks, 1.9 months, and 1.87 years, respectively, before filling the memory.

### 4.2 Accessing the Main Menu

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



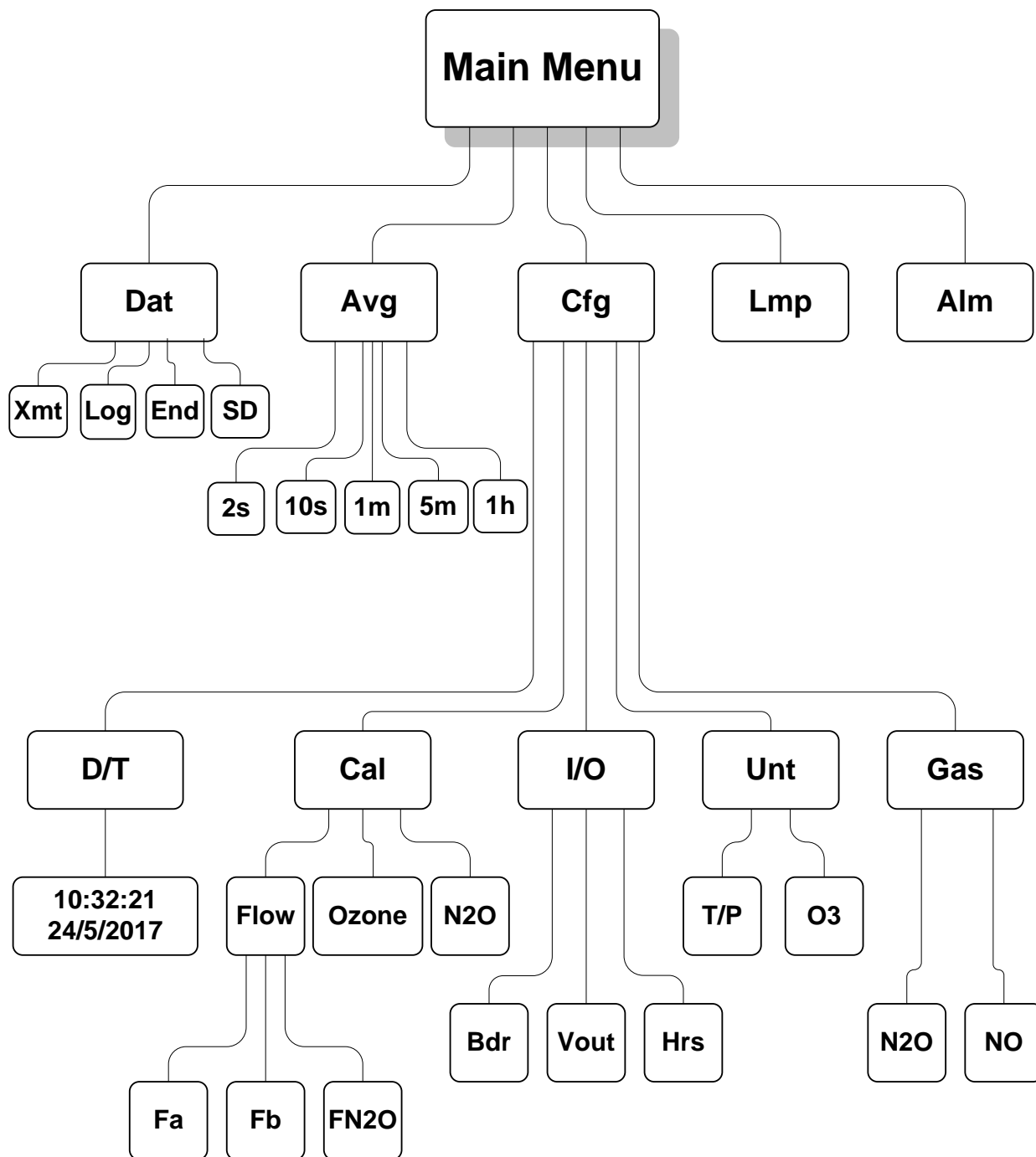
To reach the **Main Menu**, hold in the Select switch until the display shows: **Menu**. Then release the switch. The panel will now display:

**Menu**  
**Dat Avg Cfg Lmp Alm ←**

where **Dat**, **Avg**, **Cfg**, **Lmp**, and **Alm** 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 (←).

### 4.3 Menu Tree

The following diagram summarizes the complete menu.



#### 4.4 To Select the Scrubber Gas

By selecting **Gas** from the **Cfg** menu, the user can select between nitric oxide (**NO**) or nitrous oxide (**N2O**) for the scrubber gas. If **N2O** is selected, the photolysis lamp is activated to convert N<sub>2</sub>O to NO and a different flow calculation is used for measuring the scrubber gas flow. If **NO** is selected, the photolysis lamp is deactivated.

Access the **Main Menu** as described in Section 4.2. Select the **Cfg** submenu from the by rotating the Select switch until the cursor is under the “C” and then clicking the Select switch. Rotate the Select switch and click to choose either N<sub>2</sub>O or NO. Exit the submenus by clicking on the left arrow (←). Note that “←” always takes you up one level in the menu.

#### 4.5 Making Measurements without Averaging or Logging

Access the **Main Menu** as described in Section 4.2. Select the **Dat** submenu from the by rotating the Select switch until the cursor is under the “D” and then clicking the Select switch. The display will now show:

**Dat Menu**  
**Xmt Log End ←**

Click on **End** to make measurements without logging new data. Click on ← to return to the **Main Menu**. Select the **Avlg** submenu and then select “2s” to make measurements without averaging. The instrument will return to the **Main Menu**. Click ← again to exit the Main Menu and start making measurements without logging or averaging. As noted earlier, “←” always takes you up one level in the menu.

The Ozone Monitor will then display the most recent O<sub>3</sub> measurement along with alternating displays of other instrument measurements. For example, the display might read:

**O3= 30.7 ppb**  
-----  
**Fa=955 FN2O=13**  
**T=33.3 P=989.7**

where the current O<sub>3</sub> measurement is 30.7 ppb O<sub>3</sub>, Flow A is 955 cm<sup>3</sup>/min, the N<sub>2</sub>O Flow is 13 cm<sup>3</sup>/min, the temperature in the absorption cell is 33.3°C, and the pressure is 989.7 mbar (see Section 4.13 below for setting other options for the units used for T, P, and O<sub>3</sub>). A few seconds later, this display will be followed by:

**O3= 30.1 ppb**  
-----  
**LOG=OFF SGAS=N2O**  
**15:07 19/07/17**

showing that data logging is off, the scrubber gas source is set to N<sub>2</sub>O, the time is 3:07 p.m., and the date is 19 July 2017.

## 4.6 Data Averaging Using the Menu

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

**Avg Menu**  
**2s 10s 1m 5m 1h ←**

Rotate the Select switch to move the cursor to **2s**, **10s**, **1m**, **5m** or **1h** for times of 2 s (no averaging), 10s, 1 min, 5 min or 1 hr averaging, respectively. Then click on the averaging time you want to use. To return to the Main Menu, click on ←. To exit the Main Menu and start acquiring data, click on ← again.

When 2s is selected, the rapid raw output of the monitor is obtained every 2 seconds. When 10s is selected, the unit is in the default operating mode. In this mode, the average of five 2-s measurements is displayed and updated. When averaging for 1m, 5m, or 1h is selected, the first of the two displays discussed above in Section 4.5 will alternate with a display of the average, for example:

**Avg O3= 35.3 ppb**  
-----  
**LOG=OFF SGAS=N2O**  
**15:07 19/07/17**

where the most recent average value of ozone computed is 35.3 ppb O<sub>3</sub>, the time of the measurement is 3:07 p.m., and the date is 19 July 2017 (see Section 4.13 below for setting other options for the units used for O<sub>3</sub>).

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.

Averaged data may be logged, thereby greatly extending the length of time that the data logger can be used (see next section).

## 4.7 To Log Data Using the Internal Data Logger

### 4.7.1 To Start Logging Data, with or without Averaging

Data may be logged in the internal data logger. Up to 16,383 data lines containing log number, ozone concentration, internal (cell) temperature, internal (cell) pressure, cell flow rates, N<sub>2</sub>O flow rate, NO generator photodiode voltage, date, and time may be stored in internal memory. Measurement output of 2 s, and averaging options of 10 s, 1 min, 5 min and 1 hr may be selected from the menu (see above), thereby allowing the instrument to operate and log data for 9 hours, 1.9 days, 11 days, 1.9 months, and 1.9 years, respectively, before filling the memory.

To begin logging data, select the **Dat** submenu from the Main Menu using the Select switch. The display will now show:

**Data Menu**  
**Xmt Log End SD ←**

To start logging data using the internal data logger, rotate the Select switch to move the cursor to **Log** and click to select the logging mode. You will then be asked whether you want to overwrite the data stored in the logger:

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

**Warning: If you start logging, 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 Section 4.7.3 below) before starting logging.

If you have data stored in the logger that you want to keep, choose **No** and download your data to a computer before starting logging (see Section 4.7.3 below). If you are ready to start logging, then select **Yes** by moving the cursor under **Yes** and clicking. Either selection will return you to the **Dat** submenu. To start data acquisition, select ← and click.

When measurements resume, the display might read:

**O3= 56.7 ppb**  
-----  
**Log=3:0      SGAS=N2O**  
**11:23          19/07/17**

where the ozone value is the most current measurement of ozone, Log is the current log number, SGAS is the scrubber gas used, and time and date are on the bottom row. After 5 seconds (midway between the next 10-s measurement cycle), as an example, the display will be replaced by, for example:

**O3= 56.7 ppb**  
-----  
**Fa=1011      FN2O=11**  
**T=32.5        P=922.4**

where **O3** is the ozone value most recently written to the logger, Fa is the flow rate through cell A in cm<sup>3</sup>/min, FN2O is the flow rate of N2O through the photolysis chamber in cm<sup>3</sup>/min, T is the cell temperature in degrees Celcius, and P is the cell pressure in millibar. (See Section 4.13 below for setting other options for the units used for T, P, and O<sub>3</sub>).

If averaging has been selected, then the log number will be displayed differently:

**Avg O3=56.7 ppb**  
-----  
**Log= 193:4    SGAS=N2O**  
**11:29          19/07/17**



Again 193 refers to the most recent log number. 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 2-s or 10-s averaging is used, this number will always be 0. If 1-min averaging is used, this number will increment from 0 to 5; 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.

#### **4.7.2 To Stop Logging Data**

Hold the Select switch down 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 transmit the data to a computer by clicking on **Xmt** (see Section 4.7.3 below). Alternatively, you may return to the **Menu** by clicking on ←. The stored data will reside in memory (even when new measurements are being made) and can be transmitted using the **Xmt** function as often as you like.

**Warning:** All stored data are lost once logging is started again using the **Log** 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.

#### **4.7.3 To Transmit Logged Data**

Data may be transmitting to a computer via the serial port of the instrument. The **Xmt** (transmit) function may be executed from the menu (**Dat / Xmt**).

Connect the serial port of the instrument (see Figure 10.4) to the serial port of your computer using the 9-pin cable provided. (Note that this is a “straight-through” female-female cable; a “cross-over” cable will not work.) If your computer does not have a serial port, you can use the USB port by means of a serial-to-USB adapter. Such adapters are available in most computer stores or can be supplied by 2B Tech.

Enable a data acquisition program on the computer such as the 2B Technologies Display and Graphing Software, which is available for free downloading at: <http://twobtech.com/software.htm>. Appendix A gives a summary of working with this display software. Alternatively, HyperTerminal can be used (provided with early versions of Windows® platforms, usually in Start/All Programs/Accessories/Communications/HyperTerminal) 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 (2400, 4800, or 19200; see Section 4.12.1); 8 bits; no parity; 1 stop bit.

A disadvantage of Hyperterminal is that it has a 500-line buffer limit for display on the computer screen. However, both programs may be used to log an unlimited number of data lines to a file on your computer. For more details see our Tech Note #007 here: [http://www.twobtech.com/tech\\_notes/TN007.pdf](http://www.twobtech.com/tech_notes/TN007.pdf)

Hold down the Select switch to obtain the **Main Menu**. Go to the **Dat** submenu by clicking on **Dat**. Next, click on **Xmt**. The message “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.

#### 4.8 To Log Data Using the SD Card

2B Technologies provides a SD card logger with the Model 211 Ozone Monitor, along with an SD card and an SD card reader. When inserted into the instrument (bottom right of the Ozone Monitor’s front panel), the SD card automatically begins to collect and store data. (The internal data logger described in Section 4.7 will also be logging data if logging has been selected from the **Dat** submenu.) The data are saved to a .txt file in the following format:

67.4,35.3,980.6,1245,1227,10.2,0.103,1.015,15/07/17,18:31:27

where:

Ozone = 67.4 ppb

Cell temperature = 35.3°C *(may be expressed in K if chosen from menu)*

Cell pressure = 980.6 mbar *(may be expressed in torr if chosen from menu)*

Cell A volumetric flow rate = 1245 cc/min *(should be 900-1300 cc/min)*

Cell B volumetric flow rate = 1227 cc/min *(should be 900-1300 cc/min)*

N<sub>2</sub>O volumetric flow rate = 10.2 cc/min *(should be 5-30 cc/min)*

NO generator photodiode voltage = 0.103 volts (*should be 0.005-2.15 V*)  
Completeness of reaction correction factor = 1.015  
Date = July 15, 2017  
Time = 6:31:27 pm

If the Ozone Monitor has been set to the log data mode, the output serial data line will be preceded by the log number; e.g.,

2893,67.4,35.3,980.6,1245,1227,10.2,0.103,1.015,15/07/17,18:31:27

where 2893 is the log number.

Data files on the SD card are named "LOG01.txt," "LOG02.txt," etc. Note that the SD card contains a LOGCON.txt file that should not be modified or deleted.

Data logging on the SD card will continue until the instrument is powered off. A new data file is begun each time the instrument is powered on.

To eject the SD card, first save the file through the LCD menu (**Menu / Dat / SD**). Then eject the SD card by pushing it in to activate the spring mechanism. Insert the SD card into an SD card reader (one is supplied by 2B Technologies with the instrument) to download the data to your computer.

**Important:** Do not remove the SD card or power off the instrument without first saving the data through the front panel LCD menu. This minimizes the risk of losing any lines of the data. Up to 5 lines of data could be lost if the SD card is removed without first saving the data.

The Model 205 Ozone Monitor is compatible with SD and SDHC memory cards. We recommend using the SD cards available on the 2B Technologies website (<http://twobtech.com/parts-online.html>). Prior to first use, SD cards must be formatted to FAT32. As mentioned above, an SD card and SD card reader are supplied with the Model 205 Ozone Monitor.

See [Technical Note 036](#) for more information about logging and reading data via the SD card.

#### 4.9 Collecting Data from the Analog Output

The data may be logged in real time using a data logger attached to the BNC analog output (see Section 10, Figure 10.4). The range of the analog output is 0-2.5 V. The output is scaled according to a sensitivity you define in the menu. For example, you may define 1V = 100 ppb. In that case, the maximum output is 250 ppb. There is a small positive offset, typically 2 mV in the analog output, but this offset varies from instrument to instrument. The offset can be measured by simultaneously observing the panel display and measuring the analog output with a voltmeter.

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

**Analog Output**  
**1V=00200 ppb ←**

In this example, the output scaling factor is set 1 Volt = 200 ppb, i.e., 2.5 V (full scale) = 500 ppb and 1 ppb of ozone will read as 5 mV. A reading of zero ozone concentration will be output as 0 V. You can use the select switch to change the scaling factor to the value of your choice by selecting (press in) and changing (by scrolling) the individual digits in the scaling factor of either the voltage. Thus, the instrument is not limited to a fixed number of “ranges” common to most ozone monitors. Instead, any range can be defined.

As an option, the instrument can be purchased with the analog output provided as current rather than voltage. In this case, the current output will be scaled such that the full scale of 20 mA corresponds to the chosen ozone concentration. A reading of zero ozone concentration will be output as 4 mA.

#### **4.10 Collecting Data over the Serial Port in Real Time**

To transmit data to a computer over the serial port in real time, connect the Ozone Monitor to the serial port of the computer using the 9-pin cable provided. Note that this is a “straight-through” female-female serial cable. A “cross-over” cable will not work. If your computer does not have a serial port, you can use the USB port by means of a serial-to-USB adapter. Such adapters are available in most computer stores or can be supplied by 2B Tech.

Enable a data acquisition program on the computer such as the 2B Technologies Display and Graphing Software, which is available for free downloading at: <http://twobtech.com/software.htm>. Appendix A gives a summary of working with this display software. Alternatively, HyperTerminal can be used (provided with early versions of Windows® platforms, usually in Start/All Programs/Accessories/Communications/HyperTerminal) 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 (2400, 4800, or 19200; see Section 4.12.1); 8 bits; no parity; 1 stop bit.

A disadvantage of Hyperterminal is that it has a 500-line buffer limit for display on the computer screen. However, both programs may be used to log an unlimited number of data lines to a file on your computer. For more details see our Tech Note #007 here: [http://www.twobtech.com/tech\\_notes/TN007.pdf](http://www.twobtech.com/tech_notes/TN007.pdf)

The ozone mixing ratio (ppb), internal cell temperature (K or °C), cell pressure (torr or mbar), volumetric flow rates (cc/min), photodiode voltage, completeness of reaction correction factor, date, and time are sent as comma-delimited ASCII text to the serial port (2400, 4800 or 19,200 baud; 8 bits; no parity; 1 stop bit) every 2 seconds, 10

seconds, 1 minute, 5 minutes, or 1 hour, depending on the averaging time selected from the microprocessor menu. Time is provided in 24-hour (military) format, and the date is given in European style (day/month/year).

A typical data line might read:

67.4,35.3,980.6,1245,1227,10.2,0.103,1.015,15/07/17,18:31:27

where:

Ozone = 67.4 ppb

Cell temperature = 35.3°C *(may be expressed in K if chosen from menu)*

Cell pressure = 980.6 mbar *(may be expressed in torr if chosen from menu)*

Cell A volumetric flow rate = 1245 cc/min *(should be 900-1300 cc/min)*

Cell B volumetric flow rate = 1227 cc/min *(should be 900-1300 cc/min)*

N<sub>2</sub>O volumetric flow rate = 10.2 cc/min *(should be 5-30 cc/min)*

NO generator photodiode voltage = 0.103 volts *(should be 0.005-2.15 V)*

Completeness of reaction correction factor = 1.015

Date = July 15, 2017

Time = 6:31:27 pm

If the Ozone Monitor has been set to the log data mode, the output serial data line will be preceded by the log number; e.g.,

2893,67.4,35.3,980.6,1245,1227,10.2,0.103,1.015,15/07/17,18:31:27

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.

## 4.11 Setting the Calibration Parameters

All calibration parameters can be accessed through the **Cfg** submenu. Flow rates, ozone measurement, and nitric oxide generation all require separate calibration, which are performed at 2B Technologies before the instrument is packaged and shipped. Flow rate and nitric oxide generation calibration parameters should not be changed unless certain parts of the instrument are replaced, which are normally done by technicians at the factory.

### 4.11.1 To Set the Flow Meter Slopes

There are three different flow measurements that are imperative to the performance of the instrument: one to measure each cell flow and one to measure the scrubber gas flow. Do NOT change these settings unless you contact 2B Technologies.

**Fa** contains the slope setting for Cell A.

**Fb** contains the slope setting for Cell B.

**FN2O** contains the slope setting for the N<sub>2</sub>O flow.

#### 4.11.2 To Set the Ozone Measurement Calibration Parameters

The instrument is calibrated at the factory where slope and offset 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 viewable with the top cover removed. However, the calibration parameters may be changed by the user. For example, it may be desirable to provide a positive offset by a known amount (e.g., 10 ppb) if the analog output is being used for external data logging since the analog output does not go negative below zero ppb. Because of noise and/or an inherent offset, some measured values will be below zero at very low ozone mixing ratios or while zeroing the instrument with an external scrubber (supplied with your instrument at purchase). Also, the instrument zero may drift by a few ppb over time. For this reason, frequent zeroing (preferably daily) of the instrument using an external ozone scrubber to determine the offset is recommended (see Section 8). Any change in the slope (gain) of the instrument is likely due to a serious problem such as contamination, an air leak, obstruction of air flow, or a malfunctioning gas-phase ozone scrubber, but it also can be adjusted. Once the zero of the instrument is corrected, the slope may be adjusted so that the instrument readout agrees with a standard ozone source or with the readout from another instrument whose calibration is considered to be accurate (see Section 7). From the Main Menu, enter the Cal Menu:

**Cal Menu**  
**Flow Ozone N2O ←**

To change the ozone calibration parameters, select Ozone from the Cal menu. Now you can select either **Slope** or **Zero** to adjust slope factor or the zero offset.

**O3 Cal Menu**  
**Slope Zero ←**

Selecting **Slope** will allow you to finally set the slope value one digit at a time out to three decimal places.

**O3 Slope Cal**  
**Slope = 1.011 ←**

To change a digit in the slope, 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 slope is correct, clicking on ← will set the slope to that value and return the display to the **O3 Cal Menu**.

Selecting **Zero** from the menu will display:

**O3 Zero Cal**  
**Zero = -02.5 ←**

Here Zero is the offset applied (in this case -2.5 ppb). The Zero value can be edited in the same method as the Slope value. For the Model 211 Ozone Monitor, the zero value must be entered in units of ppb. If the calibration was performed in other units, convert the offset to ppb and enter that value.

The value of Zero is added to the measured ozone value, and the value of Slope is then multiplied by the measured ozone value. For example, if the instrument reads an average of 3 ppb with the external scrubber in place, the value of Z should be set to – 03.0. If after correction for the zero, the instrument consistently reads 2% low, the value of Slope should be set to 1.020.

It is recommended that the Ozone Monitor be calibrated at least annually. The user may return the instrument to 2B Technologies for calibration servicing. Alternatively, the user may calibrate the instrument. Suggested procedures are given in Section 7.

#### **4.11.3 Nitric Oxide Generation Parameters**

These parameters can be accessed through the **N2O** submenu within the **Cal** menu. Do NOT change these parameters unless you contact 2B Technologies. The slope and the offset values are derived from a factory calibration where the nitric oxide output is compared to the photolysis lamp intensity to calculate nitric oxide in ppb.

### **4.12 Input/Output**

The user can change the serial baud rate, the voltage output scaling factor, and view the total runtime hours via the **I/O** submenu.

#### **4.12.1 To Change the Output Baud Rate**

From the **Cfg** submenu, select **I/O** to give the input/output menu, for example:

**I/O Menu**  
**Bdr Ext LCD ←**

Selecting **Bdr** and clicking allows you to change the baud rate used for data transmission. The choices are 2400, 4800 and 19200 bps. The submenu appears as:

**Baud Rate**  
**2400 4800 19200 ←**

After clicking on a chosen baud rate, the display returns to the **I/O** menu.

#### **4.12.2 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 **Hrs** from the **I/O** menu.

#### **4.12.3 To Change the Analog Output Scaling Factor**

The range of the analog output is 0-2.5 V. There is a small positive offset, typically 2 mV in the analog output, but this offset varies from instrument to instrument. The offset can be measured by simultaneously observing the panel display and measuring the analog output with a voltmeter.

The output is scaled according to a sensitivity you define in the menu. To change the analog output voltage scaling factor, select **V\_Out** from the **I/O** submenu. The display will read for example:

**Analog Output**  
**1V=00200 ppb ←**

In this example, the output scaling factor is set 1 Volt = 200 ppb, i.e., 2.5 V (full scale) = 500 ppb and 1 ppb of ozone will read as 5 mV. A reading of zero ozone concentration will be output as 0 V. You can use the select switch to change the scaling factor to the value of your choice by selecting (press in) and changing (by scrolling) the individual digits in the scaling factor of either the voltage. Thus, the instrument is not limited to a fixed number of “ranges” common to most ozone monitors. Instead, any range can be defined.

As an option, the instrument can be purchased with the analog output provided as current rather than voltage. In this case, the current output will be scaled such that the full scale of 20 mA corresponds to the chosen ozone concentration. A reading of zero ozone concentration will be output as 4 mA.

## 4.13 Measurement Units

### 4.13.1 To Change the Units for Internal Cell Temperature and Pressure

From the **Unt** submenu, select **T/P** to display the following:

**Temp and Press Units**  
**T: C P: mbar ←**

Rotating the Select switch will cycle the cursor between temperature (**T**) and pressure (**P**). Temperature units may be selected as either Kelvin (**K**) or Celsius (**C**) by first clicking to obtain the blinking cursor and then rotating the Select switch to obtain the desired units. Pressure units may be selected as either **torr** or **mbar**. A click on **←** returns the display to the **Unt** submenu.

### 4.13.2 To Change the Units for Ozone

From the **Unt** submenu, select **O3** to display the following:

**Ozone Units**  
**Ozone = ppb ←**

Rotating the Select switch will cycle the cursor between the ozone units and **←**. Ozone units may be selected as ppb, pphm,  $\mu\text{g}/\text{m}^3$ , or  $\text{mg}/\text{m}^3$ . A click on **←** returns the display to the **Unt** submenu.

## 4.14 To Set the Time and Date

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



## Set Date and Time

---

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 ←.

### 4.15 To Test the Lamp Voltage and Precision

A diagnostic lamp test is provided in the **Lmp** submenu of the main menu. During the lamp test, the instrument measures “effective” ozone concentrations in the two detection cells without switching the solenoid valve on and off. These are electronic zeros and should after a few readings settle down to  $\pm 9$  ppb. If either of the values are outside the range -9 to +9, the instrument may not be operating correctly. The display also gives a standard deviation of the electronic zeros. For best results, the standard deviations should be not greater than  $\pm 2.0$ . Note that because less averaging is involved, this is not equal to the overall precision of the instrument; it is a diagnostic test of lamp fluctuations. The lamp test also measures and outputs the voltage levels of detector A and detector B.

For best performance both voltages should be in the range 0.7-2.0 volts. For detector voltages less than about 0.7 volts, the data may be noisy due to insufficient light intensity to make precise measurements. If the voltage is zero, the lamp is not ignited and may have burned out. For voltages above 2.5 volts, the A/D converter is saturated and the measured ozone value will always be zero. This could happen if the instrument is very hot so that the lamp output is too bright.

To exit the **Lmp** test, hold in the Select switch and release to return to the **Main Menu**.

### 4.16 Alarms

#### 4.16.1 Overview

To ensure proper functionality, the parameters that are essential to the measurement process are monitored to stay within certain limits. If any of these parameters is out of operating limits, an alarm is set and the LCD screen may display:

O3 = 25.3 ppb  
-----Alarm-----  
Fa=1011      FN2O=11  
T=29.6        P=987.2

where “Alarm” signifies that one or multiple parameter limits have been exceeded. By selecting **Alm** in the main menu, the status of each alarm is displayed, for example:

**Current Alarms**  
**F: ALOW BHI N2OHI**  
**V: AHI BHI CLOW**  
**Gas Conn: \*\*Check\*\***

where the row starting with “F:” displays the status of all flow alarms, the row starting with “V:” displays the status of all voltage alarms, and the row starting with “Gas Conn:” displays the status of the scrubber gas connection.

#### **4.16.2 Alarm Definitions**

The following is a list of each alarm with its corresponding definition:

##### **Flow (F)**

**No Flow Alarms:** All flow rates are within acceptable limits.

**AHI:** Cell A flow rate is above the maximum acceptable flow rate.

- Maximum flow rate Cell A = 1300 cc/min

**ALOW:** Cell A flow rate is below the minimum acceptable flow rate.

- Minimum flow rate Cell A = 900 cc/min

**BHI:** Cell B flow rate is above the maximum acceptable flow rate.

- Maximum flow rate Cell B = 1300 cc/min

**BLOW:** Cell B flow rate is below the minimum acceptable flow rate.

- Minimum flow rate Cell B = 900 cc/min

**N2OHI:** Nitrous Oxide flow is above the maximum acceptable flow rate.

- Maximum flow rate N2O = 30 cc/min

**N2OLOW:** Nitrous Oxide flow is below the minimum acceptable flow rate.

- Minimum flow rate N2O = 5 cc/min

##### **Voltage (V)**

**No Voltage Alarms:** All voltages are within acceptable limits.

**AHI:** Cell A photodiode voltage is above the maximum acceptable voltage.

- Cell A Vmax = 2.15 Volts

**ALOW:** Cell A photodiode voltage is below the minimum acceptable voltage.

- Cell A Vmin = 0.50 Volts

**BHI:** Cell B photodiode voltage is above the maximum acceptable voltage.

- Cell B Vmax = 2.15 Volts

**BLOW:** Cell B photodiode voltage is below the minimum acceptable voltage.

- Cell B Vmin = 0.50 Volts

**CHI:** NO generation lamp voltage is above the maximum acceptable voltage.

- NO Gen Lamp Voltage Max = 2.15 Volts

**CLOW:** NO generation lamp voltage is below the minimum acceptable voltage.

- NO Gen Lamp Voltage Min = 0.005 Volts

##### **Scrubber Gas Connection (Gas Conn)**

**\*\*Check\*\*:** Scrubber gas connection may be loose or not connected.

**Good:** Scrubber gas connection is secure.

## **5. REMOTE CONTROL VIA SERIAL OR USB CONNECTION**

Measurements and logging tasks can be accessed via the serial port or the USB port using data acquisition software such as the 2B Technologies Display and Graphing Software, available for free downloading at: <http://twobtech.com/software.htm>. See Appendix A of this manual for information about working with this software. Alternatively, a terminal emulator such as [Tera Term](#) or HyperTerminal running on an attached computer. Commands can be sent using the terminal emulator set with the properties listed in Section 4.9 of this manual entitled “Collecting Data over the Serial Port in Real Time.” Listed below are the lower-case letters that are commands for performing certain operations while the instrument continues to measure:

- l** Start logging and write over existing logged data
- t** Transmit logged data
- e** End logging
- h** Output serial data line header
- m** Serial menu

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

### **Menu Commands: Serial Port and USB Port**

- l** Start logging and write over existing logged data
- t** Transmit logged data
- e** End logging
- h** Output serial data line header
- a** Display list of possible averaging times and the number that must be entered to change to the desired averaging time
- z** Display current zero calibration setting and wait for new setting followed by a carriage return
- s** Display current slope calibration setting and wait for new setting followed by a carriage return
- c** Clock menu, display current date and time and wait for **d** or **t** to be entered.  
From clock menu,
  - d** Asks to enter date in DDMMYY format.
  - t** Asks to enter time in HHMMSS format.
  - n** Exit without changing time or date.
- p** Perform lamp test
- d** Turn the LCD backlight on
- g** Turn the LCD backlight off
- h** Output the serial header (also available during measurements).
- ?** Output the help menu
- x** Exit menu and return to measuring

## **6. MAINTENANCE**

The Ozone Monitor is designed to be nearly maintenance free. Components that require routine maintenance include the NO/NO<sub>2</sub> scrubber, which should be recharged at least once every two months of operation, the scrubber filter, and the air pump. The pump has a rated lifetime of 15,000 hours (~1 year and 8 months) of operation and will need to be replaced when the flow rates can no longer be brought into range. Operation with a high restriction on the sample inlet will reduce the lifetime of the pump. The instrument is designed so that pump replacement is relatively easy. Other user serviceable components include the lamp, clock battery, and solenoid valves, which are easily replaced should they fail. In addition, the sample inlet filter (user supplied) should be changed as recommended by the filter manufacturer.

A wide range of Technical Notes, many of which relate to maintenance, are provided on the 2B Tech website. The complete list with links may be found at (clickable link):

[www.twobtech.com/tech\\_notes.htm](http://www.twobtech.com/tech_notes.htm)

These Tech Notes are continuously updated and new ones created.

Also, please note that all 2B Tech instrument manuals are posted online at: [www.twobtech.com/downloads.htm](http://www.twobtech.com/downloads.htm)

For your convenience, a Service Log, which may be printed, is provided near the end of this manual for recording calibrations, replacement of pumps, lamps, etc. Records of repairs made at 2B Tech are maintained in a database at 2B Technologies as well. That database also includes detailed information about the construction and initial calibration of your instrument, including digital of photos of its interior.

## 7. CALIBRATION

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

Calibration is the process of adjusting the gain and offset of the Model 211 Ozone Monitor against some recognized standard. The reliability of the data collected from any analytical instrument depends on the accuracy of the calibration, which is largely dependent upon its analytical traceability to a reference material or reference instrument calibration. It is recommended that calibration be performed at least annually. The instrument may be returned to 2B Technologies for calibration servicing. Alternatively, the user may perform a calibration using the suggested procedures described here.

Because of the instability of ozone, the certification of ozone concentrations in a compressed gas cylinder is impossible due to loss of ozone over time. When ozone concentration standards are required, the ozone must be generated and certified on site. Ozone standards can be classified into two basic types:

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

### 7.1 Equipment Required

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

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

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

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

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

## **7.2 Instrument Preparation**

Prior to calibration, follow the steps below:

1. Turn on the Model 211 Ozone Monitor and allow it to stabilize for a minimum of one hour.
2. Connect the instrument to the manifold of the ozone calibration setup. If a particle filter will be used in normal operation, the calibration must be performed through the filter. The manifold must be vented to atmosphere so that pressure does not build up in the calibration setup. Connection of the Model 211 directly to a pressurized output of any device can damage the ozone monitor.
3. Verify that the flow rate into the manifold is greater than the total flow required by the ozone monitor and any other flow demand drawing from the manifold.

## **7.3 Calibration Setup Preparation**

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

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

### 7.3.1 Setup Check

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

### 7.3.2 Ozone Loss Test

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

### 7.3.3 Linearity Check

Since the Model 211 is inherently linear over several orders of magnitude, a linearity check provides a test that the instrument is operating properly. Instrument linearity can be checked by comparison to an ozone standard (see Section 7.4.4, **Calibration Procedure – Calibration Curve** below) or by dilution of an ozone measurement. To check the instrument linearity by dilution of an ozone measurement, generate and measure a concentration of ozone near the upper range of ozone monitor (80% of full scale is recommended). Additional ozone concentrations should be generated by accurately diluting the ozone flow with zero air and each concentration should be measured once the instrument reaches a stable response. The accuracy of the linearity test relies on the accuracy of the flow meters used to perform the dilution. The percent of nonlinearity is calculated from the formula:

$$R = \frac{F_o}{F_o + F_d} \quad (8)$$

$$E = \frac{C_1 + \frac{C_2}{R}}{C_1} \times 100\% \quad (9)$$

where:

R = Dilution ratio

F<sub>o</sub> = Ozone generator flow

F<sub>d</sub> = Diluent zero air flow

E = Linearity error, in percent

C<sub>1</sub> = Measured concentration of original concentration

C<sub>2</sub> = Measured concentration of diluted concentration

The linearity error should not be greater than 5%. If the error is greater than 5%, the accuracy of the flow dilution should be checked before assuming that the ozone monitor is not linear. Note that the inherent linearity of the Model 211 is better than the error calculated in this linearity check due to the uncertainty introduced by the flow measurements.

#### **7.3.4 Intercomparison Test**

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

### **7.4 Calibration Procedure**

A multipoint calibration should be performed at least every 12 months or within the mandated calibration frequency for certification of your application, any time major disassembly of components is performed, or any time the zero or span checks give results outside of the acceptable limits.

#### **7.4.1 Instrument Preparation**

1. Turn on the Model 211 Ozone Monitor and allow it to stabilize for a minimum of one hour.
2. Enter the calibration menu (Main Menu\Cfg\Cal\O3) and set the zero (Z) value to 0 and the slope (S) value to 1.00.
3. Connect the ozone monitor to the manifold on the ozone calibration setup. If a particle filter will be used in normal operation, the calibration must be performed through the filter. The manifold must be vented to atmosphere so that pressure does not build up in the calibration setup. Connection of the Model 211 directly to a pressurized output of any device can damage the ozone monitor.
4. Verify that the flow rate into the manifold is greater than the total flow required by the ozone monitor plus any other flow demand drawing from the manifold such as a UV photometer or ozone transfer standard.

#### **7.4.2 Measurement of Zero Air**

1. Verify that the zero-air supply is on and the ozone generator is off. The same zero air supply used in the ozone generator must be used in the zero-air measurement.
2. Allow the Model 211 to sample zero air until the response is stable.
3. Record the average zero air response.

#### **7.4.3 Measurement of Ozone Standards**

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



2. Allow the Model 211 Ozone Monitor to sample the ozone concentration standard until a stable response is measured.
3. Record the average response of the ozone monitor as well as either the average response of the UV photometer the transfer standard.
4. Generate several other ozone concentration standards. At least 5 ozone concentration standards are recommended over the range of interest.
5. For each ozone concentration standard, record the response of the ozone monitor as well as either the response of the UV photometer or the transfer standard.

#### **7.4.4 Calibration Curve**

1. Plot the Model 211 Monitor responses (y-axis) versus the corresponding standard ozone concentrations (x-axis).
2. Fit the data to a straight line ( $y = mx + b$ ) using the linear regression technique to determine the calibration relationships, where  $m$  = slope and  $b$  = intercept.
3. Determine if any points deviate significantly from the line, which is an indication of an error in determining the calibration curve. The error may be due to the calibration setup or the ozone monitor being calibrated. The most likely problems in the ozone monitor are leaks, a malfunctioning gas-phase ozone scrubber, a contaminated valve, or contamination in the optical setup. See Section 9, **Troubleshooting**, of this manual.
4. The inverse of the slope of the line ( $1/m$ ) is the gain factor ( $S$ ) and the negative of the intercept ( $-b$ , in units of ppb) is the offset ( $Z$ ) that need to be applied to the ozone monitor response to calibrate it to the primary ozone standard. If the intercept is outside of the range from -10 to 10 or the slope is outside of the range from 0.90 to 1.10, this is an indication of a problem in the calibration setup or the ozone monitor being calibrated. The most likely problems in the ozone monitor are leaks, a malfunctioning gas-phase ozone scrubber, a contaminated valve, or contamination in the optical setup. See the "Troubleshooting" section of the manual.
5. Enter the calibration menu (Main Menu/Cfg/Cal/O3) in the instrument software and set the calibration parameters  $S$  ( $1/m$ ) and  $Z$  ( $-b$ , in ppb) as determined above (see Section 4.11.2 of this manual).

Refer also to our Technical Note No. 015 on calibration of 2B Tech Ozone Monitors, posted on our website: [http://twobtech.com/docs/tech\\_notes/TN015.pdf](http://twobtech.com/docs/tech_notes/TN015.pdf).

## **8. PERIODIC ZERO AND SPAN CHECKS**

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

1. A zero check is performed by sampling zero air with the Model 211 following the “Measurement of Zero Air” Section 7.4.2 above.
2. A span check is performed by sampling an ozone concentration at the high end of the concentration range of interest following the “Measurement of Ozone Standards” Section 7.4.3 above.
3. Average measurements from the zero check or span check should be within the instrument specifications. If the measurements are not within specifications, this is an indication of problem in the calibration setup or the ozone monitor being checked. The most likely problems in the ozone monitor are leaks, a malfunctioning gas-phase ozone scrubber, a contaminated valve, or contamination in the optical setup. See the “Troubleshooting” section of the manual.

## 9. TROUBLESHOOTING AND ALARMS

If the instrument fails to operate correctly, common problems can be identified and corrected as described in Table 8.8. If the problem cannot be easily corrected, please contact Customer Service at 2B Tech via our web ticketing software at:

[www.twobtech.com/techsupport](http://www.twobtech.com/techsupport)

Alternatively, you can email us at [techsupport@twobtech.com](mailto: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 Model 211 Ozone Monitor™ so that critical components and connectors may be easily identified. A list of serviceable parts is provided in Section 11 at the end of this manual.

**Table 9.1.** *Troubleshooting the Ozone Monitor for performance problems.*

Problem/symptom	Likely cause	Corrective action
<b><i>Instrument does not turn on.</i></b>	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.
<b><i>Instrument turns on then powers off.</i></b>	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.*
<b><i>Display is blank or nonsense.</i></b>	Bad connection of display to circuit board.	Remove top cover and reconnect display to circuit board. Check solder connections to display.
<b><i>Cell temperature reads low by several 10's of degrees.</i></b>	Absent or loose connection of temperature probe cable to circuit board.	Remove top cover and reattach connector to circuit board.

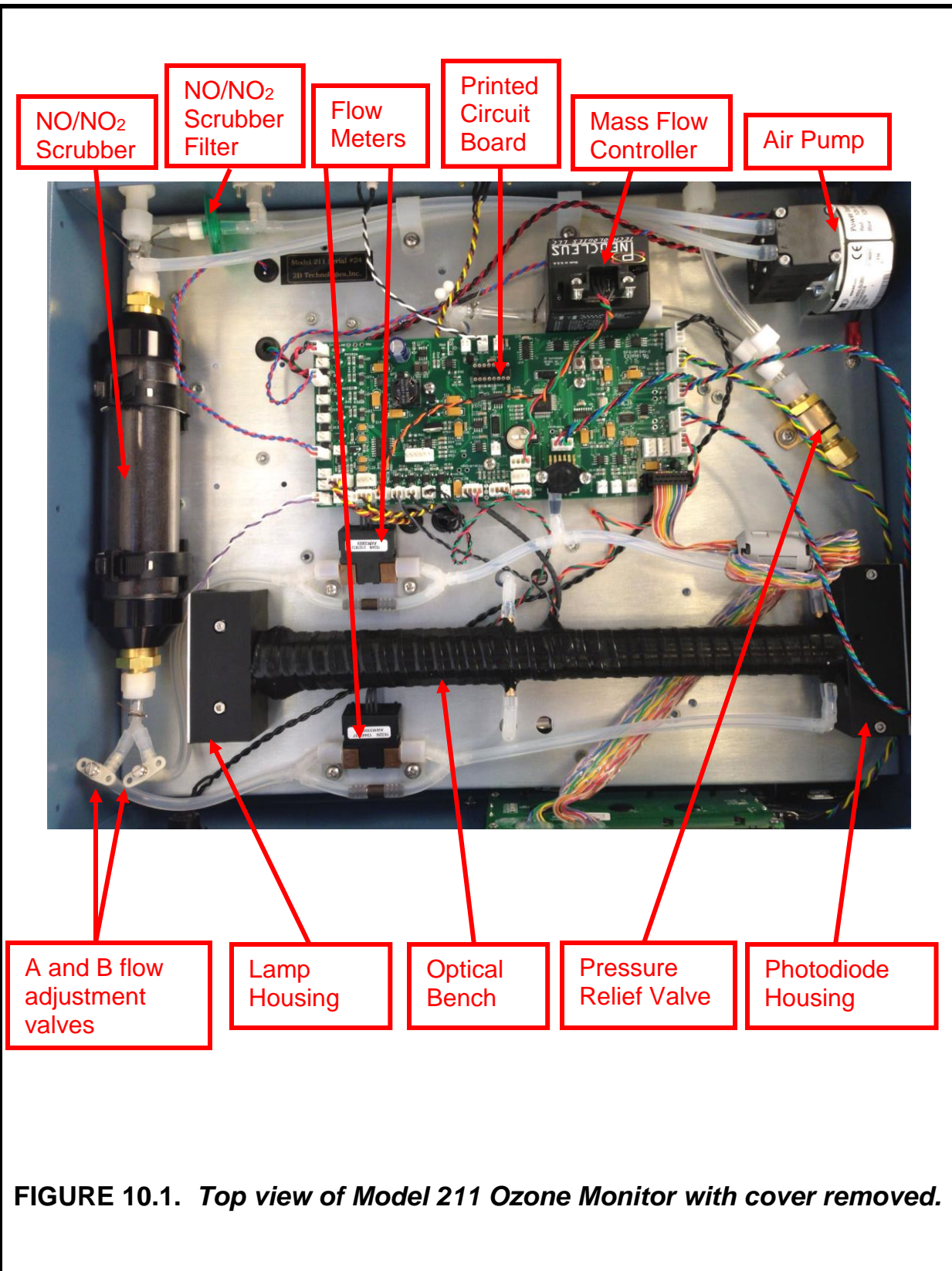
<b>Readings are noisy with standard deviations greater than 1.0 ppb.</b>	Lamp output is weak	Remove top cover and check lamp connection to circuit board. Run Lamp Test from menu. If photodiode voltage is less than 0.7 V, replace lamp.
	Excessive vibration.	Provide additional vibration insulation for the instrument such as a foam pad.
	Flow path contaminated.	Clean flow path with methanol according to the Cleaning Procedure.*
<b>Analog output is constant or does not track front display.</b>	Cable not properly connected between analog output BNC and circuit board.	Remove top cover and reconnect cable between analog output and circuit board.
	Wrong scaling factor selected In menu.	Check and reset analog output scaling factor in the Menu.
<b>Select switch does not work.</b>	Cable not properly connected between select switch and circuit board.	Remove top cover and reconnect select switch cable to circuit board.
<b>Serial port does not work.</b>	Cable not properly connected between serial 9-pin connector and circuit board.	Remove top cover and reconnect serial port cable to circuit board.
	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.	Make sure that the baud rate chosen in the menu matches the baud rate setting of your data acquisition program.

<p><b><i>Required calibration parameters are outside the adjustable range when calibrated using a standard ozone source or reliable ozone instrument.</i></b></p>	<p>Flow path is contaminated.</p> <p>Solenoid valve is contaminated and not opening and closing properly.</p> <p>Air pump is not drawing sufficient flow.</p>	<p>Clean flow path with methanol following the Cleaning Procedure.*</p> <p>Remove solenoid valve, rinse with methanol, dry with zero air, and replace.</p> <p>As a first check, hold your finger over the air inlet to determine whether air is being drawn in. If there is flow, measure the flow rate by removing the top cover and attaching a high conductance flow meter to the exit port of the pump. Air flow should be greater than 1.5 L/min. If flow is lower, check for leaks. If there are no leaks, replace air pump.</p>
<p><b><i>Instrument always reads close to zero for ozone concentration.</i></b></p>	<p>Solenoid valve cable is not properly connected to circuit board.</p> <p>NO/NO<sub>2</sub> scrubber is exhausted and N<sub>2</sub>O flow has been shut off.</p> <p>NO generator lamp is burned out.</p>	<p>Reattach solenoid valve cable to circuit board.</p> <p>Recharge or replace NO/NO<sub>2</sub> scrubber.</p> <p>Return to 2B for lamp replacement and calibration of generator.</p>

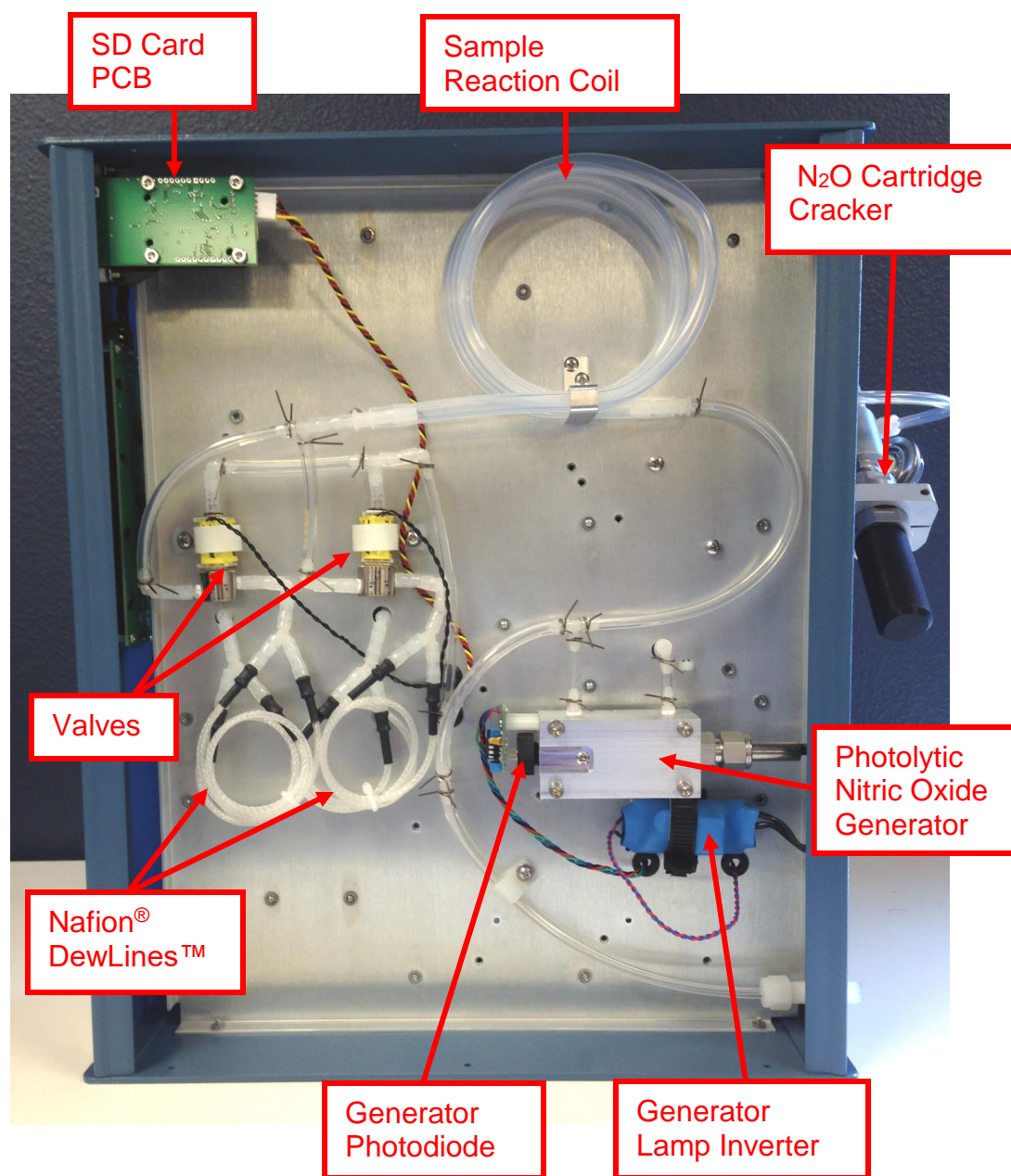
Alarm	Likely cause	Corrective action
<p><b>Flow</b>  <b>AHI or BHI:</b> Cell A or B flow rate is above the maximum acceptable flow rate.</p> <ul style="list-style-type: none"> <li>Maximum flow rate Cell A and B = 1300 cc/min</li> </ul>	<p>Sample Flow rate needle valve is out of adjustment.</p> <p>Separate needle valves for adjusting Cell A and Cell B flow need adjustment.</p>	<p>Rotate Sample Flow needle valve located on back panel counter clockwise until flow rate is reduced to 1,000 cc/min.</p> <p>If Cell A or B flow is out of range and the other of the two is in range, it is possible to adjust each flow separately (must remove lid to access: Figure 10.1). Rotate clockwise to decrease flow rate.</p>
<p><b>Flow</b>  <b>ALOW or BLOW:</b> Cell A or B flow rate is below the minimum acceptable flow rate.</p> <ul style="list-style-type: none"> <li>Minimum flow rate Cell A and B= 900 cc/min</li> </ul>	<p>Sample Flow rate needle valve is out of adjustment.</p> <p>Clogged inlet or kink in tubing.</p>	<p>Rotate Sample Flow needle valve located on back panel clockwise until flow rate increases to 1000 cc/min.</p> <p>Remove inlet line and check for kinks in tubing.</p>
<p><b>Flow</b>  <b>N2OHI:</b> Nitrous Oxide flow is above the maximum acceptable flow rate.</p> <ul style="list-style-type: none"> <li>Maximum flow rate N2O = 30 cc/min</li> </ul>	<p>Problem with Mass Flow Controller.</p> <p>Incorrect voltage going from main PCB to MFC.</p>	<p>Contact 2B Technologies technical support.</p> <p>Contact 2B Technologies technical support.</p>
<p><b>Flow</b>  <b>N2OLOW:</b> Nitrous Oxide flow is below the minimum acceptable flow rate.</p> <ul style="list-style-type: none"> <li>Minimum flow rate N2O = 5 cc/min</li> </ul>	<p>N<sub>2</sub>O or NO pressure is too low.</p> <p>Bad connection from sample gas.</p>	<p>Check gas regulator and increase pressure.</p> <p>Check inlet gas connection and tighten if needed.</p>
<p><b>Flow</b>  <b>Gas Conn:</b> <b>**Check**.</b></p>	<p>Scrubber gas connection may be loose or not connected.</p>	<p>Check gas connection.</p>

<b>Voltage</b> <b>AHI or BHI:</b> Cell A or B photodiode voltage is above the maximum acceptable voltage. <ul style="list-style-type: none"> <li>Cell A and B <math>V_{max} = 2.15</math> Volts</li> </ul>	<p>Too much light from detection lamp from high environment temperature</p> <p>Lamp not conditioned thoroughly.</p>	<p>Bring environment temperature down.</p> <p>Reduce diameter of light aperture on cell window.*</p>
<b>Voltage</b> <b>ALOW or BLOW:</b> Cell A or B photodiode voltage is below the minimum acceptable voltage. <ul style="list-style-type: none"> <li>Cell A or B <math>V_{min} = 0.50</math> Volts</li> </ul>	<p>Environment temperature too low.</p> <p>Dirty cell.</p> <p>Lamp degradation.</p>	<p>Bring environment temperature up.</p> <p>Clean flow path.*</p> <p>Replace lamp (only necessary if lamp is noisy. It is possible to run well at low voltages).</p>
<b>Voltage</b> <b>CHI:</b> NO generation lamp voltage is above the maximum acceptable voltage. <ul style="list-style-type: none"> <li>NO Gen Lamp Voltage Max = 2.15 Volts</li> </ul>	<p>Bad control circuitry to lamp.</p> <p>NO generation detector circuit shorted.</p>	<p>Disconnect lamp power to see if voltage goes to zero. Contact technical support.</p> <p>Contact 2B Technologies technical support.</p>
<b>Voltage</b> <b>CLOW:</b> NO generation lamp voltage is below the minimum acceptable voltage. <ul style="list-style-type: none"> <li>NO Gen Lamp Voltage Min = 0.005 Volts</li> </ul>	<p>Bad connection or disconnected wiring of NO generating lamp or detector.</p> <p>Bad control circuitry to lamp.</p>	<p>Check lamp and detector wire connections to circuit board.</p> <p>Contact 2B Technologies technical support.</p>
<p>* Repairs such as changing the air pump or lamp, adjusting the aperture size, cleaning the flow path, etc., may be done by the user. Please check our Tech Notes (<a href="http://twobtech.com/downloads_tech_notes.htm">http://twobtech.com/downloads_tech_notes.htm</a>) for procedures or contact us at <a href="mailto:techsupport@2btech.com">techsupport@2btech.com</a> for details. You also may return the instrument to 2B Tech for warranty and other repairs at any time.</p>		

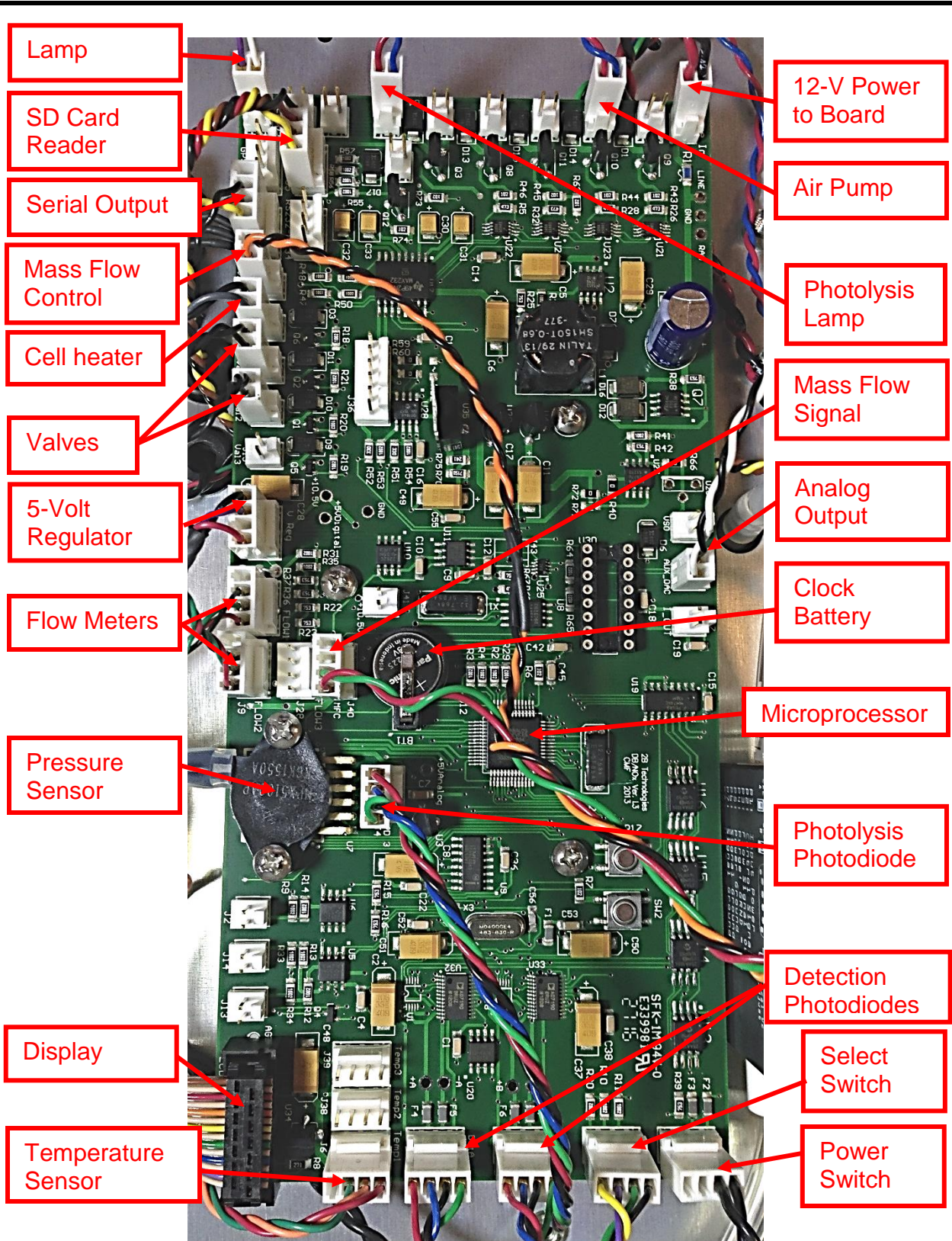
## 10. LABELED INSTRUMENT PHOTOS





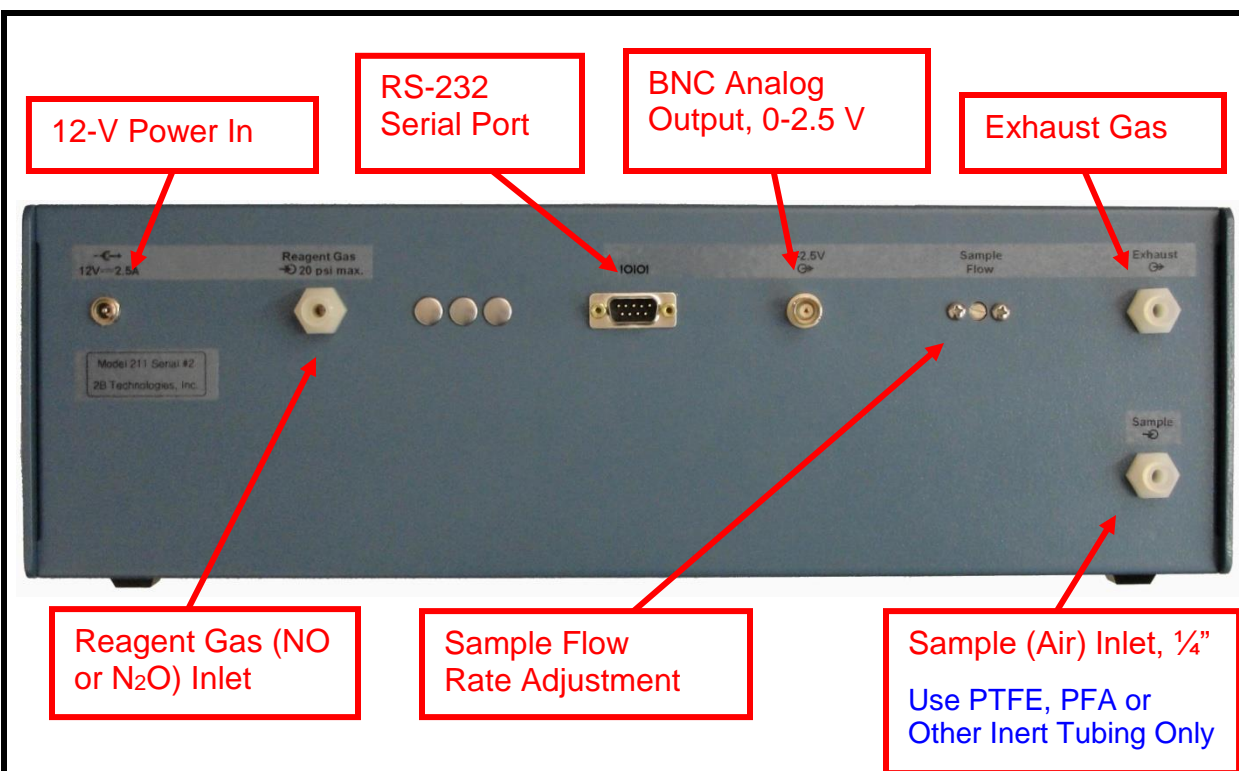


**FIGURE 10.2. Bottom view of Model 211 Ozone Monitor with cover removed.**

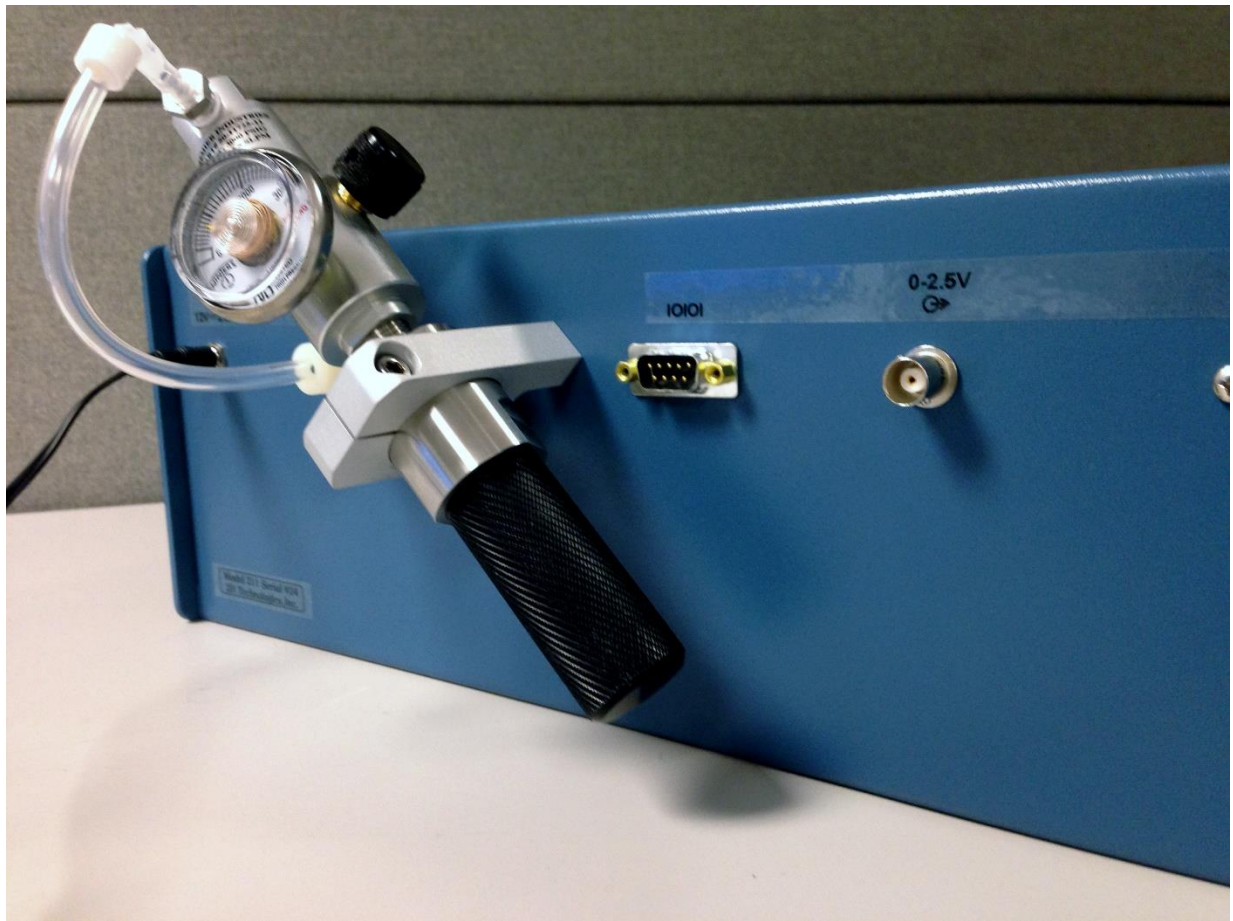


**FIGURE 10.3. Printed Circuit Board of the Model 211 Ozone Monitor.**





**FIGURE 10.4.**  
**Top: Back of Model 211 Ozone Monitor.**  
**Bottom: With the N<sub>2</sub>O Cartridge Cracker in place.**



**FIGURE 10.5. Close-up of the N<sub>2</sub>O Cartridge Cracker.**

## 11. PARTS LIST

The following list includes those parts that are user serviceable. Parts may be purchased directly online at <http://twobtech.com/shop.html> or by contacting us at [sales@twobtech.com](mailto:sales@twobtech.com).

<u>Part Number</u>	<u>Description</u>
SCRBEXT	Ozone scrubber (external)
NOXSCRBINT211	Internal NO/NO <sub>2</sub> scrubber for the Model 211 Ozone Monitor
OZLAMPAS211	Lamp and connector assembly for the Model 211 Ozone Monitor
OZPUMP211	Pump for the Model 211 Ozone Monitor
OZVLV2	Solenoid valve
N2OCRACKER211	N <sub>2</sub> O cartridge cracker for the Model 211 Ozone Monitor
OZDSP	LCD display and cable
DEW	DewLine™ (two Nafion tubes in parallel)
SERCABL	Serial port cable, straight-through, female-female (to computer)
SERUSB	Serial-to-USB adapter
PWRPK-2.5 A	2.5-amp power pack
SDCARD	SD card (thin profile recommended for the Model 211 Ozone Monitor)
SDREADER	SD card reader
TEFTYG25	Teflon-lined Tygon® tubing (25 ft)
TEFTYG05	Teflon-lined Tygon® tubing (5 ft)
SILTUB	Silicone tubing

## 12. SERVICE LOG

[illegible]



## **Appendix A: Using the 2B Technologies Display and Graphing Software**

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### **Introduction**

2B Data Display® is an easy way to display and save data from your serial or USB connection.

With easy one-click operations, data are read from your instrument and displayed on an extremely versatile chart. Two items, such as Ozone and Temperature, can be displayed simultaneously on the chart with multiple zoom levels. Data are automatically saved to a .txt file and can optionally be saved to a .CSV file to be read in Excel. Saved data can be restored for later viewing and analyzing on the chart. By requesting an account with 2B Technologies, you can upload your data and view it on a Google Earth overlay.

### **Downloading the Software**

Go to <http://twobtech.com/downloads.html> and select the Software tab. Click the link for “2B Tech Display and Download Software.” Follow the instructions, doing the two installations if needed and choosing to save the “setup.exe” file. Double-click the setup.exe download to launch the 2B Data Display application.

### **Connecting Devices**

#### ***Connect to an Ozone Monitor***

1. Select the device you are connecting to from Settings: Select Device (use the Model 211 setting).
2. Click OK.
3. Select the Connection you will be using from Settings: Connection  
Choose the settings as follows:
  - a) Port:
    - The default port is “COM1” for computers with a serial port.
    - If using a USB connection, check for the correct port in the “Device Manager” under “Ports” located in: Control Panel : System : Device Manager.
    - If using a USB to Serial adapter, check for the correct port the same as for a USB connection and look for the name of the adapter (e.g., Belkin, Prolific, or other USB to Serial adapter manufacturers).



- b) Baud Rate: The Default baud rate is 2400. Check your Ozone Monitor's settings in the "Cfg / I/O" menu and match the software with the monitor's setting. Note that for the USB port, the baud rate must match the baud rate of the Ozone Monitor at the Monitor's startup.
  - c) Parity: None
  - d) Data Bits: 8
  - e) Stop Bits: One
4. Click Start button in the Instrument Data Capture section in the upper left corner of the main screen.
- a) The "Save As" window will appear. A default file name will appear which is made of the date and time. You may change the filename and change where it is saved if you wish.
  - b) Click the "Save" button. This will start the data capture software and data will fill into the chart as they are transmitted from the device.
  - c) The red OFF text will change to green ON text. The text: Waiting for data... will appear until data arrives from the instrument. If the instrument measurement frequency is set to 2 seconds, you will see a data point every 2 seconds. Averaging frequencies can be set to 10 seconds, 1 minute, 5 minutes, and 1 hour in the Avg submenu on the instrument.

### ***Connect to Weather Station (Davis Vantage Pro)***

1. Be sure the weather station is physically connected to the USB port or Serial port of the computer.
2. Select the COM port for the weather station from *Settings : Weather Connection Settings...*
3. Select "Retrieve Weather Data" from the "Weather Link" menu. A window will appear and the software will try to retrieve the weather station data. If the connection is good, weather data will be displayed in the window. If not, an error message will appear. Try a different com port if the error message appears. You may move this window so it is out of the way or you may close it. The weather data is updated every 5 seconds.
  - Since the Ozone Monitor and the Weather Station both use COM ports, you may have to unplug one of the USB adapters from the PC to determine which device is using which COM port.
4. To bring up the window again if you have closed it, select "Display Weather Data."

## Viewing Data

### ***The Data Grid Tab***

1. Make sure the application is connected to a device or that you have opened a previously saved data file.
2. Click the *Data Grid* tab on the right side of the screen.
3. The data lines received from your instrument will be listed in a grid with the latest point at the top.
4. The header contains the device specific variables (e.g., Ozone, Cell Temp...). Log Number is always listed even if your instrument is not set to log.

### ***The Charts Tab***

1. Make sure the application is connected to a device or you have opened a previously saved data file.
2. Click the *Charts* tab on the right side of the screen.
3. Select which data items to display from the drop down windows “Data 1” and “Data 2.”
4. The data points will appear in a graph window in the middle of the screen.
5. Adjust the zoom level by pressing the + or – buttons under the *Settings* button (upper right side of screen).
6. Adjust the Y scale or set the *Auto Range* feature by pressing the *Settings* button
  - a. Check the *Auto Range* box to use autoscaling.
  - b. Uncheck the *Auto Range* box to manually set Y max and Y min for the Data 1 and Data 2 fields.

### ***The Buffer Tab***

- Selecting the Buffer tab brings up a buffer window, similar to Tera Term or HyperTerminal, where all data from the serial port are displayed.
- From this tab, the user can also send commands through the serial port by typing on the keyboard. This is only applicable if the device that is connected accepts serial commands. See the instrument manual for a list of the serial commands.
- This buffer window can also be used for troubleshooting for instances when: the baud rate, device, or serial port is unknown. For example, if the status bar in the “Instrument Data Capture area states “Receiving...” and no data appear in the Data Grid or the Charts, click on the Buffer tab to view the serial data. If the correct device is not selected, no data will be displayed in the Data Grid or the Charts, but data will be displayed in the Buffer window.

## Saving Data

### ***Saving Ozone Data to a .txt File***

1. Click the *Start* button in the Instrument Data Section to begin collecting data from the instrument.
2. A window will pop up to prompt for the name and location of the file.
3. Click *Save* to begin the data collection.
4. All data read from the ozone monitor through the COM port are written to the .txt file in real time until *Stop* is clicked.

### ***Saving Data to a .CSV or an Excel File***

NOTE: Weather data are NOT saved to the .txt file. In order to save weather data, be sure to save a .CSV file after *Stop* is clicked.

1. After collecting data, click the *Stop* button in the Instrument Data Capture Section on the main screen.
2. A window will pop up to ask you if you would like to save to a CSV file as well. Click *Yes*.
3. A default name appears from the date and time of the data capture. You may change the name and path of the file if you wish.
4. Click on the *Save* button.

## Opening Files

1. To open a file, click *Open* from the *File* menu.
2. Navigate to the folder where the file was stored.
3. Select either the .txt file or the excel file and press *Open*.
  1. NOTE: To view weather data, you must open the corresponding .CSV file.
4. Choose the correct device associated with the file.
  - a. If you are unsure, open the file in a text editor or Excel to determine which device.

## Serial and USB Commands

The menu commands are the same as given in Section 5 of this manual.

## **Appendix B: Model 211 Portable N<sub>2</sub>O Source**

**Note:** The Portable N<sub>2</sub>O Source is also referred to as the N<sub>2</sub>O Cartridge Cracker in this manual.

Either 16-gram or 8-gram cartridges may be used with the Model 211 Portable N<sub>2</sub>O Source, providing 8 hours or 4 hours of continuous operation, respectively.

### **WARNINGS**

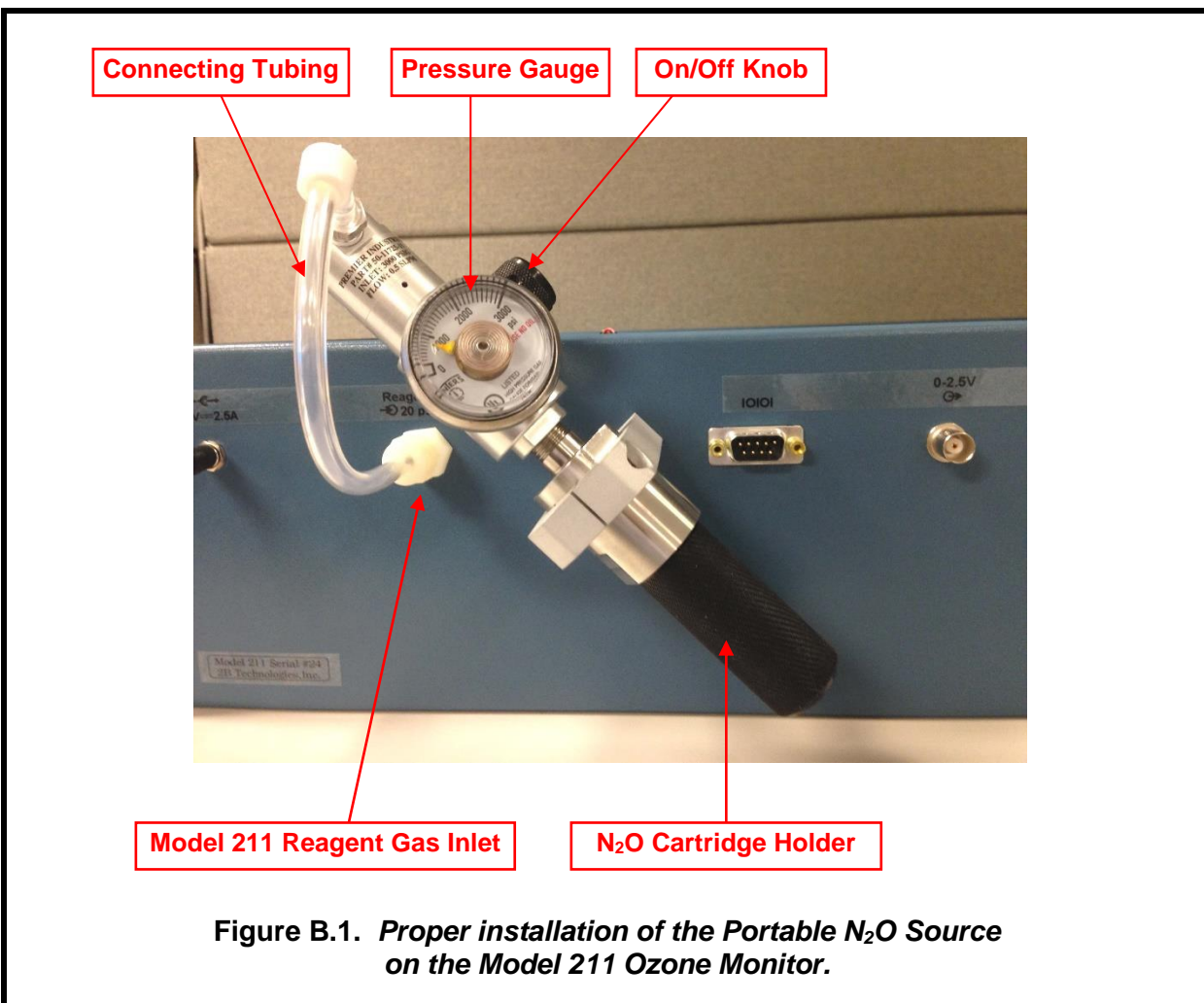
Nitrous oxide is supplied by a cartridge containing liquid N<sub>2</sub>O having a vapor pressure inside the cartridge of 58.5 bar at 20°C. These cartridges are the same or similar to ones sold as a consumer product for producing whipped cream. Nitrous oxide or “laughing gas” is also used as a general anesthetic at concentrations up to 50% and is thus well tolerated by humans. There are no known toxicological effects of N<sub>2</sub>O other than asphyxiation at extremely high concentrations due to exclusion of oxygen. N<sub>2</sub>O is not itself combustible, but it strongly supports combustion of organic materials and reducing agents. Contact with liquid N<sub>2</sub>O can cause frost bite due to cooling as the liquid rapidly evaporates. If an N<sub>2</sub>O cartridge is punctured outside the piercing device/regulator, the cartridge will act as a “rocket.” However, the N<sub>2</sub>O cartridges are commonly used consumer products available commercially and are safe to handle if the procedures below are followed.

### **INSTALLATION**

To install the Portable N<sub>2</sub>O Source follow the following steps:

- 1) Remove the cover of the Model 211 Ozone Monitor.
- 2) Remove the cartridge holder from the Portable N<sub>2</sub>O Source assembly.
- 3) Use the supplied screws to mount the Portable N<sub>2</sub>O Source bracket to the back plate of the Model 211 (see photo below).
- 4) Replace the cartridge holder and the cover of the Model 211.
- 5) Connect the tubing from the Portable N<sub>2</sub>O Source to the REAGENT GAS inlet port on the back plate of the Model 211.

The Model 211 Ozone Monitor is shipped from the factory with the Portable N<sub>2</sub>O Source installed.



## OPERATION

Please read all the following information before attempting to use the portable N<sub>2</sub>O source. For assistance, please call 2B Technologies at (303)273-0559 or email us at [techsupport@twobtech.com](mailto:techsupport@twobtech.com).

### Description

Nitrous oxide is supplied to the instrument by means of either 8-gram or 16-gram liquid N<sub>2</sub>O cartridges. The 8-gram cartridge will supply a gas flow of N<sub>2</sub>O of 13 cc/min for ~4 hours of operation of the Model 211; the 16-gram cartridge will provide ~8 hours of operation. The pressure inside the cartridge remains nearly constant as N<sub>2</sub>O evaporates and flows out of the cartridge. The evaporation of N<sub>2</sub>O causes the N<sub>2</sub>O cartridge to cool, which, in turn, slightly reduces the internal pressure of ~50 atmospheres.

**Warning:** If an N<sub>2</sub>O cartridge is punctured outside the cracker/regulator, liquid N<sub>2</sub>O can escape, and if it evaporates on skin it will cause frost bite. The cartridge will also act as a “rocket” if the seal is punctured outside the cracker/regulator. However, the N<sub>2</sub>O cartridges are commonly used consumer products available commercially and are safe to handle if the procedure below is followed.

### Attachment of the N<sub>2</sub>O Cartridge

- 1) Make sure that cartridge currently installed in the instrument is empty by checking the reading on the pressure gauge.
- 2) Close the pressure regulator by rotating the black knob on the side of the cracker clockwise until it is snug. Do not over-tighten.
- 3) Slowly unscrew the black cartridge holder from the cracker assembly. Do not completely remove the cartridge holder until you are certain that any residual N<sub>2</sub>O gas has escaped. If you hear a hissing sound, N<sub>2</sub>O is escaping. Once all the N<sub>2</sub>O has been vented, completely remove the cartridge holder and remove the old cartridge. The cartridges are made of steel and may be recycled.
- 4) Insert a new 8-g cartridge into the cartridge holder with the narrow neck of the cartridge pointed upward.

If using an 8-g cartridge, the removable insert should be left in place in the bottom of the black cartridge holder. If using a 16-g cartridge, slide the insert out of the black cartridge holder.

- 5) Reattach the black cartridge holder to the cracker. As you screw the holder onto the cracker, the cartridge seal will be punctured, and as you continue to rotate the holder a seal will be made. You should rotate the holder quickly after puncturing the cartridge to minimize loss of N<sub>2</sub>O gas. Only hand tighten the cartridge holder so that it is not difficult to remove the holder later.

### Use of the Portable N<sub>2</sub>O Source

- 1) When not using the Portable N<sub>2</sub>O Source, keep the black on/off valve closed (knob turned completely clockwise).
- 2) To use the Portable N<sub>2</sub>O Source, power on the Model 211 Ozone Monitor. Check that there is tubing connecting the source to the instrument and then open the on/off valve by turning the knob completely counter-clockwise. Use only moderate hand force to loosen the knob (do not force with tools).
- 3) The pressure gauge will read ~600 psi, until the liquid N<sub>2</sub>O in the cartridge is exhausted. Then the pressure will rapidly fall off.
- 4) To stop using the N<sub>2</sub>O source, close the on/off valve by turning the knob completely clockwise. Do not tighten the knob more than hand-tight.