NO_2/NO/NO_x Monitor

2B Technologies

OPERATION MANUAL

Model 405 nm

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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 405 nm NO_2/NO/NO_x Monitor™ used for measurement of atmospheric nitrogen dioxide (NO_2), nitric oxide (NO) and NO_x (NO + NO_2) over a dynamic range extending from a few parts per billion by volume (referred to herein as simply ppb) up to 10 parts-per-million by volume (ppm) for NO_2 and 2 ppm for NO. The Model 405 nm is approved as a Federal Equivalent Method (FEM) for NO_2 over the range of 0-500 ppb NO_2 for the operating temperature range of 20-30°C. New editions of this manual are complete revisions that reflect updates to the instrument itself, as well as clarifications, additions and other modifications of the text.

Revision A .....December 2013
Revision B .....February 2014
Revision C..... May 2015
Revision D..... June 2016
Revision E, serial number 1021-1044.....February 2017
Revision F-1, serial number 1045 and above .....August 2017
Inclusion of SD data logger as a standard feature.
Revision F-2, serial number 1045 and above .....November 2017
Updates to the power and flow specifications, and clarifications to the text regarding the Auto Zero function and interferences.
Revision G-1, serial number 1080 and above..... May 2018
Addition of error message codes in the LCD and serial data stream; removal of the Auto Zero function; updates to the schematic and the Specifications table; reorganization of Sections 1 and 3; and expanded information about zeroing and pressure control.
Revision G-2, serial number 1080 and above.....September 2018
Corrected spare parts list; updated schematic; updated website links; updated maintenance and troubleshooting information.
Revision G-3, G-4, serial number 1080 and above..... October 2018
Rev G-3 updated the internal data logger specs in Section 2 and Maintenance table in Section 6.
Rev G-4 updated Tera Term links; corrected the wire labeling for the Select Switch in Section 12.
Revision G-5, serial number 1080 and above.....November 2018
Added the baud rate choices to the Sections 2, 4.2 and 4.5, which became available in May 2018.
Revision H-1, serial number 1105 and above..... June 2019
Added the ability to output instrument serial number in the serial data stream (effective 3/7/2019).

TRADEMARKS & PATENTS

2B Technologies™, 2B Tech™, 2B™, NO_2/NO/NO_x Monitor™ and Model 405 nm™ are trademarks of 2B Technologies.

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WARRANTY STATEMENT AND SAFETY ISSUE

2B Technologies warrants its products against defects in materials and workmanship. 2B Technologies will, at its option, repair or replace products that prove to be defective. The warranty set forth is exclusive and no other warranty, whether written or oral, is expressed or implied. 2B Technologies specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

Warranty Period

The warranty period is one (1) year from date of receipt by the purchaser, but in no event more than thirteen (13) months from original invoice date from 2B Technologies.

Warranty Service

Warranty Service is provided to customers via web ticket, email and phone support, Monday - Friday, from 9:00 a.m. to 5:00 p.m., Mountain Time USA. The preferred method of contacting us is through our web ticketing software at:

https://twobtech.com/tech-support.html

This way all technical staff at 2B Tech will be alerted of your problem and be able to respond. When you receive an email reply, please click on the Ticket link provided to continue to communicate with us directly over the internet. The web ticket approach to customer service allows us to better track your problem and be certain that you get a timely response. We at 2B Tech pride ourselves on the excellent customer service we provide.

You may also contact us by email at techsupport@twobtech.com or by phone at +1(303)273-0559. In either case, a web ticket will be created, and future communications with you will be through that ticket.

Initial support involves trouble-shooting and determination of parts to be shipped from 2B Technologies to the customer in order to return the product to operation within stated specifications. If such support is not efficient and effective, the product may be returned to 2B Technologies for repair or replacement. Prior to returning the product, a Repair Authorization Number (RA) must be obtained from the 2B Technologies Service Department. We will provide you with a simple Repair Authorization Form to fill out to return with the instrument.

Shipping

2B Technologies will pay freight charges for replacement or repaired products shipped to the customer site. Customers shall pay freight charges for all products returning to 2B Technologies.

Conditions

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance, adjustment, calibration or operation by the customer. Maintenance, adjustment, calibration or operation must be performed in accordance with instructions stated in this manual. Use 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. This 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 this 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 405 nm NO_2/NO/NO_x Monitor is designed to use an internal generator of ozone (O_3) to oxidize NO to NO_2. Ozone is a toxic gas and should be handled with caution. Under normal operating conditions, the instrument will produce ~6 ppm O_3 in air. The instrument is equipped with an internal ozone scrubber to remove ozone before venting the sample. Although the scrubber is catalytic, it does have a limited lifetime and should be replaced at least every 12 months. For this reason, it is recommended to properly vent the output of the instrument to protect against any unscrubbed O_3. The outlet should not be vented near the inlet of any NO_x or ozone monitor inlets to avoid false measurements.

The NIOSH exposure limit for ozone is 0.1 ppm or 100 ppb (8-hour time-weighted average).

WARNINGS

ENGLISH

***WARNING*:**
Any operation requiring access to the inside of the equipment, could result in injury. To avoid potentially dangerous shock, disconnect from power supply before opening the equipment.

WARNING:
This symbol, on the instrument indicates that the user should refer to the manual for operating instructions.

WARNING:
If this instrument is used in a manner not specified by 2B Technologies, USA, the protection provided by the instrument may be impaired.

ESPAÑOL

ATENCION:
Cualquier operación que requiera acceso al interior del equipo, puede causar una lesión. Para evitar peligros potenciales, desconectarlo de la alimentación a red antes de abrir el equipo.

***ATENCION*:**
Este símbolo, en el instrumento indica que el usuario debería referirse al manual para instrucciones de funcionamiento.

ATENCION:
Si este instrumento se usa de una forma no especificada por 2B Technologies, USA, puede desactivarse la protección suministrada por el instrumento.

FRANÇAIS

ATTENTION:
Chaque opération à l'intérieur de l'appareil, peut causer du préjudice. Afin d'éviter un shock qui pourrait être dangereux, disconnectez l'appareil du réseau avant de l'ouvrir.

ATTENTION:
Le symbol, indique que l'utilisateur doit consulter le manuel d'instructions.

ATTENTION:
Si l'instrument n'est pas utilisé suivant les instructions de 2B Technologies, USA, les dispositions de sécurité de l'appareil ne sont plus valables.

DEUTSCH

WARNHINWEIS:
Vor dem Öffnen des Gerätes Netzstecker ziehen!

WARNHINWEIS:
Dieses, auf dem Gerät weist darauf hin, dab der Anwender zuerst das entsprechende Kapitel in der Bedienungsanleitung lesen sollte.

WARNHINWEIS:
Wenn das Gerät nicht wie durch die Firma 2B Technologies, USA, vorgeschrieben und im Handbuch beschrieben betrieben wird, können die im Gerät eingebauten Schutzvorrichtungen beeinträchtigt werden.

ITALIANO

ATTENZIONE:
Qualsiasi intervento debba essere effettuato sullo strumento può essere potenzialmente pericoloso a causa della corrente elettrica.
Il cavo di alimentazione deve essere staccato dallo strumento prima della sua apertura.

ATTENZIONE:
Il simbolo, sullo strumento avverte l'utilizzatore di consultare il Manuale di Istruzioni alla sezione specifica.

ATTENZIONE:
Se questo strumento viene utilizzato in maniera non conforme alle specifiche di 2B Technologies, USA, le protezioni di cui esso è dotato potrebbero essere alterate.

DUTCH

OPGELET:
Iedere handeling binnenin het toestel kan beschadiging veroorzaken. Om iedere mogelijk gevaarlijke shock te vermijden moet de aansluiting met het net verbroken worden, vóór het openen van het toestel.

OPGELET:
Het symbool, geeft aan dat de gebruiker de instructies in de handleiding moet raadplegen.

OPGELET:
Indien het toestel niet gebruikt wordt volgens de richtlijnen van 2B Technologies, USA gelden de veiligheidsvoorzieningen niet meer.

CHINESE

警告：
任何需要接触设备**内部的操作均可能造成人身**伤害**。为避免可能的触**电**危**险，请**在打开**设备**前切断**电**源**。**

警告：
这**个符号** **在**仪器**上表示用**户应参考说明书上的操作指南。

警告：
如果仪器**没有按照美国**2B**科技公司指定方式操作**，仪器**的保**护性能会减弱**。**

JAPANESE

警告：
機器の内部で操作する時、怪我できます。**危険な衝撃を回避するために、機器を開ける前に、電源を切断してください。**

警告：
機器でこの記号を見れば、マニュアルを読んでください。

警告：
この機器は2B テクノロジー会社、
USAの指定でしなければ、機器の保護が損なえます。

1. $NO_2/NO/NO_X$ MONITOR INTRODUCTION

1.1 Overview

The 2B Technologies Model 405 nm $NO_2/NO/NO_x$ Monitor™ is designed to enable accurate measurements of atmospheric nitrogen dioxide (NO_2), nitric oxide (NO) and NO_x (NO + NO_2) over a dynamic range extending from a few parts per billion by volume (referred to herein as simply ppb) up to 10 parts-per-million by volume (ppm) for NO_2 and 2 ppm for NO based on the absorption of visible light at 405 nanometers (nm). The Model 405 nm is approved as a Federal Equivalent Method (FEM) for NO_2 over the range of 0-500 ppb NO_2 for the operating temperature range of 20-30°C (EQNA-0217-243).

The Model 405 nm provides an absolute method for measuring NO_2 based on the Beer-Lambert Law and thus requires only infrequent calibration. The NO_2 measurement is analogous to the measurement of O_3 using a conventional absorbance-based ozone monitor; the two main differences are the use of 405 nm light for NO_2 in place of 254 nm light for O_3, and a much longer path length of ~2 meters (vs. 15-30 cm for ozone) to compensate for the much lower absorption cross section of NO_2. The long path length is achieved by use of a cell with a tubular design that provides low volume and rapid gas exchange.

Nitric oxide is measured by measuring the light intensities with and without ozone added to oxidize NO to NO_2. As described in more detail below, the result is a “semi-direct” measurement of NO in that the NO concentration is output directly and not based on subtraction of NO_2 concentration from a total NO_x concentration. Instead, the NO_x concentration is computed as the sum of the measurements of NO_2 and NO.

The $NO_2/NO/NO_x$ Monitor is provided with a NIST-traceable calibration. Because detection is based on the absolute method of absorbance, frequent calibration of the span (sensitivity) is not required.

1.2 Theory of Operation

Figure 1.1 is a simplified schematic diagram of the Model 405 nm NO_2/NO/NO_x Monitor.

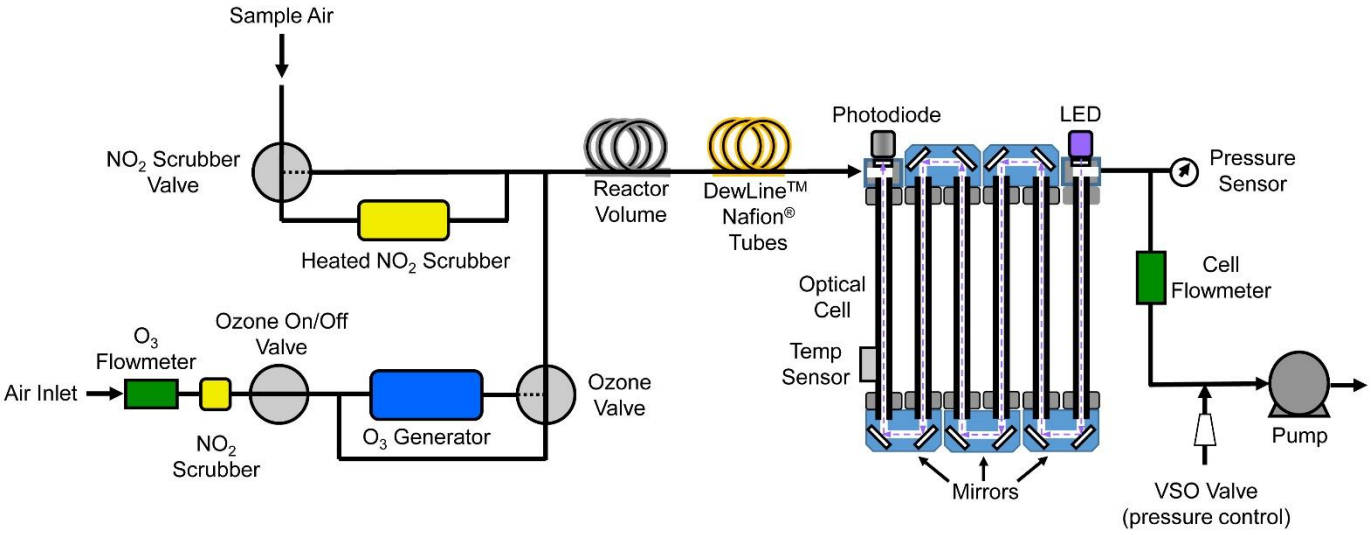


Figure 1.1. ***Schematic Diagram of the Model 405 nm NO_2/NO/NO_x Monitor.***

Sample air is continuously drawn through the instrument by the Pump at a flow rate of ~1.5 L/min. The NO_2 Scrubber Valve alternately bypasses and sends the sample air through a heated NO_2 scrubber to remove all NO_2 in the sample. The NO_2-scrubbed or unscrubbed air passes through the Reactor Volume and the DewLine™ Nafion Tubes (to equilibrate humidity), through the Optical Cell and through the Cell Flow Meter. Alternate switching of the NO_2 Scrubber Valve once every 5 seconds allows the measurement of a light intensity in the absence (I_o) of NO_2 and presence (I) of NO_2. The Beer-Lambert Law is then used to calculate the concentration of NO_2 from I and I_o:

$$[NO_2] = \frac{1}{L\sigma} ln\left(\frac{I_o}{I}\right)$$

Here, L is the path length (~2.1 m) and σ is the absorption cross section (~6.06 × 10^{-19} cm^2 $molec^{-1}$) for NO_2 averaged over the light-emitting diode (LED) emission centered on 405 nm. The measurement provides an absolute NO_2 concentration in molecules/cm^3. In order to convert this concentration to a mixing ratio (fraction of total air molecules that are NO_2), 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 air molecules, M, in the optical cell. Nitrogen dioxide in units of ppb is then given by:

$$[NO_2]_{ppb} = 10^9 \frac{[NO_2]}{[Air]} = 10^9 \frac{RT}{N_A P L \sigma} ln\left(\frac{I_o}{I}\right)$$

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

Nitric oxide is measured by bypassing the NO_2 Scrubber and measuring the light intensity while adding (I) or not adding (I_o) ozone to convert NO to NO_2 according to the well-known reaction:

$$NO + O_3 \rightarrow NO_2 + O_2 \quad (1)$$

As in all our instruments, a DewLine™ Nafion® tube is used to equilibrate humidity during I and I_o measurements, so that any water vapor interference due to refractive effects on light transmission through the optical cell is eliminated. At the conditions of the instrument, reactions of the added ozone with species other than NO are insignificant.

NO_x is obtained by adding the measurements of NO_2 and NO. The instrument may be operated in continuous NO_2 or NO modes, or in a mode where NO_2 and NO are alternately measured, once every 5 seconds.

As discussed above, the pressure and temperature within the absorption cell is measured so that the NO_2 concentration can be expressed as a mixing ratio in parts-per-billion by volume (ppb). The instrument displays and records the cell temperature and pressure in addition to the NO_2 mixing ratio. The cell pressure is displayed and logged in units of either mbar, and the cell temperature in units of °C.

In principle, the measurement of NO_2 by absorbance at 405 nm requires no external calibration; it is an absolute method. However, factors such as variability in the LED peak emission wavelength and band width, and non-linearity of the photodiode and amplifier response, can result in a small measurement error. Therefore, each instrument is calibrated against NIST-traceable standards of NO and NO_2. These results are used to calibrate the Model 405 nm 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 slope and offset calibration parameters from the front panel by entering the Menu if desired. It is recommended that the instrument be recalibrated at least once annually and preferably more frequently. The offset may drift on time scales of hours to days due to temperature change or chemical contamination of the absorption cell. As described below, it is recommended to periodically zero the instrument during use, typically at least daily for most applications.

A voltage sensitive orifice (VSO) valve is used to equalize pressure in the detection cells during I and I_o measurements. This eliminates a potentially large error resulting from the effect of pressure on the transmission of light through the optical bench. We describe this in more detail in a paper published in *Atmospheric Measurement Techniques*, linked here: https://twobtech.com/Model_405_AMT_paper.pdf

2. SPECIFICATIONS: MODEL 405 nm NO_2/NO/NO_x MONITOR

Principle of Measurement	Direct absorbance of NO_2 at 405 nm
Federal Equivalent Method (FEM)	Yes, for NO_2 (0-500 ppb, 20-30°C), EQNA-0217-243
Measurement Modes	NO_2 only; NO only; NO, NO_2 and NO_x
Linear Dynamic Range	0-10 ppm for NO_2; 0-2 ppm for NO (FEM approved for 0-500 ppb NO_2 for 20-30°C)
Resolution	0.1 ppb
Precision (1σ rms noise)	< 0.5 ppb or 0.5% of reading (with adaptive filter[1])
Accuracy	Greater of 2 ppb or 2% of reading
Limit of Detection (2σ)	< 1 ppb (with adaptive filter[1])
Flow Rate (nominal)	1.5 Liter/min
Flow Rate Requirement	Minimum: 1.4 Liter/min; Maximum: 1.6 Liter/min
Response Time, 100% of Step Change	10 s for 5-s averaging 20 s with adaptive filter[1]
Measurement Frequency	0.2 Hz (once every 5 s)
Averaging Times	5 s, 1 min, 5 min, 1 hr
SD Card Logger Capacity	Minimum 2 GB (> 2-year capacity for 5-s measurement mode)
Internal Data Logger Capacity	8,192 lines (5-s avg. = 0.47 days; 1-min avg = 5.7 days; 5-min avg = 1.0 mo; 1-hr avg = 0.94 yr)
Concentration Units	ppb, pphm, ppm
Pressure Units	mbar
Temperature Units	°C
T and P Corrected	Yes
Operating Temperature Range	10 to 50°C (FEM approved for 20-30°C for NO_2)
Power Requirement; 5-amp 110/220 VAC Power Pack (provided) or Battery	11-14 V dc or 120/240 V ac, 1.4 A at 12 V, 17 watt Max: 2.9 A at 12 V, 35 watt (warmup)
Size	Rackmount: 17" w × 14.5" d × 5.5" h (43×37×14 cm)
Weight	18.6 lb (8.4 kg)
Data Outputs	RS232, 0-2.5 V Analog Outputs for NO and for NO_2

Data Transfer Baud Rate	2400, 4800, 19200
Output Ranges	User-defined scaling factor in menu
DewLine™	Yes
Long Life Pump	Yes, 15,000 hr
Flow Meter	Yes
Options	Bluetooth for wireless data transmission; USB output (in place of RS232)

[1]An adaptive filter may be selected from the serial menu, making signal averaging similar to competing NO_x monitors. Specifications above are for default parameters: Change Difference = 40 ppb, Change Percent = 10%, Short Filter = 4 pts (20 s), Long Filter = 36 pts (3 min). Adaptive filter parameters may be adjusted by the user. See Section 3.10 and Section 5 of this manual.

3. OPERATION

Please read all the following information before attempting to install the Model 405 nm NO_2/NO/NO_x Monitor. For assistance, please call 2B Technologies at (303)273-0559.

NOTE:

Save the shipping carton and packing materials that came with the Monitor. If the NO_2/NO/NO_x 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. Operation of the Monitor

To operate the NO_2/NO/NO_x 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 provided 110-220 V AC power adapter or an external battery. The power source should be capable of supplying at least 2.9 amperes of current at 12 V (35 watts). The source can be in the range 11-14 V DC without any detrimental effects on the measurement. Note that the instrument cannot be powered via USB connection to a computer because the minimum power requirements cannot be achieved via this method. (Connection to the computer may only be used for data transmission; see Section 3.7.)

Once turned on, the instrument will display an introductory screen with the version number of the firmware installed on the microprocessor and a display of the time and date. Next, the instrument begins a warmup mode where it will display the target scrubber temperature of 110°C and the current scrubber temperature. After 10-20 minutes from a cold startup, the scrubber will reach the target temperature and the instrument will begin measurements. The instrument briefly will display a status screen showing the state of logging (either the logged number, “OFF,” or “FULL”) and then begin displaying measurements of the species selected for measurement (NO_2; NO; or NO_2 and NO) along with values of the cell flow rate (CF), ozone flow rate (O3F), and the temperature (T) and pressure (P) of the absorption cell. Alternating screens will show the Log state (logged number, OFF, or FULL) and the time and date. The first few readings may be spurious (an error byte message will appear; see Section 9). Valid readings will commence when this message disappears.

3.3. Connections and Setup

1. Attach the sample inlet line to the SAMPLE inlet port (see Section 11, Figure 11.6). 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 NO_2 or NO 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 loss of NO_x species to the internal surface and to minimize reaction of NO with ambient ozone. 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® and is recommended. A provided Teflon® inlet filter is required to prevent internal contamination of the tubing and optical cell by particulate matter. We recommend a 47 mm PTFE (polytetrafluoroethylene) membrane filter with 5-micron pore size. Also, particles can provide a positive interference to the measurement by absorbing and scattering light from the LED source. The filter should be tested for NO_2 and NO loss by measuring ambient NO_2 and NO with and without the filter attached. Replacement filters are available through 2B Technologies. See our website: https://twobtech.com/parts-online.html.

2. Vent the EXHAUST port to atmospheric pressure and out of the room or shelter. The monitor has a internal scrubbers that remove ozone (produced to oxidize NO to NO_2) and NO_2 from the sample before exiting the instrument though the EXHAUST port. However, it is recommended that the pump exhaust be vented to a well-ventilated area outside the room or shelter in case either scrubber fails.

3.4. Pre-Operation Flow Settings of the Monitor

The Model 405 nm has two independent flows, which need to be verified (via the instrument's LCD menu or serial menu) and adjusted before operating the instrument. The two volumetric flow rates that are independently adjusted are:

Cell Flow Rate (1400-1600 cm^3/min): The cell flow rate of sample gas and ozone/air through the reactor volume and optical cell.

Ozone Flow Rate (60-80 cm^3/min): The flow rate of ozone/air mixed into the sample flow stream.

These flow rates are adjusted to be in the ranges specified above at the factory. However, due to changes in altitude and thus pressure, the two flow rates need to be verified and adjusted by the user to be within the specified ranges if necessary. To do this, follow the flow rates on the LCD screen (Section 4.3.1) or serial output (see Section 3.7). The Cell Flow, displayed as **CF**, should be in the range 1400-1600 cm^3/min. This flow can be adjusted by the needle valve located on the back panel labeled "Cell Flow." The Ozone Flow, displayed as **O3F**, should be in the range 60-80 cm^3/min. The Ozone Flow can be adjusted by the needle valve located on the back panel labeled "O3 Flow." Once these flows have been verified and adjusted they should not need to be re-adjusted unless the instrument's location changes in altitude.

After adjusting the flow, the instrument power should be cycled on and off before proceeding.

3.5. Data Averaging and Data Logging

When first turned on, the instrument will start making measurements at a rate of once every 5 s (unless a different averaging time was previously chosen; see Section 4.4). Internally generated data may be logged in the internal data logger. Up to 8,192 data lines containing log number, NO_2, NO, NO_x, NO_{2_zero}, $NO_{_zero}$, Cell Temperature, Cell Pressure, Cell Volumetric Flow Rate, Ozone Volumetric Flow Rate, Sample Photodiode Voltage, O_3 Generator Photodiode Voltage, Heated Scrubber Temperature, Date, Time, and Status may be stored in internal memory. Averaging times of 5 s, 1 min, 5 min and 1 hr may be selected from the menu (Section 4.4), thereby allowing the instrument to operate for 1.4 days, 5.7 days, 1.0 months and 0.94 years, respectively, before filling the memory.

3.6. Collecting Data from the Analog Outputs

The data may be logged in real time using a data logger attached to the BNC analog outputs. There are two analog outputs: one for NO_2, and one for NO. The range of each analog output is 0-2.5 V, and the same user-selected scaling factor is applied to both outputs. The output is scaled according to a sensitivity you define in the menu. For example, you may define 2.5V = 250 ppb. In that case, the maximum output is 250 ppb, and 10 mV is equal to 1 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.

3.7. Collecting Data over the Serial Port in Real Time

To transmit data to a computer over the serial port in real time, connect the instrument to the computer using the 9-pin cable provided (and a serial-to-USB adapter cable if necessary). Note that the 9-pin cable provided is a “straight-through” female-female serial cable. A “cross-over” cable will not work. Start your data acquisition software, preferably using the 2B Technologies Display and Graphing Software (free download from https://twobtech.com/docs/docs_software.htm; see Appendix A for information on working with this software). Other terminal emulation software such as HyperTerminal (a program provided with earlier versions of Windows) or Tera Term may be used as well. Be sure to specify the baud rate setting of your data acquisition software to match the baud rate setting of your instrument. Note that the baud rate of the instrument is 2400.

The NO_2, NO and NO_x mixing ratios (ppb, pphm, ppm), internal cell temperature (°C), cell pressure (mbar), volumetric flow rate (cc/min), date, and time are sent as comma-delimited ASCII text to the serial port (2400 baud; 8 bits; no parity; 1 stop bit) every 5 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). The user should separately make note of the instrument settings for units (NO_2/NO/NO_x) and averaging time. Using the serial menu described in Section 5.1, the user may elect to output the instrument serial number at the beginning of the data line.

A typical data line might read:

1106,67.4,44.2,111.6,30.3,980.6,1576,76.2,1.2743,1.0151,110.2,00,12/07/17,18:31:27,80

where:

1106 = instrument serial number (if user has enabled this output in serial menu)
NO_2 = 67.4 ppb
NO = 44.2 ppb
NO_x = 111.6 ppb
Cell temperature = 30.3°C
Cell pressure = 980.6 mbar
Cell volumetric flow rate = 1576 cc/min
O_3 volumetric flow rate = 76.2 cc/min
Sample photodiode voltage = 1.2743 volts
O_3 generator photodiode voltage = 1.0151 volts
Heated scrubber temperature = 110.2°C
Error Byte = 00 *(No error; see Section 9 for error codes)*
Date = July 12, 2017
Time = 6:31:27 pm
Status = 80 *(Measuring NO_2 and NO) (see Section 5 for status codes)*

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

1106,289,67.4,44.2,111.6,30.3,980.6,1576,76.2,1.2743,1.0151,110.2,00,12/07/17,18:31:27,80

where 289 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. Section 5 of this manual describes the serial menu and how to access it.

3.8. Logging Data Using the SD Card

2B Technologies provides a SD card logger with the Model 405 nm NO_2/NO/NO_x Monitor, along with an SD card and an SD card reader. When inserted into the instrument (bottom right of the Monitor's front panel), the SD card automatically begins to collect and store data. (The internal data logger described in Section 3.5 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:

1106,67.4,44.2,111.6,30.3,980.6,1576,76.2,1.2743,1.0151,110.2,00,12/07/17,18:31:27,80

where:

1106 = instrument serial number (if user has enabled this output in serial menu)
NO_2 = 67.4 ppb
NO = 44.2 ppb
NO_x = 111.6 ppb
Cell temperature = 30.3°C
Cell pressure = 980.6 mbar

Cell volumetric flow rate = 1576 cc/min
O_3 volumetric flow rate = 76.2 cc/min
Sample photodiode voltage = 1.2743 volts
O_3 generator photodiode voltage = 1.0151 volts
Heated scrubber temperature = 110.2°C
Error Byte = 00 *(No error) (see Section 9 for error codes)*
Date = July 12, 2017
Time = 6:31:27 pm
Status = 80 *(Measuring NO_2 and NO) (see Section 5 for status codes)*

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

1106,289,67.4,44.2,111.6,30.3,980.6,1576,76.2,1.2743,1.0151,110.2,00,12/07/17,18:31:27,80

where 289 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. *(Note warning below.)*

To eject the SD card, push 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. *(Note warning below.)*

Important: When removing the SD card or powering off the instrument, up to 5 lines of data could be lost. (Note that if internal data logging was enabled, any lost lines could be retrieved from the internal data file.)

The Model 405 nm NO_2/NO/NO_x Monitor is compatible with SD and SDHC memory cards. We recommend using the SD cards available on the 2B Technologies website (https://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 405 nm Monitor. See Technical Note 036 for more information about logging and reading data via the SD card.

3.9. Measurement of the Zero Offset

The electronic zeros for NO_2 and NO may be periodically measured by either providing NOx-free air (typically zero grade air) or attaching a NO_x scrubber to the air inlet for a period of 5-10 minutes. Section 8 gives procedural recommendations for proper measurement of the instrumental zero offset. The observed offset, which can amount to a few ppb, can be adjusted by either changing the zero calibration parameter from the front panel, as described in Section 4.5.2 below, or by correcting the data at a later time. When making continuous measurements, it is recommended to check the zero offset at least once daily. Please refer to Section 8 for more detail.

3.10. Adaptive Filter

The Model 405 nm firmware processes sample concentration data through a built-in adaptive filter. During operation, the firmware may automatically switch between two different filter lengths based on the conditions at hand. During the measurement of stable concentrations, the firmware, by default, computes an average of the last 36 raw measurements, or 3 minutes of measurements. This provides smooth and stable readings by averaging out a considerable amount of random noise to improve the precision. If the filter detects rapid changes in concentration, the filter reduces the averaging to only 4 samples or 20 seconds to allow the analyzer to respond more quickly. Two conditions must be simultaneously met to switch to the short filter. First, the instantaneous concentration must differ from the average in the long filter by at least 40 ppb. Second, the instantaneous concentration must differ from the average in the long filter by at least 10% of the average in the long filter. The lengths of the long and short filter can be changed as well as the minimum difference and percent difference. This can be done via the serial connection as outlined in the Serial Menu section in this manual (Section 5). To disable the adaptive filter, set the short filter length to 1, the difference to 0, and the percent to 0.

3.11. Summary of Operating Recommendations

The following table summarizes operating recommendations mentioned in this manual.

Operating Recommendation	Frequency	Section Reference
Measure and adjust cell flow rate and ozone flow rate before operating instrument (restart instrument after adjustment of flows)	Whenever the instrument's location changes in altitude	3.4
Allow ~20 minutes for instrument warmup	Each startup	3.2
Inlet tubing should be made of inert materials, such as PTFE, PFA, FED, PVDF (do not use Tygon®, polypropylene, or metal tubing)	Each use	3.3
Use a Teflon or PVDF inlet filter; test it for NO_2 and NO loss	Each use	3.3
Vent exhaust to atmospheric pressure and out of room or shelter	Each use	3.3; also page vii
Check the span and zero offset	Periodically. For most applications, the zero offset should be checked daily.	8
Perform multipoint calibration	• Annually • Any time major disassembly of components is performed • Any time the zero or span checks give results outside of the acceptable limits	4.5.2; 7
If strong temperature fluctuations are expected, place the instrument in a thermally insulated box	User-defined	2
Use adaptive filter to improve precision if rapidly changing NO/NO_2 concentrations are occurring or are anticipated	User-defined	3.10; 5

4. THE MENU

4.1. Accessing the Main Menu

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

To reach the menu, hold in the Select switch (for up to several seconds) until the display shows: **Menu**. Then release the switch. The panel will now display:

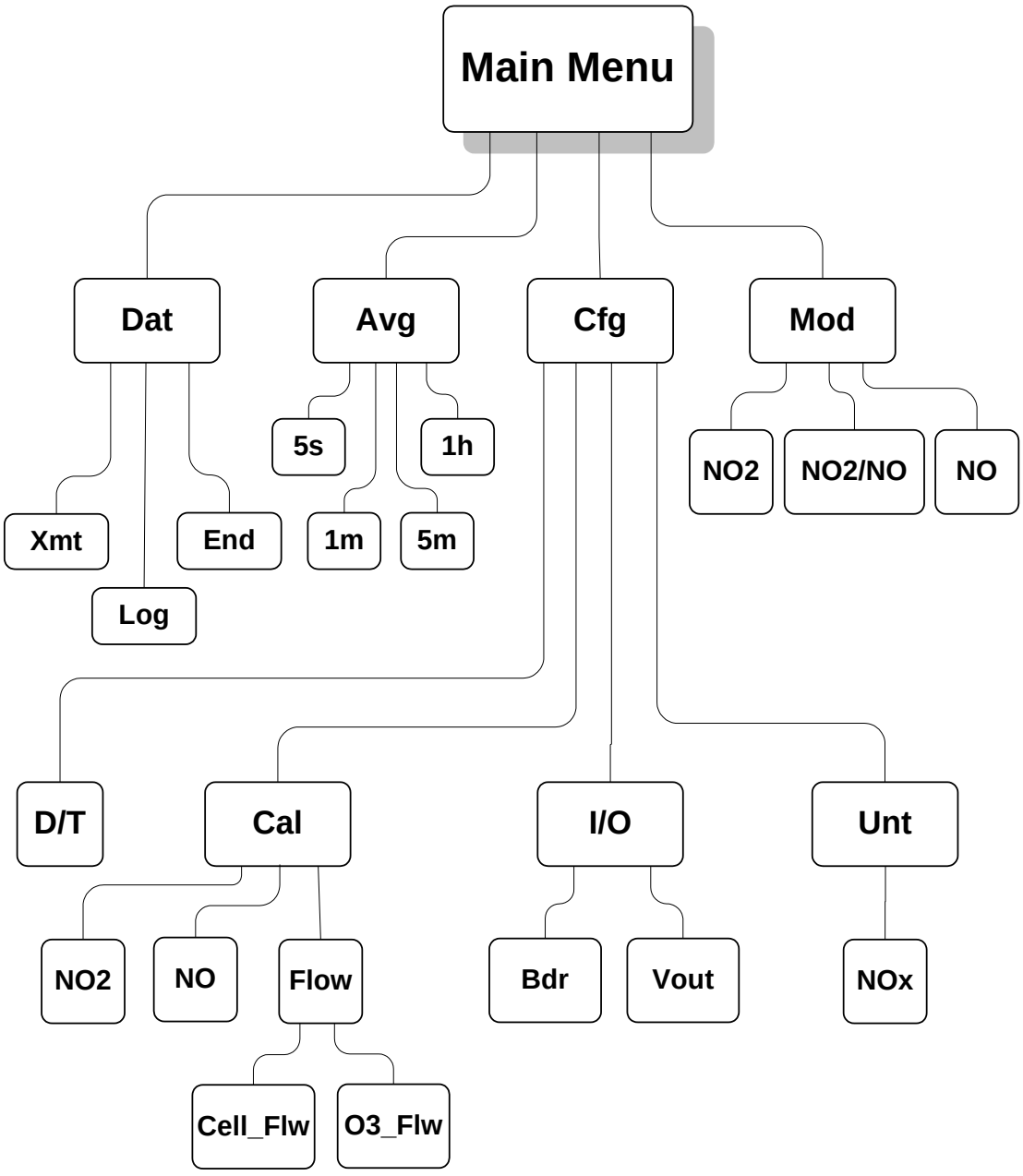
Menu
Dat Avg Cfg Mod ←

where **Dat**, **Avg**, **Cfg**, and **Mod** 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 the 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 (←). Note that "←" always takes you up one level in the menu.

A diagram of the menu structure and detailed explanations of each of the submenus are given below.

4.2. Menu Tree

The following diagram summarizes the complete menu.



4.3. Dat Submenu: Internal Data Logging

4.3.1. To Start Logging Data

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

Data Menu
Xmt Log End ←

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

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

If you select yes and 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 before restarting logging.

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 Menu**. To start data acquisition, select ← and click to return to the main **Menu** and the select ← to begin making measurements.

When measurements resume, the display might read:

NO2= 34.8 ppb

LOG=193:0 Tsc=112
14:49 04/07/2017

where the **NO2** (or **NO**) is the most current measurement of that species, **LOG** is the current log number (193 in this case), **Tsc** is the temperature (Celsius) of the NO_2 scrubber, the time of the measurement is 14:49 (2:49 pm on 24-hr clock) and the date is 4 July 2017 (European style). The "0" in "193:0" refers to the number of 5-second data points that have been measured so far for inclusion in the next average to be displayed and logged (in this case, "0" is displayed because no averaging has been selected). After 5 seconds, as an example, the display will be replaced by:

NO2= 33.7 ppb

CF=1525 O3F=75
T=35.2 P=985.7

where **NO2** (or **NO**) is the value most recently written to the logger, **CF** is the cell flow rate, **O3F** is the ozone flow rate (if **NO** is being measured), **T** is the temperature in Celsius, and **P** is the cell pressure in millibar.

If averaging has been selected (see Section 4.4 below), then the first display above will be replaced by:

AvgNO2= 56.7 ppb

LOG= 193:4 Tsc=111
14:49 04/07/2017

Again 193 refers to the most recent log number. The "4" in 193:4 refers to the number of 5-s data points that have been measured so far for inclusion in the next average to be displayed and logged. If 5-s averaging is used, this number will always be 0. If 1-min averaging is used, this number will increment from 0 to 11; for 5-min averaging, the number will increment from 0 to 59; and for 1-hr averaging, it will increment from 0 to 719. This number is displayed so that the user will know how many more 5-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 an "E:" followed by a 2-character code appears at the center of the bottom line of the LCD readout, an error has occurred, and one or more instrument parameters are out of range (e.g., scrubber temperature, cell flow rate, cell voltage, etc.). See Section 9 for a detailed list of error codes and their meaning.

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, a data line may be lost because the microprocessor writes to the logger memory in groups of two 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.

4.3.2. 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 below). Alternatively, you may return to the **Menu** and resume measurements 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. However, 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.

4.3.3. To Transmit Logged Data

Connect the serial port of the instrument to the serial port of your computer using the cable provided. If your computer does not have a serial port, you can use the computer's 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 (free download available from the 2B Technologies website at https://twobtech.com/docs/docs_software.htm), Microsoft HyperTerminal (available on earlier Windows® platforms, usually in Start/AllPrograms/Accessories/ Communications/HyperTerminal) or Tera Term, which can be downloaded at:

https://twobtech.com/teraterm-4.100.exe

Note that a disadvantage of HyperTerminal is that it has a 500-line buffer limit. However, all 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:

https://twobtech.com/docs/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 NO_2 measurements. The logged data continues to be available for transmission until a new data log is started.

4.4. Avg Submenu: To Average Data

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

Avg Menu

5s 1m 5m 1h ←

Use single clicks to move the cursor to **5s**, **1m**, **5m** or **1h** for averaging times of 5s, 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.

While in averaging mode, the current 5-s measurement is displayed alternately with the average value, as discussed in Section 4.3 above. 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.

4.5. Cfg Submenu: Instrument Configuration

Several different parameters including date/time, calibration, and input/outputs can be accessed and set through the configuration or **Cfg** submenu.

4.5.1. 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 ←
17/07/2017

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

4.5.2. Calibration Parameters - Overview

All calibration parameters can be accessed through the **Cfg / Cal** submenu. Slope and offset calibration parameters may be set for NO_2, NO, Cell Flow Rate, Ozone Flow Rate, and internal Ozone Source. Calibrations are performed at 2B Technologies and these calibration parameters are set prior to the instrument being packaged and shipped. Flow rates and flow meter calibration parameters should not be changed unless certain parts of the instrument are replaced which are normally done by technicians at the factory. The user should check and adjust flow rates if the instrument is moved to a different altitude (see Section 3.4). You may want to change the NO_2 and NO calibration parameters based on your own calibrations.

4.5.3. To Set the NO_2 and NO Calibration Parameters

The instrument is calibrated at the factory, where slope and offset parameters for NO_2 and NO 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 NO_2 or NO mixing ratios. (When measuring zero NO_2 or NO concentration, there should be an equal number of negative and positive values if the instrument is zeroed.) Also, the instrument zero may drift by a few ppb over time. For

this reason, frequent zeroing of the instrument is recommended. For most applications, zeroing the instrument once or twice daily, for a duration of at least 5 minutes, is sufficient. 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 contaminated NO_2 or NO_x 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 NO_2 or NO source or with the readout from another instrument whose calibration is considered to be accurate.

To adjust the calibration slope and zero offset calibration parameters, first access the **Cal** menu from the **Cfg** menu. There are three submenus:

Cal Menu

NO2 NO Flow ←

To change the NO_2 or NO calibration parameters, select **NO2** or **NO** from the **Cal** menu. Now you can select either **Slope** or **Zero** to adjust slope factor or the zero offset. For example, for NO_2, the submenu will appear as:

NO2 Cal Menu

Slope Zero ←

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

NO2 Slope Cal

Slope = 1.011 ←

To change a digit in the slope or the offset, 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 **NO2 Cal Menu** menu.

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

NO2 Zero Cal

Zero = -002.5 ←

Here Zero is the offset applied (in this case -2.5 ppb). The Zero value can be edited in the same manner as the Slope value. <u>For both NO and NO2, the Zero value must be entered in units of ppb.</u> 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 NO_2 or NO value, and the value of Slope is then multiplied by the measured value. For example, if the instrument reads an average of 3.2 ppb with an external scrubber in place, the value of Z should be set to –003.2. If after correction for the zero, the instrument consistently reads 2.3% low, the value of Slope should be set to 1.023.

4.5.4. To Set the Flow Meter Slopes

Two different flow measurements are critical to the performance of the instrument: one is the cell flow rate and the other is the ozone flow rate. Do NOT change these settings unless you contact 2B Technologies. To change the flow meter slope (sensitivity) calibration parameters, access the **Cfg / Cal / Flow** submenu:

Flow Cal Menu

Cell_Flw O3_Flw ←

Selecting the Cell_Flw submenu allows you to change the slope calibration parameter for the cell flow rate:

CFlow Cal Menu

CF = 1.03 ←

You may change this multiplicative calibration parameter by selecting the first numeral, and then rotating the select switch to scroll up to the desired decimal value, and deselecting. To change the ozone flow meter calibration parameters, select **O3_Flw** and set in the same manner as for the cell flow rate.

4.5.5. To Change the Analog Output Scaling Factor

Analog outputs proportional to NO_2 and NO concentrations are provided via BNC connectors at the back of the instrument for those who want to record NO_2 and NO concentration data with a chart recorder or external logger. The full scale of each analog output is 2.5 V, and the same scaling factor is applied to both analog outputs. From the **Cfg** submenu, select **I/O** to give the input/output menu, for example:

I/O Menu

Bdr Vout ←

In the **Cfg / I/O** submenu, electing **Vout** displays the submenu:

Analog Output

1V = 00200 ppb ←

In this example, the output scaling factor is set as 1.0 Volt = 200 ppb. Since the maximum output voltage is 2.5 V, the maximum output concentration in this case is 500 ppb, and 1 ppb will provide an output of 5 mV. You can use the Select switch to change the scaling factor to the value of your choice by selecting and changing the individual digits in the scaling factor. A click on ← returns the display to the **I/O** menu.

4.5.6 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 Vout ←

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:

2400 4800 19200 ←

After clicking on a chosen baud rate, use ← to return to the **I/O** menu.

4.5.7. Measurement Units for NO_2 and NO

Select the **Cfg / Unt** menu to display the following:

NOx Units

NOx: ppb ←

Select the units (ppb in this case) and rotate the Select switch to cycle the cursor between the choices of units. NO_2 (and NO) units may be selected as ppb, pphm and ppm. A click on ← returns the display to the **Unt** menu.

4.6. Mod Submenu: Measurement Modes

The Model 405 nm has the capability to measure nitrogen dioxide and nitric oxide each individually or simultaneously (5 seconds apart). There are 3 measurement modes available: NO_2 mode, NO mode, and NO_2 and NO mode. The measurement mode can be changed by entering the **MOD** menu and selecting either "NO2", "NO2/NO", or "NO". If using a serial connection, the mode can be changed using serial commands "G" for NO_2 mode, "B" for NO_2 and NO mode, or "N" for NO mode. The status byte at the end of the serial stream tells which mode you are currently in (see Section 5 for status codes).

4.6.1. NO_2 Mode

This measurement mode uses two 5 second cycles to measure I and I_o for NO_2. After each cycle, a new measurement of nitrogen dioxide is computed and output to the LCD and through the serial port depending on what averaging frequency is selected (5 sec, 1 min, 5 min, or 1 hr).

4.6.2. NO_2 and NO Mode

This measurement mode uses three 5-second cycles to measure I_o for NO_2, I for NO_2, which is also I_o for NO, and I for NO. After each 5-second cycle, a new measurement of nitrogen dioxide and nitric oxide is computed and output to the LCD and through the serial port, depending on what averaging time is selected (5 sec, 1 min, 5 min, or 1 hr).

4.6.3. NO Mode

This measurement mode uses two 5 second cycles to measure I and I_o for NO. After each cycle, a new measurement of nitric oxide is computed and output to the LCD and through the serial port, depending on what averaging frequency is selected (5 sec, 1 min, 5 min, or 1 hr).

5. REMOTE CONTROL VIA SERIAL CONNECTION

Measurements and logging tasks can be accessed via the serial port using the 2B Technologies Display and Graphing software (available as a free download from https://twobtech.com/docs/docs_software.htm; see Appendix A for information on working with this software) or a terminal emulator such as Tera Term or HyperTerminal running on an attached computer. Commands can be sent using the terminal emulator set with the properties listed in the section of this manual entitled "Collecting Data over the Serial Port in Real Time" (Section 3.7). Listed below are the lower-case letters that are commands for performing certain operations while the instrument continues to measure:

Key Stroke	Function
l	Start logging.
t	End logging and transmit data.
e	End logging.
N	Set the current mode to measure Nitric Oxide.
G	Set the current mode to measure Nitrogen Dioxide.
B	Set the current mode to measure both NO_2 and NO.
h	Output the serial header.

5.1. Serial Menu

If the letter **m** is sent as a command, measurements will stop and **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:

Key Stroke	Function
l	Start logging.
t	End logging and transmit data.
e	End logging.
a	Set average and output frequency.
z	Set the NO_2 zero offset calibration factor (in units of ppb).
s	Set the NO_2 slope calibration factor.
o	Set the NO zero offset calibration factor (in units of ppb).
g	Set the NO slope calibration factor.
c	Set the time and date. **n** Leave time and date unchanged. **t** Change time (must enter new values). **d** Change date (must enter new values).
d	Turn the LCD backlight on.
f	Turn the LCD backlight off.
i	Adaptive filter - Change Difference (ppb).
q	Adaptive filter - Percent (%).

k	Adaptive filter - Long Average (number of points).
m	Adaptive filter - Short Average (number of points).
h	Output the serial header.
j	Set serial number.
r	Output serial number.
A	Include/do not include serial number in data line.
N	Set the current mode to measure Nitric Oxide.
G	Set the current mode to measure Nitrogen Dioxide.
B	Set the current mode to measure both NO_2 and NO.
?	Output this help menu.
x	Exit the serial menu.

5.2. Status Codes

The current measurement mode can be determined from the status byte in each serial data line. The following describes all combinations of the status byte and the corresponding measurement mode:

80 = Measuring NO_2 and NO
10 = Measuring NO_2
20 = Measuring NO

6. MAINTENANCE

The Model 405 nm NO_2/NO/NO_x Monitor is designed to be nearly maintenance free. Components that require routine maintenance include the ozone and NO_2 scrubbers on the cell exhaust and the DewLine™ Nafion tubing on the cell inlet, all of which should be changed every year, 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 (see Section 3.4). 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 LED, clock battery and solenoid valves, which are easily replaced should they fail. In addition, the inlet filter (user supplied) should be changed as recommended by the filter manufacturer. See Section 9 for a description of Error Codes and see Section 10 of this manual for troubleshooting information.

A wide range of Technical Notes are provided on the 2B Tech website. The complete list with links may be found at https://twobtech.com/docs/docs_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:

https://twobtech.com/downloads.html

For your convenience, a Service Log, which may be printed, is provided at the end of this manual for recording calibrations, replacement of pumps, LEDs, 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.

Maintenance Recommendation	Frequency	Section Reference
Recalibrate instrument	At least once per year or at 4000 hours; sooner if span and offset are large, or if instrument undergoes major disassembly	7
Check flow path for contamination	Occasionally	Contact 2B Tech if contamination is suspected
Check heated NO_2 scrubber, exhaust gas NO_2 and O_3 scrubbers, and DewLine™ Nafion tubing and replace if needed	Every 6 months of continuous operation (~4,000 hrs); otherwise annually	6 [contact 2B Tech for instructions if heated NO_2 scrubber needs replacement]
Monitor flow rates and replace pump if indicated	Nominal 15,000 hours pump lifetime	6

7. CALIBRATION

Calibration of the Model 405 nm NO_2/NO/NO_x Monitor is recommended at least annually, either by the user (recommended procedure described below) or by returning the instrument to 2B Technologies for calibration servicing.

7.1. Introduction

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 NO_2 and NO monitors, please refer to the related information in Code of Federal Regulations (Title 40, Part 50, Appendix F: https://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol2/pdf/CFR-2011-title40-vol2-chapI.pdf).

Calibration is the process of adjusting the gain and offset of the Model 405 nm 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.

The calibration of NO_2 and NO monitors using compressed gas mixtures is unreliable because the gases are lost by reaction and adsorption in the cylinder and on gas handling equipment. When concentration standards are required, NO_2 and NO concentrations are generated by diluting a high concentration NO mixture and converting a fraction of the NO to NO_2 via the gas-phase titration reaction with ozone. The depletion of NO measured by the Model 405 nm provides the calibration for NO, and the appearance of NO_2 provides the calibration of NO_2. The concentration of ozone used in the gas-phase titration (GPT) reaction can be measured using a photometer with a NIST-traceable calibration to validate the difference in concentrations for both NO_2 and NO.

Commercial NO_2 and NO calibrators have dynamic dilution manifolds with an internal ozone generator and photometer. The calibrator generates NO_2 concentrations by the technique of gas phase titration (GPT), in which standard ozone concentrations are reacted with excess NO. Nitric oxide standards are generated by difference, where standard ozone concentrations are reacted with excess NO and the change in NO concentration is measured.

7.2. Equipment Required

This procedure requires the following equipment:

1. NO_2 and NO calibrator
2. Zero air source
3. Compressed NO standard (refer to the manufacturer's User Manual for the calibrator)
4. Sampling lines (inert materials 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 nitrogen dioxide and nitric oxide must be removed. The Model 405 nm will perform better if the zero air has humidity in the range 10-90 %RH. A set of DewLine™ Nafion® tubing is included with the Model 405 nm for installation between a dry gas supply and the instrument. The DewLine™ Nafion tubing introduces humidity to dry air or calibration standards without loss of NO_2 or NO.

7.3. Setup Check

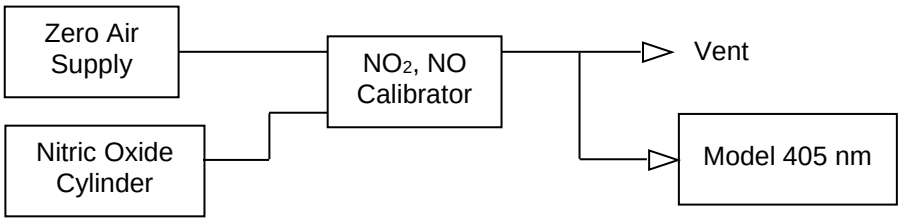
A visual inspection of the calibration setup should be performed before performing a calibration to verify that the setup is in proper order. All plumbing connections should be checked. Any obvious leaks should be fixed and the sampling tee and sampling lines should be checked for general cleanliness. For more information, refer to the manufacturer's User Manual for the calibrator.

7.4. Calibration Procedure

A multipoint calibration should be performed at least every 12 months. Within this calibration frequency, a multipoint calibration is advised whenever 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 405 nm and allow it to stabilize for a minimum of 1 hour.
2. Enter the calibration menu (Main Menu /Cfg / Cal) and set the zero values to 0 and the slope values to 1.00 for both NO_2 and NO.
3. Connect the monitor to a sampling tee from the calibrator. The outlet of the calibrator must be vented to atmosphere so that pressure does not build up in the setup. Connection of the Model 405 nm directly to a pressurized output of any device can damage the monitor.
4. Verify that there is an overflow at the vent of the sampling tee.



7.4.2. Measurement of Zero Air

1. Verify that the zero-air supply is on and the calibrator is set to output zero air only.
2. Allow the Model 405 nm to sample zero air until the response is stable.
3. Record the average zero air responses.

7.4.3. Measurement of NO_2 and NO Standards

1. Allow the Model 405 nm to sample zero air until a stable response is measured and record the average responses.
2. To equilibrate the system, generate an NO concentration significantly higher than twice the concentration range of NO_2 that will be calibrated and allow the calibrator and equipment to equilibrate for at least 10 minutes.
3. The NO concentration should not be changed for the rest of the calibration.
4. Allow the Model 405 nm to sample the NO concentration standard until a stable response is measured and record the average responses.
5. Generate an ozone concentration at the high end of the concentration range of NO_2 that will be calibrated and allow the calibrator and equipment to equilibrate for at least 10 minutes.
6. Allow the Model 405 nm to sample the NO_2 and NO concentration standards until a stable response is measured and record the average responses.
7. Generate several other ozone concentrations to produce other concentrations of NO_2 and NO. At least 4 concentration standards are recommended over the range of interest.
8. For each concentration, record the responses of the Model 405 nm.
9. Turn off the ozone generator and continue to produce the NO concentration used during the calibration process and allow the calibrator and equipment to equilibrate for at least 10 minutes.
10. Verify that the standing NO concentration used during the calibration did not change more than a few ppb from the beginning of the calibration procedure. If the NO concentration is significantly different at the beginning and end of the calibration, then the calibration setup was not adequately equilibrated before collecting measurements.
11. Allow the Model 405 nm to sample zero air until a stable response is measured and record the average responses.

7.4.4. Calibration Curve

1. Calculate the measured NO_2 as the difference between the average zero response and the response at each concentration of NO_2. Any offset from background NO_2 released from the GPT chamber will be cancelled out this way.
2. Calculate the measured NO as the difference between the average standing NO concentration during the calibration and response at each concentration of NO.
3. Calculate the average NO_2 and NO measurement for zero air and use this zero for the calibration curve.
4. Plot the Model 405 nm measurements (y-axis) versus the corresponding standard concentrations (x-axis) for both the measured NO_2 and NO.
5. 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.
6. 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 monitor being calibrated. The most likely problems in the monitor are leaks, contamination of the DewLine™ Nafion tubing, a contaminated valve, or contamination in the optical setup. See Section 10, the "Troubleshooting" section of this manual.

7. The inverse slope of the line (1/m) is the gain factor and the negative of the intercept (-b, in units of ppb) is the offset that need to be applied to the monitor response to calibrate it. If the intercept is outside of the range from -15 to 15 ppb or the slope is outside of the range from 0.90 to 1.10, this is an indication of a problem in the calibration setup or the monitor being calibrated. The most likely problems in the monitor are leaks, contamination of the DewLine™ Nafion tubing, a contaminated valve, or contamination in the optical setup. See the "Troubleshooting" section of the manual (Section 10).
8. Enter the calibration menu (Main Menu / Cfg / Cal) in the instrument software and set the calibration parameters. Note that the offset (Z) parameter must be entered in units of ppb. If the calibration has been performed in other units, convert the offset to ppb before entering the value.

8. PERIODIC ZERO AND SPAN CHECKS

To ensure the quality of the monitor data, periodic zero and span checks are recommended. For continuous monitoring or measuring low NO_x levels (< 10 ppb), the zero offset should be tested at least once daily. For all zero or span checks the instrument should be turned on and allowed to warm up for at least 30 minutes.

8.1 Zero Offset Check

The electronic zeros for NO_2 and NO are tested by introducing NO_x-free air to the analyzer. The NO_x-free air can be generated from either (1) passing ambient air through a NO_x scrubber or (2) using zero grade air from a compressed cylinder or zero air generator.

1. To perform the zero offset test, attach either a NO_x scrubber or a flow of zero-grade air to the Model 405 nm inlet. This can be done by manually changing the inlet gas connection or by introducing the NO_x-free air to the inlet via a user-provided valve system. If zero-grade air is used, it is important to use an overflow tee as described in Section 7.4.1 above.
2. Upon addition of NO_x-free air, it is likely that there will be an initial perturbation in the system pressure which can cause the Pressure control Error Byte to appear on the LCD and serial output (See Section 9 for description of the Error Byte).
3. Allow the instrument to sample NO_x-free air for at least 5 to 10 minutes. Within the first minute or two, the pressure control should be re-established

and the Error byte should be cleared (00). Record and average both the NO and NO_2 channels for the last 3-5 minutes to obtain the new offset.

8.2. Span Check

Span checks should be performed using a commercial NO/NO_2 calibrator in a similar fashion as described in Section 7.4.3. Typically, a single point span check at ~ 80% of the expected NO_2 concentration range is adequate.

1. Connect the monitor to the calibrator output via a sampling tee. This can be done by manually changing the inlet gas connection or by a user-provided valve system. The outlet of the calibrator must be vented to atmosphere using an overflow tee so that pressure does not build up in the setup. Connection of the Model 405 nm directly to a pressurized output of any device can damage the monitor.
2. An initial high concentration of NO is added to the monitor using the calibrator. The NO concentration should be higher than twice the concentration range of NO_2 that will be calibrated. Allow the calibrator output to stabilize for at least 10 minutes. This will also allow the Model 405 nm pressure control to re-establish as described above for the Zero Offset Check. Allow the Model 405 nm to sample both the NO_2 and NO concentration standards until a stable response is measured and record the average responses.
3. Generate an ozone concentration in the calibrator at ~80% of the concentration range of NO_2 of interest and allow the calibrator output to stabilize again for at least 10 minutes. Again, allow the Model 405 nm to sample the NO_2 and NO concentration standards until a stable response is measured and record the average responses.

Average measurements from the zero check or span check should be within the instrument specifications. If this is not the case, a more thorough multipoint calibration in the NO_2 concentration range of interest is advised, following the steps as described above in the “Measurement of NO_2 and NO Standards” Section 7.4.3.

9. ERROR MESSAGES

When an Error occurs, an “E:” will appear on the bottom line of the LCD followed by the error byte. There is also a field in the serial data which holds the error byte. The error byte is represented by a hexadecimal code of two characters. There are no errors if the error byte in the serial data line is “00”. If there are no errors, the LCD will not display the “E:”.

9.1. Error Definitions

The following tables list all of the possible hexadecimal codes and their corresponding error definitions. The first table lists all of the errors if there were only one error while the second table lists all of the possible error combinations with their definitions.

Single Errors	
Error byte	**Definition**
00	No errors
08	Scrubber temp out of range. Temp is either > 113 degrees or < 110.
80	Pressure control out of range by > 1 mbar
04	Cell flow out of range (< 1200 or >1600)
40	Ozone flow out of range (<30 or >110)
02	Cell voltage out of range (<0.1V or >2.4V)
20	Ozone Generator voltage out of range (< 0.01V or >2.4V)

Combination Errors	
Error Byte	**Definition**
0A	Scrubber Temp and Cell Voltage
0C	Scrubber Temp and Cell Flow
0E	Scrubber Temp, Cell Flow, and Cell Voltage
22	Cell Voltage, and Ozone Generator Voltage
26	Cell Flow, Cell Voltage, and Ozone Generator Voltage
28	Scrubber Temp and Cell Voltage
24	Cell Flow and Cell Voltage
2A	Scrubber Temp, Cell Voltage, and Ozone Generator Voltage
2C	Scrubber Temp, Cell Flow, and Ozone Generator Voltage
2E	Scrubber Temp, Cell Flow, Cell Voltage, and Ozone Generator Voltage
42	Ozone Flow and Cell Voltage
46	Cell Flow, Ozone Flow, and Cell Voltage
48	Scrubber Temp and Ozone Flow
44	Cell Flow and Ozone Flow

4A	Scrubber Temp, Ozone Flow, and Cell Voltage
4C	Scrubber Temp, Cell Flow, and Ozone Flow
4E	Scrubber Temp, Cell Flow, Ozone Flow, and Cell Voltage
82	Pressure Control and Cell Voltage
84	Pressure Control and Cell Flow
86	Pressure Control, Cell Flow, and Cell Voltage
88	Scrubber Temp and Pressure Control
8A	Scrubber Temp, Pressure Control, and Cell Voltage
8C	Scrubber Temp, Pressure Control, and Cell Flow
8E	Scrubber Temp, Pressure Control, Cell Flow, and Cell Voltage
A0	Pressure Control and Ozone Generator Voltage
A2	Pressure Control, Cell Voltage, and Ozone Generator Voltage
A4	Pressure Control, Ozone Flow, and Ozone Generator Voltage
A6	Pressure Control, Ozone Flow, Cell Voltage, and Ozone Generator Voltage
A8	Scrubber Temp, Pressure Control, and Ozone Generator Voltage
AA	Scrubber Temp, Pressure Control, Cell Voltage, and Ozone Generator Voltage
AC	Scrubber Temp, Pressure Control, Cell Flow, and Ozone Generator Voltage
AE	Scrubber Temp, Pressure Control, Cell Flow,
C0	Pressure Control and Ozone Flow
C2	Pressure Control, Ozone Flow, and Cell Voltage
C4	Pressure Control, Cell Flow, and Ozone Flow
C6	Pressure Control, Cell Flow, Ozone Flow, and Cell Voltage
C8	Scrubber Temp, Pressure Control, and Ozone Flow
CA	Scrubber Temp, Pressure Control, Ozone Flow, and Cell Voltage
CC	Scrubber Temp, Pressure Control, Cell Flow, and Ozone Flow
CE	Scrubber Temp, Pressure Control, Cell Flow, Ozone Flow, and Cell Voltage
E0	Pressure Control, Ozone Flow, and Ozone Generator Voltage
E2	Pressure Control, Ozone Flow, Cell Voltage, and Ozone Generator Voltage
E4	Pressure Control, Cell Flow, Ozone Flow, Ozone Generator Voltage
E6	Pressure Control, Cell Flow, Ozone Flow, Cell Voltage, and Ozone Generator Voltage
E8	Scrubber Temp, Pressure Control, Ozone Flow, and Ozone Generator Voltage
EA	Scrubber Temp, Pressure Control, Ozone Flow, Cell Voltage, and Ozone Generator Voltage
EC	Scrubber Temp, Pressure Control, Cell Flow, Ozone Flow, and Ozone Generator Voltage
EE	Scrubber Temp, Pressure Control, Cell Flow, Ozone Flow, Cell Voltage and Ozone Generator Voltage

9.2. LCD Display of Error Byte

If errors are occurring, the LCD might read the following:

NO2 = 34.8 ppb

LOG=193:0 Tsc=112
14:49 E:88 04/07/2017

where “88” is the error, which in this case means that the scrubber temperature is out of range and also the pressure control is out of range.

The alternate LCD view with error message is:

NO2 = 34.8 ppb

CF=1525 O3F=75
T=35.2 E:88 P=985.7

If any errors are occurring, the user can scroll left or right during operation and view all of the errors that are occurring instead of trying to decipher the error code.
If the user scrolls during operation, where the error is “E88”, the LCD would read:

Errors
Scr Temp, Press Cntl

9.3. Serial Data Line

The error byte is located in the comma delimited serial output line after the scrubber temperature and before the date. For example:

67.4,44.2,111.6,30.3,980.6,1576,76.2,1.2743,1.0151,110.2,88,12/07/17,18:31:27,80

where:

NO2= 67.4 ppb
NO = 44.2 ppb
NOx= 111.6 ppb
Cell temperature = 30.3°C
Cell pressure = 980.6 mbar
Cell volumetric flow rate = 1576 cc/min
O3 volumetric flow rate = 76.2 cc/min
Sample photodiode voltage = 1.2743 volts
O3generator photodiode voltage = 1.0151 volts
Heated scrubber temperature = 110.2°C
Error Byte = 88 *(Pressure control and scrubber temperature are out of range)*
Date = July12, 2017
Time = 6:31:27 pm
Status = 80 *(Measuring $NO_2$and NO)*

10. TROUBLESHOOTING

If the instrument fails to operate correctly, common problems can be identified and corrected using the error messages described in Section 9. In addition, Table 10.1 provides troubleshooting information that can be used to diagnose the problem. If the problem cannot be easily corrected, please contact Customer Service at 2B Tech via our web ticketing software at:

https://twobtech.com/tech-support.html

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

The figures in Section 11 provide a "guided tour" of the Model 405 nm NO_2/NO/NO_x Monitor™ so that critical components and connectors may be easily identified. A list of serviceable parts is provided in Section 13 of this manual.

Table 10.1. Troubleshooting the NO_2/NO/NO_x Monitor for performance problems.

Problem/Symptom	Likely Cause	Corrective Action
Instrument does not turn on.	Power not connected properly or circuit breaker open.	Check external power connection for reverse polarity or a short and wait a few minutes for the thermal circuit breaker to reset.
	Power cable not connected to circuit board.	Remove top cover and disconnect and reconnect power cable to circuit board.
Instrument turns on then powers off.	Burned out air pump.	Remove top cover and unplug air pump. Turn instrument on; if it remains running, then the air pump motor is burned out and shorting. Replace air pump.
Display is blank or displays unreadable characters.	Bad connection of display to circuit board.	Remove top cover and reconnect display to circuit board. Check solder connections to display.
Cell temperature reads low by several 10's of degrees.	Absent or loose connection of temperature probe cable to circuit board.	Remove top cover and reattach connector to circuit board.

Problem/Symptom	Likely Cause	Corrective Action
Readings are noisy with standard deviations much greater than 3 ppb using 5-second averaging.	LED output is weak	Remove top cover and check LED connection to circuit board. Run LED Test from menu. If photodiode voltage is less than 0.5 V, replace LED.
	Excessive vibration	Provide additional vibration insulation for the instrument such as a foam pad.
	Flow path contaminated	Contact 2B Technologies for instructions if contamination is suspected.
Analog output is constant or does not track front display.	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.
Select switch does not work.	Cable not properly connected between Select switch and circuit board.	Remove top cover and reconnect Select switch cable to circuit board.
Serial port does not work.	Cable not properly connected between serial 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 Model 405 nm menu matches the baud rate setting of your data acquisition program.

Problem/Symptom	Likely Cause	Corrective Action
Required calibration parameters are outside the adjustable range when calibrated using a known calibration gas.	Flow path is contaminated.	Contact 2B Technologies for instructions if contamination is suspected.
	Solenoid valve is contaminated and not opening & closing properly.	Remove solenoid valve, rinse with methanol, dry with zero air, and replace.
	Air pump is not drawing sufficient flow.	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** (allows air to flow freely and does not cause significant pressure drop) to the exit port of the pump. Air flow should be greater than 1.4 L/min. If flow is lower, check for leaks. If there are no leaks, replace air pump.
Instrument has a large offset	Internal heated NO_2 scrubber is exhausted or contaminated.	Contact 2B Technologies about replacement of the internal heated NO_2 scrubber.
Instrument always reads close to zero for NO_2 concentrations.	Solenoid valve cable is not properly connected to circuit board.	Reattach solenoid valve cable to circuit board.
	Internal heated NO_2 scrubber is exhausted or contaminated.	Contact 2B Technologies about replacement of the internal heated NO_2 scrubber.

11. LABELED INSTRUMENT PHOTOS

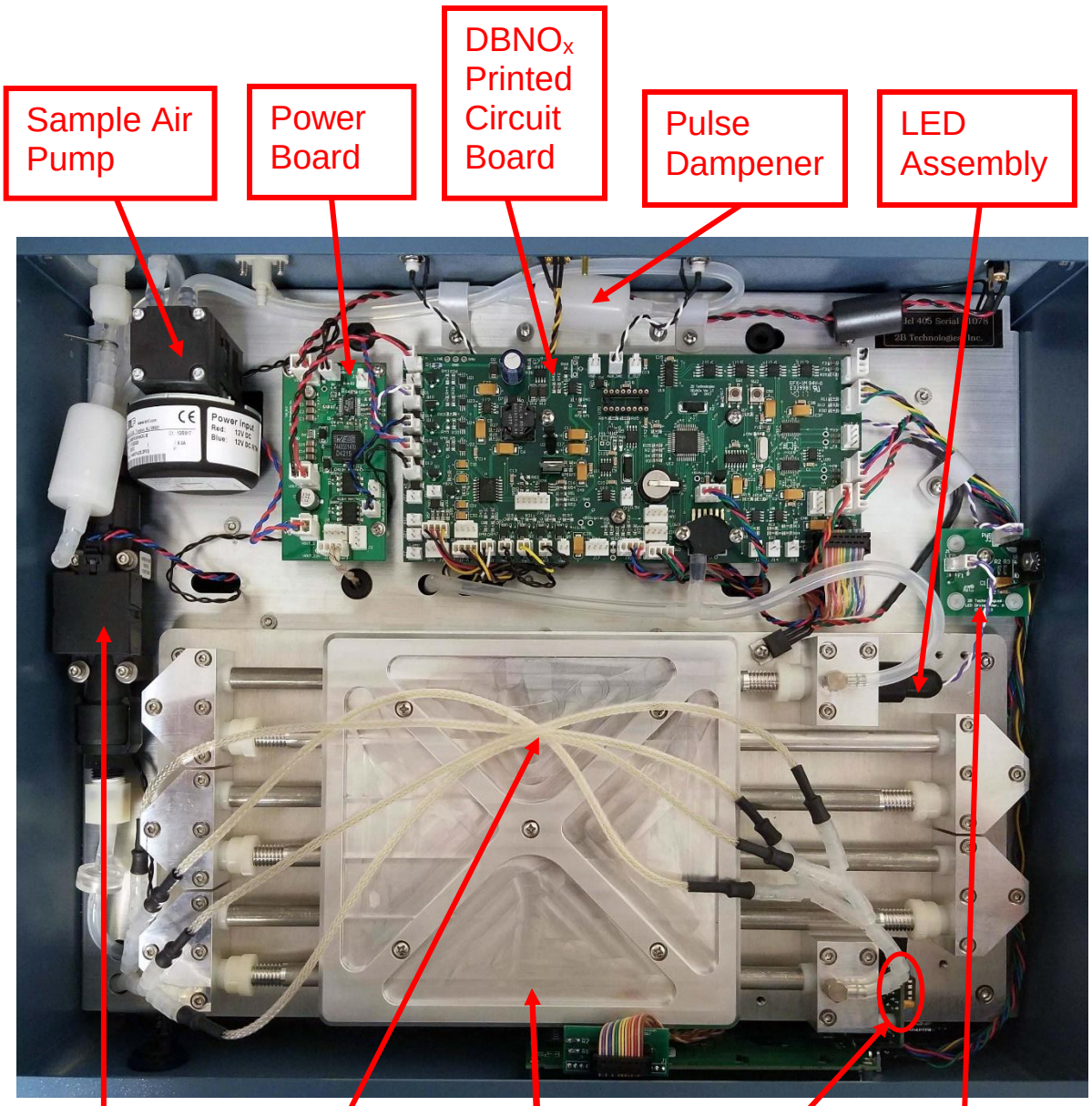


Figure 11.1. ***Top view of Model 405 nmNO_2/NO/NO_x Monitor with cover removed.***

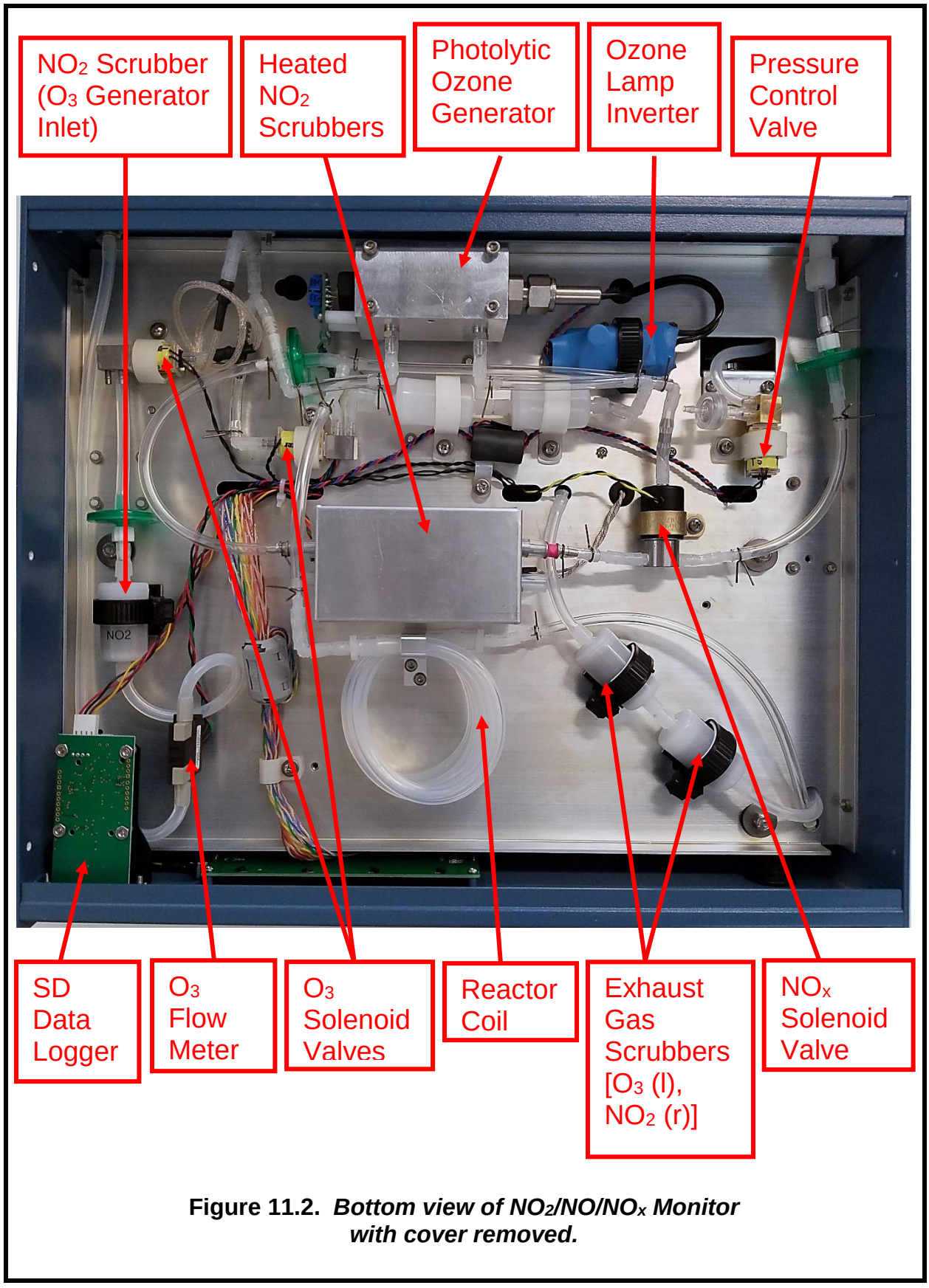


Figure 11.2. ***Bottom view of NO_2/NO/NO_x Monitor with cover removed.***

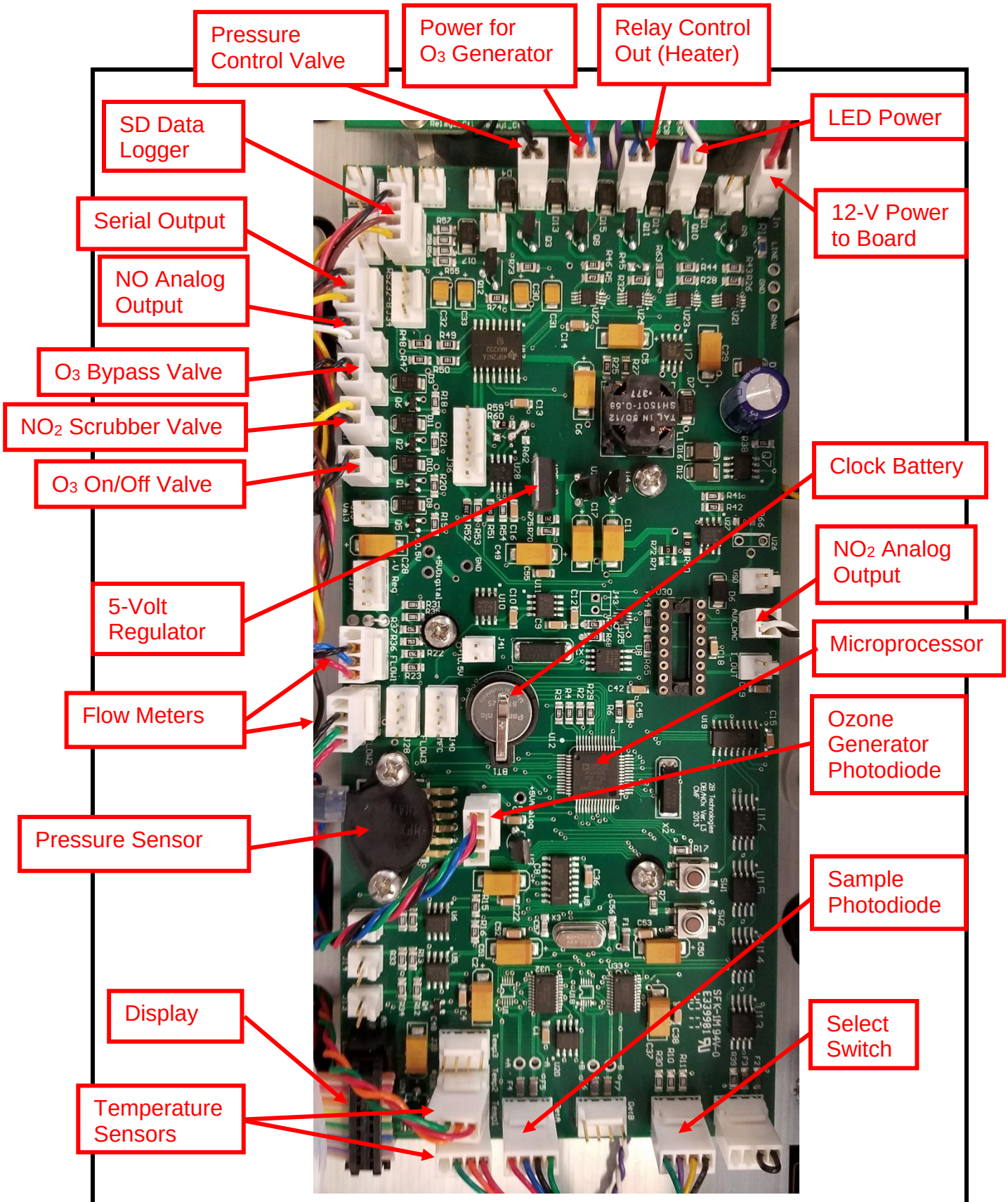


Figure 11.3. ***DBNOx Printed Circuit Board***

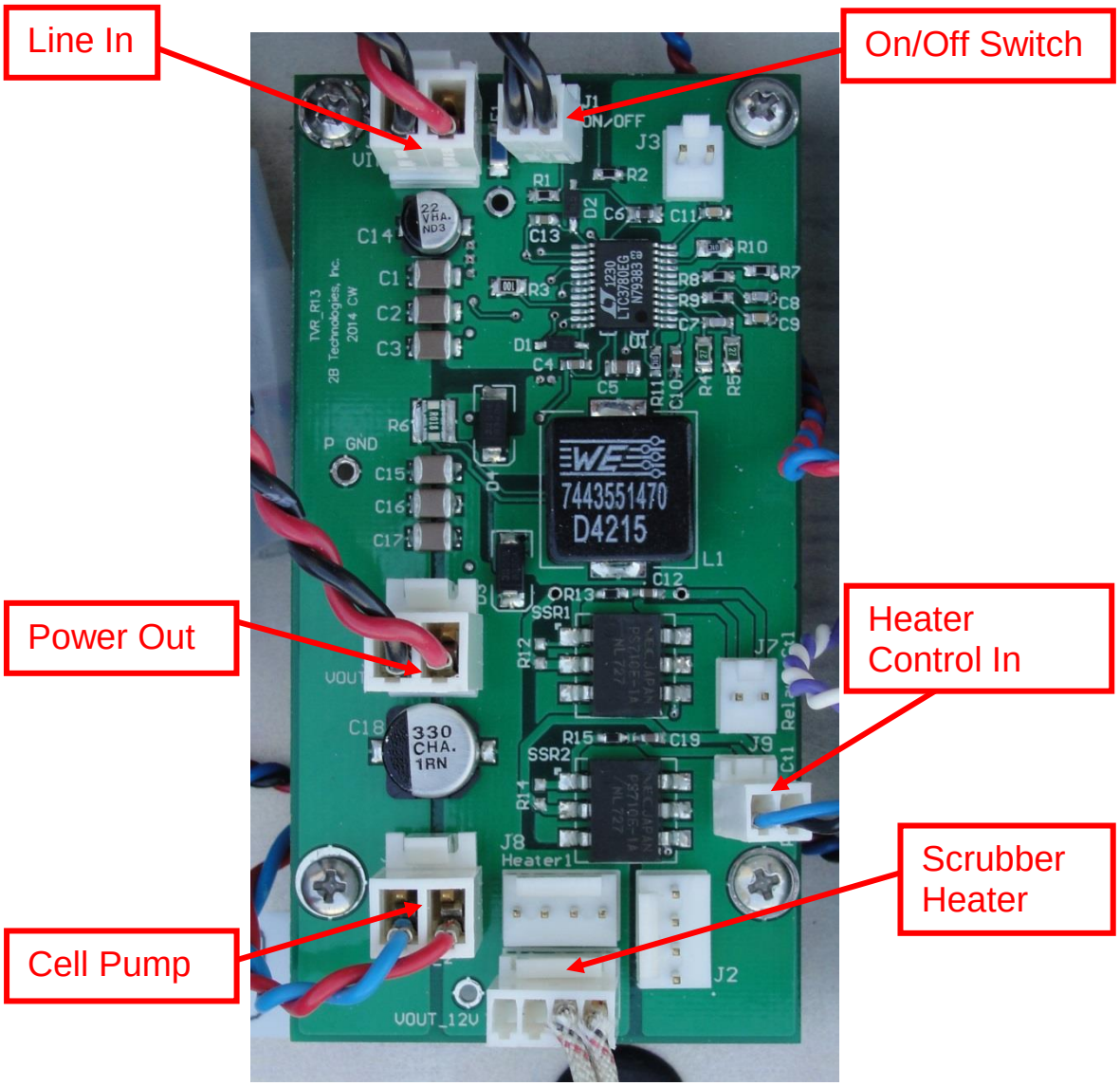


Figure 11.4. ***Power Board***

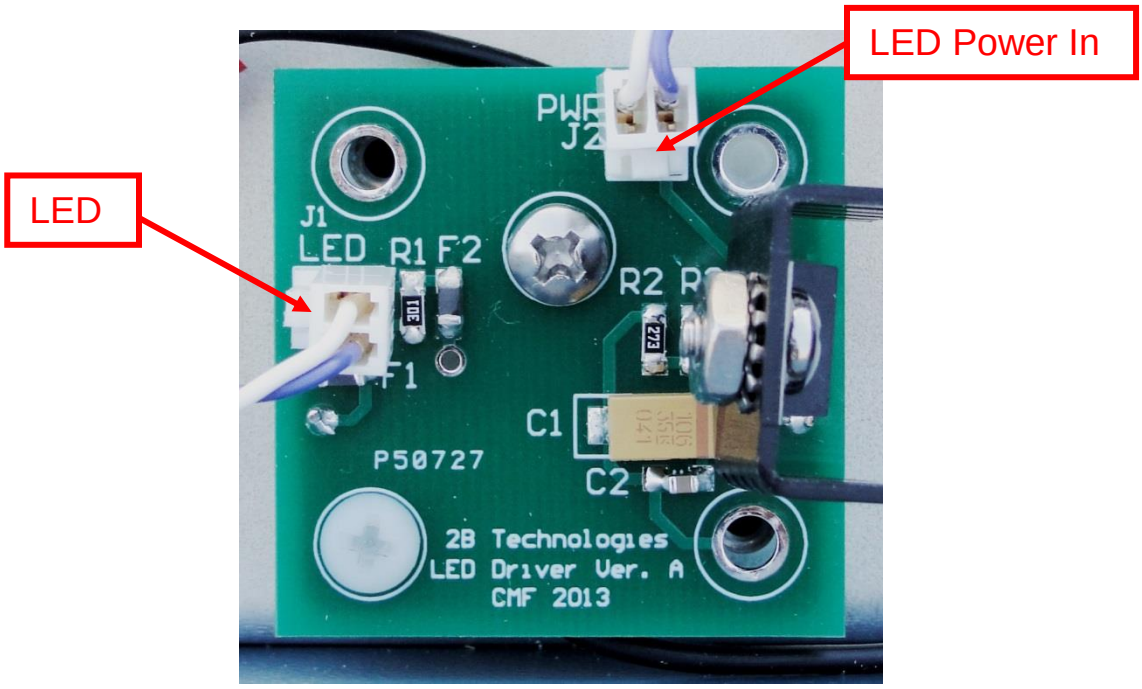


Figure 11.5. ***LED Power Board***

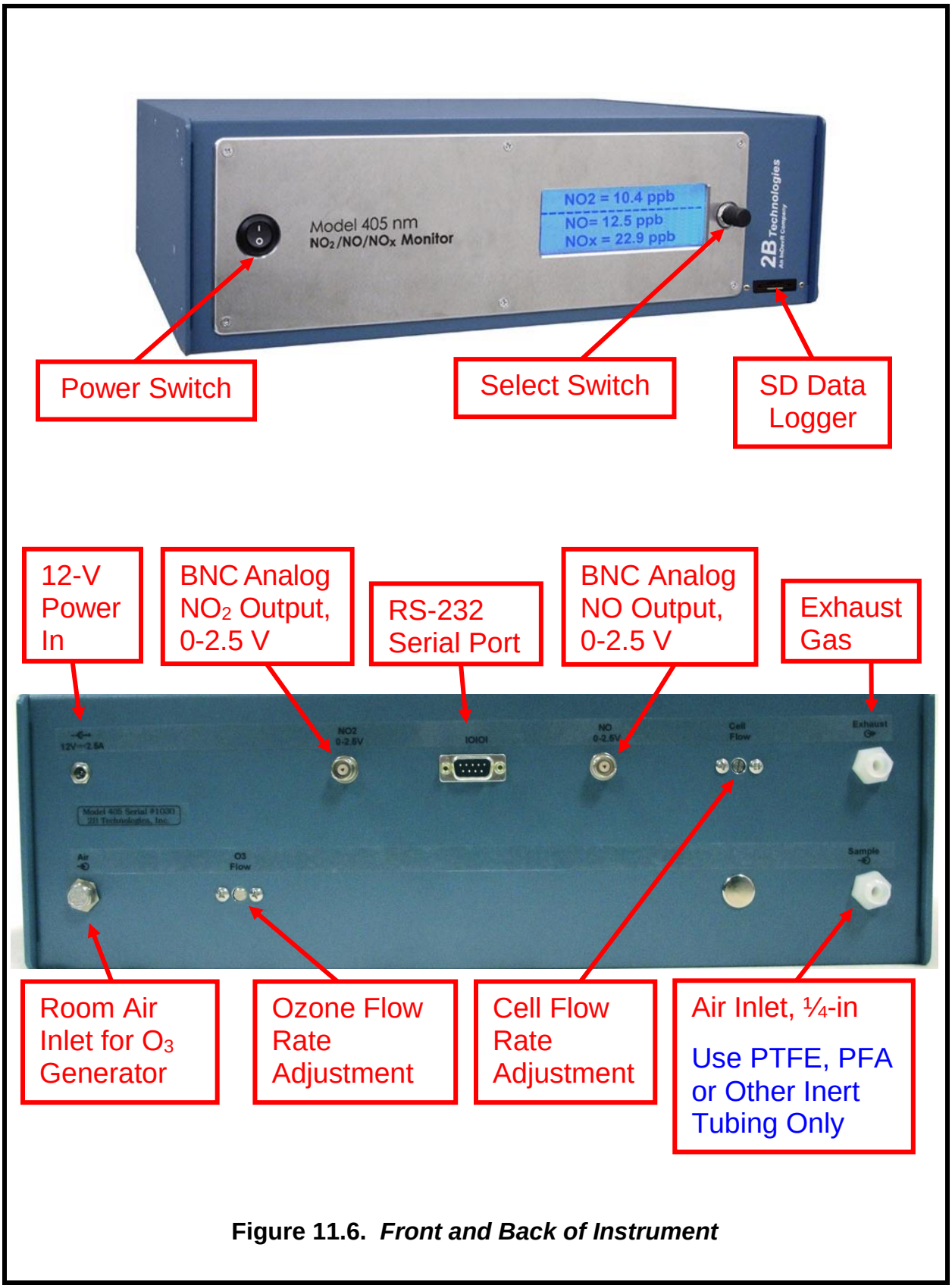


Figure 11.6. ***Front and Back of Instrument***

12. WIRING CONNECTIONS

[For DBNOx board: Counter clockwise from upper right corner of Figure 11.3.]

Description	Circuit Board	Connection	Lead Colors
Line In	Main (DBNOx)	J12	Red/Black
LED Power Out	Main (DBNOx)	J22	Purple/White
Relay Control Out (Heater)	Main (DBNOx)	J23	Blue/Black
O_3 Generator Power	Main (DBNOx)	J21	Red/Blue
Pressure Regulator	Main (DBNOx)	J20	Black/Black
SD Data Logger	Main (DBNOx)	J35	Red/Yellow/Brown/Black
Serial RS-232	Main (DBNOx)	J26	Yellow/Brown/Black
NO Analog Output	Main (DBNOx)	J11	White/Black
Ozone Valve	Main (DBNOx)	J8	Black/Black
NO_2 Scrubber Valve	Main (DBNOx)	J19	Yellow/Black
Ozone On/Off Valve	Main (DBNOx)	J18	Black/Black
Cell Flow	Main (DBNOx)	J32	Red/Blue/Black
Ozone Flow	Main (DBNOx)	J9	Red/Blue or Green/Black
O_3 Generator Photodiode	Main (DBNOx)	J4	Red/Blue/Black/Green
LCD	Main (DBNOx)	J10	Rainbow Ribbon
Cell Temperature	Main (DBNOx)	J6	Red/Orange/Green
Scrubber Temperature	Main (DBNOx)	J38	Red/Orange/Green
Sample Photodiode	Main (DBNOx)	J29	Red/Blue/Black/Green
Select Switch	Main (DBNOx)	J5	Green/Purple/Yellow/Black
Power Jumper	Main (DBNOx)	J1	Black/Black
NO_2 Analog Output	Main (DBNOx)	J7	White/Black
On/Off Switch	Power	J1	Black/Black
Line In	Power	J4	Red/Black
Power Out	Power	J5	Red/Black
Sample Pump	Power	J6	Red/Blue
Relay Control In (Heater)	Power	J9	Blue/Black
Heater	Power	J10	White/White
LED	LED Driver	J1	Purple/White
Power In	LED Driver	J2	Purple/White

13. SPARE PARTS

The following list includes those parts of the Model 405 nm NO_2/NO/NO_x Monitor that are user serviceable.

Please see the 2B Technologies website for a full and updated list of parts and pricing for the Model 405 nm: https://twobtech.com/parts-online.html

Part Number	Description
NOXPUMP405	Sample pump
NOXVLV405	NOx solenoid valve (the Model 405 uses 3 of these)
OZVLV405	Ozone solenoid valve (the Model 405 uses 2 of these)
NOXDSP405	4-line LCD display and cable
LEDASSEMBLY405	LED assembly
PDASSEMBLY405	Photodiode assembly and cable
NOXBRD405	DBNOx printed circuit board
SCRBNO2INT405	NO_2 scrubber for ozone generator inlet
SCRBEXHST405	Exhaust scrubbers (two in series, O_3 and NO_2)
DEW	DewLine™ (Nafion tubing)
SERCABL	Serial port cable, straight-through, female-to-female (to computer)
CIGADAP	12 V DC cigarette lighter adapter
SDCARD	SD card (thin profile recommended for the Model 405 Monitor)
SDREADER	SD card reader
TEFTYG25	Teflon-lined Tygon® tubing (25 ft)
TEFTYG05	Teflon-lined Tygon® tubing (5 ft)
SILTUB05	Silicone tubing (5 ft)

14. SERVICE LOG

2B Technologies Model 405 nm $NO_2/NO/NO_x$ Monitor Serial No._____ Purchase date:_____

Date	Calibrated	Cleaned	New NO_2 Scrubber	New Pump	New LED	Other

Date	Calibrated	Cleaned	New NO_2 Scrubber	New Pump	New LED	Other

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 https://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 a 2B Technologies Monitor

1. Select the device you are connecting to from Settings: Select Device...
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 Monitor's settings in the "Cfg / I/O" menu and match the software with the monitor's setting. Note that for the USB port of a Monitor, the baud rate must match the baud rate of the 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, for example, you will see a data point every 2 seconds. Averaging frequencies can be set to different values 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 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.
- 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 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 Commands

The menu commands are the same as given elsewhere in this manual.