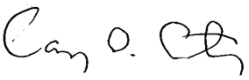
FORSYTH COUNTY OFFICE OF ENVIRONMENTAL ASSISTANCE AND PROTECTION

STANDARD OPERATING PROCEDURE (SOP)

Sulfur Dioxide (SO_2)

Signature Page

By the signatures below, the Forsyth County Office of Environmental Assistance and Protection (FCEAP) certifies that the information contained in the following Standard Operating Procedure (SOP) is complete and fully implemented as the official guidance for our Office. However, due to circumstances that may arise during the sampling year, some practices may change. If a change occurs, a notification of change and a request for approval will be submitted to EPA Region 4 at that time.

Name: Cary Gentry Signature:  Date: 6/30/21

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Name: Minor Barnette Signature:  Date: 6/30/21

Title: FCEAP Director

Name: _____ Signature: _____ Date: / /

Title:

Name: _____ Signature: _____ Date: / /

Title:

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REVISION	DATE	CHANGES TO SOP
2	06/2019	Replaced Agilaire EDAS procedures with Agilaire AV-Trend procedures. Updated figures to match current equipment/spreadsheets. In section 3.6.3, changed sample filter inspection every site visit to sample line inspection every site visit. Added section 3.8.2.19 to outline procedure for downloading and saving instrument long records via Thermo iPort. Various minor revisions…see the SOP Revision 2 Change List document on the shared drive for details.
2.1	09/2019	Replaced AV-Trend language with AirVision language. Re-worked section 3.9 by adding a subsection that outlines the quality assurance procedure for 5-minute average SO_2 data. Updated required audit levels. Updated shared drive file path for instrument test worksheet and added instructions to plug instrument into an uninterruptible power supply, if possible.
3	12/2020	A Teledyne API T100U has replaced a Thermo Scientific 43i-TLE as the primary monitor. SOP has been updated to reflect this.
3.1	6/2021	Minor edit from annual QA doc review.
3.2	06/2022	Minor formatting and language edits from annual QA doc review. Updated data logger model from ESC 8832 to ESC Spectrum 8864. Removed mention of AV-Trend as this is no longer used. Replaced HyperTerminal procedure with PuTTY.

STANDARD OPERATING PROCEDURES FOR SULFUR DIOXIDE (SO_2)

Forsyth County Office of Environmental Assistance and Protection

3.0 Introduction

All equipment, chemicals, field operating procedures, and laboratory operating procedures for the continuous measurement of sulfur dioxide in the atmosphere using the pulsed fluorescence method are selected and performed according to (equivalent method) EQSA-0495-100 requirements. The following procedure manual is to be used as a supplement to the Code of Federal Regulations (CFR). Siting and various quality assurance (QA) procedures are followed in accordance with the Code of Federal Regulation Title 40 Part 50, Part 58 and EPA-454/B-13-003: Quality Assurance Handbook for Air Pollution Measurement Systems: Volume II Ambient Air Quality Monitoring Program.

This "Standard Operating Procedure" (SOP) will provide guidance for the monitoring of SO_2 using the ESC Spectrum 8864 Data Controller, Teledyne Advanced Pollution Instrumentation Inc. (Teledyne API) T100U Analyzer (Equivalent Method Number: EQSA-0495-100), Teledyne API T700U Dynamic Dilution Calibrator and a Teledyne API T701H Zero Air Generator.

The following formatting conventions will be followed throughout the SOP:

Interactive button on instrument screen:	**EXAMPLE**
Button/checkbox label in computer software:	**Example**
Diagnostic variable on analyzer/calibrator screen:	EXAMPLE

3.1 Procurement of Calibration Standards, Zero Gases, and Monitoring Instrumentation

3.1.1 General Information

3.1.1.1 Calibration standards include known concentrations of sulfur dioxide used for calibrations, audits, precision checks, and span checks.

3.1.1.2 All calibration, audit, precision, and gas standards must be traceable to National Institute of Standards and Technology (NIST) Standard Reference Materials (SRM) or NIST/EPA approved commercially available certified Reference Materials (CRM); using EPA approved traceability Protocols. A "Certificate of Analysis" must accompany each gas certified to EPA Protocols. A copy of these certificates should be kept in the office by the QA staff member who oversees gas cylinder renewals. The Teledyne API T700U calibrator's Mass Flow Controllers (MFCs) must have their flow certified every 6 months and when necessary, calibrated to match a NIST traceable flow device. The flow certification process is covered in the Calibrator Operation SOP found in Section 12.

3.1.1.3 Zero Gases are not certified to NIST standards but must meet specific requirements (See section 3.1.2.7) and operate in good working order.

3.1.1.4 Monitoring instrumentation must be an EPA reference or equivalent method meeting the requirements specified in 40 CFR Part 53 and 40 CFR Part 58 Appendix C.

3.1.2 Specifications for Calibration Standards, Zero Gases and Monitoring Instrumentation

3.1.2.1 Calibration gases to be diluted by means of a dynamic calibration system shall contain a known concentration of SO_2 in nitrogen. The cylinder can also contain nitric oxide and carbon monoxide.

3.1.2.2 The specific concentration of a calibration standard must be certified according to EPA traceability protocol. This must be stated on the purchase order when ordering calibration gases.

3.1.2.3 Sulfur dioxide concentrations to be diluted by means of a dynamic calibration system are to be within the range of 6 - 60 ppm SO_2 in nitrogen. FCEAP runs on a 0-100 ppb range. SO_2 hourly levels at the Hattie Avenue site rarely exceed 10 ppb and the two highest hourly averages we have seen since 2010 are 93 ppb on 3/13/2010 and 31.9 ppb on 3/29/2012. Therefore, we feel comfortable operating in the 0-100 ppb range. The lower range also gives finer definition to the low ambient values we typically measure.

3.1.2.4 SO_2 concentrations used for multi-point verifications/calibrations are produced by a verified calibration standard calibrator. Multi-point calibrations consist of a zero and 4 upscale points, the highest being a concentration of 80%-90% of the calibration scale range of the analyzer. The points are listed below.

Point 1: 0 ppb SO2 (Zero)

Point 2: 90 ppb SO2 (Span)

Point 3: 70 ppb SO2 (Mid-point)

Point 4: 40 ppb SO2 (Precision)

Point 5: 30 ppb SO2 (Low-point)

3.1.2.5 Audit concentrations must be produced by a system independent of the routine calibration system. A minimum of zero and three upscale points should be chosen to bracket 80% of the ambient data if at all possible. The points chosen must be in the following ranges, contained within the operational range that the FCEAP uses, which is 0-100 ppb. For FCEAP, two of the points chosen must be in the two required levels in the following ranges. Additional points can be added and run in any other level.

Level 1: 0.3-2.9 ppb SO_2 (required)

Level 2: 3.0-4.9 ppb SO_2

Level 3: 5.0-7.9 ppb SO_2

Level 4: 8.0-19.9 ppb SO_2

Level 5: 20.0-49.9 ppb SO_2

Level 6: 50.0-99.9 ppb SO_2 (required)

Level 7: 100.0-149.9 ppb SO_2 (Over FCEAP range)

Level 8: 150.0-259.9 ppb SO_2 (Over FCEAP range)

Level 9: 260.0-799.9 ppb SO_2 (Over FCEAP range)

Level 10: 800.0-1000.0 ppb SO_2 (Over FCEAP range)

Audit standards must be independent of the standards used for calibrations/verifications.

3.1.2.6 Sulfur dioxide concentrations used to perform precision checks must be in the range of 5-80 ppb SO_2.

3.1.2.7 Zero air to be used for calibrations, 90-day verifications, bi-weekly Zero/Span/Precision (ZSP) checks, nightly auto-calibrations, and audits must be free of contaminants, which will cause a detectable response on the SO_2 analyzer. The zero air should contain < 1.0 ppb of SO_2. If using a Teledyne API T701H zero air generator, the regenerative dryer should be filled with molecular sieve and the scrubber columns should be filled with Purafil and activated charcoal. A custom zero air generator can be used as long as a series of drierite columns or similar containers loaded with Purafil, silica gel, charcoal, hopcalite, and molecular sieve are used to scrub compressed air. In either case, the compressed air is routed through a 5 μm Teflon® filter before entering the calibrator.

Audit zero air is provided by a pump (diaphragm or oil-less piston) moving air through a series of scrubbers. The audit zero air is dried with silica gel, then scrubbed through Purafil and charcoal. The audit zero air is finally filtered through a 5 μm particulate filter. The audit zero air generator is never connected to the site calibrator.

3.1.3 Gas Standard and Initial Instrument Checks

3.1.3.1 Upon receipt of gases, check to ensure that a certificate of analysis is included with each cylinder.

3.1.3.2 Check the concentration on the cylinder label against the concentration on the certificate for each cylinder.

3.1.3.3 Thoroughly check each gas cylinder to ensure that all specifications have been met by running a ZSP check on an up to date, calibrated, analyzer. Reject any gases that do not pass specifications and return them to the supplier.

3.1.3.4 Upon receipt of cylinder gas standards the following information must be clearly marked on the cylinder by affixing a tag to the cylinder:

ID Reference Number

Cylinder contents

Cylinder concentrations

Analysis and Expiration date

Cylinder usage (i.e. - cal, span, precision, etc.)

Cylinder standards must not be used after the expiration date until recertified.

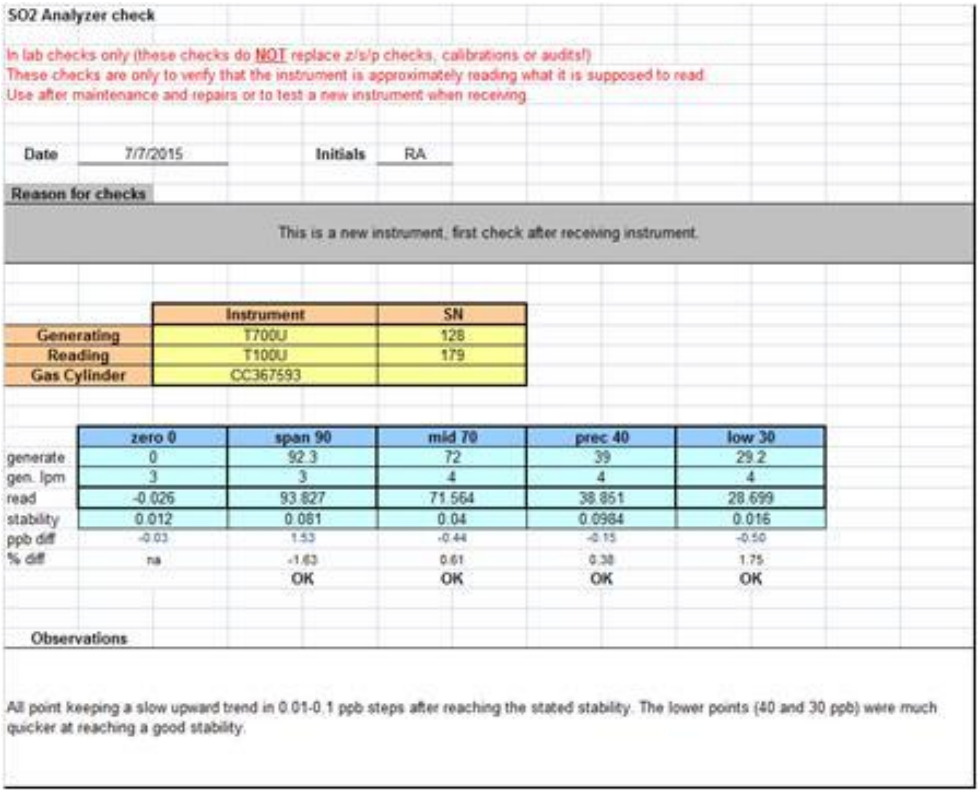
3.1.3.5 SO_2 instrumentation must meet the requirements of the Technical Assistance Document for Precursor Gas Measurements (EPA -454/R-05-003, September 2005) or be an equivalent method as described in 40 CFR, Part 53. A list of EPA designated reference and equivalent methods is available from EPA's AMTIC website: https://www.epa.gov/amtic/air-monitoring-methods-criteria-pollutants.

An EPA designation sticker must be affixed to the instrument.

A factory manual must accompany the instrument.

A record or log (hardcopy) of all maintenance done to the analyzer must be kept in the pocket on top of the analyzer. Update digital copy on SharePoint as well.

Instrument must be tested and performance documented in the FCEAP master Excel spreadsheet containing all check records for network equipment. This document is located in the Repair Supplies and Logs\Instruments checks shared directory and is called SO2 Analyzer In-Lab checks.xls. Below is the layout:



SO2 Analyzer check

In lab checks only (these checks do NOT replace z/s/p checks, calibrations or audits!)
These checks are only to verify that the instrument is approximately reading what it is supposed to read
Use after maintenance and repairs or to test a new instrument when receiving

Date 7/7/2015 Initials RA

Reason for checks

This is a new instrument, first check after receiving instrument.

	Instrument	SN
Generating	T700U	128
Reading	T100U	179
Gas Cylinder	CC367593	

	zero 0	span 90	mid 70	prec 40	low 30
generate	0	92.3	72	39	29.2
gen. lpm	3	3	4	4	4
read	-0.026	93.827	71.564	38.851	28.699
stability	0.012	0.081	0.04	0.0984	0.016
ppb diff	-0.03	1.53	-0.44	-0.15	-0.50
% diff	na	-1.63	0.61	0.38	1.75
		OK	OK	OK	OK

Observations

All point keeping a slow upward trend in 0.01-0.1 ppb steps after reaching the stated stability. The lower points (40 and 30 ppb) were much quicker at reaching a good stability.

Figure 1: In-lab checks Excel worksheet

After calibration, if 4% error tolerances are not met, inform the Program Manager and contact the manufacturer.

3.2 Initial Monitor Setup

3.2.1 Site Requirements

To ensure the uniform collection of air quality data, various siting criteria must be followed. 40 CFR 58 Appendix E outline these criteria. The criteria are summarized below for neighborhood spatial scales for SO_2.

3.2.1.1 The sample inlet must be located 2-15 meters above ground and a distance from the supporting structure > 1 meter.

3.2.1.2 The probe inlet must be > 10 meters from the drip line of trees that are located between the urban city core and along the predominant summer daytime wind direction.

3.2.1.3 The distance from the probe inlet to any obstacles such as buildings must be at least twice the height the obstacle protrudes above the probe inlet.

3.2.1.4 There must be unrestricted airflow 270° around the inlet probe, or 180° if the probe is on the side of a building. The 270° arc must include the predominant wind direction, and for the Winston-Salem area, the primary wind direction is from the SW.

3.2.1.5 The sample line should be as short as practical and should be constructed of FEP Teflon®.

3.2.1.6 If the above siting criteria cannot be followed, it must be thoroughly documented and a waiver requested from US EPA Region 4. A complete site evaluation including all dimensions, pictures, maps, and the monitoring objective should be prepared as the site is being set up. This documentation should be maintained in the annual monitoring network plan.

3.2.2 Monitor Installation – Teledyne API T100U SO2 Analyzer

3.2.2.1 The analyzer should be placed on a sturdy table or in an appropriately sized instrument rack.

3.2.2.2 The table or rack should be as vibration free as possible.

Figure 2: Site temperature device

3.2.2.3 The analyzer must operate within the temperature range of 5 - 40°C. FCEAP will operate the instrument in 20 - 30°C range.

3.2.2.4 A verified thermometer should be installed near the analyzer to observe temperature readings to insure that temperature criteria are met. It is polled and checked along with other data to make sure it falls within limits. Identify and correct problem if it is not within limits. The thermometer will be verified semi-annually to ensure proper function (Fig. 2).

3.2.2.5 Connect ambient air to be measured to the bulkhead connector labeled "SAMPLE" on the rear panel of the instrument. Care should be taken to see that dirty, wet, or incompatible materials in the sample lines do not contaminate the sample. Teflon® tubing with an OD of 1/4" and a minimum ID of 1/8" is required for all sample lines. The length of the tubing should be held to a minimum. Connect Teflon® tubing with an OD of 1/4" and a minimum ID of 1/8" from the port labeled "Exhaust" on the back of the analyzer to the exhaust manifold located behind the instrument rack. This ensures that all calibration gases are vented outside the monitoring shelter.

3.2.2.6 Confirm that a 1-µm Teflon® particulate filter is installed in the filter holder and the holder is connected to the sample line before the sample port.

3.2.2.7 If possible, plug the analyzer into an Uninterruptable Power Supply (UPS) that has active battery backup. Otherwise, plug the instrument into a surge protected power supply.

3.2.2.8 Turn on power switch.

3.2.2.9 Check that the instrument is booting the firmware. Let it warm up for at least 1 hour. Use the menu on the front panel to check the instruments diagnostics. If the sample flow is outside its ranges, check for blockages, pump condition, and/or leaks.

3.2.2.10 Ensure that the instrument is not in maintenance mode. An analyzer in maintenance mode will ignore diagnostic faults. On the front panel navigate to [SETUP] ► [MORE] ► [DIAG] ► [929] ►scroll to SIGNAL I/O ► [ENTR] ► [NEXT] navigate to 2) MAINT_MODE. This should say "MAINT_MODE=OFF". If it is on, tip the front panel down (remove the set screw on the right side, if necessary) and locate a pair of red and black switches (Fig. 3). These switches are labeled "S1" and "S2" on the board. Move switch S2 (the bottom switch) so that it is in the left position (if you are looking toward the back of the analyzer). Next move S1 to the left position. The variable in Signal I/O should show that maintenance mode is off. The instrument is now ready to collect ambient data.

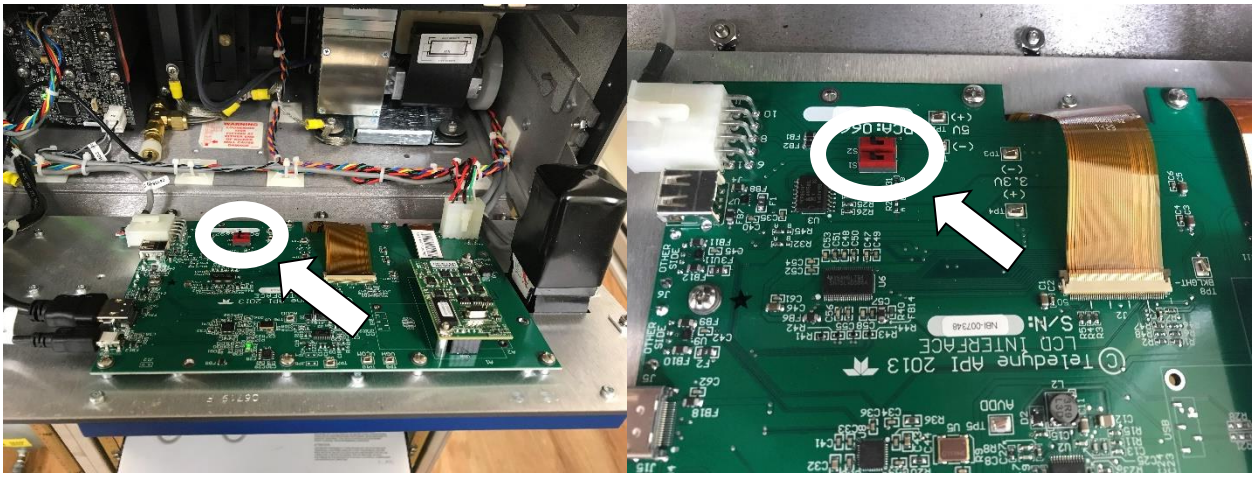


Figure 3: Maintenance mode switches

3.2.2.11 Connect the calibration standard gas produced from the calibrator to the SO_2 solenoid (Fig. 4) valve that feeds SO_2 calibrator concentrations to the sample probe box outside the building via a Teflon® (FEP) line with OD of 1/4" and a minimum ID of 1/8". The transfer standard will send SO_2 concentrations up the cal gas line into the probe box to a "tee". The tee is also connected to the short inlet line that goes to the inlet funnel and the sample feed going to the analyzer. In ambient operation the analyzer pulls ambient air from the inlet line and the cal gas line is sealed by the solenoid. In calibration operation the transfer standard supplies SO_2 concentrations through the solenoid and cal gas line up to the probe box. The analyzer pulls what it needs through the sample line and the inlet line becomes the vent for the excess cal feed. The entire sample path except the short inlet line (less than 12") is used during all reportable QC/QA checks.

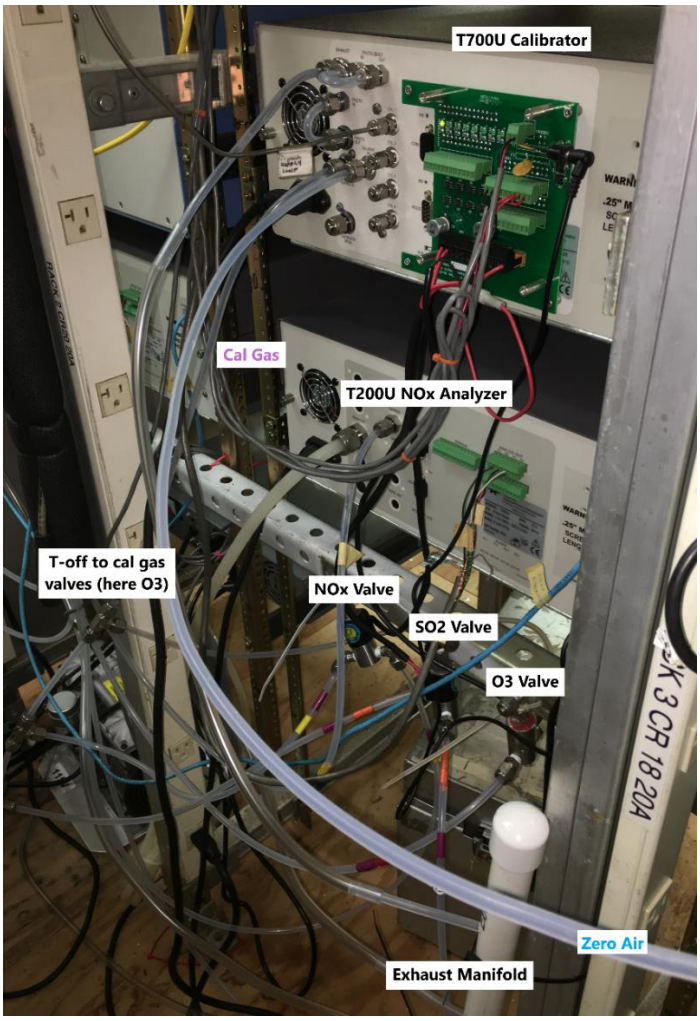


Figure 4: Plumbing behind the calibrator

3.2.2.12 An ESC Spectrum 8864 Data Controller is used as the data logger. The Teledyne API SO_2 analyzer is connected to the 8864 through an analog and/or Modbus connection. Configurations for individual channels are programmed into the AirVision server located at the Forsyth County Government Center then transferred to the 8864 Datalogger. Refer to Section 11 Datalogger 8864 SOP for more information. Check that the Datalogger channel has been properly initialized as follows:

3.2.2.12.1 To Login into the 8864, open PuTTY on the PC and connect to the 8864 by using the correct IP address. Alternatively, you can use the Link To Logger utility in AirVision.

In the Saved Sessions portion of the window, click the logger's name, then click Load. You should see the IP address appear in the window. Next click Open and you should see a terminal window open that is asking for a username and password. Ask the program manager for the proper credentials to login with as these have been omitted from this SOP for security purposes.

Press C (Configuration Menu), D (Configure (Data) Channels), C (Change Old Configuration). Press Enter to see the channel configurations.

3.2.2.12.2 Check the channel configuration entries (Fig. 5) to ensure that they correspond to the entries listed below:

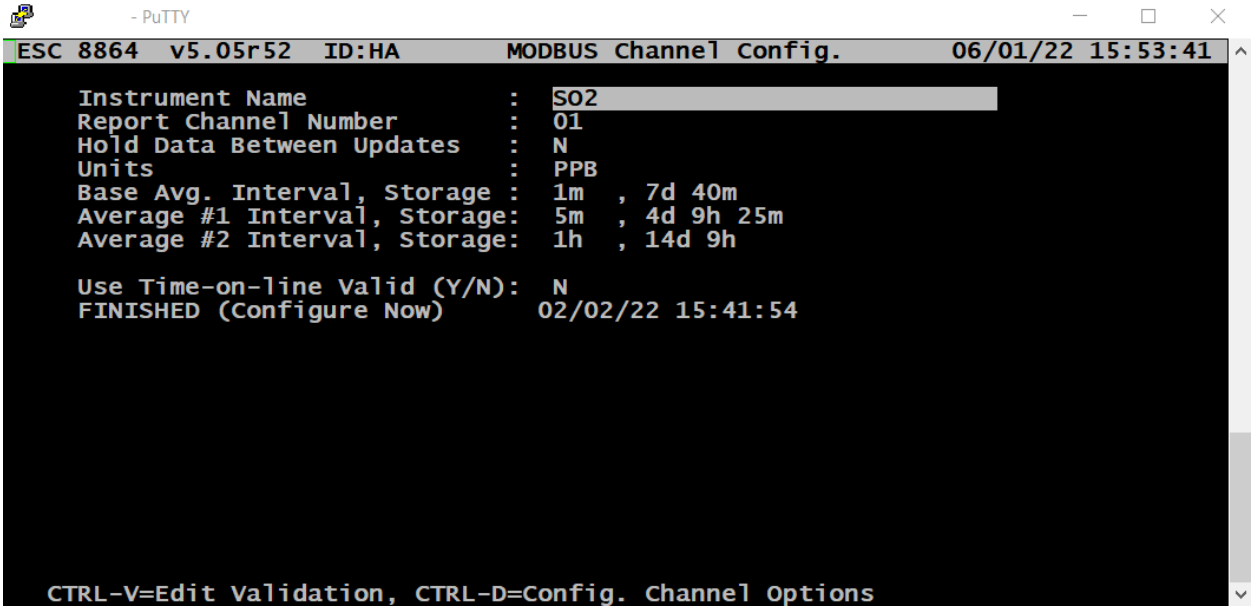


Figure 5: SO2 Channel Configuration

3.2.3 Analyzer Datalogger setup with APICOM software

3.2.3.1 The analyzer should be programmed using the APICOM software supplied by Teledyne API. Ensure that you are using APICOM version 5.05. In the iDAS screen, program a 1-minute channel and a 1-hour channel. At the very least, ensure that both CONC1 (PPB) and STABIL (PPB) are programmed into both channels. There are other diagnostic parameters that may be helpful to log. See the instrument manual for details. Store 504 hourly records and 25,000 minute records to cover the necessary length of time between site visits.

3.2.4 Initial Analyzer Checks and Adjustment

3.2.4.1 Install the T100U into an instrument rack or place analyzer on a tabletop where the unit can run. Plug power cord into the T100U and attach sample line to the sample port. If possible, plug the instrument into an Uninterruptible Power Supply (UPS).

3.2.4.2 Turn power switch to 'ON'. The instrument will display the 'Power-Up' and 'Warm-Up' screens while the instrument is warming up and conducting self-tests. Let the instrument warm up for at least 1 hour.

3.2.4.3 Check the Gas Units. Press [SETUP] ► [UNIT] ► [PPB] to set the CONC UNITS to parts per billion.

3.2.4.4 Check the mode and range. From the main screen, press SETUP ► MODE ► SNGL to set the instrument in single range mode. Press EXIT ► SET then use the buttons to type in 100.0 for the range. Press enter when finished to set the range from 0-100 ppb.

3.2.4.5 Activate pressure and temperature correction. Press SETUP ► MORE ► VARS ► 818 ► NEXT to navigate to 1) TPC_ENABLE. If this is OFF, press the EDIT button and toggle it to ON. Press ENTR when finished to activate the temperature and pressure correction.

3.2.4.6 Check the Temperatures. From the main menu, use the <TST and TST> buttons to scroll through the diagnostic variables. The internal temperature (BOX TEMP) should be between 5°C and 40°C as this is the operating range for the instrument. With that being said, the box temperature should be roughly 5 - 10°C warmer than the site shelter temperature if the cover has been left on the instrument. The sample chamber temperature (RCELL TEMP) should be between 49°C and 51°C.

3.2.4.7 Check the Pressure. Continue scrolling through the test variables on the home screen using the TST buttons until you reach PRES. The pressure should be within two inHg of ambient. In Winston-Salem, the absolute atmospheric pressure should be around 29 - 30 inHg.

3.2.4.8 Check the Flow. Continue scrolling through the test variables on the home screen using the TST buttons until you reach SAMP FL. The flow should be between 585 CC/M and 715 CC/M. The nominal flow for the T100U is 650 cubic centimeters per minute.

3.2.4.9 Check the UV lamp. Using the TST buttons on the home screen, scroll until you reach UV LAMP. The lamp intensity should be between 2000 mV and 4000 mV. Continue scrolling until you reach LAMP RATIO. The lamp ratio should be between 30-120% with an optimal reading near 100% and steady.

3.2.4.10 In the probe box on the roof, perform a system leak test by capping off the “tee” above the filter housing where the short sample inlet line is connected during normal operation. The pressure should drop to less than 10 inHg and the flow should read less than 10 cc/min. If not, the system has a leak. Trace each flow line and check all fittings for tightness. Retest. DO NOT PRESSURIZE THE SYSTEM.

3.2.4.11 After conducting steps within 3.1.3 and 3.2.4 under Initial Analyzer Checks and Adjustments the monitor can be placed into operation and a calibration performed.

3.3 Teledyne API Model T100U SO2 Analyzer Instrument Description

General Principals: An ultraviolet lamp produces light that passes through an optical filter. This filter allows the specific wavelength of light through that excites SO_2 molecules into higher energy states. This filtered UV light is focused into the sample chamber. Here, it excites SO_2 molecules into higher energy states. As these states decay the excited SO_2 molecules emit a characteristic radiation. A second filter allows only this radiation to fall on a photomultiplier tube, which turns the radiation into an electrical signal. This signal is then filtered and amplified by the electronics to levels appropriate for display. The physics of SO_2 fluorescence, the linearity of the photomultiplier tube, and good instrument design ensure that this signal is linearly proportional to the SO_2 concentration. For a better understanding of the analyzer, read the manual before operating the instrument.

3.4 Calibrations/Verifications of a Teledyne API T100U SO2 Analyzer

SO_2 analyzers are to be calibrated upon receipt, when installed, if moved from current location, and when certain repairs are made. An adjusted calibration may be necessary if an analyzer malfunctions and is repaired, or if power is lost for more than 24 continuous hours at a site.

An Adjusted Calibration, during which the lowest point (Zero) and the highest point (Span) are adjusted on the analyzer itself, is used at the start of sample collections for a site, and/or when a biweekly ZSP check or 90-day verification fails. The resulting slope and intercept values are automatically stored in the instrument's memory. The adjusted calibration resets the performance check (bi-weekly Zero/Span/Precision) schedule, starting with the performance date of the Adjusted Calibration.

During a 90-day verification (multipoint check - 4 points plus a zero) the results are recorded in "as found" condition. The 90-day verification can reset the bi-weekly Zero/Span/Precision (ZSP) schedule. The (ZSP) will remain on its previous schedule.

3.4.1 Adjusted Multi-Point Calibration

3.4.1.1 Typically the only time a Calibration is performed will be at the beginning of the analyzer's field operation or after certain maintenance or repairs.

A calibration must be performed if a 90-day verification or bi-weekly zero/span/precision (ZSP) check fails and the instrument is in good working order. Normally if either of these checks fail there is some problem within the monitoring system that needs addressing. If the Zero check is outside >± 0.005 ppm of known 0.000 or the Span check >± 10% of expected value, then an adjusted calibration will be done AFTER equipment failure is diagnosed, repaired, and instrument cleared for normal operation. If a typical slow drift causes the check to fail, no maintenance may be necessary but check with the program manager before proceeding.

3.4.1.2 Before proceeding, allow at least 1 hour for the SO_2 analyzer and the calibration standard to warm up, if they are not already on.

3.4.1.3 Always, if no major malfunctions have occurred and the monitor has been in normal operation, perform a bi-weekly zero/span/precision (ZSP) check prior to a calibration. If necessary, after the ZSP check, install a clean 1-µm Teflon® particulate filter in the monitor and/or the filter holder in the probe line box on the roof of the site. Perform a system leak check (refer to section 3.2.4.10) after replacing the filter and saturate the probe system with SO_2 by running a SO_2 span point (90 ppb). Record all information in the Excel-based site logbook (Fig. 7), AirVision electronic logbook (Fig. 15), and SO_2 minute graph located in AirVision.

3.4.1.4 Login to the 8864 using PuTTY or AirVision.

Refer to Section 11 Datalogger 8864 SOP for information about how to login with PuTTY.

Open AirVision on the site PC. Login to the central server located at the Government Center with your credentials. Navigate the Utilities menu and click Link To Logger. Select “Hattie A” from the dropdown then uncheck Server Connection. Now click the Connect button and you should see a login screen in the terminal window. Press L to login, type the password, then press Enter.

To disable the SO_2 channel, press C (Configuration Menu), D (Configure (Data) Channels), M (Disable/Mark Channel Offline). Use arrows to skip to SO_2, then, press Enter to disable the SO_2 channel. (Fig. 6)

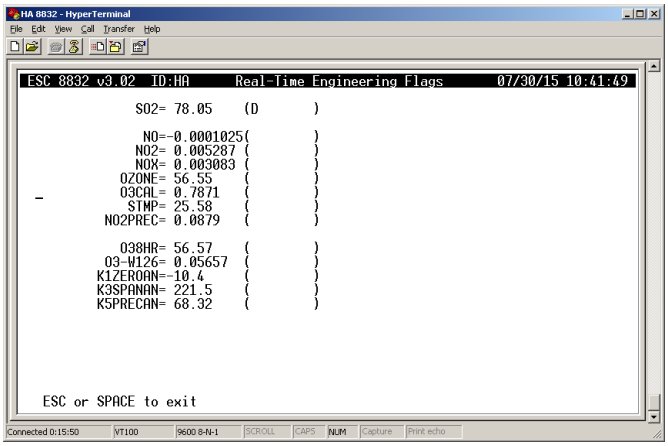


Figure 6: SO2 Channel Disabled

3.4.1.5 Prepare a calibration worksheet in the instrument logbook containing the following entries:

Date/Time; Operator; Site/AQS ID; Datalogger check; Analyzer and Calibrator Make/Model/Serial Number/Diagnostics; SO_2 Operational checks and SO_2 Readings

The following is an example of the electronic data sheet (Fig. 7) that will be used to document checks.

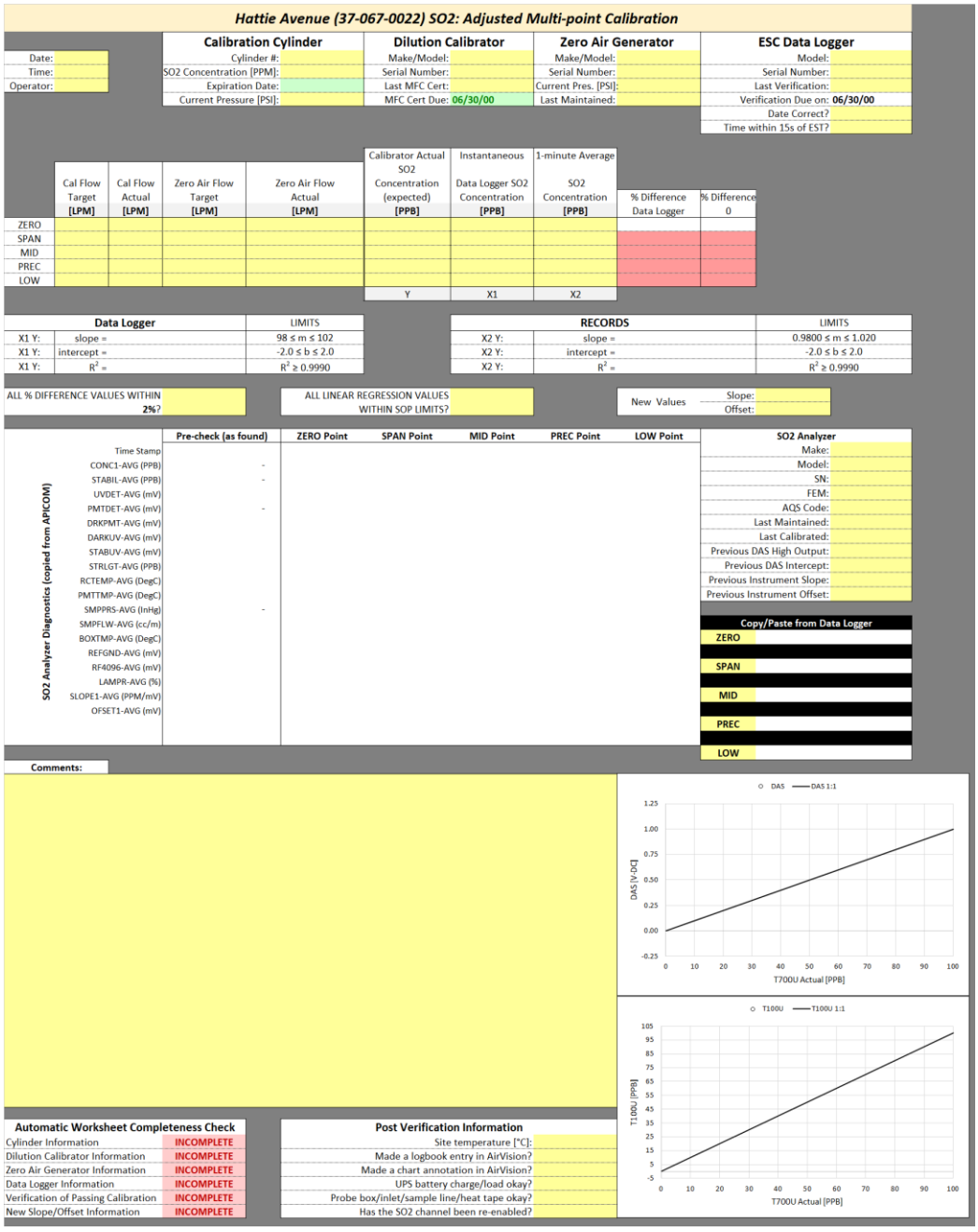


Figure 7: Instrument Logbook, Blank Calibration Worksheet

3.4.1.6 Verify that the analyzer is working within specifications (see 3.2.4.5-3.2.4.11). Connect to the analyzer using APICOM. Open APICOM 5, click the instrument then click Connect in the toolbar. Alternatively, the right click context menu can be used to connect. The simulator of the T100U should show up on the screen. (Fig. 8)

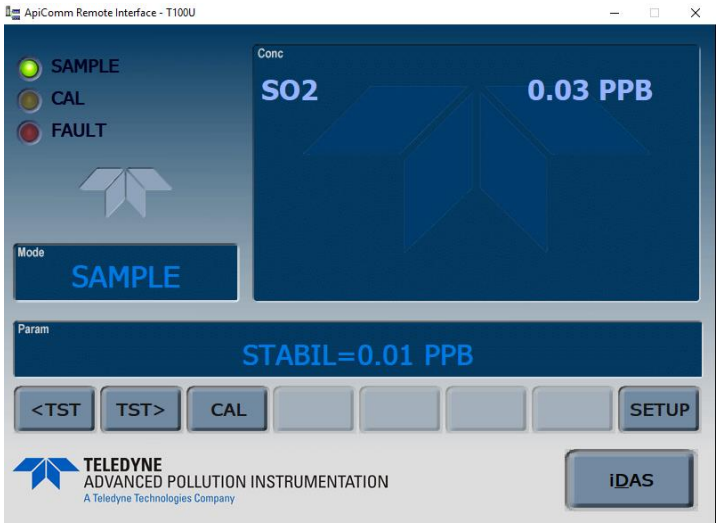


Figure 8: APICOM Simulator

3.4.1.7 Verify the output of the Gas Dilution System (Calibrator) is connected to the SO_2 solenoid so gas is supplied to the sample line of the monitor to be calibrated. See section 3.2.2.11.

3.4.1.8 Record T100U diagnostics in the calibration worksheet before beginning the calibration. This ensures that the instrument is operating normally in its "as found" state.

3.4.1.9 Use APICOM to retrieve the most recent record from the analyzer by going to the simulator and clicking the iDAS button. In the window that appears, check the box next to the 1-minute data entry. Click Get Data then select Most recent records and enter "1" into the field. Click OK. Next, click the Save Data button then select the minute data Excel file in the SO_2 directory. In the popup dialog, click Append. Navigate to that Excel file in Windows Explorer and open it. Highlight all of the data from the proper minute, Copy, then Paste Special ► Transpose into the proper diagnostic column of the calibration worksheet in the Excel logbook. Because the calibration worksheet is locked in Excel to protect formulas, you may have to paste transpose in the APICOM generated Excel file first, copy that, then paste values into the calibration worksheet.

3.4.1.10 Using the Gas Dilution System (Calibrator), from the main menu press SEQ (Fig. 9). Use the PREV and NEXT buttons (Fig. 10) to scroll to the "SO2 ZERO" sequence. This sequence is programmed into the T700U Calibrator and will supply zero air to the T100U.

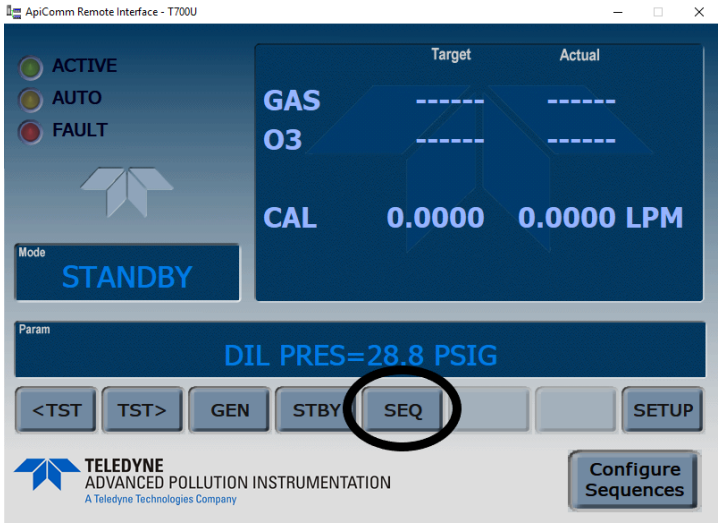


Figure 9: Calibrator Sequence Program

3.4.1.11 Verify zero air is making it into the T100U. Readings should drop near zero within 30 seconds.

3.4.1.12 Allow the T100U to sample zero air until a stable reading is obtained, at least 15 minutes. Use the TST buttons on the instrument's home screen to scroll to the STABIL parameter. Stability needs to be less than 1 ppb before calibrating the zero. Once acceptable stability is achieved, press the CAL button on the home screen. Next, press the ZERO button then press ENTR to calibrate the instrument's zero. The concentration on the screen will change to 0 ppb. Allow the SO_2 stability test variable to fall below 1 ppb again after adjustment.

3.4.1.13 After stability is good, collect an instantaneous snapshot of the SO2 concentration from the 8864 data logger. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the calibration worksheet.

3.4.1.14 Using the Gas Dilution System (Calibrator), run the "SO2 90" sequence (Fig. 9). This sequence is programmed into the T700U Calibrator and will supply a concentration of 90 ppb of SO_2 to the T100U. Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize.

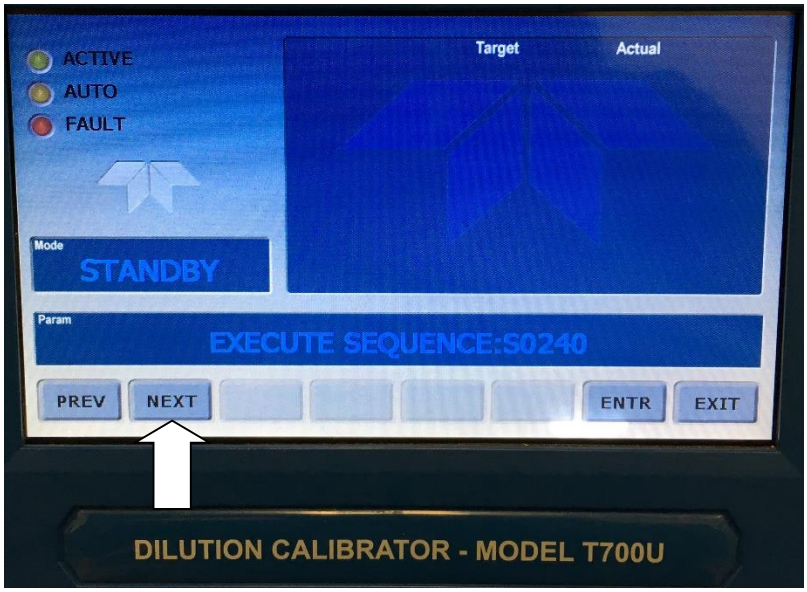


Figure 10: Calibrator Sequence Cycle Through/Selection

3.4.1.15 From the T100U main menu choose CAL. Next press the CONC button to enter the span gas concentration. Use the buttons to enter the Actual gas concentration from the Gas Dilution System (Calibrator) then press ENTR. Pressing enter will bring you back to the calibration menu. The button that used to say "zero" should now say "span". Press the SPAN button then press ENTR to calibrate the SO_2 reading to the SO_2 calibration gas. The on screen SO_2 concentration will now display the span concentration you entered previously.

3.4.1.16 After stability is good (< 1 ppb), collect an instantaneous snapshot of the SO2 concentration from the 8864 data logger and a minute average from the analyzer. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the calibration worksheet.

3.4.1.17 Using the Gas Dilution System (Calibrator), run the "SO2 70" sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 70 ppb of SO_2 to the T100U. Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize. After stability is good (< 1 ppb), collect an instantaneous snapshot of the SO2 concentration from the 8864 data logger. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the calibration worksheet.

3.4.1.18 Using the Gas Dilution System (Calibrator), run the 'SO2 40' sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 40 ppb of SO_2 to the T100U. Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize. After stability is good (< 1 ppb), collect an instantaneous snapshot of the SO2 concentration from the 8864 data logger. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the calibration worksheet.

3.4.1.19 Using the Gas Dilution System (Calibrator), run the 'SO2 30' sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 30 ppb of SO_2 to the T100U. Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize. After stability is good (< 1 ppb), collect an instantaneous snapshot of the SO2 concentration from the 8864 data logger. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the calibration worksheet. Return Calibrator to 'Standby" mode.

3.4.1.20 The percent difference for each point must be < ± 2.0%.

3.4.1.21 Review the linear regression results for SO_2 calculated in the calibration worksheet between the expected SO_2 and the observed SO_2 from the 8864. The linear regression line should meet the following specifications in order to be valid for reporting ambient air data: $0.9800 \leq m \leq 1.0200$, $-2.0 \leq b \leq 2.0$, and $r^2 \geq 0.9990$. If the line does not meet these specifications inform the Program Manager.

3.4.1.22 Review the linear regression results for SO_2 calculated in the calibration worksheet between the expected SO_2 and the observed SO_2 from the T100U. The linear regression line should meet the following specifications: $0.9800 \leq m \leq 1.0200$, $-2.0 \leq b \leq 2.0$, and $r^2 \geq 0.9990$ (the analyzer slope and intercept adjusts a ppb value to a corrected ppb value based on a best fit line across the five points). If the line does not meet these specifications inform the Program Manager. If specifications are met, the new slope and intercept can be applied to any value stored in the internal data logger in the analyzer if data is lost from the 8864.

3.4.1.23 If the above criteria cannot be met inform the Program Manager. If the criteria are met proceed with next step.

3.4.1.24 Via AirVision, open and label the 1-minute average SO_2 graph with an annotation stating what was done and look at the trace to verify points were flat and display a good "stair-step" appearance. To open the graph, click Status Displays in the left sidebar then click Realtime Data Trending. Select SO2 in the Parameter Selection section and click Manual Refresh in the ribbon. Next, highlight all minutes that were downed (i.e., shaded yellow), right click, then click Annotate Selected to leave an annotation. This ensures the annotation is applied to all minutes of the calibration.

3.4.1.25 Verify Calibrator is in 'Standby' mode. This will allow the sample line to sample ambient air once again. Confirm analyzer is reading ambient levels once again within five minutes. If slow to return run a final zero to test for drift and flush line.

3.4.1.26 Once analyzer is reading ambient levels again, enable the data logger channel by returning to the 'CONFIGURATION MENU'.

3.4.1.26.1 Click on 'Configure Data Channels'

3.4.1.26.2 Click on 'Enable/Mark Channel Online'

3.4.1.26.3 Select channel to be enabled. Press Enter to enable the channel. The SO_2 channel is now online.

3.4.2 SO2 90-day Verification

3.4.2.1 A SO_2 90-day verification check must be done at least once every 90 days. Run the following points: 0 (Zero), 90 (Span), 70, 40 (Prec), and 30 ppb and verify results are all within 10% difference. This is to verify everything is running properly in an "as found" state. This check does not replace nor reset the bi-weekly ZSP check schedule.

3.4.2.2 Verify last auto-cal results from the night before are within tolerance (10%) and confirm everything is running properly. If they are not, contact the program manager.

3.4.2.3 Login to the 8864 using AirVision or PuTTY. Refer to Section 11 Datalogger 8864 SOP for information about how to login with PuTTY.

3.4.2.4 Disable the SO_2 channel.

Open AirVision on the site PC. Login to the central server located at the Government Center with your credentials. Navigate the Utilities menu and click Link To Logger. Select "Hattie A" from the dropdown then uncheck Server Connection. Now click the Connect button and you should see a login screen in the terminal window. Press L to login, type the password, then press Enter.

To disable the SO_2 channel, press C (Configuration Menu), D (Configure (Data) Channels), M (Disable/Mark Channel Offline). Use arrows to skip to SO_2, then, press Enter to disable the SO_2 channel.

3.4.2.5 Prepare a 90-day Verification worksheet in the instrument logbook containing the following entries:

> Date/Time; Operator; Site/AQS ID; Datalogger check; Analyzer and Calibrator Make/Model/Serial Number/Diagnostics; SO_2 Operational checks and SO_2 Readings

The following example of the electronic data sheet (Fig. 11) will be used to document checks. All information fields listed above must be included.

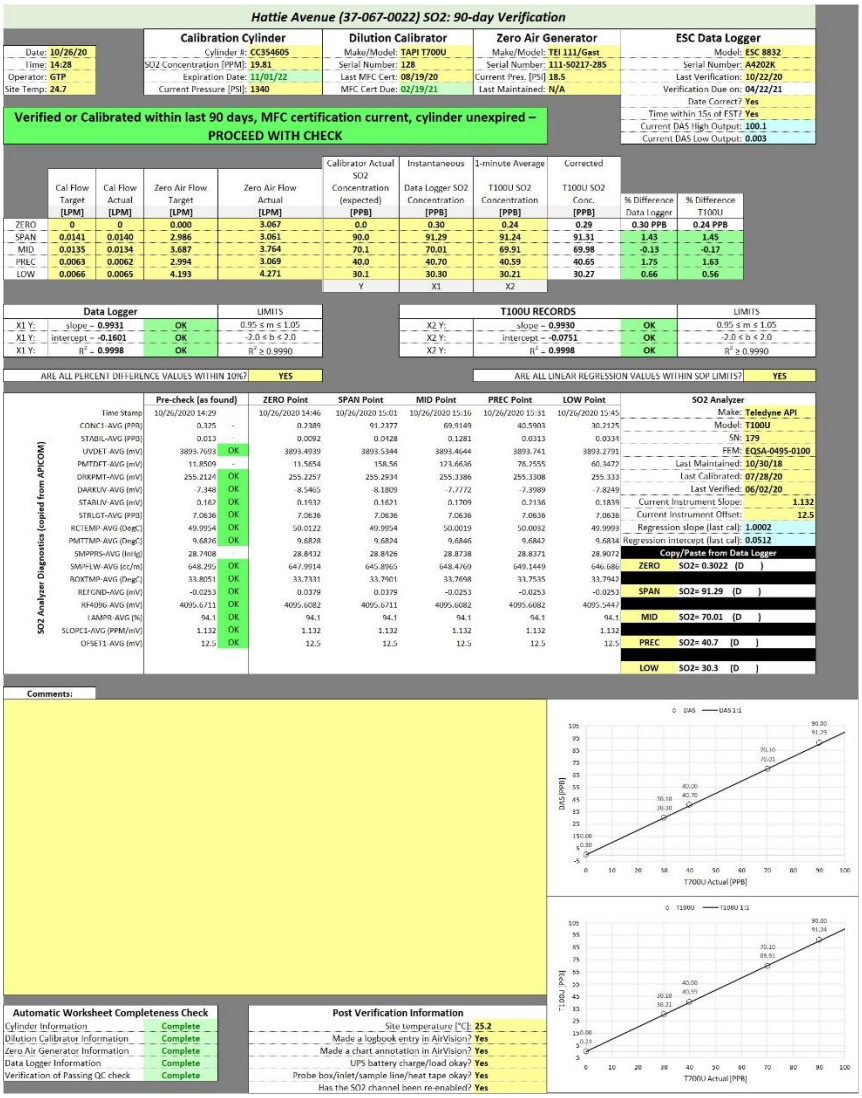


Figure 11: Instrument Logbook, 90-day Verification Worksheet

3.4.2.6 Verify that the analyzer is working within specifications (see 3.2.4.5-3.2.4.11). Connect to the analyzer using APICOM. Open APICOM 5, click the instrument then click Connect in the toolbar. Alternatively, the right click context menu can be used to connect. The simulator of the T100U should show up on the screen. (Fig. 8)

3.4.2.7 Record the diagnostic observations in the logbook. If these specifications are not met consult the instrument instruction manual for corrective action.

3.4.2.8 Verify the output of the Gas Dilution System (Calibrator) is connected to the SO_2 solenoid so gas is supplied to the sample line of the monitor to be verified. See section 3.2.2.11.

3.4.2.9 Using the Gas Dilution System (Calibrator), run the 'SO2 ZERO' sequence. This sequence is programmed into the T700U Calibrator and will supply zero air to the T100U.

3.4.2.10 Verify zero air is making it into the T100U. Readings should drop near zero within 30 seconds.

3.4.2.11 Allow the T100U to sample zero air until a stable reading is obtained, at least 15 minutes. To check stability, use the TST buttons on the instrument's home screen to scroll to the STABIL parameter. It needs to be less than 1 ppb.

3.4.2.12 After stability is good, collect an instantaneous snapshot of the ppb reading from the 8864 and a minute average from the analyzer. Use APICOM to retrieve the most recent minute average from the analyzer by going to the simulator and clicking the iDAS button. In the window that appears, check the box next to the 1-minute data entry. Click Get Data then select Most recent records and enter "1" into the field. Click OK. Next click the Save Data button then select the minute data Excel file in the SO_2 directory. In the popup dialog, click Append. Navigate to that Excel file in Windows Explorer and open it. Highlight all of the data from the proper minute, Copy, then Paste Special ► Transpose into the proper diagnostic column of the verification worksheet in the Excel logbook. Because the verification worksheet is locked in Excel to protect formulas, you may have to paste transpose in the APICOM generated Excel file first, copy that, then paste values into the verification worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration.

3.4.2.13 Using the Gas Dilution System (Calibrator), run the 'SO2 90' sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 90 ppb of SO_2 to the T100U.

3.4.2.14 Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize.

3.4.2.15 After stability is good (< 1 ppb), collect an instantaneous snapshot of the ppb reading from the 8864. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the verification worksheet.

3.4.2.16 Using the Gas Dilution System (Calibrator), run the 'SO2 70' sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 70 ppb of SO_2 to the T100U. Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize. After stability is good (< 1 ppb), collect an instantaneous snapshot of the ppb reading from the 8864. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the verification worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration.

3.4.2.17 Using the Gas Dilution System (Calibrator), run the 'SO2 40' sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 40 ppb of SO_2 to the T100U. Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize. After stability is good (< 1 ppb), collect an instantaneous snapshot of the ppb reading from the 8864. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the verification worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration.

3.4.2.18 Using the Gas Dilution System (Calibrator), run the 'SO2 30' sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 30 ppb of SO_2 to the T100U. Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize. After stability is good (< 1 ppb), collect an instantaneous snapshot of the ppb reading from the 8864. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the verification worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration. Return Calibrator to 'Standby" mode.

3.4.2.19. The percent difference for each point must be < ± 10.0%. Linear regression results must meet the following requirements:

Slope: $0.95 \leq m \leq 1.05$
Intercept: $-1.0 \leq b \leq 1.0$
R^2: ≥ 0.999

3.4.2.20 If the above criteria cannot be met inform the Program Manager. If the criteria are met proceed with next step.

3.4.2.21 Via AirVision, open and label the 1-minute average SO_2 graph with an annotation stating what was done and look at the trace to verify points were flat and display a good "stair-step" appearance. To open the graph, click Status Displays in the left sidebar then click Realtime Data Trending. Select SO2 in the Parameter Selection section and click Manual Refresh in the ribbon. Next, highlight all minutes that were downed (i.e., shaded yellow), right click, then click Annotate Selected to leave an annotation. This ensures the annotation is applied to all minutes of the 90-day verification.

3.4.2.22 Verify Calibrator is in 'Standby' mode. This will allow the sample line to sample ambient air once again. Confirm analyzer is reading ambient levels once again. If slow to return run a final zero to test for drift and flush line.

3.4.2.23 Once analyzer is reading ambient levels again, enable the data logger channel by returning to the 'CONFIGURATION MENU'.

3.4.2.23.1 Click on 'Configure Data Channels'

3.4.2.23.2 Click on ‘Enable/Mark Channel Online’

3.4.2.23.3 Select channel to be enabled. Press Enter to enable the channel. The SO_2 channel is now online.

3.5 Teledyne API T701H Zero Air Generator

A zero air system to be used in the field should be constructed as follows: a zero air generator, a valve connected to the output that is connected to two drying columns filled with fresh silica gel followed by a column of activated charcoal containing a layer of Purafil, the air is then passed through a 5 µm Teflon® filter to remove particulate.

3.5.1 A check of the zero air system should be performed annually.

3.5.2 Annually, the entire zero air system, including the zero air generator and drying columns, should be brought back to the Government Center for service.

3.5.3 At this time, replenish the drying column with fresh silica gel, activated charcoal, and fresh Purafil. Replace the filter at this time.

3.5.4 Replace the filter on rear of zero air generator. Check the canisters for leaks before re-installing them into the generator.

3.5.5 After the annual maintenance is completed, attach the zero air to a flow certified calibrator.

3.5.6 Prepare to run a zero point with the calibrator to an analyzer.

3.5.7 Let the analyzer stabilize and observe the SO_2 value which should read ± .002 ppm of zero. If not, contact the Program Manager for how to proceed.

3.6 Teledyne API T100U Maintenance

This section describes the periodic maintenance procedures that should be performed on the monitor to ensure proper, uninterrupted operation. Frequency of maintenance and service checks is indicated in each procedure.

3.6.1 Internal Sample Filter Replacement

3.6.1.1 Tip down the front panel of the instrument, first removing the set screw on the right side if necessary.

3.6.1.2 Unscrew the retaining ring, then carefully remove the window, O-ring, and filter.

3.6.1.3 Replace the internal filter with a new 1-micron filter.

3.6.1.4 If the glass window is dirty, you can use deionized water to clean it. Dry the window with compressed air and ensure that it is completely dry before reinstalling.

3.6.1.5 Once the filter is seated, place the O-ring with the notches facing up, followed by the glass window, then finally the retaining ring. The retaining ring should only be hand tightened.

For more information, see section 5.6.1 of the T100U manual (Teledyne API part number: 083730100).

3.6.2 Rebuild the Critical Flow Orifice

3.6.2.1 Turn off the instrument. Locate the critical flow orifice near the sample pump. Ensure that an arrow has been drawn on the outside of the critical flow orifice denoting flow direction. If not, draw an arrow before disconnecting lines.

3.6.2.2 Disconnect both lines from the critical flow orifice then unscrew the fitting from the housing.

3.6.2.3 Remove the spring, sintered filter, upper O-ring, critical flow orifice, and lower O-ring.

3.6.2.4 Use compressed air to clean the critical flow orifice or replace if necessary.

3.6.2.5 Place a new O-ring in the bottom of the housing, followed by the critical flow orifice. The red end of the orifice must be facing downstream of the sample flow. Next place a second new O-ring above the orifice followed by a new sintered filter, and finally a new spring.

3.6.2.6 Carefully screw the brass fitting back into the housing and tighten.

3.6.2.7 Reconnect the pneumatic lines, ensuring the arrow is pointing in the same direction that it was before disassembly.

3.6.2.8 Start the instrument and verify that the sample flow is 585 – 715 cc/min.

For more information, see section 5.6.4 of the T100U manual (Teledyne API part number: 083730100).

3.6.3 Checking the PMT for Light Leaks

3.6.3.1 Use the TST buttons to scroll to the PMT diagnostic variable on the instrument's home screen.

3.6.3.2 Supply zero air to the instrument and while the instrument is running and sampling zero air, remove the cover.

3.6.3.3 Shine a flashlight at the inlet and outlet fittings and all joints of the reaction cell as well as around the PMT housing. The PMT should not respond to the flashlight.

3.6.3.4 If the PMT does respond to the flashlight, see section 5.6.5 of the T100U manual (Teledyne API part number: 083730100) for how to proceed.

3.6.4 Pneumatic Leak Checks

3.6.4.1 Perform a simple vacuum leak check by capping the sample port on the back of the instrument. The cap must be wrench tight.

3.6.4.2 Wait for several minutes for the sample flow and sample pressure to stabilize.

3.6.4.3 If the sample pressure is ≤ 10 inHg, there are no major internal leaks. The flow should drop to near 0 cc/min during this procedure.

3.6.4.4 Turn off the instrument when finished and slowly loosen the cap to minimize sudden pressure changes.

In certain circumstances it may be necessary to perform a detailed pressurized leak check. See section 5.6.6.2 of the T100U manual (Teledyne API part number: 083730100) for information related to this procedure and never exceed 15 psig when pressurizing the system.

3.6.5 Sample Flow Calibration

3.6.5.1 Turn the instrument off then connect a certified flow meter to the sample port on the back of the instrument.

3.6.5.2 A 0-10 LPM Alicat flow meter can be used or alternatively a BIOS triCal.

3.6.5.3 With the flow meter connected, start the instrument and wait for the flow to stabilize.

3.6.5.4 The flow should be 585 – 715 cc/min. If the flow is within range, calibrate the instrument's flow to the value on the flow meter. From the instrument's main menu, press SETUP ► MORE ► DIAG ► ENTR ► NEXT (until you reach FLOW CALIBRATION) ► ENTR.

3.6.5.5 Use the buttons to enter the actual flow as measured by the flow standard. Press ENTR to calibrate the sample flow.

3.6.6 Sample Pressure Calibration

3.6.6.1 From the instrument's main menu, press SETUP ► MORE ► DIAG ► ENTR ► NEXT (until you reach PRESSURE CALIBRATION) ► ENTR.

3.6.6.2 Turn on a certified Druck Digital Pressure Indicator and ensure it is reading absolute pressure. Set the units to inHg-A. Let the pressure reading stabilize.

3.6.6.3 Use the buttons to enter the actual pressure as measured by the pressure standard. Press ENTR to calibrate the sample pressure.

3.6.7 Sample Line/Particulate Filter Replacement

Sample line inspection is necessary every site visit to ensure the Teflon® lines are free of internal condensation/liquid water or debris. The 1 µm sample filter should be replaced once a month (Fig. 12) and a leak check performed (see section 3.2.4.10). All filter replacements should be done AFTER a Quality control (QC) Zero-Span-Precision (ZSP) 14-day check.

Figure 12: Sample Probe Box Filter Housing

3.7 Routine site visits

3.7.1 Visit Requirements

3.7.1.1 The purpose of the routine site visit is to ensure the analyzer and data logger are operating properly. The following should be performed on routine site visits conducted at least every two weeks and more frequently, if necessary.

3.7.1.2 Upon arrival, visually inspect the site to ensure sample line and probe are intact, moisture free, and that there are no problems such as tree branches growing too close to the sample inlet, insect nests interfering with the probe inlets, etc.

3.7.1.3 Verify the time (EST) on 8864 data logger, analyzer, and site computer.

3.7.1.4 Examine all the AirVision graphs day by day and check for atypical data, such as questionable spikes, drops, excessive noise, and square waves in the trace. Record any discrepancies on the AirVision graph using an annotation and in the logbook, if necessary. Document any discrepancies as soon as possible, maintain the documentation in the proper files, and notify Program Manager.

3.7.1.5 In the Excel logbook, enter all of the diagnostics requested in the worksheet. These include: stability, UV detector voltage, PMT, dark PMT, dark UV, UV lamp stability, stray light, reaction cell temperature, PMT temperature, sample pressure, sample flow, box temperature, reference ground voltage, reference 4096 voltage, lamp ratio, slope, and offset. Inspect the AirVision graph. Ensure that the previous day's auto-calibration cycle is typical and that the hourly data is typical.

Corrective action should be taken if the zero is > ± 0.5 ppb SO_2 or the span is > ± 8% from the expected value. Corrective action must be taken if the zero is > ± 1 ppb SO_2 or the span is > ± 10% SO_2 from the expected value.

Check and ensure that the sample line is connected to the sampling manifold and that it is not contaminated by dirt or moisture. Any possible abnormalities should be investigated to ensure continuous uninterrupted quality controlled data collection. If any problems are found the operator is to notify the supervisor and do whatever is necessary to permanently correct the problem. If the operator is not absolutely sure the problem encountered is permanently rectified, he should visit the site later that day or the next working day to check the problem. The operator is to keep the supervisor informed on a daily basis as to the status of the problem. Detailed records of all corrective actions are to be maintained in the logbook.

3.8 Quality Assurance/Quality Control checks

Quality Assurance (QA)/Quality Control (QC) procedures include performance audits, 90-day verification checks, zero-span-precision (ZSP) 14-day checks, and calibration checks.

3.8.1 Performance Audit procedure

Audits are to be performed quarterly at a frequency ≤ 90 days apart. Analyzer accuracy audits are to be performed by an individual other than the analyst who performed the calibration. The QA staff performing the audit should also inspect the site's overall condition and report any issues to the Program Manager. Issues can include but not be limited to: safety hazards, operator oversights, EPA site requirements being met, building condition, overall neatness, and up-to-date documentation of the site's activities. The audit should be conducted using a gas dilution system, certified NIST EPA protocol cylinder gas (6 – 60 ppm range so required low audit levels can be attained), and zero air system that are independent of the normal calibration system. The following procedure should be followed when conducting audits:

3.8.1.1 The analyzer audit is conducted by challenging the measurement system with a series of known concentrations of calibration gas. The audit field procedure is similar to the 90-day verification procedure except that different points can be run. The audit must include zero and at least one point taken from three of the ten ranges:

Level 1: 0.3 – 2.9 ppb SO_2 (required)

Level 2: 3.0 – 4.9 ppb SO_2

Level 3: 5.0 – 7.9 ppb SO_2

Level 4: 8.0 – 19.9 ppb SO_2

Level 5: 20.0 – 49.9 ppb SO_2

Level 6: 50.0 – 99.9 ppb SO_2 (required)

Level 7: 100.0 – 149.9 ppb SO_2 (over-range for our monitor)

Level 8: 150.0 – 259.9 ppb SO_2 (over-range for our monitor)

Level 9: 260.0 – 799.9 ppb SO_2 (over-range for our monitor)

Level 10: 800.0 – 1000 ppb SO_2 (over-range for our monitor)

The audit is to be recorded in the audit section of the audit Excel logbook. Figure 13 should be used for a template of data that must be recorded in the logbook. Record the information but do not alter the analyzer settings in any way.

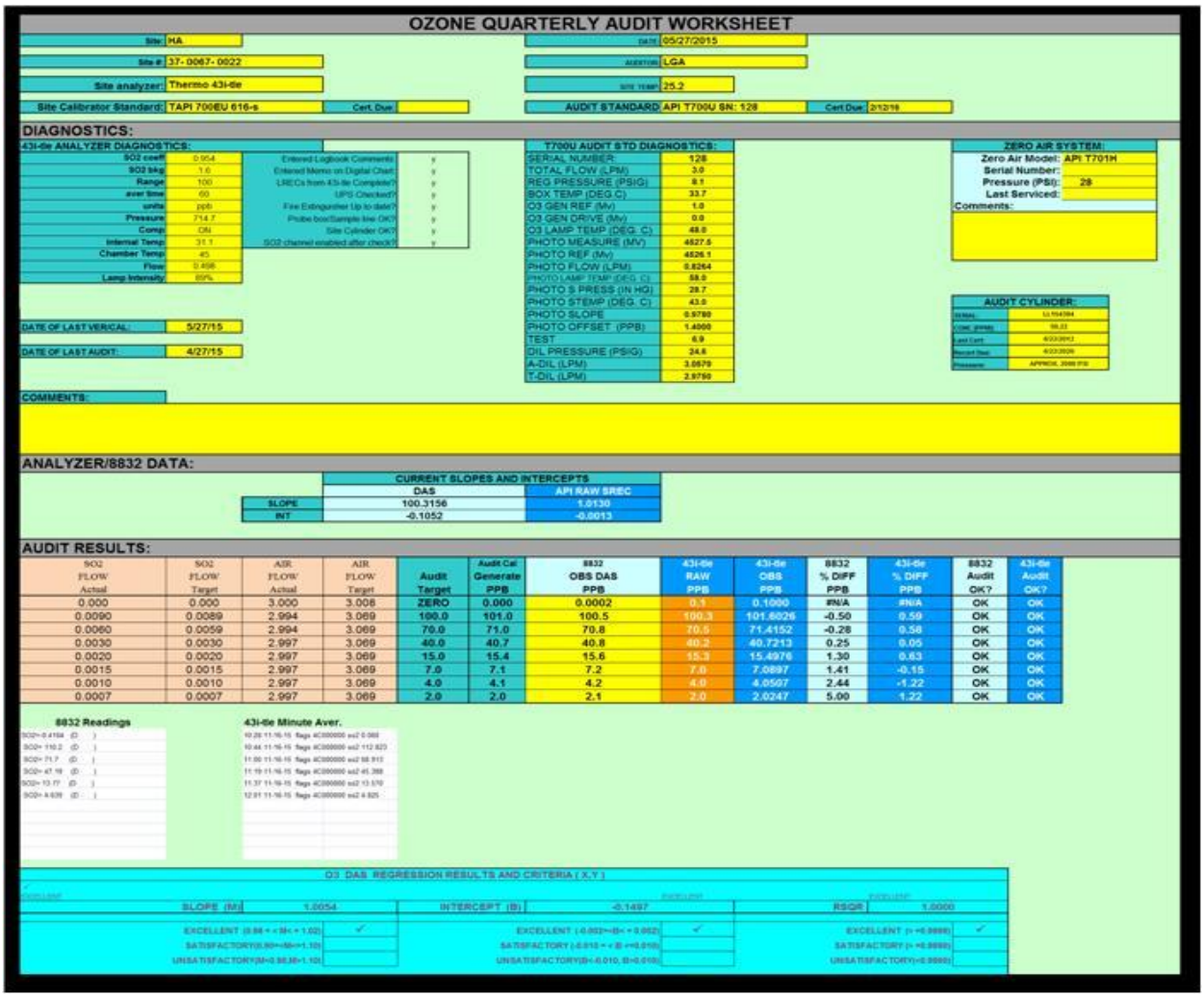


Figure 3: Performance Audit Worksheet

3.8.1.2 The audit dynamic calibrator's mass flow controllers must be certified against authoritative standards such as a NIST traceable bubble meter, a wet test meter, Alicat flow meter, or a BIOS flow calibrator within the last 6 months. The dynamic calibrator flows must be certified semi-annually.

3.8.1.3 Plug in the dynamic calibrator and turn power on. The calibration unit must warm up at least 30 minutes prior to use. Connect an independent source of zero air to the zero air inlet of the dynamic calibration unit. Turn on the zero air pump. Set the zero air delivery pressure to 25 psig. Attach a two-stage regulator to the audit SO_2 cylinder. Quickly open and close the cylinder valve on the SO_2 audit cylinder and adjust the 1st stage regulator valve to 24 psig. Open the second stage valve and allow the regulator to empty. Close the second stage valve. Repeat this process 5 times to evacuate residual gases in the regulator. The regulator evacuation should be performed in a well ventilated area. After the evacuation procedure fill the regulator with gas leaving the second stage valve closed. Connect the SO_2 regulator to the audit calibrator with the appropriate tubing (stainless steel) and fitting (stainless steel). Open the second stage regulator valve to the maximum. Adjust the second stage pressure to 24 psig. Check the fittings for leaks with Snoop®. Record the cylinder pressure.

3.8.1.4 Log in on the datalogger. Disable the SO_2 channel. See section 3.4.1.4 on how to Disable the channel.

3.8.1.5 Verify the output of the Audit Gas Dilution System (Calibrator) is connected to the SO_2 cal line so gas is supplied to the sample line of the monitor to be calibrated. See section 3.2.2.11.

3.8.1.6 Start the dynamic calibrator zero air sequence to deliver zero air to the analyzer. Use a total flow appropriate for the analyzer's needs, which should be ~3.0 LPM. Verify zero air is making it into the T100U. Readings should drop near zero within 30 seconds.

3.8.1.7 Allow the Model T100U to sample zero air until a stable reading is obtained, at least 15 minutes. Use the TST buttons on the instrument's home screen to scroll to the STABIL parameter. Stability needs to be less than 1 ppb.

3.8.1.8 After stability is good, collect an instantaneous snapshot of the ppb reading from the 8864 and a minute average from the analyzer. Use APICOM to retrieve the most recent minute average from the analyzer by going to the simulator and clicking the iDAS button. In the window that appears, check the box next to the 1-minute data entry. Click Get Data then select Most recent records and enter "1" into the field. Click OK. Next click the Save Data button then select the minute data Excel file in the SO_2 directory. In the popup dialog, click Append. Navigate to that Excel file in Windows Explorer and open it. Highlight all of the data from the proper minute, Copy, then Paste Special ► Transpose into the proper diagnostic column of the audit worksheet in the Excel logbook. Because the audit worksheet is locked in Excel to protect formulas, you may have to paste transpose in the APICOM generated Excel file first, copy that, then paste values into the audit worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration.

3.8.1.9 Using the dynamic calibrator run the next appropriate point in a given audit level per section 3.8.1.1.

3.8.1.10 Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize.

3.8.1.11 After stability is good (< 1 ppb), collect an instantaneous snapshot of the ppb reading from the 8864. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the audit worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration.

3.8.1.12 Repeat 3.8.1.10 – 3.8.1.12 until audit is complete.

3.8.1.13 The percent difference for each point must be < ± 10.0%. For audit levels 1 and 2, the result can be > ±10% as long as the raw difference is < ± 1.5 ppb.

3.8.1.14 If the above criteria cannot be met inform the Program Manager. If the criteria are met proceed with next step.

3.8.1.15 Via AirVision, open and label the 1-minute average SO_2 graph with an annotation stating what was done and look at the trace to verify points were flat and display a good "stair-step" appearance. To open the graph, click Status Displays in the left sidebar then click Realtime Data Trending. Select SO2 in the Parameter Selection section and click Manual Refresh in the ribbon. Next, highlight all minutes that were downed (i.e., shaded yellow), right click, then click Annotate Selected to leave an annotation. This ensures the annotation is applied to all minutes of the audit.

3.8.1.16 Place Calibrator in 'Standby' mode and disconnect the analyzer sample line from the audit calibrator. Reconnect the cal line back to the solenoid that controls the auto-cal air flow. This will allow the sample line to sample ambient air once again. Confirm analyzer is reading ambient levels once again. If slow to return, run a final zero to test for drift and flush line.

3.8.1.17 Once analyzer is reading ambient levels again, enable the data logger channel by returning to the 'CONFIGURATION MENU'.

3.8.1.17.1 Click on 'Configure Data Channels'

3.8.1.17.2 Click on 'Enable/Mark Channel Online'

3.8.1.17.3 Select channel to be enabled. Press Enter to enable the channel. The SO_2 channel is now online.

3.8.1.18 Close the SO_2 audit standard cylinder valve and disconnect from the calibration unit.

3.8.1.19 Enter notes of what was done in the AirVision electronic site logbook.

3.8.1.20 As soon as possible after the QA procedure is performed the supervisor should review the results. Percent differences outside the ± 10% range (or 1.5 ppb for audit levels 1 and 2) must be investigated further to see if corrective maintenance or action is necessary. The audit results should also be compared with previous audit results for the analyzer. Other unusual trends (positive or negative biases, one audit range consistently more in error than the others, etc.) should also be investigated to determine if corrective action is necessary.

3.8.2 Bi-weekly Zero/Span/Precision (ZSP) Checks

3.8.2.1 Zero-Span-Precision (ZSP) 14-day checks include a zero plus two points of a known SO_2 concentration. ZSP checks are intended to verify the analyzer multipoint calibration and may be used to validate and invalidate data. ZSP checks are to be performed at least every 14 days (More frequently if necessary).

3.8.2.2 A ZSP check is performed by challenging the analyzer with two test points after a zero test is done. The test points consist of a concentration of 30-50 ppb SO_2 and an SO_2 concentration of approximately 80% of the calibration scale (100 ppb) of the analyzer.

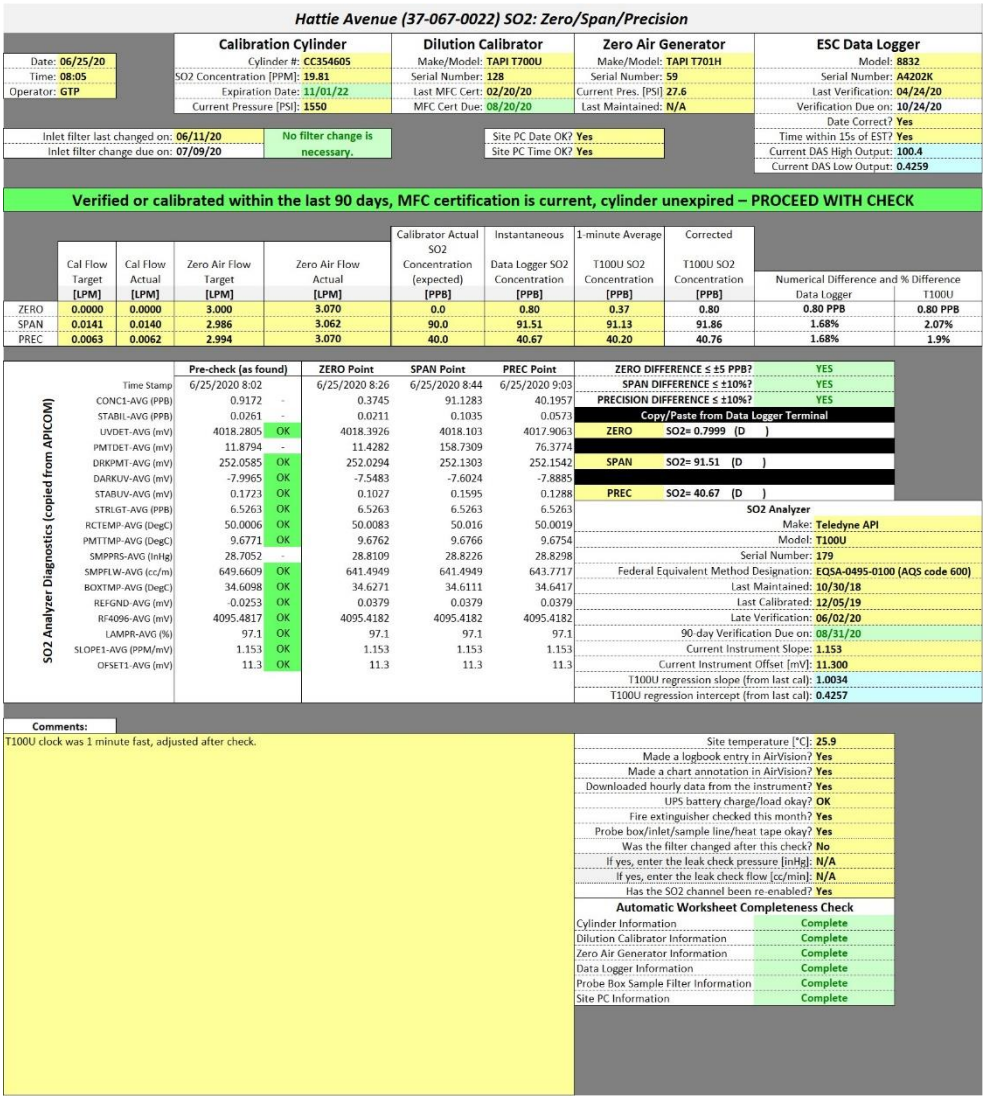
3.8.2.3 Login to the 8864 using AirVision or PuTTY. Refer to Section 11 Datalogger 8864 SOP for information about how to login with PuTTY.

3.8.2.3.1 Down/disable the SO_2 channel.

Open AirVision on the site PC. Login to the central server located at the Government Center with your credentials. Navigate the Utilities menu and click Link To Logger. Select “Hattie A” from the dropdown then uncheck the Server Connection box. Now click the Connect button and you should see a login screen in the terminal window. Press L to login, type the password, then press Enter.

To disable the SO_2 channel, press C (Configuration Menu), D (Configure (Data) Channels), M (Disable/Mark Channel Offline). Use arrows to skip to SO_2, then, press Enter to disable the SO_2 channel.

3.8.2.3.2 The SO_2 channel is now offline. Check both the data logger and analyzer times and make sure they are correct. The datalogger time should be within 1 minute of EST. Record the date, pollutant, monitor serial number, and the system operator signature in the instrument’s Excel-based logbook (Fig. 14).



Hattie Avenue (37-067-0022) SO2: Zero/Span/Precision

Date: 06/25/20	Calibration Cylinder		Dilution Calibrator		Zero Air Generator		ESC Data Logger	
Time: 08:05	Cylinder #:	CC354605	Make/Model:	TAPI T700U	Make/Model:	TAPI T701H	Model:	8832
Operator: GTP	SO2 Concentration [PPM]:	19.81	Serial Number:	128	Serial Number:	59	Serial Number:	A4202K
	Expiration Date:	11/01/22	Last MFC Cert:	02/20/20	Current Pres. [PSI]	27.6	Last Verification:	04/24/20
	Current Pressure [PSI]:	1550	MFC Cert Due:	08/20/20	Last Maintained:	N/A	Verification Due on:	10/24/20
							Date Correct?	Yes
Inlet filter last changed on: 06/11/20	No filter change is necessary.		Site PC Date OK? Yes				Time within 15s of EST?	Yes
Inlet filter change due on: 07/09/20			Site PC Time OK? Yes				Current DAS High Output:	100.4
							Current DAS Low Output:	0.4259

Verified or calibrated within the last 90 days, MFC certification is current, cylinder unexpired – PROCEED WITH CHECK

	Cal Flow Target [LPM]	Cal Flow Actual [LPM]	Zero Air Flow Target [LPM]	Zero Air Flow Actual [LPM]	Calibrator Actual SO2 Concentration (expected) [PPB]	Instantaneous Data Logger SO2 Concentration [PPB]	1-minute Average T100U SO2 Concentration [PPB]	Corrected T100U SO2 Concentration [PPB]	Numerical Difference and % Difference Data Logger	T100U
ZERO	0.0000	0.0000	3.000	3.070	0.0	0.80	0.37	0.80	0.80 PPB	0.80 PPB
SPAN	0.0141	0.0140	2.986	3.062	90.0	91.51	91.13	91.86	1.68%	2.07%
PREC	0.0063	0.0062	2.994	3.070	40.0	40.67	40.20	40.76	1.68%	1.9%

SO2 Analyzer Diagnostics (copied from APICOM)	Pre-check (as found)		ZERO Point	SPAN Point	PREC Point
Time Stamp	6/25/2020 8:02		6/25/2020 8:26	6/25/2020 8:44	6/25/2020 9:03
CONC1-AVG (PPB)	0.9172	-	0.3745	91.1283	40.1957
STABIL-AVG (PPB)	0.0261	-	0.0211	0.1035	0.0573
UVDET-AVG (mV)	4018.2805	OK	4018.3926	4018.103	4017.9063
PMTDET-AVG (mV)	11.8794	-	11.4282	158.7309	76.3774
DRKPMT-AVG (mV)	252.0585	OK	252.0294	252.1303	252.1542
DARKUV-AVG (mV)	-7.9965	OK	-7.5483	-7.6024	-7.8885
STABUV-AVG (mV)	0.1723	OK	0.1027	0.1595	0.1288
STRLGT-AVG (PPB)	6.5263	OK	6.5263	6.5263	6.5263
RCTEMP-AVG (DegC)	50.0006	OK	50.0083	50.016	50.0019
PMTTMP-AVG (DegC)	9.6771	OK	9.6762	9.6766	9.6754
SMPPRS-AVG (InHg)	28.7052	-	28.8109	28.8226	28.8298
SMPFLW-AVG (cc/m)	649.6609	OK	641.4949	641.4949	643.7717
BOXTMP-AVG (DegC)	34.6098	OK	34.6271	34.6111	34.6417
REFGND-AVG (mV)	-0.0253	OK	0.0379	0.0379	0.0379
RF4096-AVG (mV)	4095.4817	OK	4095.4182	4095.4182	4095.4182
LAMPR-AVG (%)	97.1	OK	97.1	97.1	97.1
SLOPE1-AVG (PPM/mV)	1.153	OK	1.153	1.153	1.153
OFSET1-AVG (mV)	11.3	OK	11.3	11.3	11.3

ZERO DIFFERENCE ≤ ±5 PPB?	YES
SPAN DIFFERENCE ≤ ±10%?	YES
PRECISION DIFFERENCE ≤ ±10%?	YES
Copy/Paste from Data Logger Terminal	
ZERO	SO2= 0.7999 (D)
SPAN	SO2= 91.51 (D)
PREC	SO2= 40.67 (D)

SO2 Analyzer	
Make:	Teledyne API
Model:	T100U
Serial Number:	179
Federal Equivalent Method Designation:	EQSA-0495-0100 (AQS code 600)
Last Maintained:	10/30/18
Last Calibrated:	12/05/19
Late Verification:	06/02/20
90-day Verification Due on:	08/31/20
Current Instrument Slope:	1.153
Current Instrument Offset [mV]:	11.300
T100U regression slope (from last cal):	1.0034
T100U regression intercept (from last cal):	0.4257

Comments:
T100U clock was 1 minute fast, adjusted after check.

Site temperature [°C]:	25.9
Made a logbook entry in AirVision?	Yes
Made a chart annotation in AirVision?	Yes
Downloaded hourly data from the instrument?	Yes
UPS battery charge/load okay?	OK
Fire extinguisher checked this month?	Yes
Probe box/inlet/sample line/heat tape okay?	Yes
Was the filter changed after this check?	No
If yes, enter the leak check pressure [inHg]:	N/A
If yes, enter the leak check flow [cc/min]:	N/A
Has the SO2 channel been re-enabled?	Yes

Automatic Worksheet Completeness Check	
Cylinder Information	Complete
Dilution Calibrator Information	Complete
Zero Air Generator Information	Complete
Data Logger Information	Complete
Probe Box Sample Filter Information	Complete
Site PC Information	Complete

Figure 4: Instrument Logbook, Zero/Span/Precision (ZSP) worksheet

3.8.2.4 Verify that the analyzer is working within specifications (see 3.2.4.5-3.2.4.11). Connect to the analyzer using APICOM. Open APICOM 5, click the instrument then click Connect in the toolbar. Alternatively, the right click context menu can be used to connect. The simulator of the T100U should show up on the screen. (Fig. 8)

3.8.2.5 Record the diagnostic observations in the Excel logbook. If these specifications are not met consult the instrument instruction manual for corrective action.

3.8.2.6 Verify the output of the Audit Gas Dilution System (Calibrator) is connected to the SO_2 cal line so gas is supplied to the sample line of the monitor to be calibrated. See section 3.2.2.11.

3.8.2.7 Using the Gas Dilution System (Calibrator), run the 'SO2 ZERO' sequence. This sequence is programmed into the T700U Calibrator and will supply zero air to the T100U.

3.8.2.8 Verify zero air is making it into the T100U. Readings should drop near zero within 30 seconds.

3.8.2.9 Allow the Model T100U to sample zero air until a stable reading is obtained, at least 15 minutes. To check stability, use the TST buttons on the instrument's home screen to scroll to the STABIL parameter. It needs to be less than 1 ppb.

3.8.2.10 After stability is good, collect an instantaneous snapshot of the ppb reading from the 8864 and a minute average from the analyzer. Use APICOM to retrieve the most recent minute average from the analyzer by going to the simulator and clicking the iDAS button. In the window that appears, check the box next to the 1-minute data entry. Click Get Data then select Most recent records and enter "1" into the field. Click OK. Next click the Save Data button then select the minute data Excel file in the SO_2 directory. In the popup dialog, click Append. Navigate to that Excel file in Windows Explorer and open it. Highlight all of the data from the proper minute, Copy, then Paste Special ► Transpose into the proper diagnostic column of the ZSP worksheet in the Excel logbook. Because the ZSP worksheet is locked in Excel to protect formulas, you may have to paste transpose in the APICOM generated Excel file first, copy that, then paste values into the ZSP worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration.

3.8.2.11 Using the Gas Dilution System (Calibrator), run the 'SO2 90' sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 90 ppb of SO_2 to the T100U.

3.8.2.12 Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize.

3.8.2.13 After stability is good (< 1 ppb), collect an instantaneous snapshot of the ppb reading from the 8864. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the ZSP worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration.

3.8.2.14 Using the Gas Dilution System (Calibrator), run the 'SO2 40' sequence. This sequence is programmed into the T700U Calibrator and will supply a concentration of 40 ppb of SO_2 to the T100U. Allow the instrument to come to a stable reading. It may require 10 to 30 minutes for the point to stabilize. After stability is good (< 1 ppb), collect an instantaneous snapshot of the ppb reading from the 8864. Download the latest minute average from the analyzer via APICOM (see section 3.4.1.9) and paste both into the ZSP worksheet. Never use the concentration on the front panel of the analyzer. For the expected concentration from the calibrator, use the value on the data logger if available, otherwise, use the calibrator's front panel actual concentration.

3.8.2.15 The percent difference for each point must be < ± 10.0%. The zero results should be <± 0.5 ppb but must be <± 1.0 ppb.

3.8.2.16 If the above criteria cannot be met inform the Program Manager. If the criteria are met proceed with next step.

3.8.2.17 Via AirVision, open and label the 1-minute average SO_2 graph with an annotation stating what was done and look at the trace to verify points were flat and display a good "stair-step" appearance. To open the graph, click Status Displays in the left sidebar then click Realtime Data Trending. Select SO2 in the Parameter Selection section and click Manual Refresh in the ribbon. Next, highlight all minutes that were downed (i.e., shaded yellow), right click, then click Annotate Selected to leave an annotation. This ensures the annotation is applied to all minutes of the ZSP.

3.8.2.17.1 Record the visit in the AirVision electronic site logbook (Fig. 15).

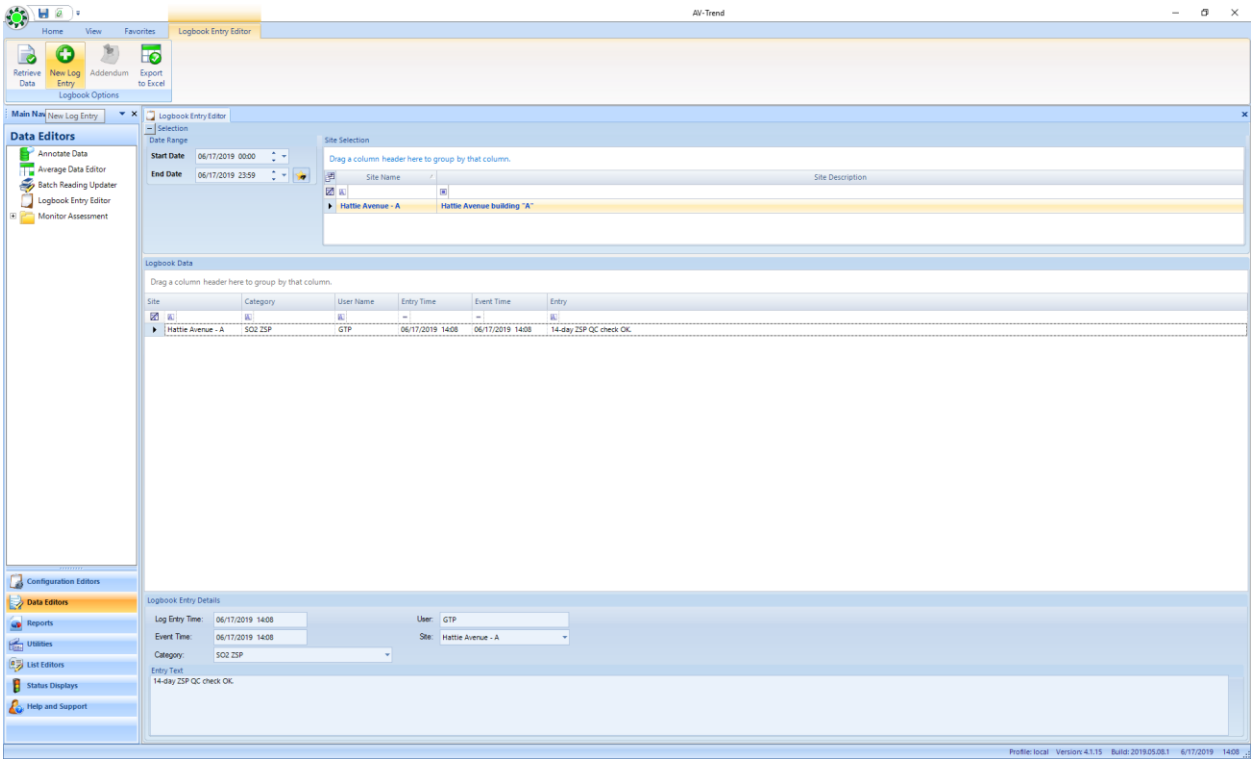


Figure 5: Agilaire AirVision electronic logbook entry

3.8.2.18 Download 1-hour average records from the analyzer's internal data logger. On the APICOM T100U simulator, click the iDAS button. In the window that appears, check the box next to the "1-hour" or "hourly" data entry. Click Get Data then select Most recent records and enter "400" into the field. Click OK. Next click the Save Data button then take the default filename, saving the hourly data Excel file in the SO_2 directory. Upload the hourly data file to the proper directory of SharePoint.

3.8.2.19 Place Calibrator in ‘Standby’ mode. This will allow the sample line to sample ambient air once again. Confirm analyzer is reading ambient levels once again. If slow to return run a final zero to test for drift and flush line.

3.8.2.20 Once analyzer is reading ambient levels again, enable the data logger channel by returning to the 'CONFIGURATION MENU'.

3.8.2.20.1 Click on ‘Configure Data Channels’

3.8.2.20.2 Click on ‘Enable/Mark Channel Online’

3.8.2.20.3 Select channel to be enabled. Press Enter to enable the channel. The SO_2 channel is now online.

3.8.3 Teledyne API T100U SO2 Analyzer Nightly Auto-Calibrations

Each night an auto-calibration is triggered by the datalogger and controlled by the calibrator to further test and confirm the equipment’s operational status. This program starts at a selected time when ambient readings for a specific pollutant are at their lowest point in a typical diurnal pattern. The datalogger triggers the auto-cal to start but then hands over control to the calibrator. The timing of the check for both the datalogger and calibrator are in sync so the datalogger can capture expected results from the calibrator and the analyzer at the right moment. These records are flagged by the datalogger as calibrations and the results are reported to AQS as 1-point QC checks. All auto-cals run at least a zero point and a precision point (a point near the current standard) but could include additional points if needed. Auto cal results have to meet the 10% difference threshold. If it does not meet this then corrective action is required. Some troubleshooting may be needed if results are greater than 7% so data loss can be avoided. Most auto-cals are also programmed so reportable hours are not lost in the process. Operators and staff review the results of the auto-cals every workday since all values show up on a daily report (see Data Handling and Reporting SOP section 10).

3.9 Data Handling - Documentation, Analysis, Editing, and Reporting

3.9.1 Quality Assurance Procedure

For hourly data, see the Data Handling and Processing SOP, which is Section 10. Once the monthly report is complete for the hourly data, please complete the steps in section 3.9.2 for 5-minute average SO_2 data before submitting the monthly data package to the quality assurance personnel.

3.9.2 5-minute SO2 Quality Assurance Procedure

FCEAP submits 5-minute average SO_2 data to EPA’s Air Quality System (AQS). The site data logger is programmed to automatically calculate and store 5-minute averages. The central AirVision server polls these data for long-term storage in the FCEAP AirVision SQL database. Please follow these steps to prepare the 5-minute data for upload to AQS:

3.9.2.1 Open AirVision client and navigate to the Data Editors Menu, clicking on the Average Data Editor entry.

3.9.2.2 Select your site and pollutant, set the date/time range, and choose “005m 5-minute average from 5 minutes” as your average interval (Fig. 16). Click Retrieve Data in the ribbon. Note, since this is a month’s worth of 5-minute, it may take a moderate amount of time for AirVision to load the data.

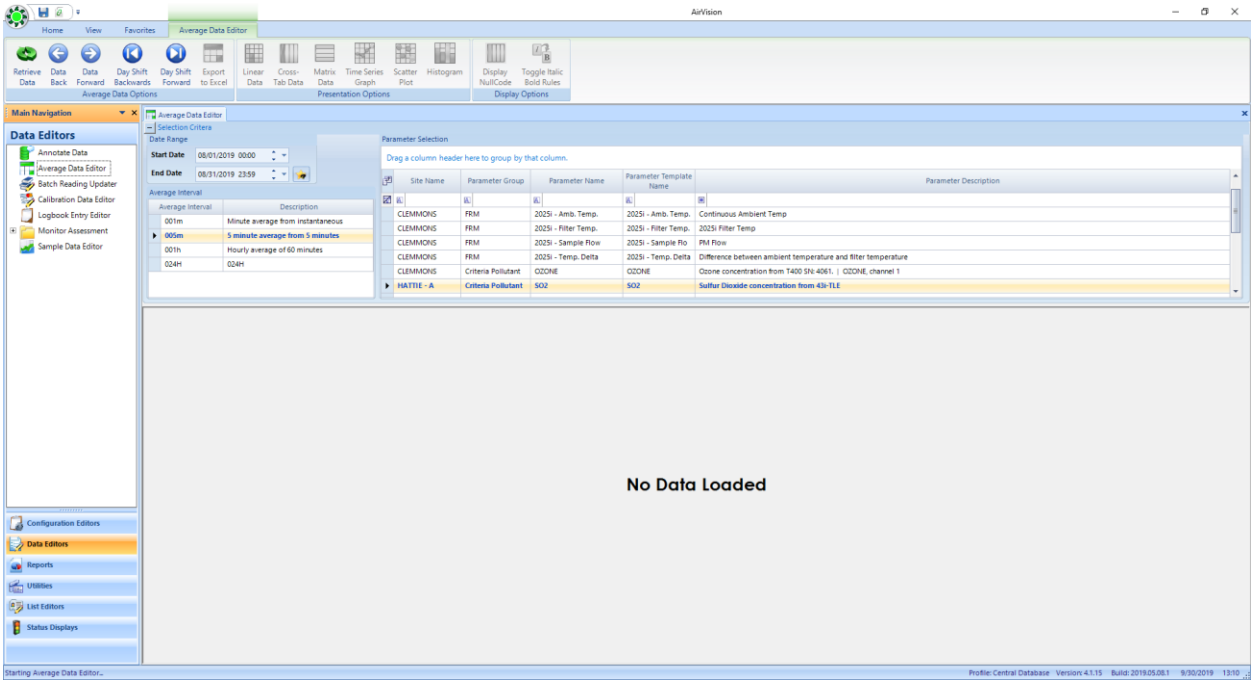


Figure 6: Average Data Editor parameter selection screen

3.9.2.3 Using the Linear Data, Cross-Tab Data, or Matrix Data views located in the ribbon, apply flags and null codes to the 5-minute data, ensuring they match those applied to the hourly data. To do this, highlight the 5-minute blocks that need null codes, right click, then click Set AQS Null Code in the right click context menu (Fig. 17).

3.9.2.4 Either type in your desired null code or select it from the dropdown. Click OK. A prompt will appear asking if you would like to mark the data invalid, click Yes. You should now see the null codes in the AQS Null Code column along with an “I” flag in the Flags column.

3.9.2.5 Continue applying null codes and flags in this manner as necessary. For all hours to which null codes were applied during the monthly report process, please ensure that all corresponding 5-minute blocks have matching null codes and flags. Additionally, ensure that all 5-minute blocks during auto cals are invalidated with null code “BD” which is used for auto calibrations.

3.9.2.6 Please note that AirVision does not automatically save changes to the database. Once you are satisfied with your changes, click the Save button above the ribbon.

3.9.2.7 These steps should be completed before passing the monthly report along to the quality assurance personnel. This helps ensure consistent null code application.

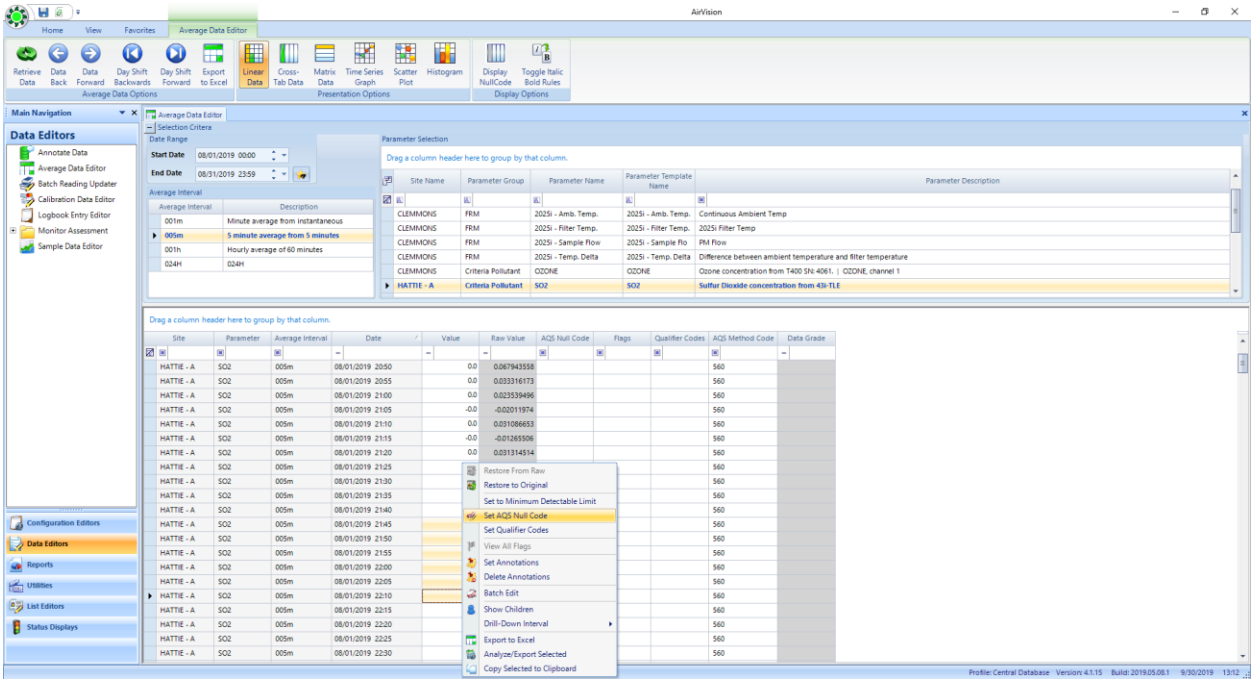


Figure 7: Average Data Editor right click context menu

REFERENCES

United States Environmental Protection Agency (2013).

Models T100 and T100U UV Fluorescence SO_2 Analyzers with NumaView software (2019). *T100U UV Fluorescence Analyzer*. Teledyne Advanced Pollution Instrumentation, Inc., San Diego, CA.

Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II- Ambient Air Specific Methods, EPA-454/B-13-003 (2013), U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Research Triangle Park, N.C. 27711.

Title 50 Code of Federal Regulations Part 58- Ambient Air Quality Surveillance. 1993.

Transfer Standards for Calibration of Air Monitoring Analyzers for SO2. Technical Assistance Document. EPA-454/B-10-001. United States Environmental Protection Agency, November, 2010.