$NO_2/NO/O_3$ Calibration Source™

OPERATION MANUAL

Model 714

Technical Support:
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Contents

The Model 714 is described in a paper we published in *Atmospheric Measurement Techniques.* It is linked below.

Portable calibrator for NO based on the photolysis of N_2O and a combined NO_2/NO/O_3 source for field calibrations of air pollution monitors, *Atmospheric Measurement Techniques* (2020), **13**, 1001-1018.

IDENTIFICATION RECORDS

Record the following information for future reference:

Unit serial number: ____

Warranty start date: ____
(date of receipt)

PRINTING HISTORY

This manual describes the theory, operation, maintenance, and troubleshooting procedures for the Model 714 NO_2/NO/O_3 Calibration Source™. The Model 714 is a portable instrument that can provide calibrated mixing ratios of NO_2, NO, or O_3 in air, for use in the calibration of gas analyzers and for other applications where a precise and accurate supply of one or more of these species is required. New editions of this manual are complete revisions that reflect updates to the instrument itself, as well as clarifications, additions and other modifications of the text.

Revision A-1 (serial no. 1006 and above)..December 2018

Revision A-2 (serial no. 1006 and above)..December 2018

Corrected number of sequences to 99 in Section 2 Specifications table; updated schematic in Section 1; other minor edits.

Revision A-3 (serial no. 1006 and above).. March 2019

Updated cartridge lifetimes for the Portable N_2O Source. New photos for Figures 7.1 and 7.2 to reflect small plumbing and construction changes.

Revision A-4 (serial no. 1006 and above)..May 2019

Updated pictures showing the dryer; updated Specifications table; augmented instructions about o-rings in the Portable N_2O Source; augmented instructions about calibrating and operating using the external overflow scrubber; new figure and notes about the new Admin submenu on the Settings View screen in Section 4.4.

Revision A-5 (serial no. 1013 and above)... July 2019

Updated flow rate specifications in Section 2 table, Section 1 schematic, and text. Change to the overflow scrubber and associated pictures. Updated the calibration instructions in Section 7.3.

Revision B-1 (serial no. 1019 and above)... August 2019

Software revision to remove correction for NO_2 made in side reactions (Sections 1.1.3, 4.1.5). Plumbing changes near flow meter (Fig. 9-2). Addition of ferrite beads near the printed circuit board (Fig 9-1).

Revision C-1 (serial no. 1026 and above) ....May 2020

Addition of Ethernet and remote operation capabilities. Extensive software revision to improve performance, functionality, and appearance. New dilution flowmeter and associated updates to Figures 9-1, 9-2, and 9-3.

Revision C-2 (serial no. 1026 and above) ....September 2020

Additions to Sections 1.1 and 1.2 noting the presence of N_2O in the NO and NO_2 output of the Model 714.

Revision D-1 (serial no. 1040 and above) ....June 2022

Update to several pictures in Section 9, in several places in Section 3, and elsewhere to reflect new USB hub, new SS bulkheads, and other instrument modifications. New capability in settings menu for the humidity offset. New Section 4.4.6 regarding this setting and related new information in Section 8.2 and the Troubleshooting table in Section 8.5. Mentioned and provided links to our published paper and patent in Section 1.1.

Revision D-2 (serial no. 1040 and above) ....December 2023

Updated hyperlinks.

TRADEMARKS & PATENTS

2B Technologies™, 2B Tech™, 2B™, $NO_2/NO/O_3$ Calibration Source™, and $NO_2/NO/O_3$ Cal Source™ are trademarks of 2B Technologies. Aspects of the $NO_2/NO/O_3$ Calibration Source™ are covered by a patent: P.C. Andersen, C.J. Williford, and J.W. Birks, "Method to Produce a Calibration, Reagent or Therapeutic Gas by Exposing a Precursor Gas to Ultraviolet Light," U.S. Patent Number 10,207,927, issued 19 February 2019.

CONFIDENTIALITY

The information contained in this manual may be confidential and proprietary and is the property of 2B Technologies. Information disclosed herein shall not be used to manufacture, construct, or otherwise reproduce the goods disclosed herein. The information disclosed herein shall not be disclosed to others or made public in any manner without the expressed written consent of 2B Technologies.

WARRANTY STATEMENT

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

Warranty Periods

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

Warranty Service

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

https://2btech.io/support/

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

You may also contact us by email at techsupport@2btech.io or by phone at +1(303)273-0559. In either case, a web ticket will be created, and future communications with you will be through though that ticket.

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

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 the Model 714 NO_2/NO/O_3 Calibration Source operation manual. Usage of maintenance materials purchased from suppliers other than 2B Technologies will void this warranty.

Limitation of Remedies and Liability

The remedies provided herein are the Customer's sole and exclusive remedies. In no event shall 2B Technologies be liable for direct, indirect, special, incidental or consequential damages (including loss of profits) whether based on contract, tort or any other legal theory. The Model 714 NO_2/NO/O_3 Calibration Source user manual is believed to be accurate at the time of publication and no responsibility is taken for any errors that may be present. In no event shall 2B Technologies be liable for incidental or consequential damages in connection with or arising from the use of the Model 714 NO_2/NO/O_3 Calibration Source user manual and its accompanying related materials. Warranty is valid only for the country designated on the 2B Technologies quote or invoice.

SAFETY WARNINGS

Toxic Gases O_3, NO, NO_2: The Model 714 NO_2/NO/O_3 Calibration Source is designed specifically to produce calibrated concentrations of NO_2, NO, or O_3. NO_2, NO, and O_3 are toxic gases and should be handled with caution. The same kind of care should be taken in handling the output of the NO_2/NO/O_3 Calibration Source as for any other toxic gas that, for example, may come from a compressed gas cylinder. Under normal operating conditions, the instrument will produce NO_2, NO, and O_3 in air at concentrations as high as 1 to ppm (for NO) and 0.5 ppm (for NO_2 and O_3). The main danger is from inhalation of such high concentrations of these gases, especially NO_2 and O_3. Thus, when calibrating gas analyzers using an overflow tee, one should know in advance how the excess NO_2, NO, and O_3 gases and the gases exiting the analyzer are to be handled. Attach a NO_2/NO/O_3 scrubber on the overflow tee, as well as on the outlet of the analyzer you are calibrating. 2B Technologies provides high conductance NO_2/NO/O_3 scrubbers. Alternatively, one can perform the calibration inside a chemical hood. Note that the instrument calibration is sensitive to the restrictions on the overflow tee, so operation and calibration should both use the same configuration for the overflow attachments. The factory calibration is done with the external overflow scrubber in place.

The Safety Data Sheets (SDS) for NO, NO_2, and O_3 may be downloaded below:

NO_2: https://www.airgas.com/msds/001041.pdf
NO: https://www.airgas.com/msds/001039.pdf
O_3: https://ozonesolutions.com/blog/material-safety-data-sheet-for-ozone/

N_2O Cartridge and Regulator Warnings: Nitrous oxide (N_2O) is used in the generation of NO and NO_2 in the Model 714 NO_2/NO/O_3 Calibration Source. Using the Model 714's Portable N_2O Source, the nitrous oxide is supplied by a cartridge containing liquid N_2O having a vapor pressure inside the cartridge of 850 PSI at 20°C. These cartridges are the same or similar to ones sold as a consumer product for producing whipped cream. Nitrous oxide or "laughing gas" is also used as a general anesthetic at concentrations up to 50% and is thus well tolerated by humans. There are no known toxicological effects of N_2O other than asphyxiation at extremely highly concentrations due to exclusion of oxygen. N_2O is not itself combustible, but it strongly supports combustion of organic materials and reducing agents. Contact with liquid N_2O can cause frost bite due to cooling as the liquid rapidly evaporates. The Safety Data Sheet (SDS) for N_2O is located at https://www.airgas.com/msds/001042.pdf.

- Do not exceed the minimum or maximum temperature listed on the N_2O cartridges.
- Store N_2O cartridges out of the reach of children.
- Do not use N_2O cartridges for any purposes not described in this manual.
- Never use excessive force to remove or install N_2O cartridges. Contact 2B Tech if you are having trouble installing or removing cartridges.
- Whenever there is a pressurized N_2O cartridge in the regulator assembly, keep the instrument level and do not invert the N_2O cartridge.
- Do not make any modifications or repairs to the pressure regulator assembly yourself.
- Never use the pressure regulator assembly if dropped or damaged (e.g., cracked or dented). In that case, return it to 2B Tech for a safety inspection.

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. INTRODUCTION

The Model 714 NO_2/NO/O_3 Calibration Source™ is a portable source that can provide calibrated mixing ratios of nitrogen dioxide (NO_2), nitric oxide (NO), and ozone (O_3). The Model 714 may be used to calibrate any NO_2, NO, and/or O_3 monitor, or to supply a calibrated source of one or more of these gases for experiments such as exposure studies. Major features of the Model 714 are:

- The instrument scrubs NO_2, NO, and O_3 from ambient air and produces either:
  - > zero air; or
  - > air having a calibrated mixing ratio of either:
    - **NO_2** in the range of 0 to 500 parts per billion by volume (ppbv or ppb, hereafter designated as ppb);
    - **NO** in the range of 0 to 1000 ppb; or
    - **O_3** in the range 0-500 ppb.

  The desired analyte mixing ratio is chosen from the touch screen display. As described below, the gas stream containing calibrated NO_2 will also have NO present. Also, the gas stream containing calibrated NO will have a small amount of NO_2 present. This is discussed later.
- The instrument can be programmed to output up to 15 different sequences, each with up to 15 individual NO_2, NO, or O_3 step concentrations over a chosen time interval, for uses such as calibrating gas analyzers.
- The total output volumetric flow rate is typically 2.5 to 2.7 L/min.
- The NO_2, NO, and O_3 mixing ratios are controlled so as to be independent of ambient temperature, pressure, and humidity.
- Remote operation can be accomplished via a Modbus interface and software application package available for free download from the 2B Tech website.

The Model 714 NO_2/NO/O_3 Calibration Source output may be used to calibrate any gas analyzer (provided that the analyzer's sampling rate is less than the output flow rate of the Model 714, which is typically 2.5 to 2.7 L/min). No compressed gas cylinders are required, making the Model 714 a portable option for research and monitoring applications in the field. Another important advantage of the Model 714 is that it provides a known concentration of NO_2, NO, and O_3 in analyte-scrubbed ambient air containing the same level of humidity as the air sample to be measured.

The Model 714 is factory calibrated against a NIST-traceable O_3 standard, with the mixing ratios of NO and NO_2 determined by an internal gas-phase titration of NO by O_3. However, the calibration parameters may be changed in the menu in case the user wants to recalibrate the instrument against separately maintained standards; i.e., the NO_2/NO/O_3 Cal Source can be used as a transfer standard for NO_2, NO, or O_3. The Model 714 may be used, for example, for maintaining the calibration of a large number of NO_x and O_3 monitors in the field relative to a highly stable laboratory instrument. In this case, a huge advantage of the Model 714 is its portability.

Besides its use as a calibrator of gas analyzers, the Model 714 may be used as a calibrated source of NO_2, NO, or O_3 for studies of the effects of these chemical species on materials (rubber, plastics, paints, etc.) and on biological organisms such as plants.

1.1 Theory of Operation

The Model 714 NO_2/NO/O_3 Calibration Source combines the 2B Technologies Model 306 Ozone Calibration Source™ and the Model 408 Nitric Oxide Source™ to produce calibrated sources of O_3, NO and NO_2. Thus, the Model 714 makes use of two low-pressure mercury lamps, one to photolyze oxygen to produce O_3, and a second lamp to photolyze nitrous oxide (N_2O) to produce NO. Nitrogen dioxide is produced in the stoichiometric reaction of O_3 with excess NO to convert NO to NO_2. Please see below and also refer to our published paper in Atmospheric Measurement Techniques and our related patent.

1.1.1 Ozone Production by O_2 Photolysis

For the production of ozone, the vacuum UV emission lines of a low-pressure mercury lamp near 185 nm are absorbed by O_2 to produce oxygen atoms, and the oxygen atoms rapidly attach to O_2 via a collisionally stabilized reaction to form O_3. The well-known mechanism, which also is responsible for the presence of Earth's protective ozone layer, is as follows:

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

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

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

where $h\nu$ symbolizes a photon of light and M is any molecule (e.g., N_2, O_2, H_2O, Ar) that removes the energy released in reaction (2). Absorption of one photon of light by O_2 results in the formation of two O_3 molecules. The concentration of O_3 produced in a flowing stream of air depends on the intensity of the photolysis lamp, the concentration of oxygen (determined by pressure and temperature), and the residence time in the photolysis cell (determined by volumetric flow rate and cell volume). By holding these parameters constant, it is possible to produce a flow of air containing a constant concentration of O_3, and the concentration of O_3 produced can be varied most conveniently by varying the lamp intensity.

1.1.2 Nitric Oxide Production by N_2O Photolysis

For the production of NO, the vacuum UV emission lines of a low-pressure mercury lamp near 185 nm are absorbed by N_2O to produce electronically excited oxygen atoms, O ($^1D_2$). A large fraction (~59%) of these highly energetic oxygen atoms react with N_2O to form NO:

$$N_2O + h\nu \rightarrow N_2 + O(^1D_2) \qquad (4)$$

$$O(^1D_2) + N_2O \rightarrow 2\,NO \qquad (5)$$

$$\text{Net:}\ 2\,N_2O + h\nu \rightarrow N_2 + 2\,NO \qquad (6)$$

where the term hν represents a photon of light.

Reaction of $O(^1D_2)$ with N_2O also produces molecular oxygen and nitrogen as well via the reaction:

$$O(^1D_2) + N_2O \rightarrow N_2 + O_2 \quad (7)$$

which occurs in the remaining ~41% of collisions of $O(^1D_2)$ with N_2O. The O_2 produced in reaction (7) can react to a small extent with NO to make NO_2 via the very slow reaction:

$$O_2 + 2\,NO \rightarrow 2\,NO_2 \quad (8)$$

Therefore the NO produced by the Model 714 will have a small amount (~2%) of NO_2 present from reactions 7 and 8. A small amount of unreacted N_2O, <2.5%, will also be present in the NO produced by the Model 714.

The concentration of NO produced in a flowing stream of air depends on the intensity of the photolysis lamp, the concentration of N_2O (determined by pressure and temperature), the branching ratio for reactions 5 and 7, and the residence time in the photolysis cell (determined by volumetric flow rate and cell volume). By holding these parameters constant, it is possible to produce a flow of air containing a constant concentration of NO, and the concentration of NO produced can be varied most conveniently by varying the lamp intensity. The nitrous oxide can be supplied by a 16-g or 8-g disposable cartridge (e.g., Whip-It or other whipped cream charger) in the Model 714's Portable N_2O Source, thereby eliminating the need for a compressed gas cylinder.

1.1.3 NO_2 Production by Gas Phase Titration

Nitrogen dioxide is produced by reacting a known concentration of O_3 with a large excess of NO according to the reaction:

$$NO + O_3 \rightarrow NO_2 + O_2 \quad (9)$$

In order to avoid complications from secondary reactions (see reactions 10 and 11 discussed below in Section 1.2), nitric oxide is always generated in excess (by a minimum of a factor of 2) to completely consume all of the O_3. Reaction (9) is stoichiometric (one NO molecule destroyed and one NO_2 molecule formed for every O_3 molecule added), so the concentration of NO_2 produced is $[O_3]_o$, where the subscript "$_o$" indicates the initial concentration before reaction, and the remaining NO concentration is $[NO]_o - [O_3]_o$. This method of producing known amounts NO_2 equal to the amount of ozone added ($[O_3]_o$) has long been referred to as the "gas phase titration" (GPT) method – although technically it is a stoichiometric conversion rather than a titration. The calibrated NO_2 stream will therefore also contain the excess NO, as well as any unreacted N_2O as mentioned in Section 1.1.2 above.

1.2 Summary of Schematic Diagram

Figure 1-1 (next page) is a schematic diagram of the NO_2/NO/O_3 Calibration Source. The system is comprised of two separate photolysis chambers – one that produces NO from pure N_2O (reactions 4-6) and another that produces O_3 from oxygen in scrubbed ambient air (reactions 1-3). By powering the appropriate lamp, one can choose to produce only a calibrated amount of NO, only a calibrated amount of O_3, or one can power both lamps simultaneously to produce a calibrated amount of NO_2 (with attendant excess NO and unreacted N_2O as noted in Section 1.1.3 above).

Producing O_3 (lower left in diagram):

A flow of ambient air is directed through a particle filter, next through a NO_x/O_3 scrubber, then through a mass flow meter (Total Flow Meter), and into a cross which splits the air flow into (i) a small flow (~50 cc/min) that enters the ozone photolysis chamber, and (ii) a diluent stream of ~2.0 to 2.7 L/min. One side of the cross is connected to a pressure meter. The small flow of air passing through the ozone photolysis chamber is controlled by a voltage sensitive orifice (VSO) with feedback from the Ozone Flow Meter. A dryer reduces the humidity of the air stream and enables more precise control of ozone produced in the photolysis chamber. The photolysis chamber contains a low-pressure mercury lamp where absorption of atomic lines near 185 nm produces ozone according to reactions 1-3 above. The ozone concentration is controlled by pulse width modulation of the lamp intensity, as measured at the photodiode (PD). Pressure within the gas stream is measured but not controlled. Instead, the lamp intensity is varied to compensate for changes in pressure.

If only the ozone lamp is on, only the calibrated ozone stream is output from the Model 714 (i.e., no N_2O is flowing, and neither NO nor NO_2 is being produced by the Model 714).

Producing NO (upper left in diagram):

A mass flow controller (MFC) is used to control a ~40 cc/min flow of nitrous oxide from an N_2O cartridge or gas cylinder into the N_2O photolysis chamber to produce NO (reactions 4-6).

If only the N_2O lamp is on, only the calibrated NO stream is produced by the Model 714 (with a small amount of NO_2 and unreacted N_2O, as explained in Section 1.1.2).

Producing NO_2 (right side of diagram):

When both lamps are on, an excess of NO reacts with a known amount of O_3 to form NO_2 (reaction 9). The NO stream combines with the ozone stream in the Reaction Zone prior to dilution with the ~2.0 to 2.7 L/min of diluent air, thus assuring high concentrations that will react rapidly if both species are present. The firmware of the Model 714 assures that a sufficient NO excess (by a factor of 2 or greater) is present to cause the complete reaction of the known amount of O_3.

If both lamps are on, only the calibrated NO_2 stream is produced by the Model 714 (an excess of NO and a small amount of unreacted N_2O are also present in the output, as described in Section 1.1.3 above).

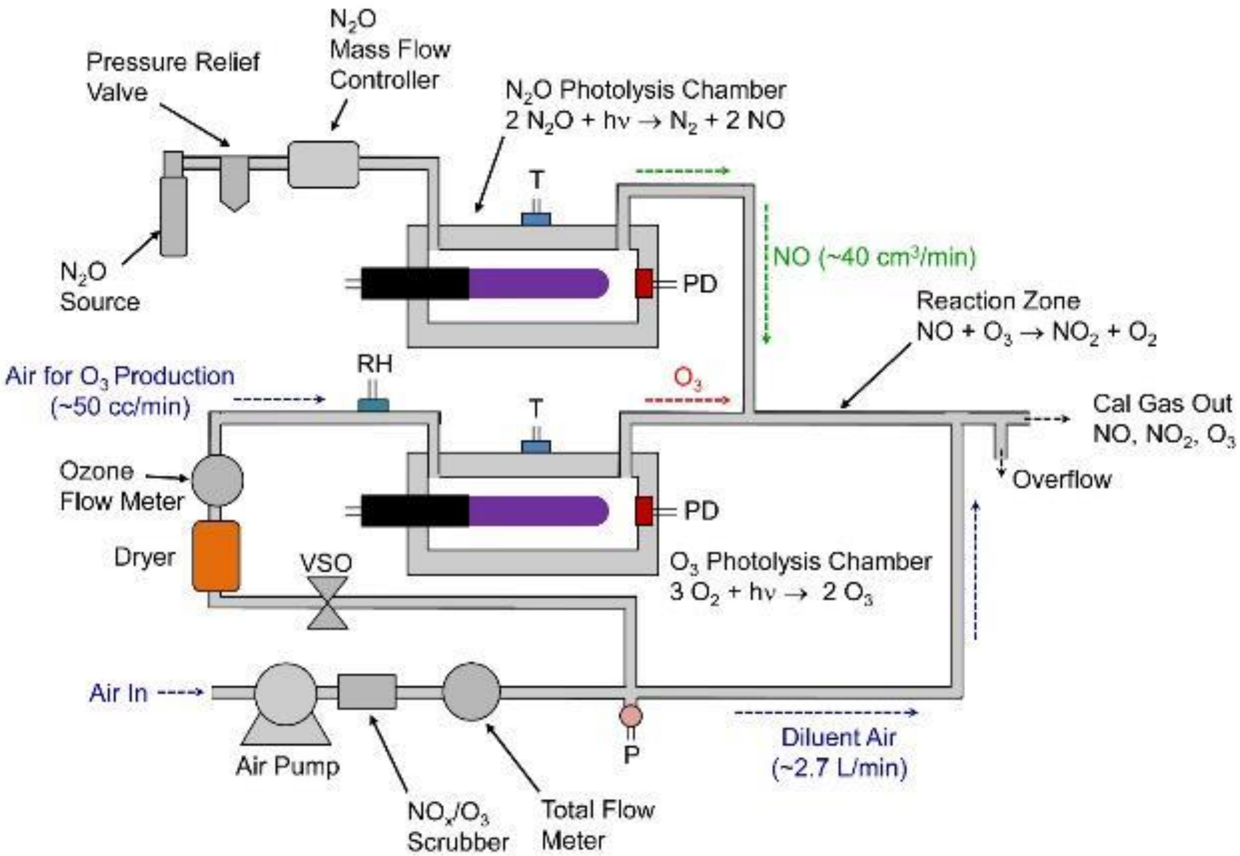


Figure 1-1. Schematic diagram of the Model 714 NO_2/NO/O_3 Calibration Source.

Temperature is measured in both photolysis cells and controlled to be 40°C in order to maintain a constant lamp output for a chosen duty cycle. Note that in the normal use of a GPT calibrator, NO is always used in excess (typically at least a factor of two higher initial concentration) instead of using ozone in excess. The reason for this is that in the presence of excess ozone, a small amount of NO_2 will react back with ozone to form N_2O_5 via the reaction sequence:

$$NO_2 + O_3 \rightarrow NO_3 + O_2 \qquad (10)$$

$$NO_3 + NO_2 + M \rightarrow N_2O_5 + M \qquad (11)$$

Thus under excess ozone conditions, the concentration of NO_2 produced will be less than the initial concentration of NO. The use of excess ozone is prevented in the firmware of the Model 714. If you have an application that requires using ozone in excess (e.g., if you need to prevent any NO from being present), please contact us at techsupport@2btech.io for assistance.

We published a journal article describing the Model 714: Portable calibrator for NO based on the photolysis of N_2O and a combined NO_2/NO/O_3 source for field calibrations of air pollution monitors, *Atmospheric Measurement Techniques* (2020), **13**, 1001-101.

2. *SPECIFICATIONS: MODEL 714 NO_2 / NO / O_3 CALIBRATION SOURCE*

Method of NO Production	UV photolysis of Nitrous Oxide (N_2O) at 185 nm
Method of O_3 Production	UV photolysis of Oxygen (O_2) at 185 nm
Method of NO_2 Production	Reaction of O_3 with excess NO (gas-phase titration, GPT)
NO_2 Concentration Range	0-500 parts per billion by volume (ppb)
O_3 Concentration Range	0-500 ppb
NO Concentration Range	0-1000 ppb
Output Flow Rate	~2.0 to 2.7 L/min volumetric (2.5-2.7 L/min typical)
Precision and Accuracy	Greater of 2.0 ppb or 2.0% of NO or O_3 concentration
Response Time for Change in Calibrant Gas Output Concentration	< 30 s to reach 95% of selected concentration
Input and Output	Touchscreen LCD Display
Dimensions	Rackmount: 17" w × 14.5" d × 5.5" h (43 × 37 × 14 cm)
Weight	16.6 lb (7.53 kg)
Power Requirements	120/240 V AC with 5-amp power pack, or 12V DC; Run, O_3 channel: 0.91-2.79 A at 12V, 10.9-33.5 watt Run, NO channel: 1.16-3.10 A at 12 V, 13.9-37.2 watt Warmup Max: 3.38 A at 12V, 40.6 watt
Programmable Calibrated Gas Output	Yes, up to 99 different repeatable sequences may be specified by the user for NO, NO_2 or O_3 output, with up to 15 steps for each sequence from 0 to 500 ppb for O_3 and NO_2 (1000 ppb for NO); stored in internal memory
Remote Operation Capability	Yes, Modbus, via Ethernet TCP/IP and 2B Tech software tool
Transportation and Temperature Storage Ranges	−20°C to 60°C

3. STARTUP OPERATION

Please read all the following information before attempting to install the Model 714 $NO_2/NO/O_3$ Calibration Source™.

For assistance, please call 2B Technologies at (303)273-0559 or email us at techsupport@2btech.io.

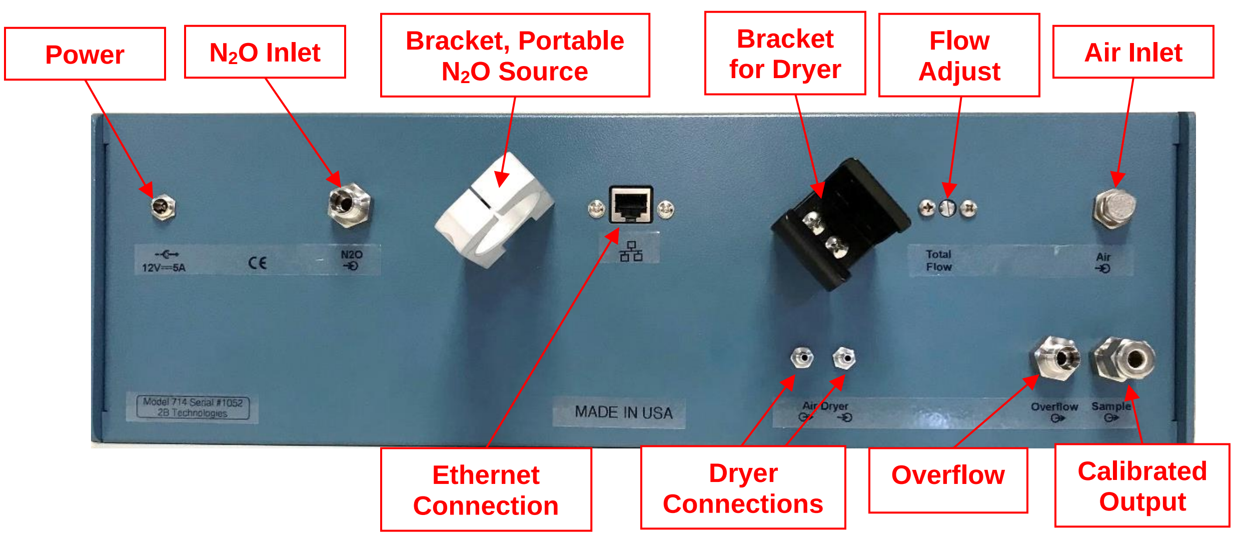
NOTE:
Save the shipping carton and packing materials that came with the Model 714 $NO_2/NO/O_3$ Calibration Source. If the instrument must be returned to the factory, pack it in the original carton. Any repairs as a result of damage incurred during shipping will be charged.

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 Setup and Startup of the $NO_2/NO/O_3$ Calibration Source

The Model 714 is shipped from the factory as shown below, with 2 brackets pre-installed on the back of the instrument:



The small amount of assembly and other procedures required for startup are described below.

3.2.1 Connect the Dryer

The Model 714 uses a dryer packed with silica gel to remove humidity from the small flow of air that is used to make O_3 in the O_3 photolysis chamber (see Section 1.2 and

Figure 1-1 discussed previously). Reducing the humidity enables more precise control of the ozone made in the photolysis chamber. This dryer is shipped with silica gel and tubing connections ready for installation on the back panel of the instrument.

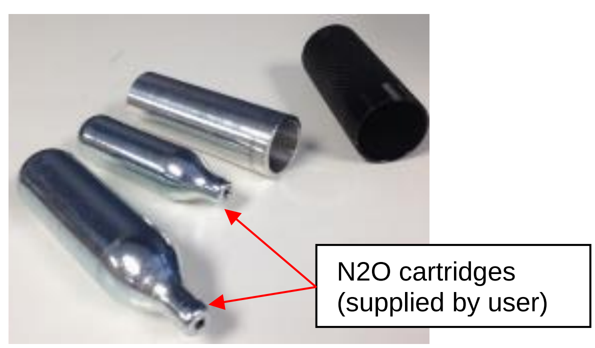
To connect the dryer, firmly press it into the black clamp on the back panel of the instrument. Note orientation in photo below. Connect tubing as shown by pressing onto the inlet and outlet nipples on the back of the instrument.

The silica gel shipped with the Model 714 has a moisture indicator (orange when dry, greenish when wet). As the silica gel adsorbs water, the color change indicates that the gel should be replaced or regenerated. The Model 714's calibrated ozone production requires that the dryer be in place and effectively removing humidity. See the Maintenance instructions in Section 8 of this manual for the simple procedure to use in regenerating the silica gel.

3.2.2 Connect a Source of N_2O

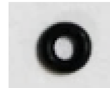
Portable N_2O Generation System (supplied by 2B Technologies)

The Model 714 $NO_2/NO/O_3$ Calibration Source uses nitrous oxide (N_2O) to make NO and NO_2. The instrument comes with a Portable N_2O Source, which is a small regulator and assembly for use with disposable N_2O cartridges. This enables portable operation of the Model 714 without the need for a compressed-gas cylinder of N_2O. The user must supply either an 8-gram or 16-gram commercially available N_2O cartridge for use with this system.

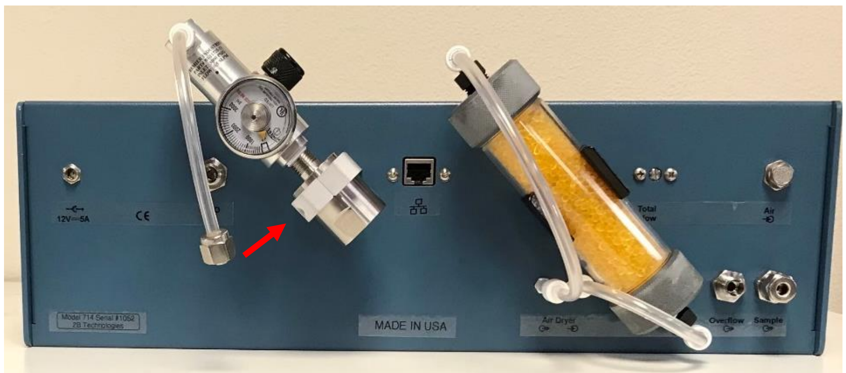


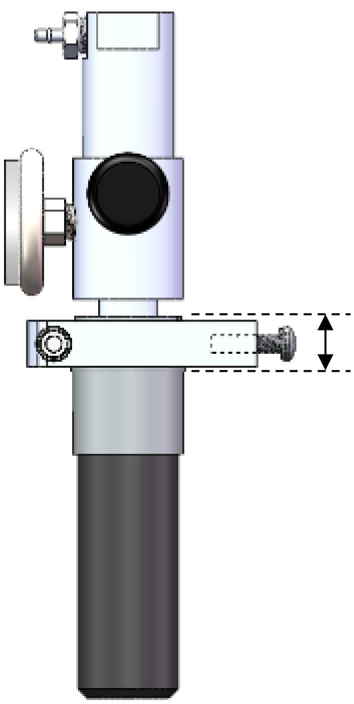
To install the regulator:

1. Make sure the o-ring that seals the N_2O cartridge to the regulator is in place.



2. Insert the N_2O regulator in the regulator bracket on the back of the Model 714 and tighten the screw (5/32" hex driver, see red arrow) to secure it as shown:





3. Attach Swagelok nut from tubing connected to regulator to bulkhead on back panel (see also photo on p. 10). Hand-tighten and then use a 9/16" wrench to tighten an additional ¼ turn.

4. Rotate valve on regulator clockwise to close.

5. The black cartridge holder and your N_2O cartridge will be installed later when you are ready to generate NO or NO_2. However, it is recommended that you connect the cartridge holder when it is empty/not in use to prevent internal parts from getting dirty or damaged. Rotate the holder to screw it on/off the regulator.

<u>Gas Cylinder of N_2O</u>

As an alternative to the regulator supplied by 2B Technologies for use with small, disposable N_2O cartridges, the user may elect to use a compressed gas cylinder of pure N_2O (<u>99.5% purity or greater</u>). In this case, the user should attach their tank and associated regulator to the N_2O inlet on the back of the instrument. The N_2O should be supplied at a pressure no greater than 25 PSI, to avoid damage to the Model 714. (If the pressure should exceed 50 psi, an overpressure release inside the 714 will open so the tubing will not burst.)

This method of supplying the N_2O could be more practical for applications that require extended and/or remote operation of the Model 714.

3.2.3 Connect Overflow Scrubber

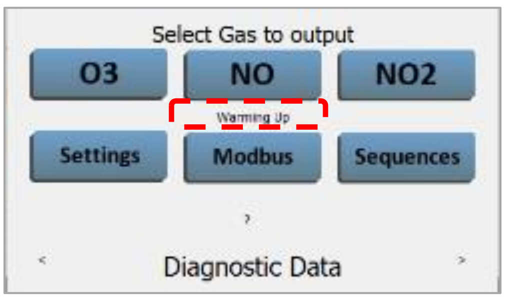
The Model 714 has a built-in overflow tee, to vent the excess flow of the Model 714 output (typically 2.5-2.7 L/min) and avoid over pressurizing your system or the instrument you are calibrating. An external scrubber must be attached to the overflow bulkhead, to avoid exposure to excess O_3, NO, NO_2, and N_2O that may be present in the overflow stream. An overflow scrubber is provided with your instrument upon purchase. <u>The instrument calibration has been performed with this scrubber in place, and therefore this scrubber must be in place when the instrument is in use</u>.

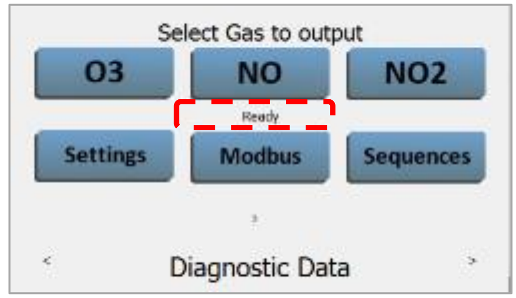
3.2.4 Power Connection

To operate the Model 714 NO_2/NO/O_3 Calibration Source, connect it (upper left of back panel) to an external power source and turn the instrument on by flipping the front panel switch. The instrument requires a 12 V DC source which can be supplied by: 1) the 110-220 V AC power adapter (5 amp or higher; one provided with your instrument), 2) a cigarette lighter adapter plugged into a 12 V DC source such as found in an automobile or many light aircraft, or 3) a 12 V battery. The source must be very close to 12 V because of the power requirements of the instrument's pump. When using a battery, be certain to attach the positive (red) and negative (black) wires correctly. A slow-blow fuse and diode are installed on the circuit board in case of an electrical short or incorrect battery attachment. If activated, the fuse will reset itself after a few minutes.

3.2.5 Warmup

Once turned on, the instrument will briefly display a startup script and then a 2B Technologies image. After about a minute, the instrument will display the main screen shown below on the left:





The "Status" will say "Warming Up" until the temperatures of the two photolysis chambers reach the set points of 40°C. Warmup will take approximately 15 minutes. When warmup is complete, the Status will say "Ready."

3.2.6 Check Dilution Flow Rate and Other System Parameters

Scroll through the system parameters at the bottom of the screen using the arrows

< Diagnostic Data >

to find the Dilution Flow reading. If it appears in red, it is out of the acceptable range of ~2.0 to 2.7 L/min. Use the adjustment screw on the back of the instrument to increase or decrease the flow to bring it within the acceptable range (2.5 to 2.7 L/min typical):

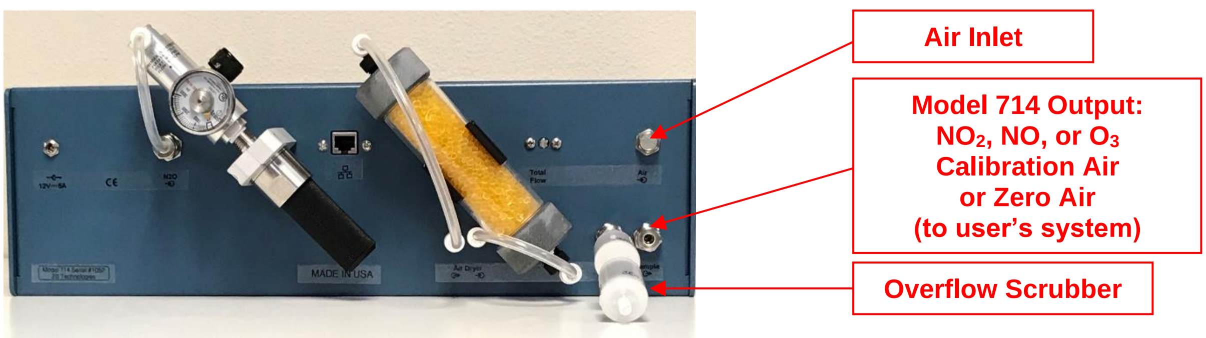
Other system parameters can be viewed by scrolling through using the arrows. Use the "**?**" symbol located above the parameter to find explanatory information about each of the parameters as you go through.

With the instrument warmed up but not outputting calibrated O_3, NO_2, or NO, the readings should be:

O3 Voltage: 0 Volts
NO Voltage: 0 Volts
O3 Flow: ~50 cc/min *(set at factory)*
N2O Flow: 0 cc/min
Dilution Flow: ~2.0 to 2.7 L/min *(2.5-2.7 L/min typical; user-adjustable as described above)*
O3 Temperature: ~40°C *(set at factory)*
NO Temperature: ~40°C *(set at factory)*
O3 Lamp Duty Cycle: 0%
NO Lamp Duty Cycle: 0%
O3 Heater Duty: [cycles as required; will often read 0% but cycle up to ~70% every few minutes]
NO Heater Duty: [cycles as required; will often read 0% but cycle up to ~100% every few minutes]
O3 Flow Duty: [varies as required to maintain~50 cc/min flow; will often read ~30%]
N2O Flow Duty: 0%
System Temperature: [ambient temperature, °C]
System Humidity: [humidity of the O_3 flow, %]
Date/Time: [military 24-hour time format, European date format dd/mm/yy]

3.2.7 Connect Model 714 to Your System

The user's NO_2, NO, or O_3 monitor, or other experimental system, can be attached to the outlet of the Model 714 to receive air containing calibrated amounts of NO_2, NO, or O_3.



Attach a tubing connection from the outlet of the Model 714 to the inlet of the instrument you are calibrating or to your system. See Section 5 or 6 for tubing recommendations. A length of tubing is supplied with your instrument upon purchase.

Note: The Model 714 has a built-in overflow tee to vent the excess flow of the Model 714 output (typically 2.5-2.7 L/min) and avoid over pressurizing your system or the instrument you are calibrating. An external scrubber should be attached to the overflow bulkhead as shown above, to avoid exposure to excess O_3, NO, NO_2, and N_2O that may be present in the overflow stream. See Section 3.2.3 above. The calibration at the factory is done with this external overflow scrubber in place and the calibration is valid only if the instrument is operated with the scrubber.

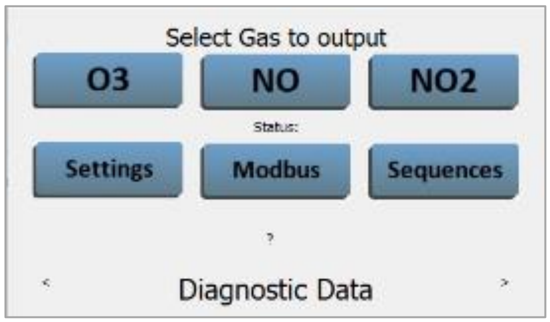
4. OPERATION

Please note the safety warnings on pages viii-ix of this manual and as shown within the sections below.

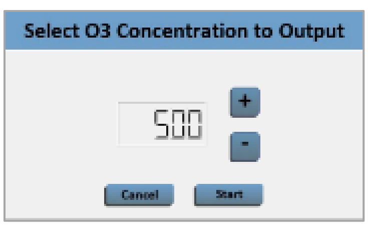
4.1 Outputting a Gas Concentration

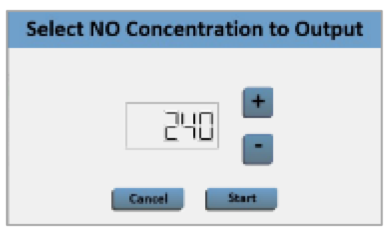
4.1.1 Overview

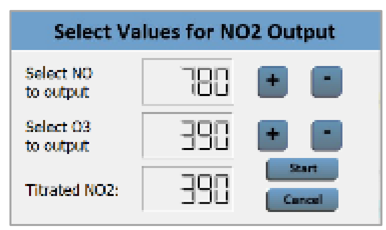
The main screen is shown below:



The bottom of the screen displays different system parameters. Calibrated gases are output by selecting either “O3”, “NO”, or “NO2” to obtain the screens shown below. Next, use the ‘**+**’ and ‘**−**‘ buttons on these screens to increase or decrease the concentration (in increments of 5 or 10 ppb, depending on the gas).





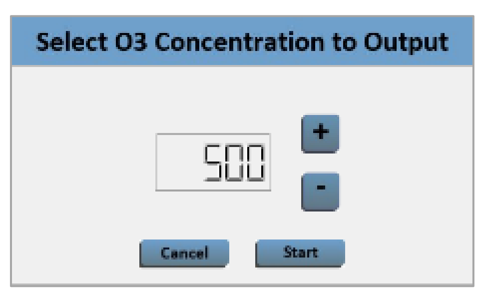


In general, the user will press “Start” to begin outputting the chosen gas at the concentration selected. Press cancel to go back to the main window.

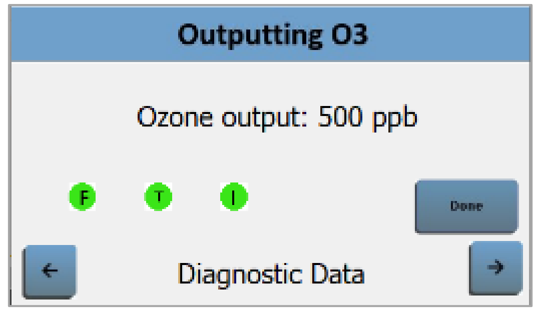
Additional specific information for outputting each gas is given below.

4.1.2 Outputting Ozone (O_3)

- Select “O3” from the main screen to obtain the following selection screen.
- Enter the desired output concentration in ppb.
- **Note: Ozone levels above 70 ppb are unsafe to breathe. Be sure the output of the Model 714 as well as the output of your system are properly vented to avoid unsafe exposure to ozone.**



- Select "Start" to begin outputting the calibrated ozone stream. The following screen will appear:



- Three indicators are shown: Flow (F), Temperature (T), and Lamp Intensity (I). Each parameter is shown in green if it is within the acceptable range, yellow if in transition, and red if out of range.
- The calibrated output is valid if all three indicators are green. The adjustment period for "all green" may take a minute or two. For outputting very low amounts of O_3 (e.g., below 30 ppb), it may be necessary to reduce the PID gain in order to have a stable Lamp Intensity reading; see Section 4.4.1.
- The system parameters should now show a nonzero "O3 Voltage." The value will depend on the chosen output concentration. "O3 Lamp Duty" will also be nonzero. The "O3 Flow Duty" and "O3 Heater Duty" will continue to cycle, as the ozone heater temperature and the flow rate of air into the ozone photolysis chamber are always maintained even if ozone is not being produced.
- Press the "Done" button when finished. The main window will be displayed, the ozone photolytic lamp will power down, and the unit will output zero gas.

4.1.3 Providing an N_2O Source for the Model 714 (for output of NO or NO_2)

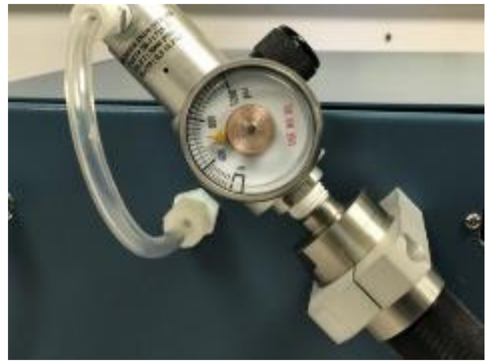
In the Model 714, nitric oxide (NO) is supplied by the photolysis of nitrous oxide (N_2O), as described in Section 1.1.2 of this manual, and NO_2 is supplied by reaction of ozone with NO. Therefore, to output NO or NO_2, the source of N_2O must be enabled.

<u>If using the Portable N_2O Source supplied with the Model 714, follow these steps:</u>

1. Install the N_2O regulator on the back of the instrument as described in Section 3.2.2, making sure that the o-ring that seals the cartridge to the regulator is in place.
2. Insert 16-gram or 8-gram "Whippit" style N_2O cartridge in the black cup provided with the regulator (if you are using an 8-gram cartridge, place the silver adapter inside the black cup). The narrow neck of the cartridge should point upward.

3. Attach the black cup to the N_2O regulator on the back of the Model 714. Rotate the black cup clockwise firmly using force until it cannot rotate. This pierces the cartridge.

CAUTION: Be sure that the pressure relief hole, located just above black cartridge holder on the regulator, is not pointed at you when installing a new N_2O cartridge. When the N_2O cartridge is first pierced, you may feel a burst of pressure and hear loud hissing until it is completely sealed into regulator! This is completely normal.



The regulator pressure should read > 400 PSI.

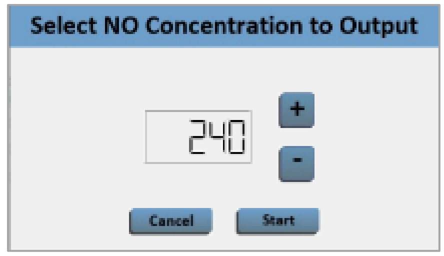
4. When ready to generate NO, rotate the valve knob on the regulator counterclockwise until it stops. This will open the N_2O to the mass flow controller (MFC) in the Model 714. The pressure from the regulator to the MFC is < 25 PSI. If the pressure should exceed 50 psi, an overpressure release inside the 714 will open so the tubing will not burst. The pressure regulator is designed to not exceed 25 psi.

5. The 8-gram cartridge will last for about 2 hours; the 16-gram cartridge will last for about 4 hours. When not outputting NO or NO_2, the Model 714's mass flow controller closes the flow off from the N_2O source. However, it is good practice to close the regulator knob when a flow of N_2O is not required. Do not over-tighten the on/off valve knob in either the open or closed position, because this will damage the valve.

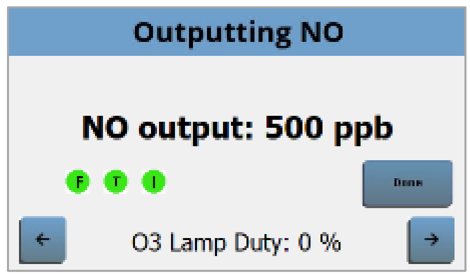
Warning: If an N_2O cartridge is punctured outside the cracker/regulator, liquid N_2O can escape, and if it evaporates on skin it will cause frost bite. The cartridge will also act as a "rocket" if the seal is punctured outside the cracker/regulator. However, the N_2O cartridges are commonly used consumer products available commercially and are safe to handle if the above procedure is followed. See p. viii for more safety tips.

If using a tank of >99.5% pure N_2O instead of the above system: Attach it to the N_2O Source Inlet on the back of the Model 714 (see picture on p. 7). The regulator should be set for an output pressure of < 25 PSI. Take care to make this setting, as higher pressures could damage the Model 714. (If the pressure should exceed 50 psi, an overpressure release inside the 714 will open so the tubing will not burst.)

4.1.4 Outputting Nitric Oxide (NO)



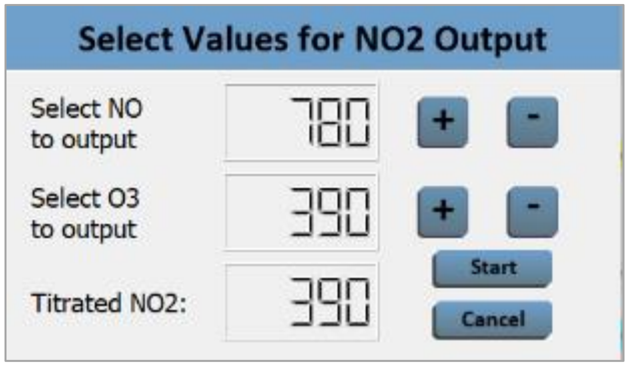
- Activate your source of N_2O by opening the regulator, as described above in Section 4.1.3.
- Select "NO" from the main screen to obtain the following selection screen. ⟶
- Enter the desired output concentration in ppb.
- **Note: The NIOSH exposure limit for nitric oxide is 25 ppm (8-hour time-weighted average). The Model 714 produces NO/Air in the range of 0 to 1 ppm. However, an instrument failure could result in small volumes of air containing NO at higher concentrations. Take proper precautions to vent the output of the Model 714 and the exhaust of your analyzer or system, so as to minimize human exposure.**



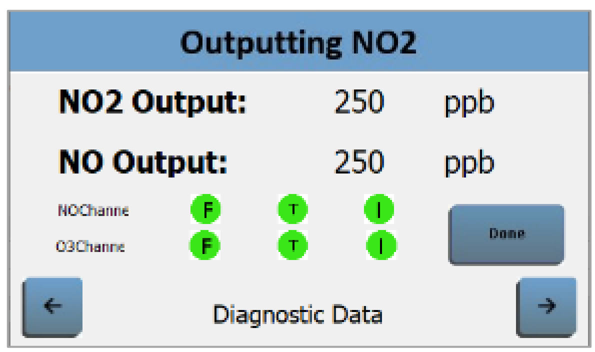
- Select "Start" to begin outputting the calibrated NO stream.
- The following screen will appear. ⟶
- Three indicators are shown: Flow (F), Temperature (T), and Lamp Intensity (I). Each parameter is shown in green if it is within the acceptable range, yellow if in transition, and red if out of range.
- The calibrated output is valid if all three indicators are green. The adjustment period for "all green" may take a minute or two.
- The system parameters should now show a nonzero "NO Voltage." The value will depend on the chosen output concentration. "NO Lamp Duty" will also be nonzero. The "N2O Flow" parameter should read ~40 cc/min.
- When outputting NO, there is about 2% NO_2 produced by secondary reactions (reactions 7 and 8; see Section 1.1.2 discussion). This means that when outputting 500 ppb of NO, for example, you should expect to see about 10 ppb of NO_2.
- Press the "Done" button when finished. The main window will be displayed, the NO photolytic lamp will power down, and the unit will output zero gas. The N_2O flow will also be shut off by the mass flow controller inside the Model 714.
- Close the N_2O regulator.

4.1.5 Outputting Nitrogen Dioxide (NO_2)

- Activate your source of N_2O by opening the regulator, as described above in Section 4.1.3.
- Select "NO2" from the main screen to obtain the selection screen shown here:



- Set the concentrations for NO and O_3. The O_3 will be completely reacted to form an equal amount of NO_2, so set the O_3 amount to the desired value of NO_2. Be sure to enter at least 2X the amount of NO as O_3 to ensure complete titration (reaction 9, Section 1.1.3). The firmware of the Model 714 is set to require a sufficient flow of excess NO.
- **Note: The OSHA exposure limit for nitrogen dioxide (NO_2) is 25 ppm (8-hour time-weighted average), 5 ppm (15-minute workplace exposure). The Model 714 produces NO_2/Air in the range of 0 to 1 ppm. Under normal operating conditions, the instrument will produce NO_2 in air at concentrations up to ~0.5 ppm. However, an instrument failure could result in small volumes of air containing NO_2 at higher concentrations. The instrument outputs the NO_2 in an excess of NO, which is also a toxic gas as described above in Section 4.1.4. Take proper precautions to vent the output of the Model 714 so as to minimize human exposure.**
- Select "Start" to begin outputting the calibrated NO_2 stream.
- The screen shown here will appear.
- Indicators are shown for NO and O_3: Flow (F), Temperature (T), and Lamp Intensity (I). Each parameter is shown in green if it is within the acceptable range, yellow if in transition, and red if out of range.



- The calibrated output is valid if all indicators are green. The adjustment period for "all green" may take a minute or two.
- The system parameters should now show a nonzero "NO Voltage." The value will depend on the chosen output concentration. "NO Lamp Duty" will also be nonzero. The "N2O Flow" parameter should read ~40 cc/min.
- Press the "Done" button when finished. The main window will be displayed, the NO photolytic lamp will power down, and the unit will output zero gas. The N_2O flow will also be shut off by the mass flow controller inside the Model 714.
- Close the N_2O regulator.

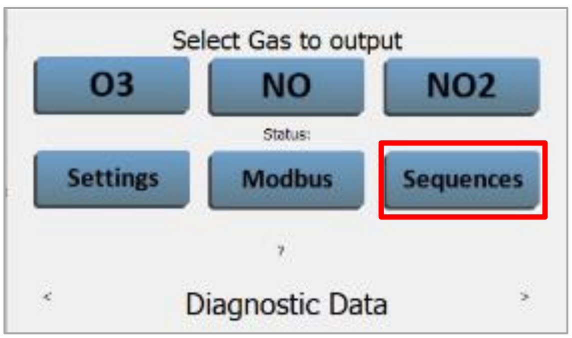
4.2 Creating a Sequence

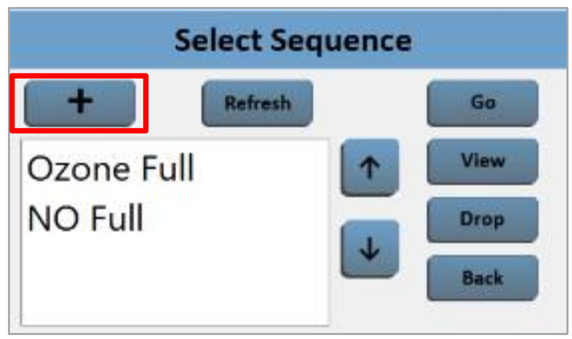
The Model 714 enables the user to run multiple steps of instructions (sequences) that have been preprogrammed in memory. Each step can be set to output scrubbed air, O_3, NO_2, or NO, and the duration of each step can be selected. Up to 15 steps can be entered in each sequence, and 99 different sequences may be stored in the Model 714. Each sequence may be programmed to repeat up to 99 times. Sequences are particularly convenient when generating multiple steps in a calibration procedure.

Note that when executing a sequence involving NO or NO_2, your source of N_2O must be enabled.

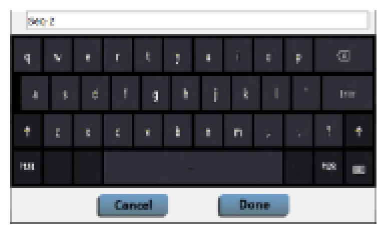
To create a sequence:

- From the main menu, press the "SEQ" button and then select "**+**" to add a sequence:

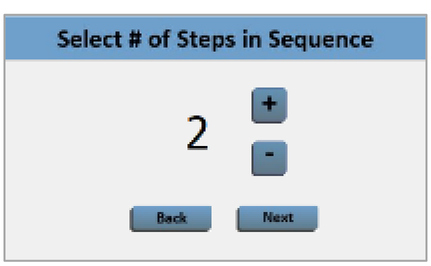




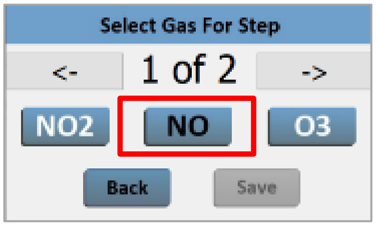
- A keyboard will appear, enabling you to enter a name for your new sequence in the text box, if desired. If you do not wish to name the sequence, simply press "done" and the sequence will automatically be named sequentially.

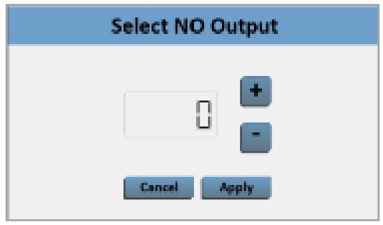


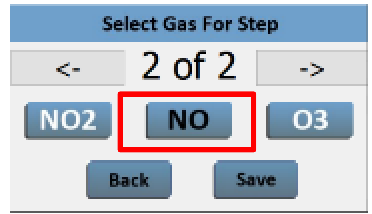
- Enter the number of steps (maximum 15) desired in the sequence using the +/- buttons. The time (in minutes) of each step is then specified by the user. In setting the time, keep in mind that a transition time of 15 to 60 seconds is needed between concentration outputs (depending on the difference between the two desired concentrations).



- Next select the gas to be output in each step (NO in this example) and specify the concentration:

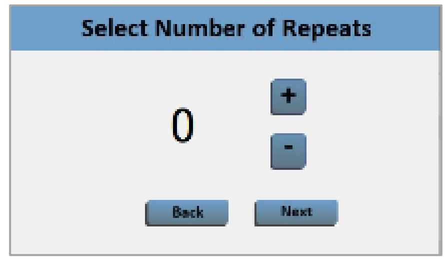




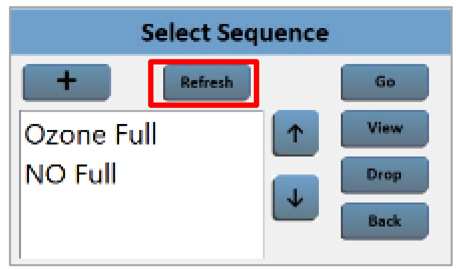


…etc.

- Continue setting up all the steps in your sequence.
- When finished with the steps, select the number of times you want the sequence to repeat (maximum 99):

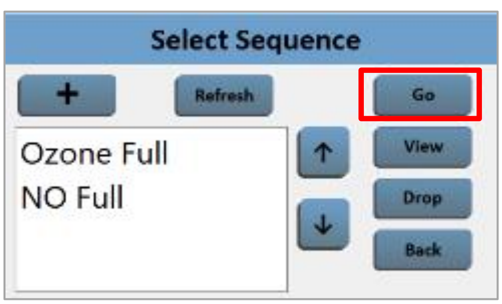


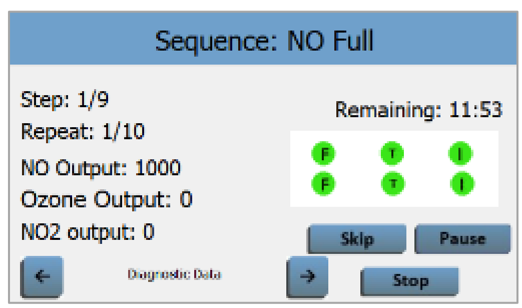
- “Refresh” to view your new sequence in the listing.
- Up to 99 different sequences may be stored.



4.3 Running, Viewing, or Dropping a Sequence

- Run a sequence by selecting it from the sequence view and pressing the “GO” button. A display screen will show each step as it is being executed.

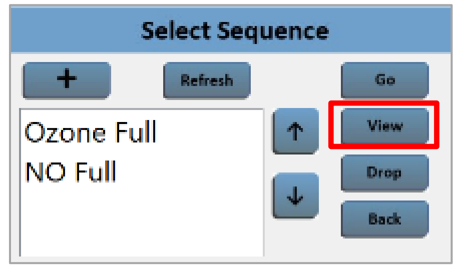


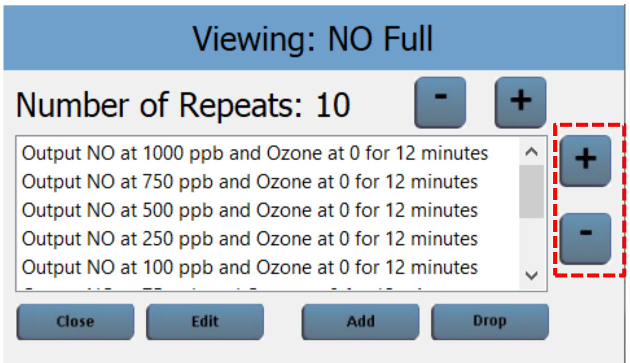


Note that when executing a sequence involving NO or NO_2, your source of N_2O must be enabled.

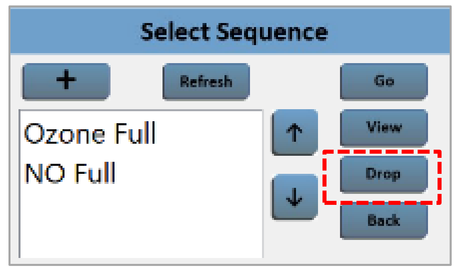
- Steps are automatically incremented after each step’s time is completed. The sequence either ends after the last step ends, or it repeats if specified to do so as described in Section 4.2 above. After the sequence ends, the sequence menu appears. NO_2, NO, and O_3 are all set to zero and the N_2O flow is shut off by the Model 714 mass flow controller. A step can be skipped by pressing the “Skip” button or paused by pressing the “Pause” button. A sequence can be ended immediately by pressing the “Stop” button.

- View the steps of a selected sequence by pressing the "View" button.





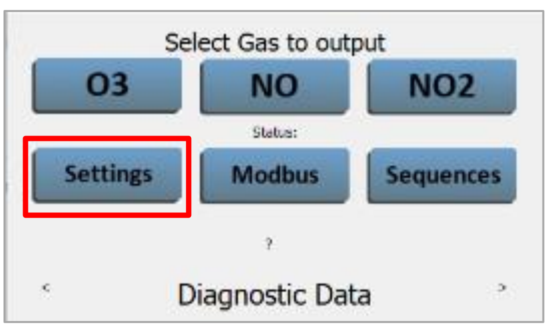
Use the scroll bars or +/- buttons to navigate through the sequence.

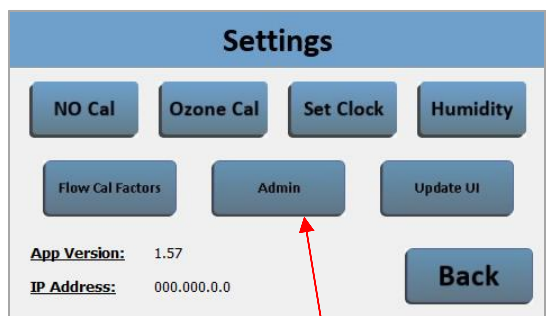


- A sequence cannot currently be edited, but it can be dropped and then a new amended sequence entered. Drop a selected sequence by pressing the "Drop" button. (**Caution**: There is no option to undo this!)

4.4 Changing the Settings for Calibration Factors and Date/Time

The Settings menu may be entered from the main screen.





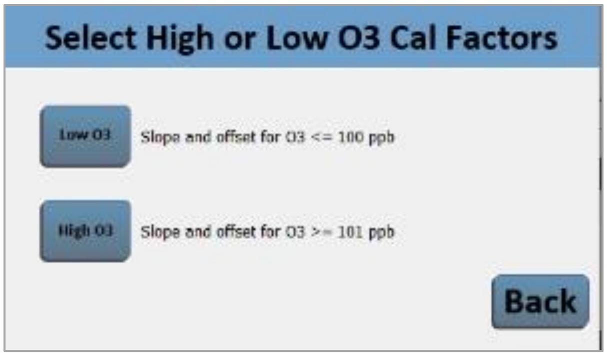
Note: The Admin menu is for factory use only. It is used when initializing your instrument, and if new lamps are installed. Please do not alter the entries within this menu unless advised by a 2B Technologies technical representative.

To change the calibration factors, set the date/time, or update the User Interface, select from the user submenus on the Settings View screen as described below.

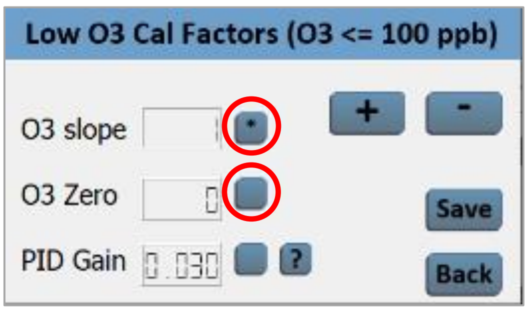
4.4.1 Setting the O_3 Calibration Factors

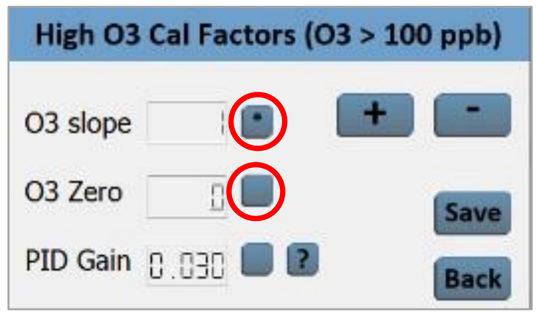
Select "Ozone Cal" from the Settings screen shown on the right above.

A screen will next appear to enable you to set high and low calibration factors:



Different calibration factors are used for low ozone (100 ppb or less) and high ozone (>100 ppb). These factors are determined at the factory and programmed in prior to shipment of the instrument to you. If you determine that your calibration factors need to be remeasured, you may return the instrument to us for our Calibration Service, or carry out the calibration yourself following the guidelines given in Section 7 of this manual. To enter the new parameters, select each range to obtain the screens that enable you to do this:

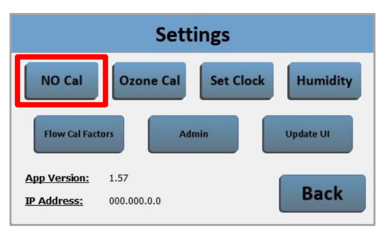




Check the box next to slope or zero and use the +/- buttons to adjust the settings. Select "SAVE." Note that it is necessary to SAVE after each individual parameter is changed (i.e., slope <u>set and saved</u>, then zero <u>set and saved</u>). Also note that the external overflow scrubber must be in place when doing a calibration and using the instrument.

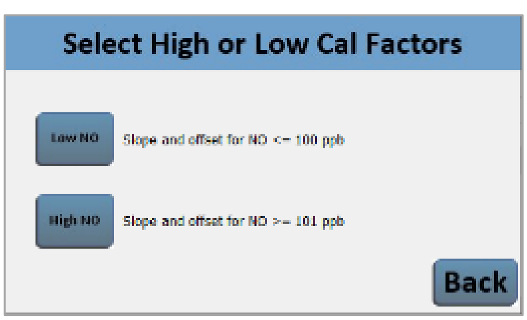
Note, the PID gain (proportional-integrative-derivative controller) is normally set to 0.030. It can be adjusted to change the response time of the instrument to concentration changes. For greater stability, decrease the PID gain. Reducing the PID gain (for example, to 0.010) can be particularly helpful if generating low concentrations.

4.4.2 Setting the NO Calibration Factors

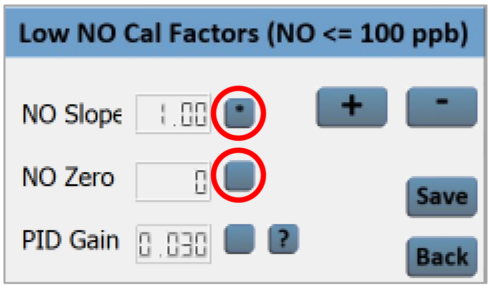


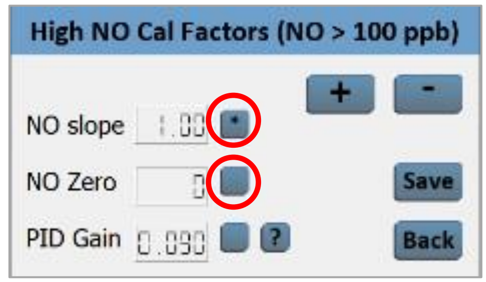
Select "NO Cal" from the Settings screen:

A screen for the cal factors will next appear:



Different calibration factors are used for low NO (100 ppb or less) and high NO (>100 ppb). These factors are determined at the factory and programmed in prior to shipment of the instrument to you. If you determine that your calibration factors need to be remeasured, you may return the instrument to us for our Calibration Service, or carry out the calibration yourself following the guidelines given in Section 7 of this manual. To enter the new parameters, select each range to obtain the screens that enable you to do this:



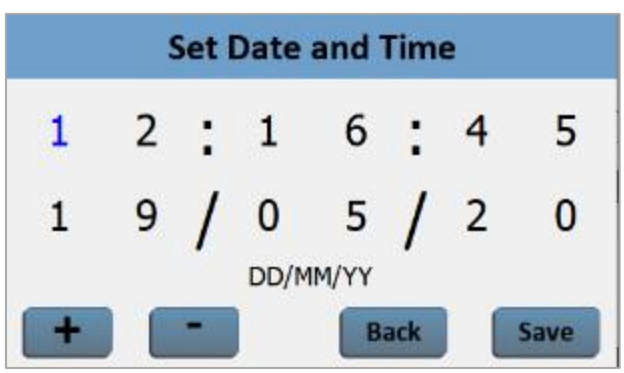


Check the box next to slope or zero and use the +/- buttons to adjust the settings. Select "SAVE." Note that it is necessary to SAVE after each individual parameter is changed (i.e., slope <u>set and saved</u>, then zero <u>set and saved</u>). Also note that the external overflow scrubber must be in place when doing a calibration and using the instrument.

Note, the PID gain is normally set to 0.030. It can be adjusted to change the response time of the instrument to concentration changes. For greater stability, decrease the PID gain. Reducing the PID gain (for example, to 0.010) can be particularly helpful if generating low concentrations.

4.4.3 Setting the Date/Time

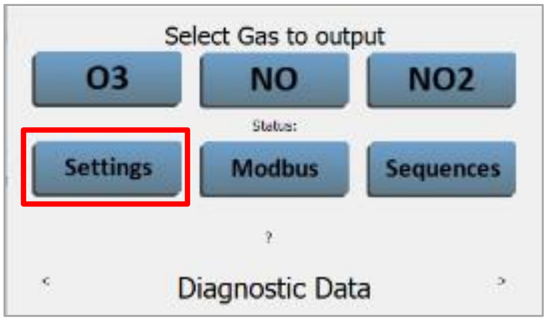
To change the date/time, select "Set Clock" from the Settings screen. A screen will next appear, for example:

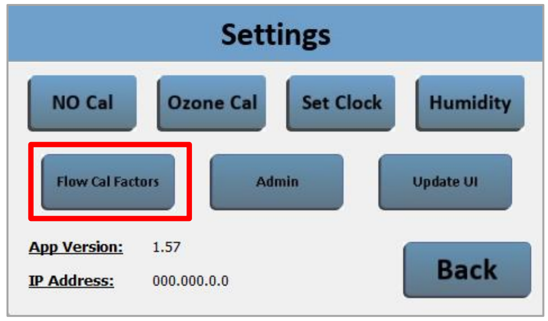


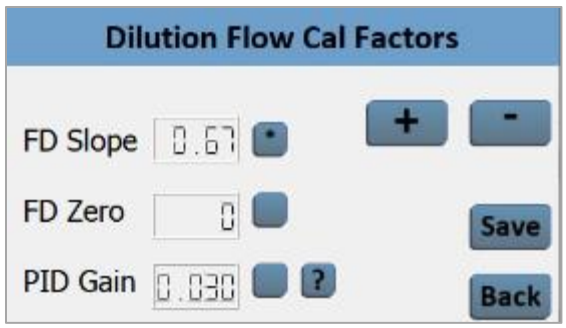
Adjust the digits as needed and select "SAVE." Note that the time is entered as 24-hour military time (12:16:45 pm in the example) and the date is in European format (19 May 2020 in the example).

4.4.4 Flow Calibration Settings

The calibration parameters for the dilution flow meter are set at the factory. However, if the user wishes to recalibrate the dilution flow meter, the values for slope and intercept can be adjusted by accessing the screens below:



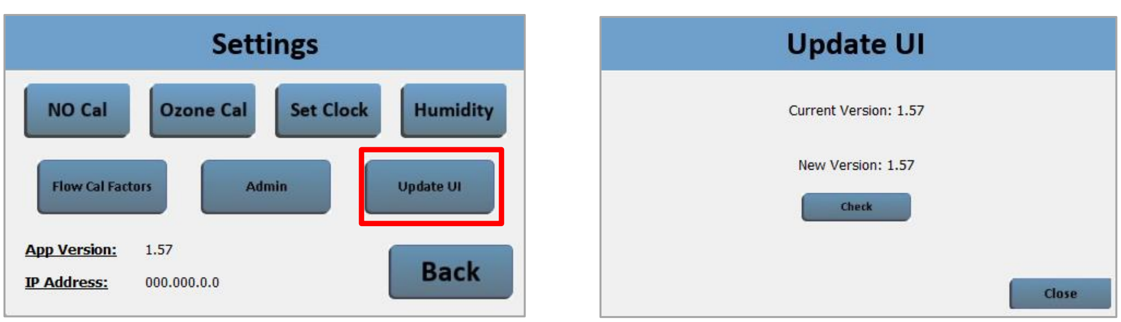




The PID gain is usually 0.030. It can be adjusted to change the response time of the instrument to concentration changes. For greater stability, decrease the PID gain. Reducing the PID gain (for example, to 0.010) can be particularly helpful if generating low concentrations.

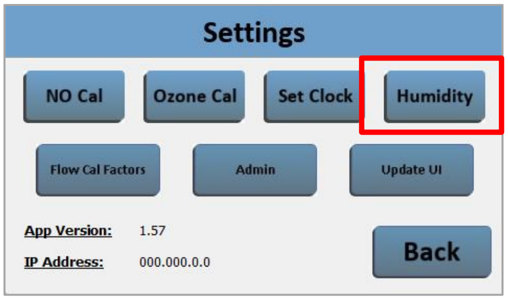
4.4.5 Updating the User Interface

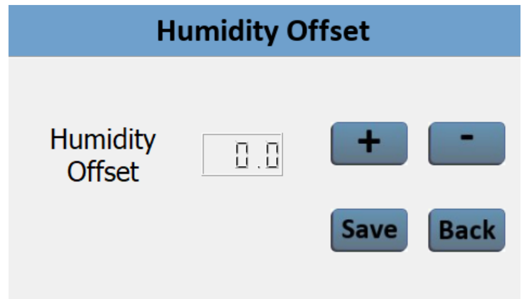
With this feature, the user can access and install any updates we've made to the User Interface, provided there is a valid network connection via Ethernet cable attached to the back panel of the instrument. Press "Check" to find the latest version available. Similar to a home computer, it would be advisable to check every couple months or so, to see if there is a new version.



4.4.6 Humidity Sensor Offset Setting

The humidity sensor offset value is set at the factory. Generally, this does not need to be changed by the user. However, if you change the drier material and notice that the humidity reading in the Diagnostic readout is not zero, the offset should be changed to read zero (the sensor does sometimes drift slightly over time). It is important to be sure that the drier has no leaks, and the drier material is orange, before you adjust the offset. Contact 2B Tech if you have any questions about this.

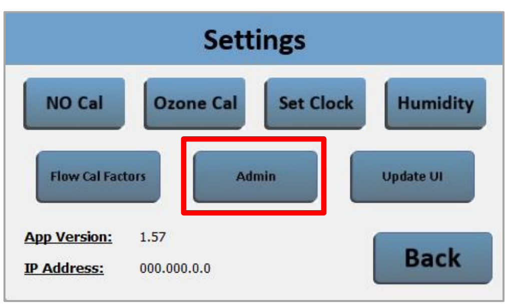


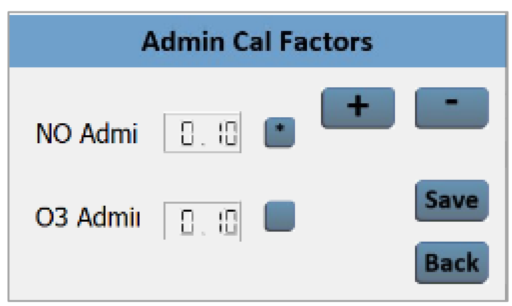


Allow at least 30 minutes of runtime after installing a recharged drier, prior to changing the humidity sensor offset. This will allow residual humidity in the plumbing to be removed. Then check the humidity level via the Diagnostic scroll screen at the bottom of the main (home) screen (see Section 3.2.6). If a freshly charged and leak-free drier is installed, this reading should be zero. If it instead reads 0.3% humidity, for example, adjust the humidity offset to minus 0.3 (-0.3).

4.4.7 Admin Settings

The Admin menu is for <u>factory use only</u>. It is used when initializing your instrument, and if new lamps are installed. Please do not alter the entries within this menu unless advised by a 2B Technologies technical representative.

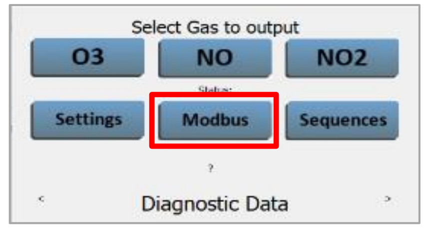




4.5 Remote Operation of the Model 714 Calibrator

Remote operation of the Model 714 makes it possible for the user to adjust the parameters of the Model 714 during runtime and carry out calibrations without being co-located with the instrument. Because many users have applications that require remote operation, we have added this capability to the Model 714.

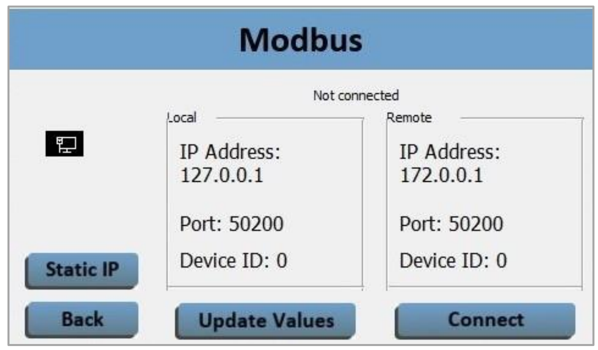
The remote operation of your Model 714 is accomplished via a Modbus TCP/IP interface through an Ethernet connection to your computer. The Modbus communication and control feature is accessed from the home screen shown here.



In the simplest configuration, the controlling computer and the Model 714 instrument are connected on the same network. However, a computer anywhere in the world can be connected, for example via TeamViewer or port sharing.

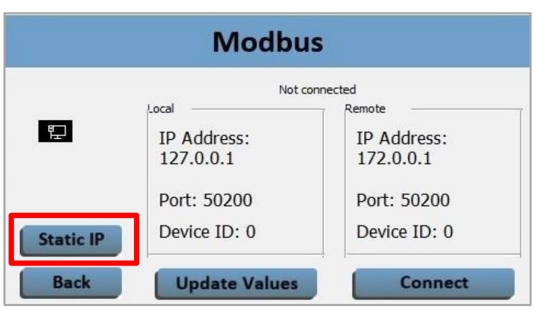
We have developed a software tool that enables you to use the Modbus feature. This tool is downloaded as a free application package to your Windows computer from our website (https://2btech.io/downloads/). The Model 714 Remote Software Application package is compatible with Windows-10. If you unable to use a PC and must use a Mac computer, please contact us. (Note that in the future, we plan to enable the user to develop their own tools for accessing the Modbus feature.)

Pressing "Modbus" in the screen shown above leads to the Modbus Home Screen shown here. Detailed steps for using this screen and establishing remote operation using Modbus and the 2B Tech software tool are given in Appendix A of this manual.



Setting Up a Static IP Address

Pressing the "Static IP" button of the Modbus Home Screen pulls up a screen that allows you to choose a set/unchanging (static) IP address for your instrument, provided that you know the correct subnet mask and gateway for your network. Although most users don't need static IP addresses, they normally matter more when external devices or websites need to remember your IP address. Click on the address areas and enter your Static IP/Gateway/Subnet mask values in the screens that pop up. Press "Apply" when ready, and then "Back" to return to the Modbus screen.



Warning: The static IP must be set to a valid IP address and not an IP address which is already assigned to another networked device, or it could cause errors/instrument failure. If you need assistance with this setting, consult your system administrator or contact 2B Technical Support.

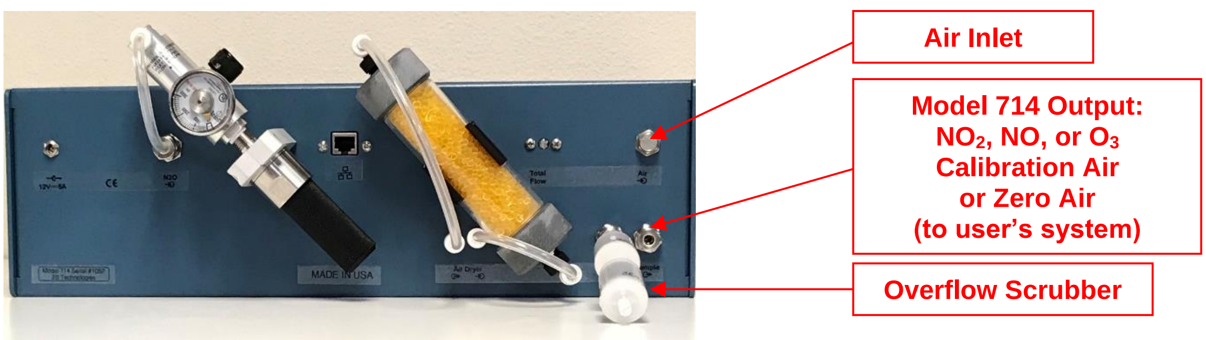
5. USING THE MODEL 714 TO CALIBRATE AN NO_2, NO, or O_3 MONITOR

5.1 Flow Requirement

The flow requirement of your NO_2, NO, or O_3 monitor must be less than the output capacity of the Model 714, which is typically ~2.5 to 2.7 L/min (range ~2.0-2.7 L/min).

5.2 Attaching the Model 714 NO_2/NO/O_3 Cal Source to Your Monitor

For calibration of a monitor, tubing may be attached from the ¼-inch Swagelok outlet fitting on the back of the Model 714 NO_2/NO/O_3 Cal Source, to the inlet of the monitor. The tubing should be made of PTFE (Teflon®), PFA, or some other inert material that does not destroy O_3, NO, or NO_2 and that does not desorb plasticizers and other organics that can contaminate the flow path. The length of tubing should be kept as short as possible (not more than a few feet) to minimize destruction of the NO_2, NO, or O_3 that you are generating with the Model 714. Tygon®, polypropylene (which may look like Teflon®), and metal tubing should not be used. Teflon-lined Tygon® tubing provides the flexibility of Tygon® and the inertness of Teflon®. A length of tubing is supplied with the instrument at the time of purchase.



The Model 714 has a built-in overflow tee to avoid over pressurizing the monitor you are calibrating. If not using the Model 714 inside a fume hood, it is recommended that you attach the external overflow scrubber provided with your instrument to the overflow outlet bulkhead to protect users from exposure to elevated amounts of NO_2, NO, N_2O, or O_3. Also the factory calibration of your instrument was done with the scrubber in place, and the scrubber must be in place for the Model 714's calibrated output to be valid.

Please review the safety warnings on p. viii, Section 3.2.3, and Section 3.2.7 of this manual.

5.3 Delivering NO or NO_2

A source of pure N_2O is necessary if NO or NO_2 is the desired output of the Model 714. The instrument comes with a regulator for use with disposable N_2O cartridges, which can be purchased by the user from commercial sources. As noted in Section

4.1.3, an 8-gram cartridge will last for about 2 hours of continuous operation, and a 16-gram cartridge will last for about 4 hours. Alternatively, the user can supply the N_2O using a compressed gas cylinder of >99.5% pure N_2O. Please see Section 4.1.3 for more details.

5.4 Running a Calibration of Your Monitor

Once the connections are established between the Model 714 outlet and the inlet of your NO_2, NO, or O_3 monitor, the calibration may be performed.

<u>If outputting NO or NO_2, your source of N_2O must be activated.</u>

For your calibration, the output of the Model 714 may be changed manually from the LCD menu (Section 4.1) or from a programmed sequence of up to 15 steps that you have created (see Sections 4.2 and 4.3).

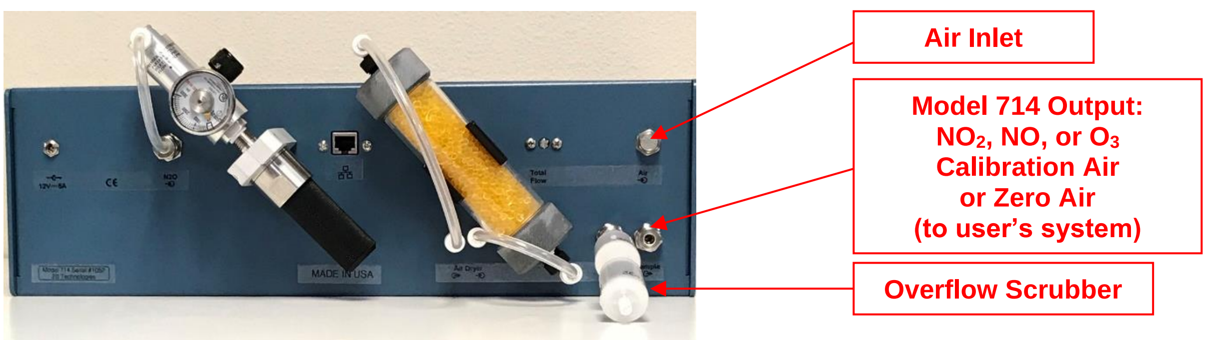
6. USING THE MODEL 714 WITH YOUR GAS DELIVERY SYSTEM

The Model 714 NO_2/NO/O_3 Calibration Source may be used to supply calibrated concentrations of either of the gases NO_2, NO, or O_3 to your gas delivery system. An example of a potential application of the Model 714 is for exposure studies involving vegetation or materials.

To provide calibrated gas to your system, tubing may be attached from the ¼-inch Swagelok outlet fitting on the back of the Model 714 NO_2/NO/O_3 Cal Source to the inlet of your system. The tubing should be made of PTFE (Teflon®), PFA, or some other inert material that does not destroy O_3, NO, or NO_2 and that does not desorb plasticizers and other organics that can contaminate the flow path. The length of tubing should be kept as short as possible (not more than a few feet) to minimize destruction of the NO_2, NO, or O_3 that you are generating with the Model 714. Tygon®, polypropylene (which may look like Teflon®), and metal tubing should not be used. Teflon-lined Tygon® tubing provides the flexibility of Tygon® and the inertness of Teflon®. A length of tubing is supplied with the instrument at the time of purchase.

6.1 Flow Considerations

The output capacity of the Model 714 NO_2/NO/O_3 Cal Source is ~2.0 to 2.7 L/min (2.5-2.7 L/min typical). If your gas delivery system requires a lower flow rate, the Model 714's built-in overflow tee will avoid over-pressurizing your system.



If not using the Model 714 inside a fume hood, it is recommended that you attach the external overflow scrubber provided with your instrument to the overflow outlet bulkhead to protect users from exposure to elevated amounts of NO_2, NO, N_2O, or O_3. Please see the safety warnings on p. viii of this manual. This overflow scrubber is necessary for the factory calibration to be valid.

6.2 Delivering NO or NO_2

A source of pure N_2O is necessary if NO or NO_2 is the desired output of the Model 714. The instrument comes with a regulator for use with disposable N_2O cartridges, which can be purchased by the user from commercial sources. As noted in Section 4.1.3, an 8-gram cartridge will last for about 2 hours of continuous operation, and a 16-gram cartridge will last for about 4 hours. Alternatively, the user can supply the

N_2O using a compressed gas cylinder of >99.5% pure N_2O. Please see Section 4.1.3 for more details.

6.3 Using Programmed Sequences

For some applications, it may be convenient to make use of the Model 714's capability to run programmed sequences. This could allow the user to carry out experiments involving changing concentrations, without requiring the continued presence of the user. See Sections 4.2 and 4.3 for more information about this capability.

7. *CALIBRATING THE MODEL 714 NO_2/NO/O_3 CALIBRATION SOURCE*

Every analytical instrument is subject to some drift and variation in response, making it necessary to periodically check the calibration. 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.

Calibration of the Model 714 for both NO and O_3 is recommended at least annually. This may be done by returning the instrument to 2B Technologies for calibration service, or the user may elect to perform the calibration by following procedures outlined below.

For the setups described below, be sure to use appropriate tubing for connections from the Model 714 to other instruments. Tubing must be made of inert materials, such as PTFE or FEP. Teflon-lined Tygon tubing is appropriate and is available for purchase from 2B Technologies. Please contact us at sales@2btech.io to place an order.

The calibration is sensitive to the restrictions on the overflow exhaust line, so if an overflow scrubber will be used during operation (recommended), it must also be used during the calibration. Note that factory calibrations are performed with the overflow scrubber in place.

7.1 Calibrating the Ozone Output of the Model 714

Calibration of the O_3 output of the Model 714 involves using the Model 714 to generate several concentrations of O_3, measuring the Model 714 output concentration versus the readings observed by a calibrated O_3 monitor, and adjusting the gain and offset of the Model 714 nm as needed.

The concentration of ozone produced in the photolysis chamber is linear with light intensity. This is because the absorption of 185-nm light by oxygen is very weak ($\sigma \sim 2 \times 10^{-22}$ cm^2/molec) and the absorbance is optically thin due to the short pathlength in the chamber. In the optically thin regime, only a very small fraction of the emitted light is absorbed by oxygen to produce ozone.

In practice, however, a slight curvature in the calibration plot is observed when the ozone concentration is extended to 500 ppb. This could be due to a number of factors, one of which is a lack of a constant ratio of the intensities of the emission lines at 185 nm and 254 nm as the lamp power is varied. Since 185 nm falls in the vacuum UV where light intensity is difficult to measure, the ozone output of the Model 714 NO_2/NO/O_3 Calibration Source is actually calibrated against the measured intensity of the 254-nm emission line. In order to remove the small curvature observed in the plot of ozone concentration produced and lamp intensity at 254 nm, ozone calibration parameters are determined in two ranges: Low Ozone (0-100 ppb) and High Ozone (101-500 ppb).

Four parameters are used to calibrate the ozone output of the instrument, consisting of low and high offsets (Z_L and Z_H) and slopes (S_L and S_H). The offset Z_L and slope S_L are determined for the range of output ozone concentrations of 0-100 ppb. The offset Z_H and slope S_H are used to produce the most accurate ozone concentration in the range 101-500 ppb. These calibration parameters are determined at the factory and are entered into the instrument before shipment.

We recommend returning the Model 714 NO_2/NO/O_3 Calibration Source to us annually for a new calibration of the O_3 output. Alternatively, you can calibrate the instrument against your own reference ozone monitor (such as a 2B Technologies Model 106L, Model 202, Model 205, or Model 211 Ozone Monitor). Using your reference ozone monitor, sample several concentrations of ozone from the Model 714 over either the high or low calibration range. Plot the observed ozone concentration against the setpoint ozone concentration of your Model 714, and obtain the linear regression slope *m* and intercept *b*. For example, for the low range of ozone outputs (0-100 ppb):

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

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

If you want to extend the calibration to higher concentrations, plot measured ozone vs setpoint ozone in the range 101-500 ppb and obtain the linear regression slope *m* and *b* as above:

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

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

If you don't plan to output concentrations higher than 100 ppb, simply set S_H = S_L and Z_H = Z_L.

Equipment Needed

- Model 714
- Calibrated Ozone Monitor (such as a 2B Technologies Model 106L, Model 202, Model 205, or Model 211)
- Sampling line (inert materials such as PTFE or FEP only)

Setup

- Attach a tubing connection from the outlet of the Model 714 to the inlet of the calibrated ozone monitor you are using.
- The Model 714 has a built-in overflow tee to vent the excess flow of the Model 714 output and avoid over pressurizing the ozone monitor (the instrument total flow rate is typically 2.5 to 2.7 L/min).
- It is best to use the shortest feasible lengths of tubing.

Procedure

Use the Model 714 to output several concentrations of O_3 in the low range and in the high range to obtain the four calibration parameters as described above. (Note that a sequence can be used to carry out this calibration. See Section 4.2 of this manual.)

7.2 Calibrating the NO Output of the Model 714

Calibration of the NO output of the Model 714 NO_2/NO/O_3 Calibration Source is recommended at least annually, either by the user (recommended procedure described below) or by returning the instrument to 2B Technologies for calibration servicing.

Calibration of the NO output of the Model 714 involves using the Model 714 to generate several concentrations of NO, measuring the Model 714 output concentration versus the readings observed by a calibrated NO monitor, and adjusting the gain and offset of the Model 714 nm as needed.

As described above for ozone, there is a small curvature observed in the plot of NO concentration produced and lamp intensity at 185 nm. Therefore, NO calibration parameters are determined in two ranges: Low NO (0-100 ppb) and High NO (101-1000 ppb). As a consequence, four parameters are used to calibrate the NO output of the instrument, consisting of two offsets Z_L and Z_H, and two slopes S_L and S_H. The offset Z_L and slope S_L are determined for the range of output NO concentrations of 0-100 ppb. The offset Z_H and slope S_H are used to produce the most accurate NO concentration in the range 101-1,000 ppb. These calibration parameters are determined at the factory and are entered into the instrument before shipment.

We recommend returning the Model 714 NO_2/NO/O_3 Calibration Source to us annually for a new calibration of the NO output. Alternatively, you can calibrate the instrument against your own reference NO monitor (such as a 2B Technologies Model 405 nm NO_2/NO/NO_x Monitor). Using your reference NO monitor, sample several concentrations of NO from the Model 714 over either the high or low calibration range. Plot the observed NO concentration against the setpoint NO concentration of your Model 714, and obtain the linear regression slope *m* and intercept *b*. For example, for the low range of NO outputs (0-100 ppb):

$$[NO]_{L\_measured} = m[NO]_{L\_setpoint} + b$$

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

If you want to extend the calibration to higher concentrations, plot measured NO vs setpoint NO in the range 101-1,000 ppb and obtain the linear regression slope *m* and intercept *b* as above:

$$[NO]_{H\_measured} = m[NO]_{H\_setpoint} + b$$

Then, S_H = 1/*m* and Z_H = -*b* (in units of ppb). Use of two sets of slope/intercept calibration factors allows expansion of the calibration range while maintaining the accuracy within the specifications of 2 ppb or 2% of the NO setpoint.

If you don't plan to output concentrations higher than 100 ppb, simply set S_H = S_L and Z_H = Z_L.

> Note: Generating accurate amounts of NO and NO_2 using compressed gas mixtures is unreliable because the gases are lost by reaction and adsorption in the cylinder and on gas handling equipment.

Equipment Needed

- Model 714
- Calibrated NO Monitor (such as a 2B Technologies Model 405 nm NO_2/NO/NO_x Monitor)
- Sampling line (inert materials such as PTFE or FEP only)

Setup

- Attach a tubing connection from the outlet of the Model 714 to the inlet of the calibrated NO monitor you are using.
- The Model 714 has a built-in overflow tee to vent the excess flow of the Model 714 output and avoid over pressurizing the NO monitor (the instrument total flow rate is typically 2.5 to 2.7 L/min).
- It is best to use the shortest feasible lengths of tubing.

Procedure

Use the Model 714 to output several concentrations of NO in the low range and in the high range to obtain the four calibration parameters as described above. (Note that a sequence can be used to carry out this calibration. See Section 4.2 of this manual.)

7.3 Calibrating or Verifying the NO_2 Output of the Model 714

Calibration

If a calibrated NO monitor is available, the NO_2 output may be calibrated versus NO based on the stoichiometric reaction of NO with O_3:

$$NO + O_3 \rightarrow NO_2 + O_2 \quad (9)$$

In the Model 714, NO is used in excess of O_3 to generate NO_2. The calibration is performed by addition of varying concentrations of ozone to an excess of NO. Nitrogen dioxide is calibrated based on the increase in NO_2 signal relative to the decrease in the NO signal. This method is consistent with the methods described by the U.S. EPA (https://www.govinfo.gov/app/details/CFR-2012-title40-vol2/CFR-2012-title40-vol2-part50-appF).

Equipment Needed

- Model 714 (already calibrated for O_3)
- Calibrated NO Monitor (such as a 2B Technologies Model 405 nm NO_2/NO/NO_x Monitor)
- Sampling line (inert materials such as PTFE or FEP only)

Setup

- Attach a tubing connection from the outlet of the Model 714 to the inlet of the calibrated NO monitor you are using.
- The Model 714 has a built-in overflow tee to vent the excess flow of the Model 714 output and avoid over pressurizing the NO monitor (the instrument total flow rate is typically 2.5 to 2.7 L/min).
- It is best to use the shortest feasible lengths of tubing.

Procedure

1. Use the Model 714 to output a concentration of NO_2 in the lower range of output (i.e., 0-100 ppb). For example, for 80 ppb NO_2, Set and O_3 to 80 ppb and NO to at least 160 ppb. A best practice is to set the NO level to twice the value of the highest NO_2 value you wish to calibrate, keeping that NO level constant as you go through a range of O_3 concentrations from 0 to your highest NO_2 cal value.
2. Note the output of your calibrated NO monitor before and after several O_3 concentrations within the lower range (i.e., 0-100 ppb).
3. Repeat Step 1 using the Model 714 to output a concentration of NO_2 in the higher range of output (i.e., 101-500 ppb). For example, for 400 ppb NO_2, Set O_3 to 400 ppb and NO to at least 800 ppb (or at twice the value of the highest NO_2 value you wish to calibrate, as noted in step 1).
4. Note the output of your calibrated NO monitor before and after several O_3 concentrations within the higher range (i.e., 101-500 ppb).
5. If either of the calibrations falls outside acceptable limits, conduct further tests to see if the sampling lines are destroying NO_2, or if the problem occurs primarily in the low or high concentration ranges. Also, recheck your O_3 calibration, as a faulty O_3 calibration will propagate to the NO_2 calibration.

<u>Verification</u>

The Model 714 generates a calibrated concentration of NO_2 by using an excess of NO to quantitatively convert a calibrated concentration of O_3 into an equal amount of NO_2 via the reaction discussed previously:

$$NO + O_3 \rightarrow NO_2 + O_2 \qquad (9)$$

Therefore, when the instrument is calibrated for O_3, it is also calibrated for NO_2—provided the conversion of the O_3 is complete (this is assured through the design of the Model 714), and also assuming that there are no significant losses of NO_2 in the sampling lines.

The user can verify these assumptions by performing a check of the Model 714 output versus a calibrated NO_2 monitor. To do this, first perform the O_3 calibration as noted in Section 7.1. Then proceed as described below.

Equipment Needed

- Model 714 (already calibrated for O_3)
- Calibrated NO_2 Monitor (such as a 2B Technologies Model 405 nm NO_2/NO/NO_x Monitor)
- Sampling line (inert materials such as PTFE or FEP only)

Setup

- Attach a tubing connection from the outlet of the Model 714 to the inlet of the calibrated NO_2 monitor you are using.
- The Model 714 has a built-in overflow tee to vent the excess flow of the Model 714 output and avoid over pressurizing the NO_2 monitor (the instrument total flow rate is typically 2.5 to 2.7 L/min).
- It is best to use the shortest feasible lengths of tubing.

Procedure

1. Use the Model 714 to output a concentration of NO_2 in the lower range of output (i.e., 0-100 ppb). For example, for 80 ppb NO_2, Set and O_3 to 80 ppb and NO to at least 160 ppb. A best practice is to set the NO level to twice the value of the highest NO_2 value you wish to verify, keeping that NO level constant as you go through a range of O_3 concentrations from 0 to your highest NO_2 value.
2. Note the output of your calibrated NO_2 monitor. If it is within the greater of 3 ppb or 3% of the Model 714 output setting, the verification is successful.
3. Repeat Step 1 using the Model 714 to output a concentration of NO_2 in the higher range of output (i.e., 101-500 ppb). For example, for 400 ppb NO_2, Set O_3 to 400 ppb and NO to at least 800 ppb (or at twice the value of the highest NO_2 value you wish to verify, as noted in step 1).
4. Note the output of your calibrated NO_2 monitor. If it is within the greater of 3 ppb or 3% (12 ppb, in this example) of the Model 714 output setting, the verification is successful.
5. If either of the verifications fails, conduct further tests to see if the sampling lines are destroying NO_2, or if the problem occurs primarily in the low or high concentration ranges. Also recheck your O_3 calibration, as a faulty O_3 calibration will propagate to the NO_2 calibration.
6. If problems persist, contact 2B Technologies for assistance.

8. MAINTENANCE/TROUBLESHOOTING

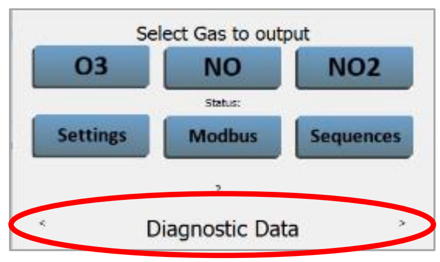
The Model 714 NO_2/NO/O_3 Cal Source is designed to be nearly maintenance free. The only components that require routine maintenance are the dryer, the two particle filters, the internal NO_2/NO_x/O_3 scrubber (see Figure 9-1), and the overflow scrubber. Other user-serviceable components include the lamps, air pump, and a VSO valve, all of which are easily replaced should they fail. Parts can be ordered by emailing us at sales@2btech.io or by calling us (see Section 10 for the parts list).

8.1 Replacing Filters and Scrubber

The filters and internal scrubber should be changed at least annually, or more often under heavy use of the instrument. These components may be purchased from 2B Technologies (see Section 10). It is recommended that the user have a set of these components on hand, to avoid interruptions in use of the instrument.

8.2 Regenerating the Silica Gel of the Dryer

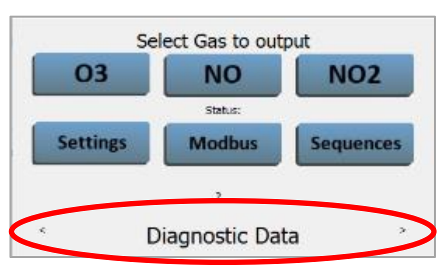
The dryer on the back of the Model 714 removes humidity from the ~50 cc/min air flow that is used to make ozone (see Section 1.2 and Figure 1-1). <u>It is important to properly maintain the dryer so that stable amounts of ozone are made in the ozone photolysis chamber</u>. The silica gel of the dryer will gradually fade from its initial orange color as it absorbs water. Also, periodically check the humidity reading in the Diagnostic Data scroll screen at the bottom of the main (home) menu, to see if it is creeping upward above zero. The silica gel should be regenerated or replaced when this occurs.



The silica gel is easily removed from the dryer by unscrewing the dryer cap at either end. A convenient way to regenerate the silica gel is to pour it into an open container such as a beaker and heat it inside a laboratory oven at 255°F for 12 hours. When reinstalling regenerated or fresh silica gel, be sure you have no leaks in the drier. Allow ~30 minutes runtime while producing ozone, and then check the humidity reading in the Diagnostic Data. They will be zero if the silica gel is recharged and there are no leaks in the drier. *Only when you are sure there are no leaks*: *adjust the humidity offset if needed (see Section 4.4.6).*

8.3 Checking the Instrument Flow Rates

Some instrument problems may be diagnosed by checking the flow rates of the instrument. The flow rate of the air used to make ozone in the photolysis chamber should be ~50 cc/min. The flow rate of the N_2O used to make NO should be ~40 cc/min. These may be checked using the diagnostics readouts on the bottom of the main instrument screen:



The total instrument flow rate can likewise be checked from this screen. However, if the user wishes to do an independent check of the total flow rate being output from the instrument, a flow meter can be attached to the outlet of the Model 714. For this check, be sure to cap off the built-in overflow tee of the Model 714. See also Section 4.4.4 regarding the calibration settings of the flow meter.

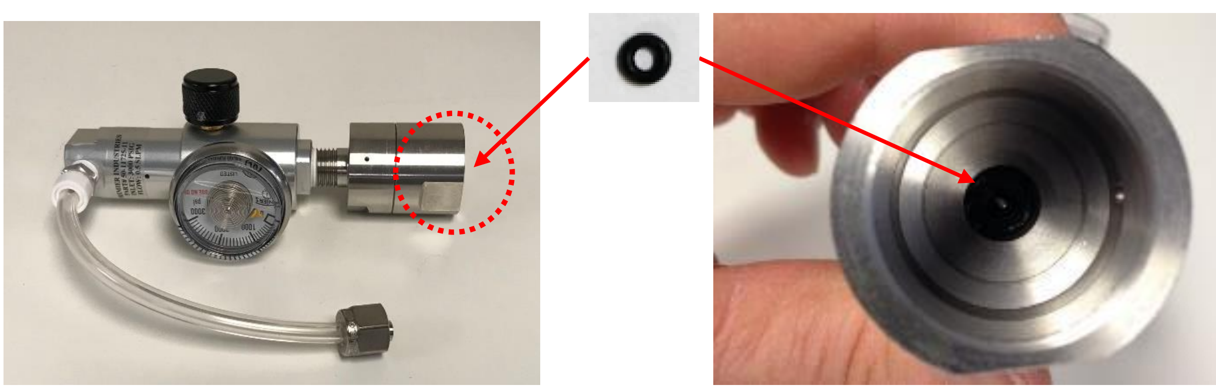
8.4 Proper Operation of the Portable N_2O Source

The Portable N_2O Source must be used as described in Section 4.1.3. Common issues that can arise during use are:

i. Forgetting to use the silver adapter with smaller (8-gram) N_2O cartridges;

ii. Not puncturing the cartridge properly when installing a new cartridge in the Portable N_2O Source [either by not tightening the black cup properly, or not using the silver adapter; listen for a noise when the cartridge is punctured]; and

iii. Leaks in the Portable N_2O Source. A leak in the Portable N_2O Source would cause more-rapid depletion of the N_2O cartridges and could lead to an erratic flow rate of N_2O into the photolysis chamber. (If the outside of the Portable N_2O Source is unusually cold, this would indicate a leak.) A common source of a leak is deterioration or improper seating of the o-ring that seals the regulator needle valve inside the regulator, or the o-ring that seals the N_2O cartridge against the body of the Portable N_2O Source. Also take care that the o-right shown on the right does not fall out during handling of the Portable N_2O Source. Extra o-rings are provided when you purchase the instrument.



8.5 Troubleshooting

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

https://2btech.io/support/

Alternatively, you can email us at techsupport@2btech.io 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 photos in Section 9 provide a "guided tour" of the instrument so that critical components and connectors may be easily identified. Section 10 gives a parts list.

Table 8-1. *Troubleshooting the Model 714 NO_2/NO/O_3 Calibration Source for performance problems.*

Problem/symptom	Likely cause	Corrective action
Instrument does not turn on.	Power not connected properly or circuit breaker open. Power cable not connected to circuit board.	Check external power connection for reverse polarity or a short and wait a few minutes for the thermal circuit breaker to reset. 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 (Figure 9-3). Turn instrument on; if it remains running, then the air pump motor is burned out and shorting. Replace air pump.
Display is blank or nonsense.	Bad connection of display to circuit board.	Remove top cover and reconnect display to circuit board (Figure 9-3). Check solder connections to display.
Target temperature is never reached for O_3 or NO photolysis chambers.	Absent or loose connection of temperature probe cable to circuit board. Heater is burned out.	Remove top cover and reattach connector to circuit board (Figure 9-3). Replace cartridge heater.
Instrument does not output O_3, NO, or NO_2.	Photolysis lamp is burned out in O_3 or NO chamber. Cable not properly connected between lamp and circuit board.	Replace lamp and recalibrate instrument. Remove top cover and reconnect lamp cable to circuit board (Figure 9-3).
Lamp Intensity does not stabilize when generating O_3 or NO	Lamp is overshooting and undershooting when target concentrations are low (less than ~30 ppb)	Reduce the PID gain (e.g., to ~0.010 from default value of 0.030). See Sections 4.4.1 and 4.4.2.

O_3 values do not seem accurate	The drier is not removing all of the humidity from the input air	Check silica gel and regenerate or replace if needed (i.e., orange color has faded substantially). Adjust humidity offset if needed (only recommended if you have thoroughly read and followed instructions in Sections 8.2 and 4.4.6)
N_2O cartridges are running out too quickly	One or both of the o-ring seals in the regulator are corrupted, or the o-ring has fallen out of cartridge housing area.	Replace o-rings in valve or cartridge housing (Viton, 1/8” ID, ¼” OD, 70 durometer). See Section 8.4.

9. LABELED INSTRUMENT PHOTOS

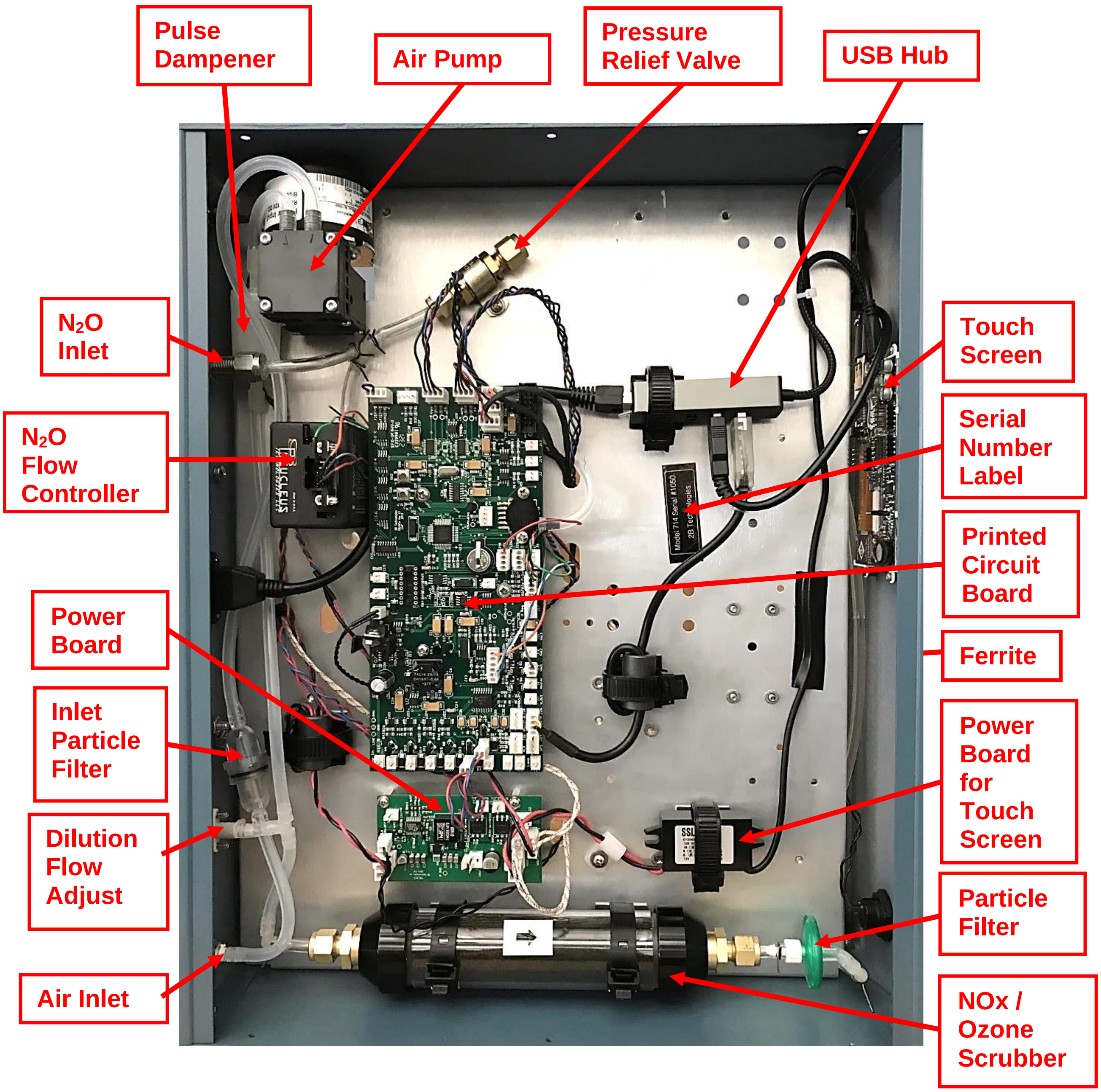


FIGURE 9-1: ***Top view of Model 714 NO_2/NO/O_3 Cal Source™ with cover removed.*** *Refer to schematic in Figure 1-1.*

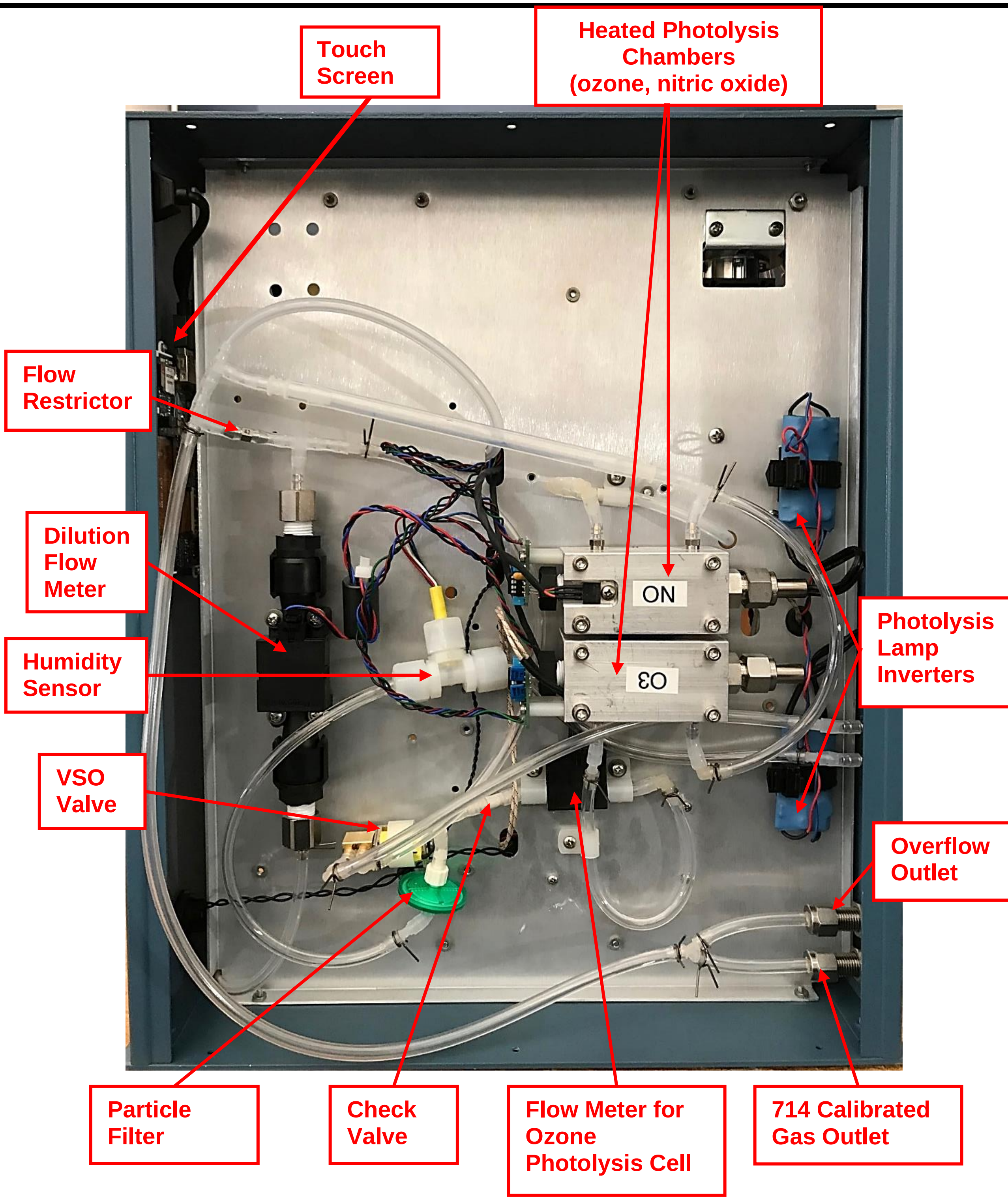


FIGURE 9-2: ***Bottom view of Model 714 NO_2/NO/O_3 Cal Source™ with cover removed.*** *Refer to schematic in Figure 1-1.*

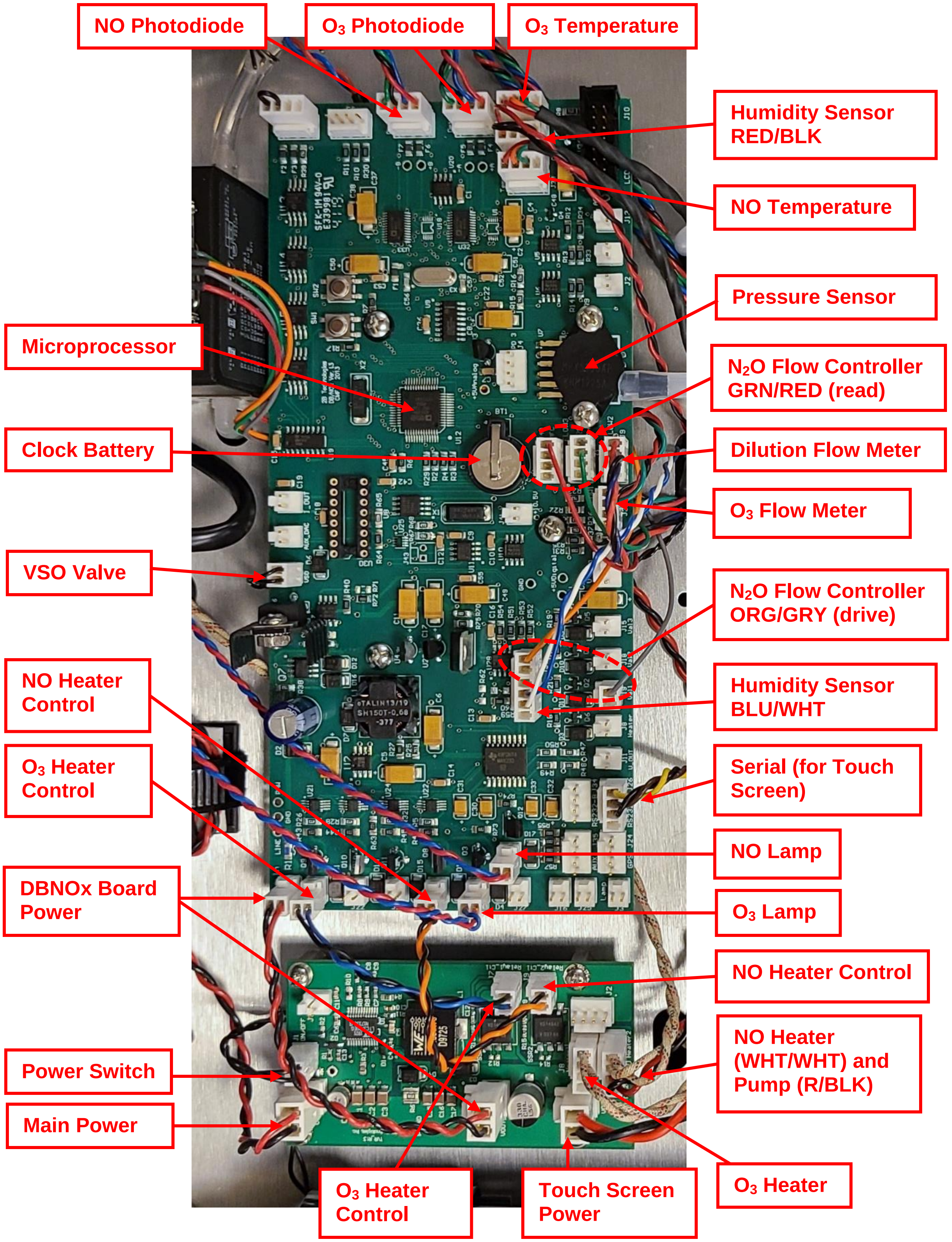


FIGURE 9-3: ***Printed Circuit Boards of Model 714 NO_2 /NO/O_3 Cal Source™.***

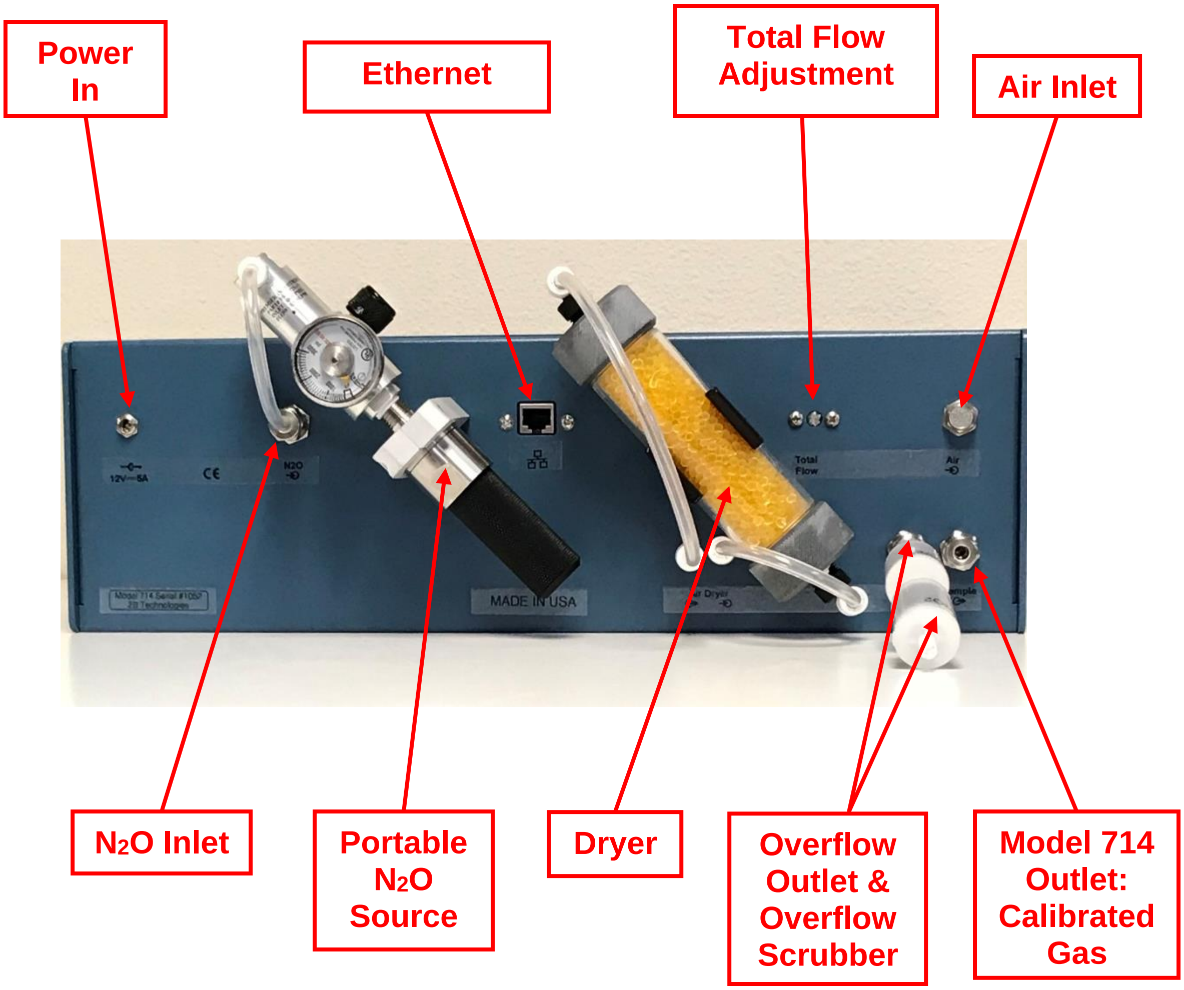


FIGURE 9-4: ***Back panel of Model 714 NO_2 /NO/O_3 Cal Source™ .***

If the silica gel has discolored from the orange color shown here, it has become wet and needs to be regenerated. See Section 8.2.

10. PARTS LIST

The following list includes those parts of the Model 714 NO_2/NO/O_3 Calibration Source[TM] that are user serviceable.

Part Number	Description
OZPUMP714	Air pump (15,000 hr), KNF, for Models 714
PDASSEMBLY714	Photodiode assembly for Model 714 *(PD for use with either the O_3 or the NO generator)*
FLOWMETERDILUTION714	Dilution flow meter assembly for Model 714
OZVLV714	VSO/Flow Control Valve and cable for Model 714
PWRASSY714	Internal power jack and cable for Model 714
PWRPK-5 A	5-amp power pack for Model 405, 106-W, 714
SCRBINTNOXO3714	Internal O_3/NOx scrubber assembly, Model 714
SCRBEXTNOXO3714	External overflow O_3/NO_x scrubber assembly, Model 714
NOXO3SCRBFILTER	Disc Filter for internal NOx/O_3 scrubber, Model 714
MASSFLOWCONTROLLER714	Mass Flow Controller, Model 714
NDLVLV	Needle valve, inlet flow adjust
DRYER714	Dryer and plumbing assembly, Model 714 *Note, the Dryer is filled with silica gel when shipped. Please contact us for information about obtaining an additional supply of the silica gel: sales@2btech.io, 303 273-0559.*
N2OCRACKER211	Portable N_2O Source (used in Models 211, 408, 714) *Note, N_2O cartridges for use with the Portable N_2O Source are obtained separately. Please contact us for information: sales@2btech.io, 303 273-0559.*

11. SERVICE LOG

2B Technologies Model 714 NO_2/NO/O_3 Calibration Source™

Purchase Date: _______________ **Serial No.**_______________

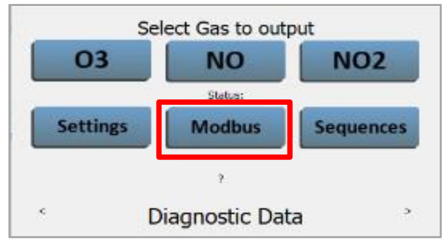
Date	Calibrated for NO	Calibrated for O_3	Cleaned	New O_3/NO_x Scrubber	New Pump	New Lamp (O_3, NO, or both?)	Other

Date	Calibrated for NO	Calibrated for O_3	Cleaned	New O_3/NO_x Scrubber	New Pump	New Lamp (O_3, NO, or both?)	Other

Appendix A: Remote Operation of the Model 714 Calibrator

Remote operation of the Model 714 makes it possible for the user to adjust the parameters of the Model 714 during runtime and carry out calibrations without being co-located with the instrument. Because many users have applications that require remote operation, we have added this capability to the Model 714.

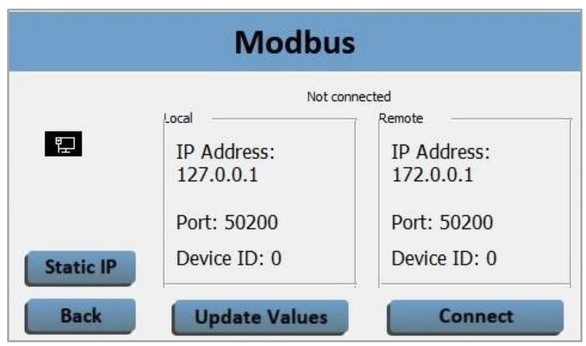
The remote operation of your Model 714 is accomplished via a Modbus TCP/IP interface through an Ethernet connection to your computer. The Modbus communication and control feature is accessed from the home screen shown here.



In the simplest configuration, the controlling computer and the Model 714 instrument are connected on the same network. However, a computer anywhere in the world can be connected, for example via TeamViewer or port sharing.

We have developed a software tool that enables you to use the Modbus feature. This tool is downloaded as a free application package to your Windows computer from our website (https://2btech.io/downloads/). The Model 714 Remote Software Application package is compatible with Windows-10. If you unable to use a PC and must use a Mac computer, please contact us. (Note that in the future, we plan to enable the user to develop their own tools for accessing the Modbus feature.)

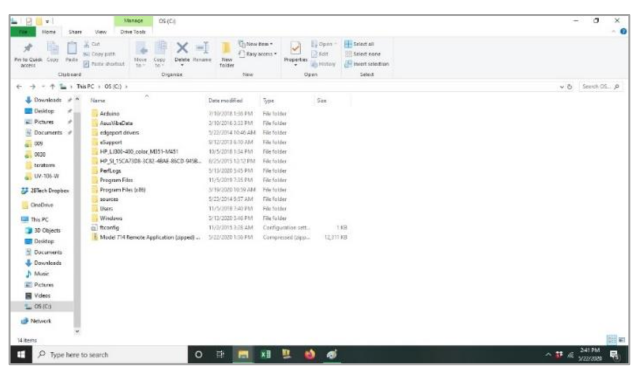
Pressing "Modbus" in the screen shown above leads to the Modbus Home Screen shown here:



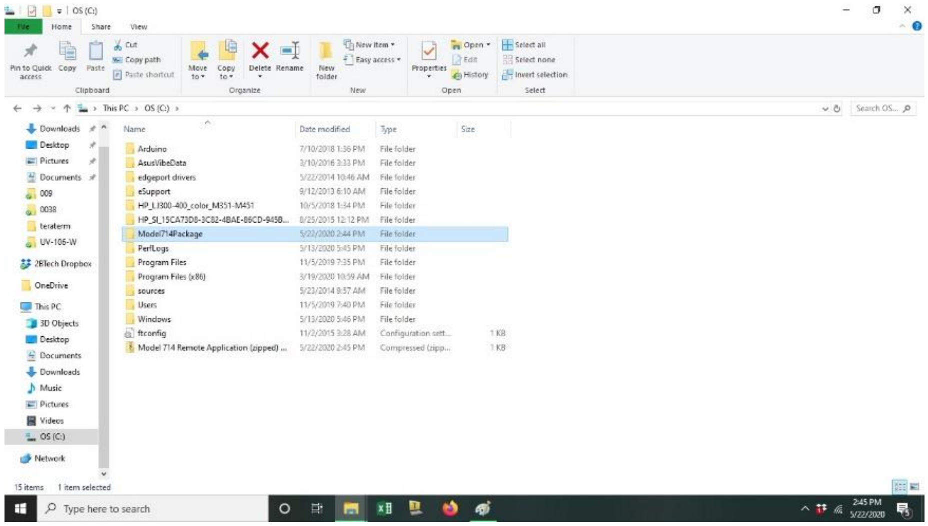
Detailed steps for using this screen and establishing remote operation using Modbus and the 2B Tech software tool are given in this Appendix. If you are unable to get the Modbus feature working after this tutorial, please contact 2B Technical Support.

Steps

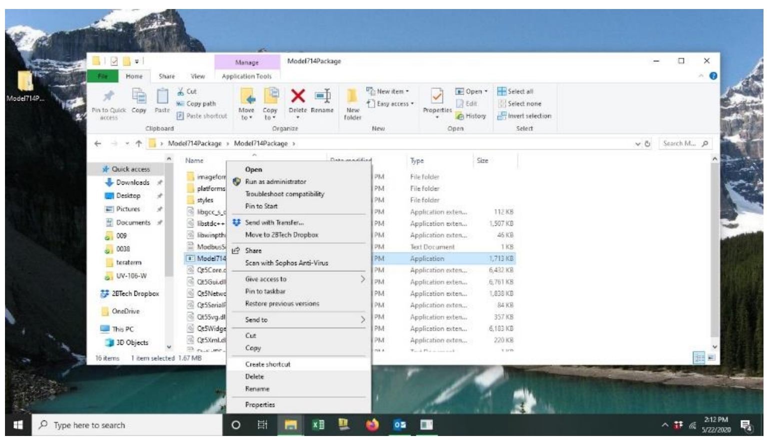
1) Download the Model 714 Remote Application Zipped folder: Go to https://2btech.io/downloads/, select the Software tab, and download the folder named "Model_714_remote_software_zipped_folder.zip" to the desired directory on your computer (in this example the folder is saved to the "C:" drive).

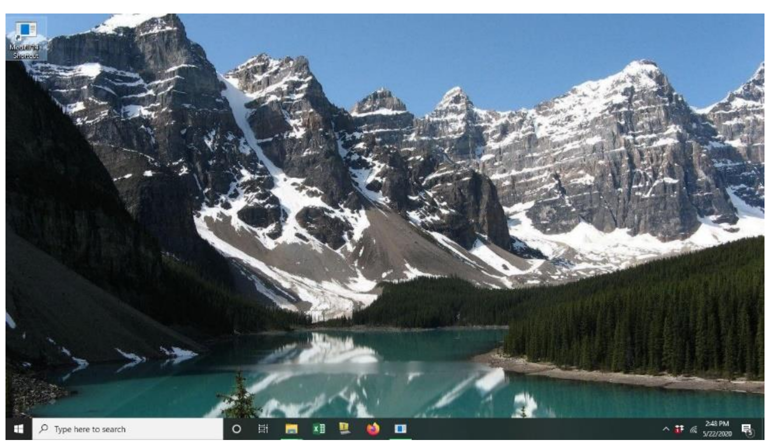


2) Extract the Model 714Package folder to the desired directory (in this example the folder is saved to the “C:” drive).

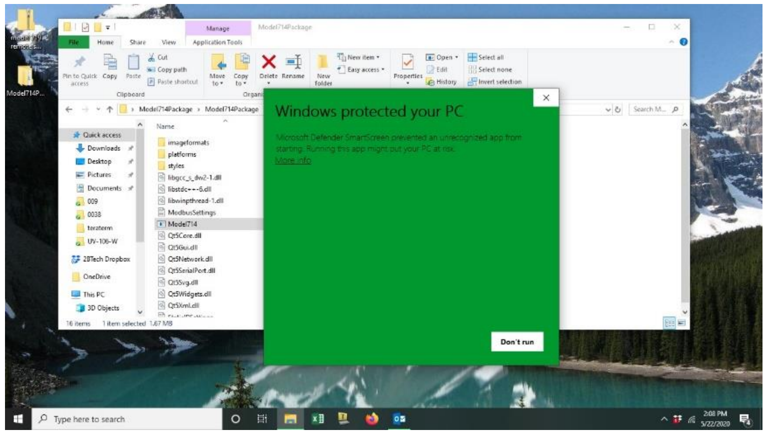


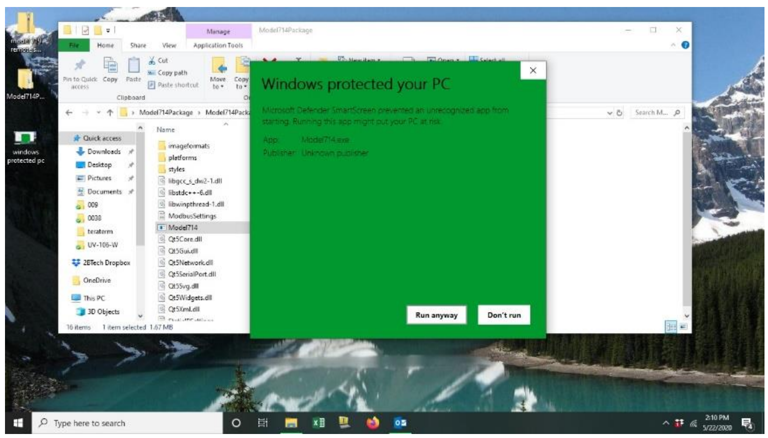
3) Create a Shortcut to the application and move it to the computer’s Desktop or other desired location.



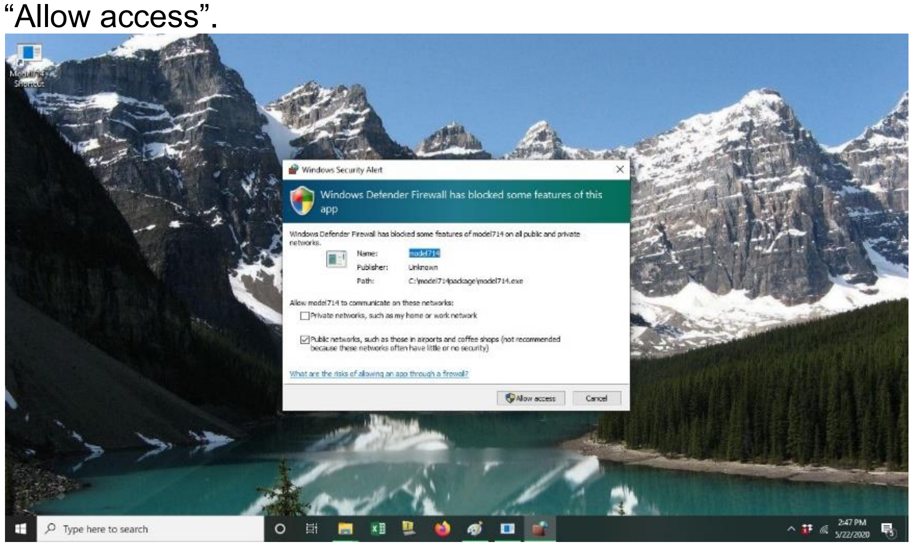


4) Click on the shortcut you created to open the application. If you are using Windows 10, Windows may try to block the application. Allow the application to run by clicking the “More Info” button then clicking the “Run anyway” button.

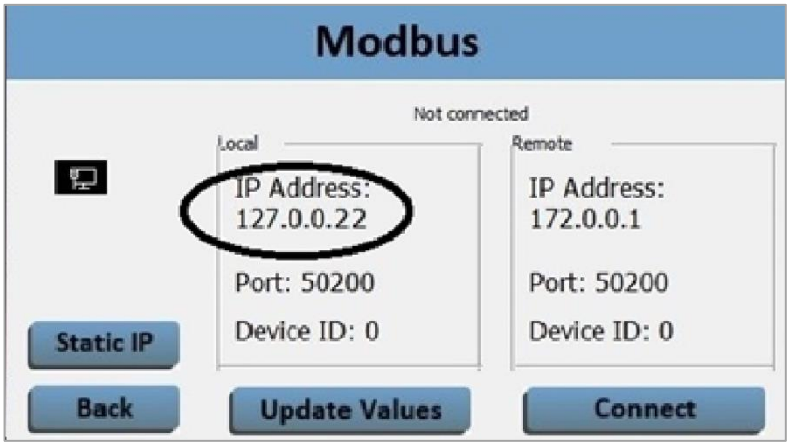




5) If you are using Windows 10, Windows Defender Firewall may also try to block the application. Allow the application to run by clicking both check boxes and then clicking “Allow access”.



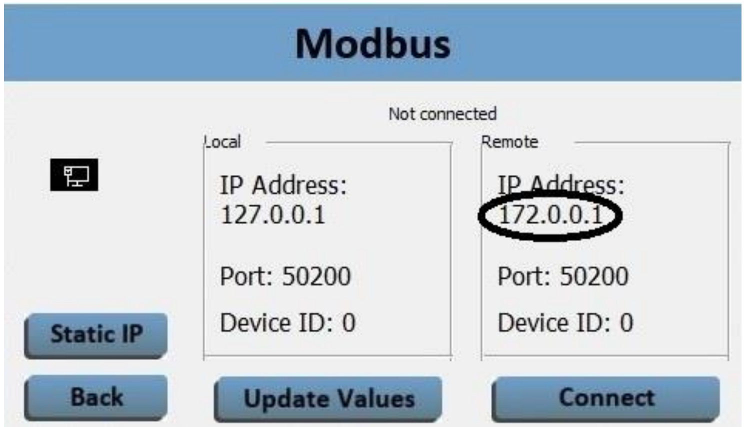
6) With the Model 714 powered OFF, plug an Ethernet cable connected to your network device into the instrument via the back panel. Next, power ON the instrument and click on the Modbus button. If the instrument is properly connected to your network, you will see a valid IP Address listed in the circled location below.



7) On your computer application then click on the Modbus screen.

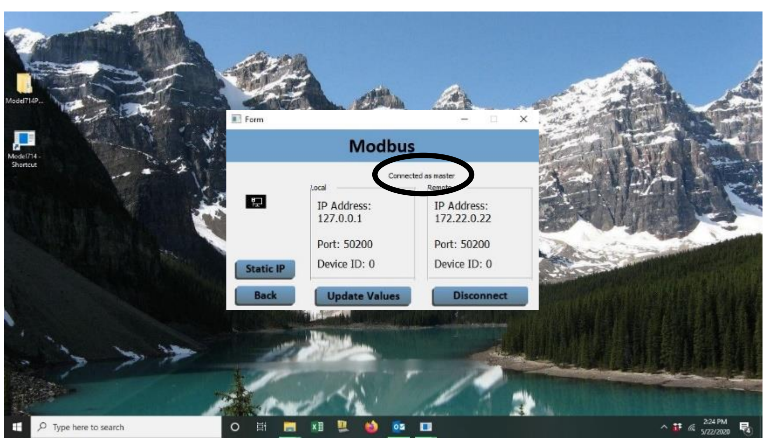
The next screen that appears is shown below:

8) On the application click on the IP Address listed under “Remote”.

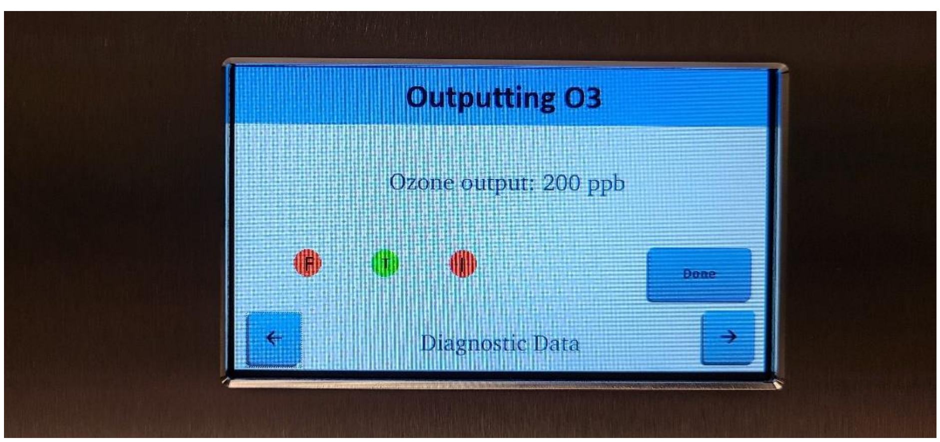


9) On the next screen that pops up in the application, enter the correct IP Address for your Model 714 instrument (which is listed under “Local”) then push “Apply”.

10) Click on the Connect button. You should now be connected to your Model 714 and ready for remote control. If you are properly connected, the Modbus screen on the application with say “Connected as Master”, and the Modbus screen on the instrument will say “Connected as Slave”.

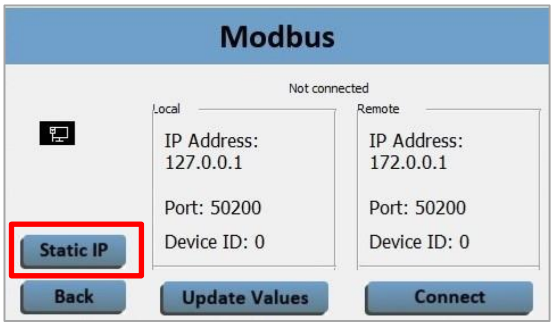


11) Click Back, then try to produce a gas to verify the application is properly controlling the Model 714. In this example, the O3 button was clicked on the application (controlling computer), then the ozone was set to 200 ppb, and then Start was pushed to produce the desired concentration of ozone. After the Please Wait screen, check your instrument's screen to verify that the Model 714 is producing the appropriate concentration of gas.



Setting Up a Static IP Address

Pressing the “Static IP” button of the Modbus Home Screen pulls up a screen that allows you to choose a set/unchanging (static) IP address for your instrument, provided that you know the correct subnet mask and gateway for your network. Although most users don't need static IP addresses, they normally matter more when external devices or websites need to remember your IP address. Click on the address areas and enter your Static IP/Gateway/Subnet mask values in the screens that pop up. Press “Apply” when ready, and then “Back” to return to the Modbus screen.



Warning: The static IP must be set to a valid IP address and not an IP address which is already assigned to another networked device, or it could cause errors/instrument failure. If you need assistance with this setting, consult your IT administrator or contact 2B Technical Support.