Roy Cooper
Governer
Elizabeth Biser
Secretary
Michael A. Abraczinskas
Director

NORTH CAROLINA
Environmental Quality

DAQ-08-002.1 Standard Operating Procedure (SOP)

Model T500U Nitrogen Dioxide (NO_2) Monitoring System

Electronics and Calibration Branch (ECB) Responsibilities

Revision 1.0

NORTH CAROLINA
Department of Environmental Quality

1.0 APPROVAL SIGN-OFF SHEET

I certify that I have read and approve of the contents of the Model T500U Nitrogen Dioxide (NO_2) Monitoring System Electronics and Calibration Branch (ECB) Responsibilities Standard Operating Procedure (SOP) with an effective date of June 17, 2022.

Director, Air Quality Division
Michael Abraczinskas
Signature: DocuSigned by: Michael Abraczinskas D5013FED0218423... Date: 6/16/2022

Ambient Monitoring Section Chief
Patrick Butler
Signature: DocuSigned by: Patrick Butler 4200A7E2D2A0420... Date: 6/16/2022

Laboratory Analysis Branch Supervisor
Jim Bowyer
Signature: DocuSigned by: Jim Bowyer C06804826C9B41D... Date: 6/16/2022

Projects and Procedures Branch Supervisor
Joette Steger
Signature: DocuSigned by: B278F8186CEC4DC... Date: 6/16/2022

Electronics and Calibration Branch Supervisor
Derrick House
Signature: DocuSigned by: Derrick House 2BFD2E5865E148E... Date: 6/16/2022

Primary SOP Author, Environmental Chemist
Kay Roberts
Signature: DocuSigned by: Kay Roberts BE4009EE242941D... Date: 6/16/2022

This document, and any revision hereto, is intended solely as a reference guide to assist Electronics and Calibration Branch (ECB) technicians in the setup, calibration, maintenance, operation, and the collection of data related to the North Carolina Division of Air Quality's (DAQ) Ambient Monitoring Program. This document is intended as a supplement to, and not a substitute for, the education, training, and experience in addition to other DAQ Reference Manuals, Quality Assurance Project Plans (QAPPs) and United States Environmental Protection Agency (EPA) Guidance. It is not a substitute for the extensive training and experience required for the efficient operation of ambient air monitoring equipment needed for scientifically valid data.

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2.0 SCOPE AND PURPOSE

The Electronics and Calibration Branch (ECB) of the Ambient Monitoring Section (AMS) of the Division of Air Quality (DAQ) is responsible for the selection, evaluation, and procurement of the nitrogen dioxide (NO_2) monitoring equipment and related accessories. Further ECB is responsible for the receipt, assembly, testing (at its facility) and installation of NO_2 monitors in the field, evaluation of the on-going performances of NO_2 monitors and related support equipment and scheduled and unscheduled maintenance of the system. As part of its responsibilities, ECB is also expected to maintain a sufficient inventory of monitors, support equipment and replacement parts to minimize loss of NO_2 ambient monitoring data.

Additionally, ECB staff is also responsible for procuring and maintaining dedicated traceable nitric oxide (NO) standards for the certification of all calibrators and for the independent accuracy auditing of the ambient air quality NO_2 monitors. These standards provide a direct link to established national standards and thus become the basis for the collection of the highest quality ambient monitoring NO_2 data in accordance with current procedures and existing federal regulations and guidelines. The continual accuracy audits performed by the ECB staff provide an ongoing evaluation of the NO_2 monitor's performance and site operator's adherence to DAQ approved operating procedures.

The ECB also maintains permanent records of all NO standards used in the calibration and auditing of monitors and sampling equipment used in support of DAQ monitoring activities. There are permanent records at ECB for each NO_2 monitor and samplers used to analyze ambient air quality in the State of North Carolina. Each major component of the NO_2 monitoring system, such as analyzer, calibrator, zero-air supply system, etc., is assigned a dedicated logbook. These logbook records include information relate to the performance evaluations and complete records detailing the instruments and equipment placed at each monitoring site. Both permanent records are updated continuously.

The ECB is also responsible for evaluating, developing, and recommending changes in the equipment and operating parameters to improve the quality of data collected and procedures used in the collection of data.

3.0 EQUIPMENT SELECTION AND PROCUREMENT

The North Carolina ambient air NO_2 monitoring system must meet or exceed the reference and equivalent method requirements in 40 Code of Federal Regulations (CFR) Part 53.1 and 40 CFR Part 58, Appendix C. The North Carolina ambient NO_2 monitoring system consists of the items listed in Section 3.1, below. Minor components are not specified but included by reference.

3.1 Equipment and Material List

- Teledyne Model T500U NO_2 Monitor
- Teledyne – Advanced Pollution Instrumentation (API) Model T700U Dynamic Gas Calibrator
- Teledyne – API Model 701 Zero Air Generator
- EPA Protocol NO gas cylinder
- Teflon™ Sampling Line
- Data Management System (e.g., Envidas Ultimate/Envista Air Resources Manager [ARM])
- Dedicated Windows compatible site computer
- Ethernet / modem connectivity
- Temperature controlled monitoring shelter

The ECB is responsible for ensuring that all components are compatible with the measurement of ambient levels of atmospheric NO_2. The ECB is responsible for the performance of a complete system evaluation prior to the field installation and ensuring the system is fully functional at the completion of the installation. On an ongoing basis as needed the ECB provides equipment and instrumentation maintenance and operational support to maximize the collection of the highest quality ambient air pollution data possible in accordance with accepted and approved procedures.

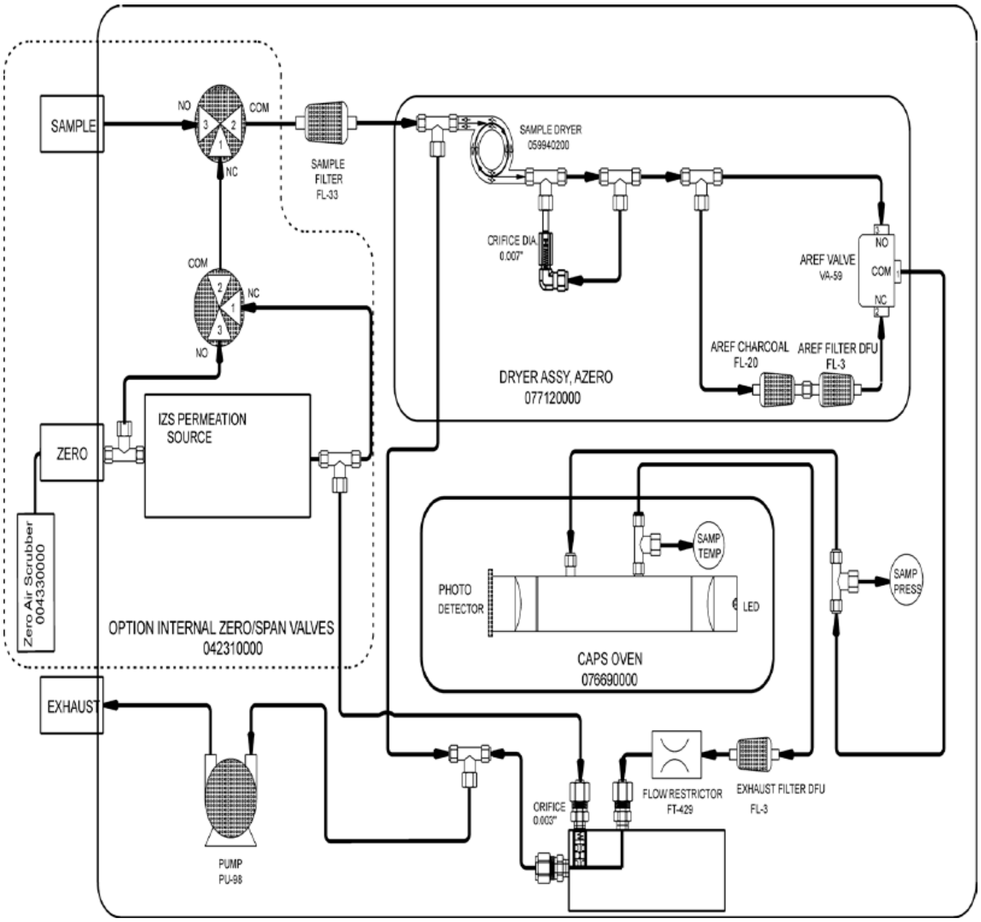
4.0 TELEDYNE MODEL T500U DESCRIPTION AND SPECIFICATIONS (from Manual)

The Teledyne Model T500U CAPS NO_2 Analyzer uses Cavity-Attenuated Phase-Shift (CAPS) spectroscopy to render true measurements of NO_2. The T500U operates as an optical absorption spectrometer, wherein the absorbance (lost light) is directly proportional to the path-length and the concentration of the absorbing gas (Beer-Lambert law), providing direct measurement of NO_2.

The T5000U uses few components: an optical cell, a pair of highly reflective spherical mirrors centered at 450 nanometers (strong NO_2 absorbance band), a light emitting diode (LED), and a vacuum photodiode detector behind the other mirror at the opposite end of the cell. The LED emits ultraviolet (UV) light into the cell; the light reflects back and forth between the two mirrors, building intensity and running a very long path length. The long path length extends the “time” or “life” of the photon, thus providing ample time to measure absorbance when NO_2 is present. Through the use of precisely timed data acquisition coupled with a proprietary algorithm the measured absorption is translated into a phase shift, from which the NO_2 concentration is calculated. The phase shift decreases as the NO_2 signal increases.

The CAPS method is faster than the traditional chemiluminescence method since the sample does not require cycling through a catalytic converter to calculate a difference measurement. Its speed also makes measurement more precise due to the ability to capture samples closer to “real time” before ventilation vortices (e.g., urban canyons and other traffic-related forces) can scatter the concentration.

Teledyne Model T500U NO_2 analyzer front panel display



T500U Pneumatics with Internal Zero Span Values Option

5.0 DESCRIPTION OF EQUIPMENT AND CHECKS

5.1 Teledyne T500U CAPS Monitor Testing

The CAPS monitor should be tested thoroughly before deployment at the monitoring site. This testing should include but is not limited to:

- Pre-calibration electronic adjustment
- Data Acquisition output adjustments
- Setting initial calibration factors and adjustments
- NO_2 operational test
  - Zero / Span / Precision Sequence
  - Calibration phases
  - Verification Sequence

Only the main components of the CAPS NO_2 monitoring system are discussed briefly here for their operation details. For further details of other NO_2 monitoring system related components refer to the "Model T500U CAPS NO_2 Analyzer, Operation Manual, 07834D DCN6998, 01 Jun 2015.

5.2 Teledyne T700U Dynamic Gas Calibrator

The T500U analyzer is calibrated using a T700U calibrator, which must have flows certified by ECB and traceable to a primary standard according to the requirements in the SOP for Teledyne API Gas Calibrators (DAQ-13-007.1 R2.0). The three mass flow controllers and ozone (O_3) photometer in the T700U "audit calibrator" is certified for twelve (12) months and the "field calibrator" certifications are good for twelve (12) months.

The calibrator is an accurate mass flow-controlled gas dilution system that meets the 40 CFR Part 50 requirements of ± 2 percent (%) accuracy. "NO" gas (usually in an inert gas such as nitrogen) from a National Institute of Standards and Technology (NIST) traceable protocol certified cylinder (of ± 2% accuracy or less) is blended with "zero-air" to provide the desired concentrations. From the known calibration of the three mass flow controllers, the exact concentration can be calculated. The typical dilution ratio of 100:1 to 1000:1 is generally used to generate appropriate concentrations.

The Model T700U dynamic gas calibrator supplies the required concentration of "NO" to perform Zero, Precision, Span Checks, Calibrations and Multi-point Verification by gas phase titration (GPT).

The principle of GPT is based on the rapid gas phase reaction between NO and O_3, which produces quantities of NO_2 as shown by the following equation:

$$NO + O_3 \longrightarrow NO_2 + O_2 + h\nu \text{ light}$$

It has been empirically determined that under controlled circumstances the NO-O_3 reaction is very efficient (<1% residual O_3), therefore the concentration of NO_2 resulting from the mixing of NO and O_3 can be precisely predicted and controlled as long as the following conditions are met:

- The amount of O_3 used in the mixture is known;

- The amount of NO used in the mixture is *at least* 10% greater than the amount of O_3 in the mixture;
- The volume of the mixing chamber is known; and
- The NO and O_3 flow rates (which determine the time the two gasses are in the mixing chamber) are low enough to give a residence time of the reactants in the mixing chamber of >2.75 parts per million minute.

Given the above conditions the amount of NO_2 being output by the T700U calibrator will be equal (at a 1:1 ratio) to the amount of O_3 added.

The O_3 flow rate of the T700U O_3 generator is a set fixed value (typically about 0.105 liters per minute) and the GPT chamber's volume is known. Thus, once the *total gas flow* requirements, the source concentration of NO, and the target concentration for the O_3 generator are entered into the calibrator's software, the T700U adjusts the NO flow rate and diluent (zero air) flow rate to create the appropriate NO_2 concentrations at the output.

5.3 Zero Air Generator and Certification

The Teledyne Series 701 Zero Air Generator is a pure air generator system that is capable of continuous delivery of up to 20 standard liters per minute (SLPM), 30 pounds per square inch (PSI) of dry, contaminant-free air. The air is suitable for use as: a zero-reference calibration gas, ultra-pure combustion air for flame ionization detector, and service air for pneumatically operated valves. The system can deliver air free from water vapor, particulates, sulfur dioxide (SO_2), hydrogen sulfide (H_2S), NO, NO_2, O_3, and carbon monoxide (CO). The delivery pressure should be set to 30 ± 2 pounds per square inch gauge (psig).

The Teledyne API Model 701 Zero Air Generator system is a source of clean, dry purged air. The 701 produces scrubbed air via an oil and diaphragm free pump which removes SO_2, NO, NO_2, O_3 and H_2S. Inlet air is pulled through a water trap and pre-cooler to remove moisture. The scrubbed air then passes through a regenerative dryer for final drying operations. Lastly, outlet air then passes through a filter to assure clean, dry, zero air with a dew point of less than -20 degrees Celsius (°C) independent of the inlet dew point.

5.3.1 Zero Air Generator Checks

Model 701 Zero Air Generator Checks:

- The pollution scrubber/converter media should be replaced annually by the ECB.
- Verify that the delivery pressure is set to 30 ± 2 psig. (If the delivery pressure is outside of the ± 2 psig range, adjust the pressure using the pressure adjust control knob.)
- Check the drain from the air generator for condensation.

5.3 EPA Protocol Gas Cylinder

The ECB shall procure certified EPA Protocol procedure G1 gas cylinders for the AMS. Primary "NO" standards are used when calibrating and during the nightly calibration checks, manual performance checks and internal performance audit of the CAPS NO_2 monitors. The primary "NO" standard used must be a certified, commercially prepared compressed gas standard with a certified accuracy of no worse than ± 2 percent.

Standards in the concentration range of approximately 10 parts per million are suitable choices for dilution to prepare low concentration mixtures.

- Extreme care must be taken to ensure compatibility for all components. Flow rates and concentration outputs must meet the requirements of the monitor.
- All EPA Protocol G1 calibration gas standards must be certified to be traceable to NIST Standard Reference Materials (SRM). A written statement of certification should be obtained which provides the following:
    1. A brief description of the certification procedure,
    2. Cylinder numbers,
    3. Cylinder gas concentrations,
    4. Replicate analysis data,
    5. Balance gas used
    6. NIST Standard Reference Material (SRM) numbers used as standards, and
    7. Last analysis date.

A copy of this certification should be available to users and will be kept on file in the ECB files

- The calibration gas standards will have their own certifications and will be considered as expired after 3 years.
- NO cylinder gas should not be used below a cylinder pressure of 500 psig as shown by the cylinder gas regulator.
- Each “NO” span gas cylinder shall contain the following minimum traceability information on a label or tag affixed to the cylinder or valve:
    1. The concentration of cylinder gas
    2. The last analysis date,
    3. The expiration date,
    4. The initials of the person performing the analysis,
    5. Cylinder number, and
    6. Balance gas.

5.4 Dedicated Site Computer and Modem with a Data Acquisition System

The ECB is responsible for providing dedicated instrumentation and an operating system compatible computer, Data Acquisition System (DAS), and a modem communication system. The operating system, data collection and storage capability, and remote communication system must be designed and acquired to maximize ease of data collection and transferring of date remotely. The entire data collection and communication system must be compatible with data retrieval programs operated by the database manager of the AMS. The ECB is encouraged to evaluate procedures, equipment, and systems to improve the data collection, data storage and data transferring capabilities of the North Carolina ambient monitoring system.

5.5 Temperature Controlled Monitoring Shelter

Each CAPS monitoring site shelter must be maintained in good repair. Each shelter must be temperature controlled within the EPA requirements of 5.0 – 40.0 °C with a daily fluctuation less than 2.1 °C standard deviation over a 24-hour period, if the CAPS is in its own shelter, or within 20.0 to 30.0 °C, if needed for other monitors. The temperature is monitored and recorded every minute through Envidas Ultimate via the Comet temperature probe/sensor. The back-up temperature recording system is the HOBO temperature sensor, which must be manually downloaded by the site operator at least once per month. Also, a certified mineral thermometer is kept at each site and serves as the primary standard to compare the Comet and HOBO values to assure accuracy. At installation, the ECB verifies the temperature with a standard calibrated and certified thermometer (Omega Resistance Temperature Detector [RTD]) and assures that the Comet and Hobo sensor displays agree with the standard. The hourly site temperature can be viewed by the site operator, Regional Monitoring Coordinator, and the Central Office Staff, and quality assurance is confirmed daily to assure no data will be lost because of the site temperature drifting. During the internal performance evaluation audits, the ECB staff again checks the temperature against a standard verified and certified thermometer. If drift or deviation occurs outside of the 5.0 – 40.0 °C range, then the data are disqualified, and a void code (AE) is submitted in the daily data by the operator / reviewer to invalidate any potential erroneous equipment operation because of a temperature drift. In addition, the monitoring shelter provides a secure hazard proof facility for both instrumentation and monitoring personnel.

6.0 INITIAL LABORATORY SET-UP

The ECB shall conduct operational tests after receipt and unpacking of each instrument. Following the Teledyne T500U Instruction Manual (Sections 3 - 10) and Section 3.0 (Equipment Checks) and Section 5.0 (Detailed Procedures) of North Carolina DAQ-08-001.2 Operator's SOP. The instrument must sample calibration gas at atmospheric pressure. After initial set-up and instrument checks, the instrument is either approved or returned to the manufacturer if any damage or problems that cannot be fixed are identified.

Upon approval of the tested unit, the unit shall be added to the fixed asset system. For each monitor, apply an inventory decal and complete an inventory load sheet showing the planned monitor location. Submit the inventory load sheet to the ECB supervisor.

Prior to deployment in the field, all instruments will undergo basic operational tests in the ECB lab, with results recorded in the instrument's logbook which is filed in the ECB lab. (See Section 5.0 of the T500U Instruction Manual) The instrument should be set-up with accompanying calibrator, zero air generator, cylinder and data logging system.

6.1 Inspection

Visually inspect the exterior of all items for damage. Remove the cover and inspect the electronics assembly and circuit boards for loose wires, cables, broken components, or other damage. Reconnect any loose components and if necessary, contact the manufacturer.

6.2 Initial Laboratory Set-up

Prior to deployment in the field, all instruments will undergo basic operational tests in the ECB lab with results recorded in the instruments logbook which is filed in the ECB lab.

6.2.1 Calibrator Set-up

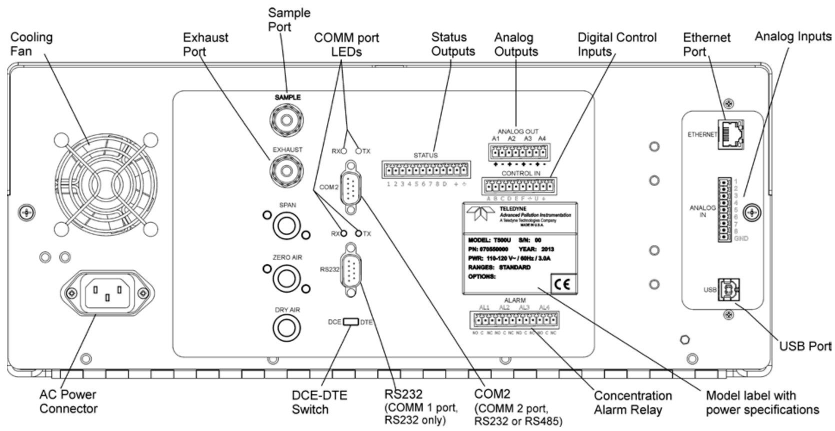
- Attach a vented Teflon™ tube (Fluorinated Ethylene Propylene [FEP] Teflon type only) from the fitting labeled "CalGas Out" on the rear panel of the calibrator to the "Span and Zero Air" input of the monitor. Connect a source of zero-air to the inlet port labeled "Diluent In". Connect the standard NO gas cylinder to the port labeled CYL 1.
- Assure the correct cylinder concentration is entered into the T700U. Bleed the cylinder.
- Plug in power cord and turn on power to instrument.

6.2.2 T500U Set-up

- Plug in power cord and turn on power to instrument.
- Connect the rear panel bulkhead labeled "Exhaust" to a suitable vent outside of the ECB lab or the monitoring room, *do not* vent to room air. (See diagram below.)
- Establish a connection and communication between the monitor, dedicated personal computer and the current DAS in use.
- Set the range of the monitor to 200 parts per billion (ppb).
- Using DAS software, create the necessary sequences and phases needed for operators to complete NO_2 operational test such as:
  - Zero / Span / Precision Sequences

- Calibration phases
- Verification Sequence

Each sequence and phase should be thoroughly tested prior to deployment of the NO_2 monitoring system at a site.



Teledyne Model T500U NO_2 analyzer rear panel display

6.3 Diagnostic Checks and Setting

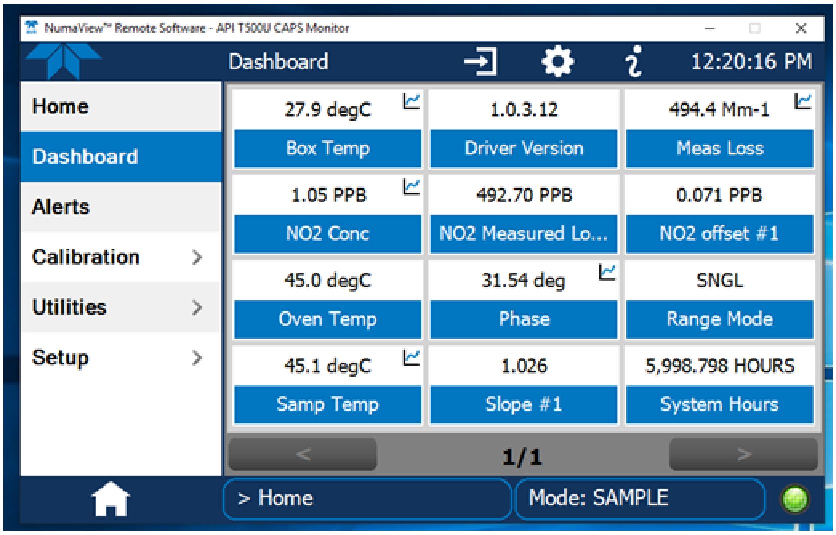
The following are diagnostic menu set points for the T500U NO_2 analyzer:

Parameter	**Expected Value**
Instrument Range/Concentration Units	200 PPB
Sample Pressure (Inches of mercury actual (In Hg A)	26 – 29 In Hg A
AREF_L (Mm-1)	< 650 Mm-1 [1] while running zero air
Box Temperature (°C)	Ambient ± 5.0 °C
Oven Temperature (°C)	45 ± 1 °C
Phase (degree of angle)	> 25 degrees while running zero air
NO_2 Measured Loss	< 650 Mm-1 [2] while running zero air
Range Mode	Single
Slope #1	-0.8 to 1.2, Optimal is 1.000
NO2 Offset #1	± 10.0 ppb, Optimal is 0.0 ppb

[1] Mm-1: Unit of measurement to express light absorption, expressed in MEGA (10^6) per meter

[2] Mm-1: Unit of measurement to express light absorption, expressed in ppb for NO_2

The diagnostic menu is best accessed via the NumaView Dashboard:



6.4 Monitor Filters

The T500U operates with an internal in-line sample filter along with an Auto Reference (AREF) filter assembly (backup particle filter and charcoal filter, which is an NO_2 gas scrubber). The manufacturer recommends these filters be changed annually or when the number of system hours is between 8750 and 9000 hours, or more frequently if needed. If the AREF is observed to be increasing significantly or approaching values near 1100 Mm-1, ECB should be notified as this is an indicator that the monitor requires maintenance. Annual filter changes should be scheduled with and completed by ECB personnel.

6.4 Leak and Flow Tests

Leak tests and sample flow checks should be performed periodically as part of the standard maintenance of the T500U and during internal performance audits.

6.4.1 Detailed Pressure Leak Check

Obtain a leak checker that has a small pump, shut-off valve, and pressure gauge to create an over-pressure condition, less than or equal to (≤) 10 psig. Alternatively, a tank of pressurized gas, with the two-stage regulator adjusted to ≤ 10 psig, a shutoff valve and a pressure gauge may be used. See Appendix A or Section 5.6.5 of the manual for step-by-step instructions for completing the pressure leak check.

6.4.2 Sample Flow Check

Sample flow checks are useful for monitoring the actual flow of the instrument. A decreasing sample flow may point to slowly clogging pneumatic paths, most likely the sample flow restrictor or the sample filter. See Appendix B or Section 5.6.5.2 of the manual for step-by-step instructions for completing the sample flow check.

7.0 ON-SITE INSTALLATION

The ECB will install the monitor and its support equipment. Acquiring access to a site, and approval of the site is the responsibility of the DAQ regional office and the Projects and Procedures Branch (PPB). Internet / wireless service and electrical power should be secured along with any needed permits, new wiring, etc., prior to installation of the monitor and support equipment. The site location must meet the applicable site requirements and be approved by the Chief, PPB Supervisor and EPA.

Electrical circuits should be dedicated and properly sized prior to the installation of any monitoring equipment and auxiliary components. The site should be inspected for integrity and safety. The ECB staff is responsible for the installation of all State of North Carolina operated Teledyne T500U monitoring systems.

The monitor should be replaced on an as needed basis: the calibrators require recertification every twelve (12) months and should be replaced prior to their certification expiration date or as needed. The EPA protocol gas cylinder should be replaced when the tank pressure is <500 psig or prior to the expiration date. All procedures should be documented on the 109 Form and all applicable site and instrument logbooks.

7.1 Monitoring Equipment Site Installation

Installation at the monitoring site includes:

- Teledyne Model T500U NO_2 monitor
- Teledyne Model T700U gas calibrator
- Teledyne Model 701 Zero Air Generator
- EPA Protocol NO gas cylinder
- Teflon™ tubing sample line with a Teflon™ inlet screen
- Data management system (e.g., Envidas Ultimate/Envista ARM)
- Dedicated Windows compatible site computer
- Ethernet / modem connectivity

The T500U monitor and auxiliary equipment must be installed in a building where room temperature extremes do not fall below 5.0 °C or exceed 40.0 °C. Check to ensure that the heater and air conditioner are in working order and do indeed maintain the desired temperature range, irrespective of the time of the day and season. Remove the air conditioner filter and clean if necessary. Check for any problems related to the building such as leaks, infestations, etc. Allow a warm-up period (~ 1 hour) for the monitor and auxiliary equipment after powering up before running any diagnostic test.

7.2 Siting Criteria

To ensure the uniform collection of air quality data various sample probe-siting criteria must be followed (see 40 CFR Part 58, Appendix E for details). These criteria are summarized below:

- The monitor probe shall be 2 to 15 meters above ground level.
- There must be unrestricted airflow 270 degrees (°) around the probe inlet or 180 ° if the probe inlet is on the side of a building.

- The probe must be at least 10 meters or further from the drip line of trees and optimally greater than or equal to 20 meters.
- The sample line should be as short as practical and should be Perfluoroalkoxy (PFA) Teflon™ or equivalent. The sample line is replaced every two years.

7.3 Site Computer, DAS and Modem

The ECB is responsible for providing instrumentation and an operating system compatible computer, DAS, and a modem communication system. The operating system, data collection and storage capability, and remote communication system must be designed and acquired to maximize ease of data collection and transferring of data remotely. The entire data collection and communication system must be compatible with data retrieval programs operated by the database manager of the AMS. The ECB is encouraged to evaluate procedures, equipment, and systems to improve the data collection, data storage, and data transferring capabilities of the North Carolina NO_2 monitoring system.

7.4 Leak and Flow Checks

Leak and sample flow checks should be performed as part of any standard maintenance of the T500U.

7.4.1 Detailed Pressure Leak Check

Obtain a leak checker that has a small pump, shut-off valve, and pressure gauge to create an over-pressure condition, ≤ 10 psig. Alternatively, a tank of pressurized gas, with the two-stage regulator adjusted to ≤ 10 psig, a shutoff valve and a pressure gauge may be used. See Appendix A or Section 5.6.5 of the manual for step-by-step instructions for completing the pressure leak check.

7.4.2 Sample Flow Check

Sample flow checks are useful for monitoring the actual flow of the instrument. The measured sample flow should be between 810 – 990 cubic centimeters per minute (cc/min). A decreasing sample flow may point to slowly clogging pneumatic paths, most likely the sample flow restrictor or the sample filter. See Appendix B or Section 5.6.5.2 of the manual for step-by-step instructions for completing the sample flow check.

7.5 Diagnostic Checks upon Installation

In order to ensure the monitoring equipment was not damaged in transit or during installation, ECB should initiate functionality testing for each sequence and each phase in a sequence. The installation functionality tests are intended to verify the instrument (and its associated components) have not suffered a catastrophic mishap from lab bench to field shelter. A functionality test is a test of the monitor, calibrator, cylinder, or zero air supply to evaluate whether the system is performing as expected. It may include running a zero and span or multiple points. This procedure ***is not*** a substitute for the initial calibration to be performed by the regional monitoring technician.

7.6 Method Detection Limit (MDL) Determination

The MDL refers to the lowest concentration of a substance that can be reliably determined by a given procedure and typically is not provided by the vendor. A site-specific MDL establishes an estimate based on the routine operation (and conditions) of the specific instrument in the network and provides a meaningful evaluation of data as it is aggregated across the precursor gas network. By establishing site specific MDLs, values less than the MDL can be flagged which would allow data users a more informed decision on the use of that data.

The MDL is determined by a series of low concentration standards and the average blank background. These aspects are input into the MDL procedure to establish the lowest concentration that is distinguishable from background with 99% confidence. See DAQ-15-007.1 for detailed procedures for MDL determination for continuous gaseous criteria pollutant methods.

Currently the DAQ does not perform annual method detection limit, or MDL studies using the CAPS monitor but relies on the manufacturer's specification for instrument detection limit, or IDL, or something similar.

8.0 ROUTINE MAINTENANCE

8.1 Teledyne T500U NO2 Analyzer

Periodic maintenance procedures should be performed when necessary to ensure proper operation of the analyzer. Maintenance includes preventive, routine and corrective tasks. The ECB is expected to be entirely responsible for the corrective maintenance issues and to assist with preventative and routine maintenance that may fall outside the regions' comfort levels or capabilities. All maintenance activities must be documented by ECB personnel in the monitor's maintenance logbook. Step-by-step procedures for all maintenance activities should be followed as presented by the manufacturer in the instrument's operation manual.

Items requiring maintenance by ECB include but are not limited to:

- Replacing the sample filter (annually or when the number of system hours is between 8750 and 9000 hours;
- Replacing the AREF filter and charcoal filter (annually);
- Leak test and flow checks (performed after annual filter change and during performance evaluations);
- Replacing the internal pump; and
- Replacing the sample flow restrictor (every two years, when sample flow drops below 810 cc/min or when the monitor response to changes in sample, zero or span gas become too slow)

8.2 Teledyne Model T700U Calibrator

Periodic maintenance and/or adjustment of the calibrator is required to ensure proper operation. In addition to mass flow controller and O_3 photometer re-certifications, which occur every 12 months, the following maintenance activities are performed only when the calibrator malfunctions as determined by the site operator or ECB. Items requiring ECB maintenance are:

- Leak checking;
- Solenoid replacement and testing to determine where failures occurred;
- Circuit board replacement;
- Mass flow controller replacement;
- Internal adjustments; and
- Certification of mass flow controllers (reference SOP DAQ-13-007.1 for more details).

8.3 Model 701 Zero Air Generator Checks

Periodic maintenance and/or adjustment for the zero air generator is required to ensure proper operation. The ECB shall re-certify the zero-air system once per year by:

- Verify the pressure gauge on the zero air generator is reading 30 ± 2 psig.
- Replacing chemicals that have been depleted (reference SOP 2.3.5 for more details).

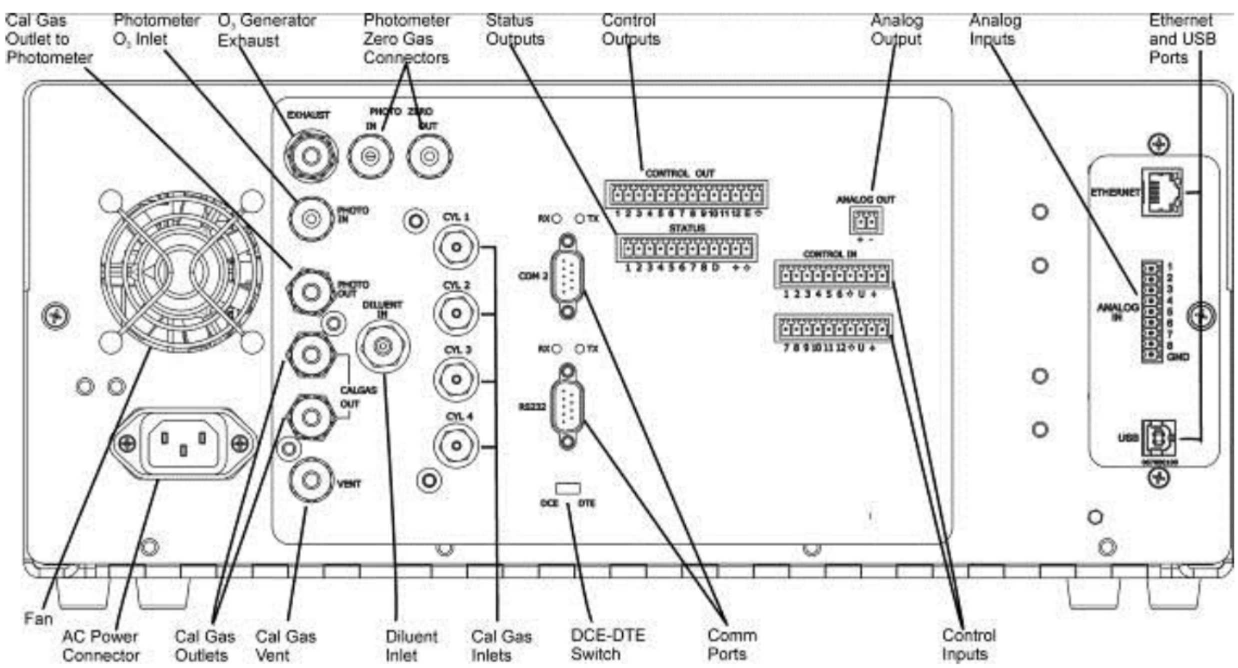
9.0 ACCURACY AUDITS

Each analyzer must be audited by the ECB annually (that is once each calendar year and every 365 days) unless specified otherwise in the applicable QAPP. The audit must be performed using a calibrator and gas cylinder standard that is different from the standard and calibrator used for routine calibration and 1-point QC checks. The audit calibrator must be certified against the primary flow standard every 12 months. The auditor must not be the operator who conducts the routine monitoring, calibrations, and analysis. No adjustments should be made prior to completing the audit. The monitor must operate in its normal sampling mode, and the concentration of the audit test gas and the concentration indicated by the analyzer is used to assess the accuracy of the monitoring data. Several routine items that shall be included in the audit are:

- Security of the building;
- Site / building temperature (document NIST on the audit form); and
- Condition of the sample line, probe, and funnel (replace as needed) checked during each audit.

9.1 Audit Procedures

1. Allow the audit calibrator to equilibrate at least one-half hour before challenging the monitor.
2. Using DAS software set the NO_2 channel flag to "Audit".
3. Connect the audit calibrator to the monitor and the zero-air system to the audit calibrator as per manufacturer's instructions (see Figure 3-15, page 45 of the instruction manual).



Rear Panel of the T700 Calibrator

4. Secure a separate certified protocol cylinder of NO gas, connect and purge the regulator. Check for leaks.
5. Verify the audit calibrators' certification date recorded on the front panel label.
6. Using the AQ-121 form record site and audit device information as listed for each piece of equipment and gas cylinder.

7. Perform audit – at least 3 concentrations at Level 1, 5 and 6 and zero must be introduced to the analyzer by sequentially activating a GPTPS (Gas Phase Titration Pre-Set) and then GPT with the NO concentration set 10% greater than O_3 concentration. The generated O_3 ppb concentration is equivalent to the resulting actual concentration of NO_2.
8. Complete an audit form (AQ-121) using the minute data collected during each audit point, recording the audit concentrations and five 1-minute averages.
9. The audit results should be within ± 15 % of expected.
10. When complete, disconnect the audit calibrator, zero air system and audit cylinder. Reconnect site calibrator, zero air generator, and site cylinder as found upon arrival.
11. Set the NO_2 channel to "OK" and log out of site computer.

If the audit results are suspicious or unacceptable, the ECB supervisor or PPB staff will initiate an investigation of the problem and notify the responsible Regional Coordinator of the issue. Investigation of the audit results may include:

- Examination of the audit equipment;
- Review of the precision zero span records (both auto and manual); and
- Confirming the audit results with a follow-up audit.

The NO_2 performance audit Is a "Pass-Fail" evaluation. The criteria for evaluating the acceptance or failure of the NO_2 monitoring site are listed in the table below:

Nitrogen Dioxide Performance Audit Acceptance Limits

Audit Level	NO2 Audit Concentration	Site Monitor
Zero	0	< ± 1.5 ppb
Level 1	2.5	< ± 1.5 ppb or < ± 15.1 %
Level 5	25	< ± 15.1 %
Level 6	100	< ± 15.1 %

10.0REVISION HISTORY

1. Modified Cover Page Header to current management
2. Changed temperature range of monitor to 5.0 – 40.0 °C
3. Removed reference to Background Monitoring QAPP
4. Added reference to updated T500U manual (05 Sep 2019)
5. Added reference for Alicat Mass Flow Meter
6. Added Appendices A (Leak Check Procedure)
7. Added Appendices B (Sample Flow Check Procedure)
8. Editorial changes throughout

11.0REFERENCES

1. Model T500U CAPS NO2 Analyzer Operation Manual
2. NumaView™ Software Addendum to T-Series Analyzer Manual
3. Model T500U CAPS NO2 Analyzer with NumaView Software
4. Alicat Mass Flow Meter Manual

12.0APPENDICES

1. Appendix A Detailed Instructions for Leak Check Procedure
2. Appendix B Detailed Instructions for Flow Check Procedure
3. Appendix C Tare Instruction for Alicat Mass Flow Meter

Appendix A Detailed Instructions from Manual for Leak Check Procedure

5.6.5. Checking for Pneumatic Leaks

This section covers a simple leak check and a detailed leak check.

> **CAUTION - TECHNICAL INFORMATION**
> **Do not exceed 15 psi when pressurizing the system during either Simple or Detailed checks.**

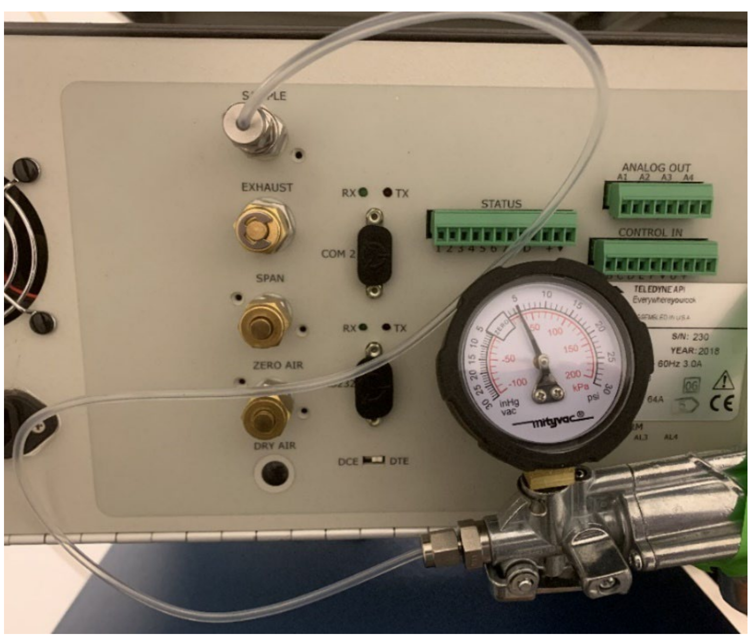
5.6.5.1. DETAILED PRESSURE LEAK CHECK

Obtain a leak checker that contains a small pump, shut-off valve, and pressure gauge to create both over-pressure and vacuum. Alternatively, a tank of pressurized gas, with the two-stage regulator adjusted to ≤ 10 psi, a shutoff valve and a pressure gauge may be used.

> **ATTENTION**
> **COULD DAMAGE INSTRUMENT AND VOID WARRANTY**
> **Once tube fittings have been wetted with soap solution under a pressurized system, do not apply or reapply vacuum as this will cause soap solution to be sucked into the instrument, contaminating inside surfaces.**

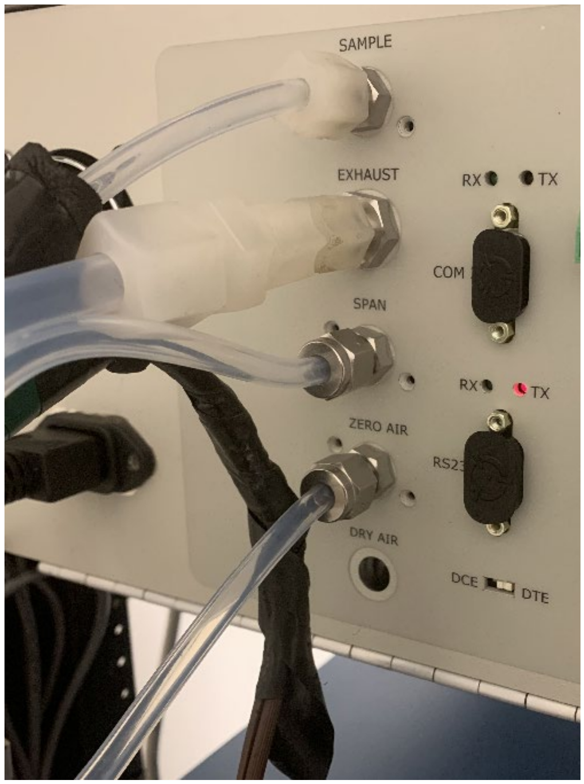
1. Turn OFF power to the instrument and remove the instrument cover.
2. Install a leak checker on the sample inlet at the rear panel.
3. Cap rear panel ports and cap the pump port.
   - If zero/span valves are installed, disconnect the tubing from the zero and span gas ports and cap the ports (Figure 2-2).
4. Pressurize the instrument with the leak checker, allowing enough time to fully pressurize the instrument.
   - Do not exceed 10 psi pressure.

NOTE: If the leak check fails notify ECB immediately



Rear of Analyzer during Leak Check

5. The leak-down rate of the indicated pressure should be less than 1 psi in 5 minutes after the pressure is turned off.
6. If the leak check passes, reconnect the sample line and pump lines and replace the cover. Restart the analyzer.



Rear of Analyzer before and after Leak check

Appendix B Detailed Instructions from Manual for Sample Flow Check

5.6.5.2. PERFORMING A SAMPLE FLOW CHECK

Important

IMPACT ON READINGS OR DATA

Use an external calibrated flow meter capable of measuring flows between 0 and 1000 cm³/min to measure the gas flow rate though the analyzer.

Sample flow checks are useful for monitoring the actual flow of the instrument. A decreasing sample flow may point to slowly clogging pneumatic paths, most likely the sample flow restrictor or the sample filter. To perform a sample flow check:

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a flow meter to the sample inlet port on the rear panel.
   - Ensure that the inlet to the flow meter is at atmospheric pressure.
3. Check that the sample flow measured with the external flow meter is within specification.
4. If sample flow is out of specification, first check for kinks in the tubing, then check for leaks.
5. Once kinks and leaks are ruled out, first replace the sample flow restrictor, and if the sample flow is still out of specification, replace the sample filter.
6. If flow is still out of spec, call Technical Support.

Appendix C Tare Instruction for Alicat Mass Flow Meter

M Series Mass Flow Meter Operation

The M Series Mass Flow Meter provides a multitude of useful flow data in one simple, rugged device. The M Series can have several screen "modes" depending on how the device is ordered. All M Series meters have a default Main Mode, Select Menu Mode, a Gas Select Mode (the Gas Select Mode may not be available on meters calibrated for a custom gas or blend), a Communication Select Mode, Manufacturer Data Mode and a Miscellaneous Mode. In addition, your device may have been ordered with the optional Totalizing Mode (page 38). The device defaults to Main Mode as soon as power is applied to the meter.

Main Mode

The main mode screen defaults on power up with the mass flow on the primary display. The following parameters are displayed in the main mode as shown in Figure 6:

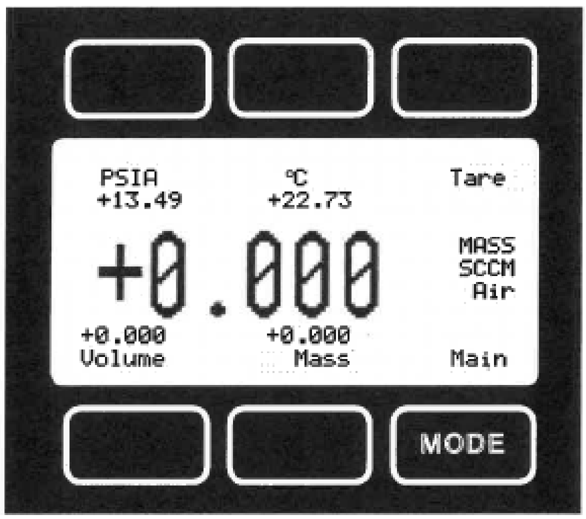


Figure 6. Main Mode Display, M Series Flow Meter

The "MODE" button in the lower right hand corner toggles the display between the Main display and the Select Menu display.

Tare – Pushing the dynamically labeled "Tare" button in the upper right hand corner tares the flow meter and provides it with a reference point for zero flow. This is a simple but important step in obtaining accurate measurements. It is good practice to "zero" the flow meter each time it is powered up. If the flow reading varies significantly from zero after an initial tare, give the unit a minute or so to warm up and re-zero it.

If possible, zero the unit near the expected operating pressure by positively blocking the flow downstream of the flow meter prior to pushing the "Tare" button. Zeroing the unit while there is any flow will directly affect the accuracy by providing a false zero point. If in doubt about whether a zero flow condition exists, remove the unit from the line and positively block both ports before pressing the "Tare" button. If the unit reads a significant negative value when removed from the line and blocked, it is a good indication that it was given a false zero. It is better to zero the unit at atmospheric pressure and a confirmed no flow conditions than to give it a false zero under line pressure.