Air Pollution Control Division

Technical Services Program

APPENDIX QA1

Standard Operating Procedure for Performance Evaluations / Audits

January 12, 2023

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Table of Contents

1.1. Objective 9
1.2. Quality Assurance 9
1.3. Format and Purpose 9
1.4. Definitions 9
1.5. Health and Safety / Equipment Care 10
2. Site Inspections 11
3. Carbon Monoxide Audit Procedure 12
3.1. Introduction 12
3.2. Accuracy 12
3.3. Audit Equipment Checklist 14
3.4. CO Audit Procedure 15
3.4.1. Collect Analyzer Information, Disable Data logger and Perform Leak Check 15
3.4.2. Analyzer Quality Control and Audit Equipment Setup 17
3.4.3. Level 3, Level 2 and Level 1 Accuracy Audit 20
3.4.4. Calculate Analyzer Error 25
3.4.5. Completion of Audit 25
3.5. Data Processing 26
4. Nitrogen Dioxide Audit Procedure 27
4.1. Introduction 27
4.2. Accuracy 27
4.3. Audit Equipment Checklist 31
4.4. NO_2 Audit Procedure 31
4.4.1. Collect Analyzer Information, Disable Data logger and Perform Leak Check 31
4.4.2. Analyzer Quality Control and Audit Equipment Set up 33
4.4.3. Level 4, 3, 2 and 1 Accuracy Audit 36

4.4.4. Calculate Analyzer Error 45
4.4.5. Completion of Audit 47
4.5. Data Processing 48
5. Sulfur Dioxide Audit Procedure 49
5.1. Introduction 49
5.2. Accuracy 49
5.3. Audit Equipment Checklist 51
5.4. SO_2 Audit Procedure 52
5.4.1. Collect Analyzer Information, Disable Data Logger and Perform Leak Check 52
5.4.2. Analyzer Quality Control and Audit Equipment Set up 54
5.4.3. Level 3, Level 2 and Level 1 Accuracy Audit 56
5.4.4. Calculate Analyzer Error 62
5.4.5. Completion of Audit 62
5.5. Data Processing 63
6. Ozone Audit Procedure 64
6.1. Introduction 64
6.2. Accuracy 64
6.3. Audit Equipment Checklist 66
6.4. O_3 Audit Procedure 67
6.4.1. Collect Analyzer Information, Disable Data Logger and Perform Leak Check 67
6.4.2. Analyzer Quality Control and Audit Equipment Setup 69
6.4.3. Perform Accuracy Audit 71
6.4.4. Calculate Ozone Test Concentrations 74
6.4.5. Calculate Analyzer Error 74
6.4.6. Completion of Audit 75
6.5. Data Processing 76
7. PM_{10}/TSP High Volume Sampler Audit Procedure 77

7.1. Introduction 77
7.2. Accuracy 77
7.3. Audit Equipment Checklist 78
7.4. PM_{10}/TSP High Volume Audit Procedure 78
7.4.1. Collect Analyzer Information and Perform One-Point Flow Rate Audit 79
7.4.2. Audit Failure 82
7.4.3. Completion of Audit 83
7.5. Data Processing 83
8. R&P Partisol 2000 PM FRM Single Sampler Audit Procedure 86
8.1. Introduction 86
8.2. Accuracy 86
8.3. Audit Equipment Checklist 87
8.4. Federal Reference Monitor (FRM) Audit Procedure 87
8.4.1. Pre-Audit 87
8.4.2. Flow Rate Audit 92
8.4.3. Completion of Audit 93
8.5. Data Processing 94
9. Low Volume R&P Partisol Plus 2025 FRM PM Sampler Audit Procedure 96
9.1. Introduction 96
9.2. Accuracy 96
9.3. Audit Equipment Checklist 97
9.4. Federal Reference Method (FRM) Audit Procedure 97
9.4.1. Pre-Audit 97
9.4.2. Flow Rate Audit 101
9.4.3. Completion of Audit 102
9.5. Data Processing 102
10. Audit Procedure for the MetOne SASS and Super SASS 105

10.1. Introduction 105
10.2. Quality Assurance 105
10.3. Audit Equipment Checklist 105
10.3.1. Audit Procedure 106
10.4. Data Processing 117
11. URG 3000N Chemical Speciation Sampler Audit Procedure 120
11.1. Introduction 120
11.2. URG 3000N Audit Procedure 120
11.3. Audit Equipment Checklist 120
11.4. URG Audit Procedure 120
11.4.1. AUTO MODE To Audit Menu Screens 120
11.4.2. Ambient Temperature Audit 121
11.4.3. Barometric Pressure Verification 123
11.4.4. Leak Check Verification 124
11.4.5. Flow Rate Verification 126
11.5. Data Processing 128
11.5.1. Continuous Particulate Sampler (TEOM) Audit Procedure 131
11.6. Introduction 131
11.7. Accuracy 131
11.8. Audit Equipment Checklist 132
11.9. TEOM Audit Procedure 132
11.9.1. Collect Analyzer Information and Disable Data logger 132
11.9.2. Accuracy Leak Check 134
11.9.3. Accuracy Ambient Temperature Audit 136
11.9.4. Accuracy Ambient Pressure Audit 136
11.9.5. Accuracy Flow Audit 137
11.9.6. Accuracy Mass Transducer Verification 139

11.9.7. Completion of Audit 141
11.10. Data Processing 141
12. Grimm EDM 146 143
12.1. Introduction 143
12.2. Accuracy 143
12.3. Audit Equipment Checklist 144
12.4. GRIMM Audit Procedure 144
12.4.1. Pre-Audit 144
12.4.2. Zero/leak Check 146
12.4.3. Ambient Temperature Verification 152
12.4.4. Ambient Pressure Verification 152
12.4.5. Flow Verification 153
12.4.6. Completion of Audit 155
12.5. Data Processing 156
13. TAPI Model T640 PM Mass Monitor 158
13.1. Introduction 158
13.2. Accuracy 158
13.3. Audit Equipment Checklist 159
13.4. T640 Audit Procedure 159
13.4.1. Pre Audit 159
13.4.2. Leak Test / Zero Test 161
13.4.3. Ambient Temperature Verification 162
13.4.4. Ambient Pressure Verification 162
13.4.5. Flow Verification 163
13.4.6. Completion of Audit 164
13.5. Data Processing 164
14. TAPI Model 633 Aethalometer® 166

14.1. Introduction 166
14.2. Accuracy 166
14.3. Audit Equipment Checklist 167
14.4. Aetholometer Audit Procedure 167
14.4.1. Collect Analyzer Information and Disable Data Logger 167
14.4.2. Accuracy Ambient Temperature Audit 169
14.4.3. Accuracy Ambient Pressure Audit 169
14.4.4. Leak Check 169
14.4.5. Flow Verification Procedure 171
14.4.6. Completion of Audit 173
14.5. Data Processing 173
15. Meteorological Audit Procedures 174
15.1. Introduction 174
15.2. Accuracy 174
15.3. Audit Equipment Checklist 174
15.4. Meteorological Tower Audit Procedure 175
15.4.1. Initial Cross-arm Orientation Audit Procedure 175
15.4.2. Login to Site Computer and Disable Data Logger Channels 177
15.4.3. Lower Meteorological Tower 178
15.4.4. Wind Speed Translator and Diagnostic Checks 178
15.4.5. Wind Direction Translator Output and Diagnostic Checks 180
15.4.6. Temperature Sensor Translator Output and Diagnostic Checks 182
15.4.7. Raise and Secure the Tower 182
15.4.8. Enable Data Logger Channels 182
15.4.9. Final Cross-Arm Orientation Audit 183
15.5. Calculations and Reports to Management 183
15.6. Data Processing 184

Introduction

1.1. Objective

The objective of this Quality Assurance (QA) document is to provide guidance for conducting system and performance audits and to also provide standardized audit procedures when performing audits in the field. These QA audits are designed to validate data collected by assessing instrumentation accuracy, operator performance, site configuration and maintenance. In addition, these QA audits help create data within a specified level of data quality to show compliance with ambient air quality standards, to help decision makers' use the final ambient data to set policy and help researchers perform health related research. The Code of Federal Regulations (CFR) has mandated a required number of audits for each monitoring parameter set forth in 40 CFR, Part 58 Appendix A. The Air Pollution Control Division (APCD) has set goals to perform more than the required number of audits set forth in the CFR and those goals along with the audit procedures are detailed in each parameter section below.

1.2. Quality Assurance

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets or exceeds the quality requirements for its intended use. The core elements of the APCD Quality Assurance Program consist of randomly scheduling monitoring site visits by an independent auditor to perform ambient air sampler performance checks. These random monitoring site visits are performed at a specified frequency depending on the type of pollutant. Information obtained by these events provides essential input into processes used by the APCD to assess the bias, precision, accuracy, representativeness and completeness of the ambient air quality monitoring program. APCD must adhere to QA/QC protocol as prescribed in 40 CFR Part 58, Appendix A.

1.3. Format and Purpose

The sequence of topics covered in these audit procedures follows 2007 EPA QA/G-6 "Guidance for Preparing Standard Operating Procedures (SOPs)". These procedures were also written to help auditors understand why (not just how) key procedures are performed. Cross references to other sections are cited simply by section number. The *EPA Quality Assurance Handbook for Air Pollution Measurement System, Volume II, last revised May 2013 (hereon abbreviated to the QA Handbook)* is cited in this document, is a must read for any auditor working for APCD and is recommended for reference purposes.

1.4. Definitions

Learning new acronyms, abbreviations, and specialized terms is an important task of any staff member because these items are a part of the organizational culture. But if these terms are not somewhat intuitive and are not defined in writing, they will remain unintelligible jargon. In Part I, Page ix of the EPA Quality Assurance Handbook, Volume II, there is a list of many commonly used acronyms and abbreviations. Standard Operating procedures (SOPs) should contain similar lists of terms specific to them, while also defining each term upon first usage in the document. An additional list of terms and Acronyms can be found in Appendix P2 of this QAPP.

1.5. Health and Safety / Equipment Care

To prevent personal injury and equipment damage, take the following precautions into consideration when working on and around sampling equipment:

- Always use a third ground wire on all instruments.
- Always unplug the sampler when servicing or replacing parts.
- Use extreme caution if any electrical outlets or connections have come into contact with water.
- If it is necessary to work inside an analyzer while it is in operation, use extreme caution to avoid contact with high voltage inside the analyzer. The analyzer has high voltages in certain parts of the circuitry, including a 220 volt DC power supply, a 110 volt AC power supply, and a start-up lamp voltage of more than 1000 volts. Refer to the manufacturer's instruction manual and know the precise locations of these components before working on the instrument. Avoid electrical contact with jewelry. Remove rings, watches, bracelets, and necklaces to prevent electrical burns.
- Always vent any excess audit gas to the exterior of any sample shelter.
- Use caution on ladders and rooftops, especially in inclement weather or under snow pack conditions. Only one person at a time on a ladder is safe. Strap the ladder in place where possible. Use a rope to pull equipment up to the roof.
- Strap inlets, front panels, and timer or sampler box doors into open positions while auditing particulate samplers to avoid unexpected movement due to winds or uneven weight distribution.
- Sturdy work shoes with a good traction sole are recommended.
- Sunscreen and UV eye protection are recommended.
- Maintain an awareness and familiarity with immediate surroundings including activities of pedestrians below the sampling location and near the ladder.
- Use cleaning procedures outlined in the manufacturer's instruction manual.
- Keep the interior of the analyzer clean.
- Inspect the system regularly for structural integrity.
- To prevent major problems with leaks, make sure that all sampling lines are reconnected after required checks and before leaving the site.
- Sample gas should be delivered to the instrument at atmospheric pressure.

Field personnel must keep in mind that it is up to the individual to incorporate safe work practices to prevent personnel injury or damage to equipment.

2. Site Inspections

A site inspection is conducted every time an auditor goes to a monitoring station to perform an audit. The inspection procedure includes, but is not limited to, the following actions:

- Note on site/station log form the date and arrival time. Initial this new entry on the site/station log form.
- Check that all monitors' operational parameters such as vacuum, temperature, and sample flow look normal compared to the values recorded on their calibration stickers and station log sheets. The set allowable ranges for instrument parameters will be inside the operator’s manual and on the station instrument log sheets. Parameters such as gain control intimately and directly affect the calibration of an instrument and should not be changed unless a full calibration is performed. If any parameter on any analyzer is out of bounds then the station operator and work lead should be notified that day.
- Check that the station temperature high/low readings are within a range of 20 – 30 ºC and use a temperature standard to verify the station I-temp sensor is within +/- 2 ºC. If the I-temp sensor does not agree with the QA standard notify the station operator or the Gaseous and Meteorology Monitoring (GMM) or Particulate Monitoring (PM) work lead or unit manager. Record the I-temp verification values on both the auditing sheet and on the Site/station log form.
- Check the station logs for non-routine actions.
- Check that the modem is on.
- Check that the data logger is running and not locked up on the CRT screen. If it is (i.e. there is no response to CRT keyboard keystrokes) contact the GMM unit work lead, particulate unit work lead or site operator personnel immediately.
- Check that all analyzers and meteorological (met) sensors appear to be reading ambient values that are reasonable given outside conditions and past readings for that individual station. This is done by looking at both the front panel displays and at the data logger display for all analyzers and met sensors.
- Check visually that the meteorological tower's instrument crossbar is properly aligned. Check that the meteorological sensors aren't damaged and are moving without binding.

- Check that the station structure is not damaged and shelter roof is not leaking. Any sign of water damage should be noted and passed on to site operator personnel.
- Check that all digital chart recorders are set on the proper time and are displaying data that corresponds to the analyzer readings.
- Check that all pumps are running smoothly and are not overly hot to the touch.

If anything is found out of the ordinary it is recorded on the station log, along with the date and the auditor's initials. The site operator must be notified that day (or the work lead or supervisor of the GMM or particulate unit if that person is not available). Maintenance should be performed if appropriate and within the scope of the auditor's resources.

3. Carbon Monoxide Audit Procedure

3.1. Introduction

Carbon monoxide (CO) is a colorless, odorless and tasteless gas. Carbon monoxide is produced by the incomplete combustion of fossil fuels. It is a component of vehicle exhaust, which contributes most of the CO emissions nationwide. High concentrations of CO can be found in areas with high traffic congestion. Peak CO emissions typically occur in the colder months when automobile emissions are higher and temperature inversions are more common. It is a hazardous compound as it combines with hemoglobin and reduces the oxygen carrying ability of the blood.

3.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true (expected) or accepted value. Quantitative comparisons are made between these two values during audits. Generally, three upscale points and a zero point are utilized for comparison.

The APCD is required to perform accuracy audits on at least 25% of the carbon monoxide (CO) monitoring network each quarter, such that each CO analyzer is audited at least once per year. The APCD goal is to exceed this requirement by auditing each analyzer twice per year. The audit is made by challenging the analyzer with an audit gas of known concentration from at least three of the following ranges (see Table 3.1) that fall within the measurement range of the analyzer being audited. Two of the audit points should fall within the range of where 80% of the ambient data values occur. One point should be performed at either the highest concentration level seen over the past three years or at the NAAQS, whichever is higher. A zero air level should be audited. Additional audit concentrations can be taken if it is needed to better characterize analyzer performance. The lowest concentration ranges in the table below are intended for trace gas analyzers.

The Environmental Protection Agency (EPA) and Office of Air Quality Planning and Standards (OAQPS) has put out a memorandum dated Nov. 10, 2010, giving guidance to monitoring organizations on new expanded audit levels (bins) (detailed in the Table 3.1 below). Also in the memorandum, is guidance allowing an auditor to skip one bin. While the CFR states that the audit levels must be consecutive, the new guidance states "with the expansion to ten audit levels and the reduction of the concentration span within each audit level, it is appropriate to allow an audit level to be skipped while still auditing a minimum of three levels. Even with this increased flexibility, at least two audit levels should still be chosen to bracket 80% of the ambient data. Every year a data review of the network's past three years of ambient data levels is evaluated to determine where 80% of the ambient concentration data is collected. The goal is to choose levels that best reflect the concentrations at your monitoring sites". This means that an auditor may choose two consecutive levels and skip one level for the third required audit level. Auditors within APCD will run 4 to 5 audit levels to bracket where 80% of the ambient data is captured and to test the full scale of the instrument where feasibly possible.

In addition, Zero Drift of the CO analyzer must be taken into consideration when selecting audit ranges. The EPA has reevaluated the Zero Drift requirements put forth in the 2013 QA Handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program. The current recommendations can be found here: https://www3.epa.gov/ttnamti1/files/ambient/pm25/qa/Final%20Handbook%20Document%201_17.pdf. Keep in mind that the lowest two levels of the Target Audit Concentration Chart fall below the Zero Drift limit (0.41 ppm is the current zero drift), making these levels unrealistic target audit concentrations for non-trace analyzers. APCD's current carbon monoxide monitoring network only employs trace-level analyzers. Current APCD protocol is to only zero correct audit data if the ambient data has justification for zero correction and has been adjusted and or reasonable justification to do so has been found. The boxes highlighted in yellow represent APCD's current target concentrations, taking the proposed Zero Drift criteria into consideration.

Table 3.1: CO Target Audit Concentration Ranges

Audit level	Concentration range (ppm)
1	0.020-0.059
2	0.060-0.199
3	0.200-0.899
4	0.900-2.999
5	3.000-7.999
6	8.000-15.999
7	16.000-30.999
8	31.000-39.999
9	40.000-50.000
10	50.000-60.000

The standards from which audit gas concentrations are obtained are directly traceable to Certified Reference Materials (CRM) using analysis procedures specified by the EPA and detailed in the EPA Traceability Protocol for Assay and Certification of Gasesou Calibration Standards, 2012. When tanks arrive at APCD they are then tested against the APCD in-house standards using Appendix GM9 : "SOP for In-House Comparison of Certified Gas Tanks". Personnel audit standards and equipment used in carbon monoxide accuracy audits are always different than those used in instrument calibration or Quality Control (QC) checks.

An audit is performed by introducing an audit test atmosphere into the station analyzer in its normal sampling mode, such that the test atmosphere passes through all filters, scrubbers and as much of the ambient air inlet system as is practical.

The APCD audit staff employs calibrators with verified NIST traceable mass flow controllers. These mass flow controllers are compared to the APCD's NIST traceable primary laboratory flow standard minimally on a yearly basis. This mass flow controller verification procedure can be found in the APCD's QAPP, Appendix QA2 "Standards Verifications and Calibrations". Calibrators with verified mass flow controllers are simple to operate and are typically microprocessor controlled. To obtain standard operating procedures for a particular type of calibrator, please refer to the appropriate operations manual.

The APCD utilizes an Access Database to enter and process audit results. The database used for all continuous gaseous and particulate instruments within APCD's network is called the "QA Audits Database". A printout of a blank CO Audit form is used as the Carbon Monoxide Analyzer Audit Field Form in which raw data is hand entered by blue or black ink (see Figure 3.2). Information from the hand written Carbon Monoxide Analyzer Audit Field Form is then input into the Access Database. The hand written Carbon Monoxide Analyzer Audit Field Form is archived incase the electronic copy is lost or damaged. A copy of the Access Database is stored on the auditor's notebook computer and backed up on a thumb drive while in the field after each audit entry is completed. After returning to the office the laptop computer is used for uploading all the audit information to a table linked, master copy of the database located on the J: Drive within APCD's local area network. The location of the master database within APCD's network is J: \ QA Audit Programs \ P&A Database \ QA Audits Database.mdb. At the end of each quarter the audits are reviewed for accuracy and completeness. Accuracy strings are generated, and uploaded to EPA's AQS database. Hard copy printouts are also archived and stored in case the electronic copy is lost or damaged. For carbon monoxide, the form used for storing audit data can be located by opening the QA Audits Database, clicking <Enter New Audit> and selecting Carbon Monoxide from the main page of the database.

3.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on a CO analyzer:

i. Auditing Dilution Gas Calibrator with current verified Mass Flow Controllers (annual certification, or more frequently).
ii. Clean air source/pack.
iii. A catalytic oxidizer (catox) may also be needed if the zero air supply chosen does not have one already incorporated into the overall zero air system.
iv. Audit sample delivery line set up with “t” and additional Teflon sample line with fittings (see Figure 3.1).
v. Calculator.
vi. Personal Laptop for data entry and audit verification. Loaded with Instrument manuals file.
vii. NIST-traceable thermometer.
viii. Copy of the Carbon Monoxide Audit Accuracy Form (Figure 3.2) for use as the Carbon Monoxide Analyzer Audit Field Form.
ix. NIST-traceable CO gas cylinder with regulator.
x. Tools and spare Teflon sample lines and fittings.

Sample Line Note: When possible and practical it is best to audit all gaseous instrumentation through the complete sample line inlet. This practice is best because the auditor can test the condition of the sample line. Over time, sample lines can build up dust and other various forms of debris, or they can degrade from extreme weather conditions causing leaks. Build-up of debris can create interferences in the analyzer concentration measurements (see Appendix GM1: CO SOP for more details on positive and negative analyzer interferences). It is best practice to replace or clean sample lines on an annual basis unless it is proven through various testing procedures that the sample line is not effecting the ambient concentrations being analyzed for. The GMM unit has procedures set in place to replace the sample lines annually. Additionally, GMM site operators periodically trim the inlet end of the tubing during the year (for more details on this, see the Appendix GM1: CO SOP). Most of the gaseous sites in the network are set up to run the station zero, span and precision QC checks through the sample line inlet automatically every night, giving the GMM unit regular information on the condition of the sample inlet.

3.4. CO Audit Procedure

3.4.1. Collect Analyzer Information, Disable Data logger and Perform Leak Check

1. Collect required information from the CO analyzer being audited by scrolling through parameters on the front panel of the analyzer. Tracked parameters should be recorded on the station CO analyzer site log located in the sample shelter. This information is compared to the instrument operation specifications and to the last set of parameters the operator recorded to assure the analyzer is functioning properly before starting an audit.

2. Enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field:
    - The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
        i. Logger ID # is usually written on the upper left corner of the monitor in two digit form. If not, hit "ESC ESC . . AQM" and logger ID number should appear on screen. Hit "Escape" key twice
        ii. Input "logger ID" + "AQM"
        iii. Password for the ESC Systems is "GO VOLS"

    - The second type of logger system is the Agilaire. This is a windows based system and the password to log into this system is "Agilaire".

3. Before an audit can be performed, the CO channels must be disabled on the data logger so that all data collected during the time the audit was performed is flagged as invalid. To disable the CO channels for each type of data logging system, follow the procedures listed below:
    - ESC System:
        i. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter", or by typing the letter associated with the command and hitting enter.
        ii. From this menu select "Configure Data Channels".
        iii. Next go into "Disable/Mark Channel Offline". To put channels back online at the end of the audit, choose "Enable/Mark Channel Online"
        iv. From here you will see a list of enabled reporting channels. Highlight the desired channel and press "enter". This process will take the channels offline so the audit data is not reported as ambient concentrations.
        v. Repeat task iii and iv as necessary to flag all affected channels as offline.

    - Agilaire System:
        i. From the Home page of the **AV-Trend**, go to the " Utilities" drop down menu and choose "Site Node Logger Toolbox"
        ii. You will find a list of all the channels at the station. All channels which are active should be "False". To mark the channel as offline, click "False" for the CO channel, in the "Disabled Flag" column and it should change to "True" which indicates that it is now offline.

4. Read the data logger's current time. Record the time on the station CO analyzer log and on the Carbon Monoxide Accuracy Audit Field Form.

5. Record calibration information on the Carbon Monoxide Analyzer Audit Field Form (see Figure 3.2). Information about the most recent calibration is obtained from the calibration sticker. This information includes analyzer serial number, calibration date, prior sampler flow setting, and zero and gain settings at the time of the calibration. Verify that the gain from the calibration sticker is the same as the gain recorded for the instrument parameters and on the CO analyzer site log form.

6. If working at a station where there is a manifold, confirm that the station manifold fan is operating and that the fan motor housing is not hot to the touch if one is present. Currently APCD does not utilize manifolds. If a manifold is being used, remove sample line from the station manifold. Cap off the open port at the manifold to prevent shelter air from entering the manifold.

7. Perform a leak check if needed. Remove the sample line from the back of the analyzer, and follow the operator manual directions for conducting a leak check. Record leak check results on the Carbon Monoxide Analyzer Audit Field Form and on the station CO analyzer site log form.

3.4.2. Analyzer Quality Control and Audit Equipment Setup

1. First, run the analyzer through the nightly station zero and span tests to ensure the analyzer is functioning properly and that all station Quality Control (QC) checks are passing specifications. Record stabilized readings on the Carbon Monoxide Audit Analyzer Form. Wait to perform the precision test until after the audit has been performed to verify the station analyzer is left in operable condition.

2. Connect the "diluent in" port of the auditing dynamic dilution calibrator (audit calibrator) to the output end of the audit clean air system (zero-air) with quarter-inch tubing. Make sure the supplied zero-air source does not exceed 35 PSI delivery to prevent damage to internal O-rings and gaskets of the audit calibrator. (It is best to start with a low pressure delivery from the zero air source and ramp it up when the audit calibrator is in operation.) Verify the pressure reading on the audit calibrator system for the dilution "DIL Pressure" is between 25-35 psi. It is ideal to keep this pressure approximately 30 psi for the entire audit process. Be aware that changes in

output concentrations and ambient conditions can affect "DIL Pressure" so adjustments to the zero air regulator may be necessary throughout the audit process.

3. Evaluate the station plumbing to determine if you will be performing a Through the Probe (TTP) or a Back of Analyzer (BOA) audit:
    - If the station analyzer is set up to perform Through The Probe (TTP) nightly precision, span and zero testing, then disconnect the *precision/span* delivery line from the STATION calibration system (or from the back side of the solenoid that delivers the nightly checks to the CO inlet), and place the *precision/span* delivery line on the AUDITING calibration system sample output port.

    - If the CO analyzer is not set up to run TTP nightly checks, then the following set up is required;
        i. Place a Teflon audit sample delivery line on the auditing calibrator's sample outlet port (ensure that all unused sample outlet ports on the back of the audit calibrator are caped with stainless steel caps only).
        ii. The analyzer sample line is then connected to one side of a T-fitting. Attach a long piece (~5-8 ft.) of Teflon tubing to the other side of the T fitting for venting purposes to maintain ambient pressure in the analyzer being tested.
        iii. The third piece of Teflon is connected to the remaining opening on the "T" fitting while the other end is attached to either the sample inlet (if doing a TTP audit, which in most cases is the preferred audit type) or the back of the analyzer sample inlet port (the BOA is only used when a TTP audit cannot be performed due to safety issues). For operator safety the excess sample flow should be vented to the outside of the station (See Figure 3.1).

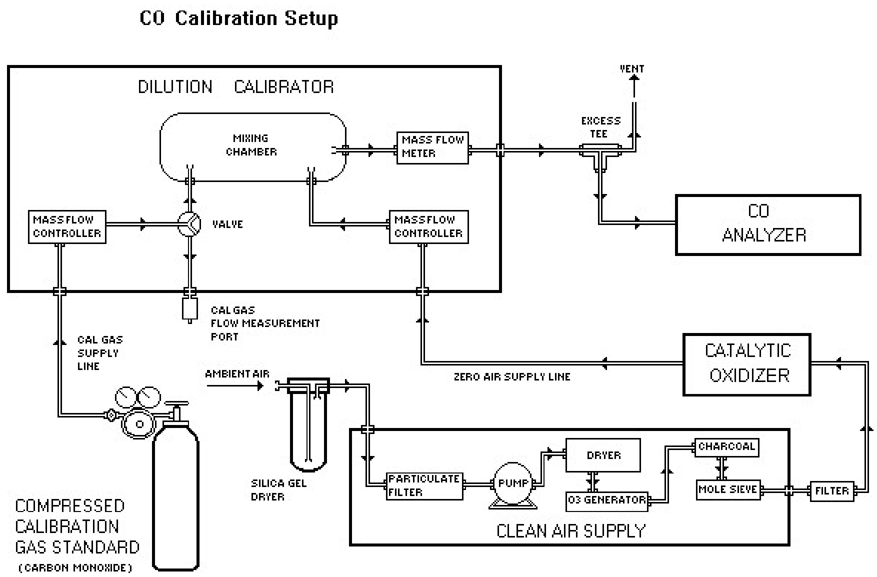


Figure 3.1: CO Audit Sample Train Setup

4. Connect the audit CO cylinder to one of the gas input ports of the audit calibrator Cal with 1/8" Teflon tubing and a stainless steel fitting. Adjust cylinder regulator to a delivery pressure of 25-35 psi (Again, if in doubt it is always better to start with a lower pressure and turn the delivery pressure up after connecting to assure excess pressure will not damage the calibrator). Verify the pressure reading on the audit calibrator system given from the tank to the calibrator as "CAL Pressure". It is ideal to keep this pressure approximately 30 psi for the entire audit process. Be aware that changes in output concentration can affect "CAL Pressure" so adjustments to the calibration regulator may be necessary throughout the audit process.
Note: each port on the back of the audit calibrator is specific for each type of audit gas. This must be verified by checking the program in the audit calibrator when the calibrator is in "standby" by going to Setup>Gas>Cyl mode and then checking each port. Also, confirm that the concentration of the audit gas is input correctly for that particular gas cylinder.

5. Turn on the clean air source and dilution calibrator and allow system to warm up for approximately 15 minutes.

6. Record the clean air source information (vacuum and gauge pressure), gas cylinder identification numbers, gas cylinder CO concentrations, and regulator pressures for station and audit tanks on the back page of the Carbon Monoxide Analyzer Audit Field Form.

3.4.3. Level 3, Level 2 and Level 1 Accuracy Audit

1. To ensure the readings in question are stable, it is helpful to use a graphical display to better visualize when a reading has stabilized:
   - For the DOS based ESC data logging system, use the digital chart recorder located onsite, usually located above the analyzer.

   - For the Windows based Agilaire data logging system, utilize the *AV-Trend* program which offers a graphical display:
     i. Go to the “Status Displays” drop down menu and choose “Realtime Data Trending”.
     ii. Highlight the parameter you wish to monitor and number of hours you would like to look back, typically “1 hour” will do.
     iii. Make sure the Average Interval is “1 minute”.
     iv. Highlight “Realtime Data Trending” on the top menu and choose “Auto Refresh”. This should bring up graphical display which is updated every minute.

   It typically takes at least ten minutes of stable audit sample delivery to get good quality readings. At least 5 minutes of stable delivery readings at every audit level is required for a point to be considered valid.
2. Recorded readings are determined by which type of data system is being utilized;
   - For the ESC data system, record the:
     - ➢ CO Concentration from data logger (ppm)
     - ➢ Analyzer display (ppm).
     - ➢ A cal and A dil calibrator output flows (lpm)
     - ➢ Output concentration from the audit calibrator (ppm).

     The procedure for taking real-time concentration and voltage readings from the ESC data logger system is as follows;
     - ➢ From the main menu, go into the “Real – Time Display Menu” by hitting the letter “D” on the logger keyboard.
     - ➢ From this menu type “F” to “Display Readings w/flags”. This will continuously display the data logger CO concentration response with

flags. If the analyzer has been correctly taken offline there will be a "D" displayed in parentheses after the CO concentration.

- For the Agilaire data system:
  - ➢ Record the data logger response (ppm) from the "Site Node Logger Toolbox" concentration or "Value" display.
  - ➢ Record analyzer front panel display response (ppm).
  - ➢ A cal and A dil calibrator output flows (lpm)
  - ➢ Output concentration from the audit calibrator (ppm).

  Take the analyzer CO readings after the CO concentration has stabilized; record ten values and average these readings as the analyzer response (ppm). Record these readings on the *Carbon Monoxide Analyzer Audit Field Form*.

3. Next, verify that the audit calibrator is providing approximately 3-4 L/min of zero air to the analyzer and verify that no source gas is being introduced to the analyzer at this time. After the zero reading has stabilized, record the required readings on the *Carbon Monoxide Analyzer Audit Field Form*. Again, recorded readings are determined by the type of data logger being utilized.
   Note: Part of making sure the zero air system is producing a clean zero air is to perform yearly maintenance to the machine. This includes replacing all the associated scrubber materials within the zero air generator.

4. Next, adjust the calibrator so that clean zero air and Audit cylinder CO are mixed in the calibrator to a gas concentration appropriate for the **Level 3** audit point from the 10-tiered audit level bins in table 3.1. Because it is necessary to condition sample lines and fittings to these high CO concentrations, this high concentration audit point could take up to 30 minutes to stabilize.
   Note: When adjusting the audit gas flow on the audit calibrator, it must be taken into consideration that there are two Mass Flow Controllers (MFCs) dedicated for the audit gas flow located within the audit calibrator. It is important to try to only use one MFC at a time to eliminate an additional margin of error. The MFCs are rated for use between 5-50cc/min and 20-200cc/min. However, the primary standard being used to verify the flow rates on the low end of the 0-50cc/min mass flow controller is only calibrated by the manufacturer down to 13cc/min. When selecting gas flows try to keep the audit gas flows between 10-49cc and 52-199cc to eliminate the possibility of two mass controllers functioning at the same time and to avoid problems associated with use of flow rates outside the range of traceability.

5. From the auditing calibrator, enter the known concentration being produced by the calibrator in the *Carbon Monoxide Analyzer Audit Field Form* Concentration Out (ppm) column.

6. Watch the CO graphical display to determine when the instrument response to the **Level 3** test concentration has stabilized. After about ten minutes of stable operation, record the required readings on the *Carbon Monoxide Analyzer Audit Form.* Also record the auditing dynamic dilution calibrator's indicated readings for both the Actual Cal. Gas Flow (lpm) and Actual Dilution flow (lpm) rates on the *Carbon Monoxide Analyzer Audit Field Form*. These flow rates are important to help calculate the actual concentration coming out of the audit calibrator.

7. Adjust the calibrator so that clean zero air and cylinder CO are mixed in the calibrator to a gas concentration appropriate for the **Level 2** audit point from the 10-tiered audit level bins in table 3.1. From the audit calibrator, enter the known concentration being produced by the calibrator on the *Carbon Monoxide Analyzer Audit Field Form's* Concentration Out (ppm) column.

8. Observe the CO graphical display to determine when the instrument response to the **Level 2** test concentration has stabilized. After about ten minutes of stable operation, record the required readings on the *Carbon Monoxide Analyzer Audit Field Form.* Also record the dynamic dilution calibrator's indicated readings for both the Actual Cal. Flow (lpm) gas and Actual Dilution flow (lpm) rates on the field CO Analyzer audit sheet.

9. Adjust the calibrator so that clean zero air and cylinder CO are mixed in the calibrator to a gas concentration appropriate for the **Level 1** audit point from the 10-tiered audit level bins in table 3.1. From the audit calibrator, enter the known concentration being produced by the calibrator on the *Carbon Monoxide Analyzer Audit Field Form.*

10. Watch the CO or graphical display to determine when the instrument response to the **Level 1** test concentration has stabilized. After about ten minutes of stable operation, record the required readings on the *Carbon Monoxide Analyzer Audit Field Form.* Also record the dynamic dilution calibrator's indicated readings for both the gas Actual Cal. Flow (lpm) and Actual Dilution flow (lpm) rates on the field CO Analyzer audit sheet.

11. Perform a second end of audit zero point on the site analyzer for all CO accuracy audits. Make sure the audit calibrator is placed in “ZERO” mode to perform this function.

12. Enter any remaining pertinent data into the *Carbon Monoxide Analyzer Audit Field Form*. Enter the data from the field form into the database and save the audit record to the archive by selecting the button titled “Save to Archive” at the bottom of the data sheet. To verify the audit was saved and archived, click the “View Audit Archive” button, this will bring up the QA Audits Archive showing all the saved audits within the archive.

Figure 3.2: Carbon Monoxide Analyzer Audit Form

Carbon Monoxide Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080310026
Site Name	LA CASA
Monitor	42101

POC	1	Method Code	554	AQS Units	7 (ppm)
Auditor	Harkwell, Brett	Initial CO	0.28	Calibrator SN	76-S
Audit Type	Semiannual	Time Offline	9:17	Zero Air SN	59
Audit Date	9/26/2019	Final CO	0.269	Station Temp.	24.0
Audit Time	9:17	Time Online	11:50	Audit Temp.	23.0

Analyzer Information

Serial #	2967	Slope	1.097	Intercept	7.608	Full Scale	5

Audit Set Point	Target (ppm)	Cylinder	Cylinder Conc. (ppm)	Dilution Flow (l/min)	Cal. Flow (l/min)	Indicated (ppm)
Zero	0.000			3.5000	0.0000	0.000
Level 5	4.500	FF31701	101.100	3.4690	0.1537	4.700
Level 4	2.500	FF31701	101.100	4.2230	0.1095	2.600
Level 3	0.800	FF523337	25.120	4.1610	0.1416	0.825
Level 2	0.075	FF523337	25.120	5.3050	0.0159	0.075
Level 1						

Do you want to zero correct the analyzer? ☐ Upload to AQS? ☑

Audit Set Point	Conc. Out (ppm)	DAS Value (ppm)	Zero Corr. (ppm)	% Relative Error	Display Value (ppm)	% Relative Error
Pre-Audit Precision and Span Evaluation						
Zero	0.000	0.000			-0.001	
Span	4.000	3.910	3.910	-2.2%	3.910	-2.2%
Precision	1.000	0.960	0.960	-4.0%	0.964	-3.6%
Audit Summary						
Zero	0.000	0.000			0.000	
Level 5	4.289	4.400	4.400	2.6%	4.410	2.8%
Level 4	2.555	2.440	2.440	-4.5%	2.440	-4.5%
Level 3	0.827	0.770	0.770	-6.9%	0.773	-6.5%
Level 2	0.075	0.060	0.060	-20.1%	0.061	-18.7%
Level 1						

3.4.4. Calculate Analyzer Error

1. The raw data logger response (ppm) is used to assess the analyzer performance.

2. Each of the Level 1 through 3 data logger responses can be zero-corrected using the averaged data logger response from both the pre and post audit zero testing levels by clicking the zero correct button on the Carbon Monoxide Analyzer Audit Form. As a general rule APCD does not zero correct audit data unless the ambient data was zero corrected for the same time period that the audit occurred, or reasonable justifiable evidence has been found to do so.

3. A percent relative error at each of the audit points is calculated using the data logger response.

4. For bin levels 3-10 in table 3.1, the percent difference for each tested "indicated" analyzer value must fall within ±15% of the "true/actual" audit concentration to pass the criteria for regulatory auditing. For audit bin levels 1 & 2 from the table 3.1, the tested "indicated" analyzer value must be within ±0.031 ppm or ±15% of the "true/actual" audit concentration. However, APCD considers anything over 10% difference to be in the warning range, and the GMM group would like to be notified immediately of audits that appear to be out more than 7%.

5. At the end of each quarter the supervisor of the APCD's GMM Unit receives a digital copy of all carbon monoxide audits performed for the previous quarter. Additionally, a summary of all failed audits, for all pollutants, is reported to the appropriate Technical Services Program Supervisor(s) immediately after a failed audit has occurred.
   Note: All the above calculations are performed by the Access Database (QA Audits Database) when the data recovered is correctly entered into each audit form.

3.4.5. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the station is left in the condition it was found or better. The following is a checklist of items to be completed before exit:

1. Remove all audit equipment and tubing from the sample train.

2. Connect sample lines to the correct ports on analyzer and verify, by checking concentration readings on front panel of analyzer, that the readings are reasonable for conditions observed.

3. Run the site analyzer through a site *precision/zero check* to ensure the analyzer is running as-per-design and record the stabilized readings on the Carbon Monoxide Analyzer Audit field form.

4. Once the analyzer is in ambient sampling condition, it is time to place the parameters back online following the procedure discussed above in section 3.4.1 #3.

5. Place comments of activities performed on the site hardcopy logs located inside the station. Most importantly, comment what time the analyzer was taken offline, put back online and that an audit was performed with a date and the initials of the auditor.

6. A note of activities performed must be placed on the site electronic logs by following the procedures below for each type of data logger:
   - For the ESC data system, starting at the main page:
     - Select “S” (Status Menu)
     - Select “M” (Message Menu)
     - Select “C” (Leave a Message for Central)
     - Input Message of activities performed and hit enter (time channel was taken on and off line, for what reason and auditor initials).

   - For the Agilaire data system, starting at the home menu:
     - Select the “Data Editors” drop down menu.
     - Select “LogBook Enty Editor”.
     - Highlight “LogBook Enty Editor” on the top menu bar and select “New Log Entry”.
     - Input Message of activities performed then hit arrow on left side of screen, next to new message, to save message (time channel was taken on and off line, for what reason and auditor initials).

     Note: Be mindful of what information you are sharing on these electronic messages, as after they are saved they are permanent record and cannot be edited or removed.

7. Remove all equipment from site and double check site for any irregularities.

3.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years. A detailed description of the accuracy data processing procedures is located in Appendix QA2 of this QAPP.

Within 90 days of the end of a calendar quarter, all carbon monoxide accuracy data are verified and validated, then downloaded to an ASCII-format data file and then uploaded into the AQS database. These data processing operations are performed by Quality Assurance Unit staff.

4. Nitrogen Dioxide Audit Procedure

4.1. Introduction

In its purest state Nitrogen Dioxide (NO_2) is a reddish brown gas with a pungent odor. It is corrosive and a strong oxidizing agent. As a pollutant in ambient air, however, it is virtually colorless and odorless. NO_2 is reactive with the cells that line the respiratory tract in humans, causing damage to these cells. This gas is also an essential ingredient in the formation of ground level ozone, another reactive lung irritant. High temperature fuel combustion processes from cars, trucks and power plants produce oxides of nitrogen. Exposure to NO_2 causes a range of harmful effects on the lungs, including: increased inflammation of the airways, worsened cough and wheezing, reduced lung function, increased asthma attacks, greater likelihood of emergency department and hospital admissions, and an increased susceptibility to respiratory infection, such as influenza [1]. Studies in animals have reported biochemical, structural, and cellular changes in the lung when exposed to NO_2 above the level of the National Ambient Air Quality Standard (NAAQS). Gas phase chemiluminescence and Cavity Attenuated Phase Shift Spectroscopy (CAPS) are two methods APCD utilizes to measure NO_2 in ambient air. Both of these methods have been designated as equivalent reference measurement principles for the measurement of nitrogen dioxide in the ambient atmosphere. Continuous analyzers based on these measurement principles may be calibrated with NO_2 either from the gas phase titration of nitric oxide (NO) and ozone (O_3), an NO_2 cylinder orfrom an NO_2 permeation device. Nitrogen Dioxide test gas from cylinders and permeation tubes are currently not used by APCD due to the lack of reliability and consistency from these methods.

[1] U.S. Environmental Protection Agency. Integrated Science Assessment for Oxides of Nitrogen -- Health Criteria. EPA/600/R-08/071. July 2008. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=194645

4.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true (expected) or accepted value. Quantitative comparisons are made between these two values during audits. Generally, three or more upscale points and a zero point are utilized for comparison.

The APCD is required to perform accuracy audits on at least 25% of the nitrogen dioxide (NO_2) monitoring network each quarter, such that each NO_2 analyzer is audited at least once per year. The

APCD goal is to exceed this requirement by auditing each analyzer once per quarter. The audit is performed by challenging the analyzer with audit gases of known concentration from at least three of the following ranges (see Table 4-1) that fall within the measurement range of the analyzer being audited. At least two of the audit concentration levels should bracket 80% of the ambient concentrations being measured by the analyzer. A zero level and one additional level at the NAAQS level or at the highest values recorded over the past 3 years should also be evaluated, whichever is higher. The lower concentration ranges are intended for trace gas analyzers.

The Environmental Protection Agency (EPA) and Office of Air Quality Planning and Standards (OAQPS) has put out a memorandum dated Nov. 10, 2010, giving guidance to monitoring organizations on new expanded audit level bins (detailed in Table 4.1 below). Also in the memorandum is guidance on allowing the auditor to skip a bin. While the CFR states that the audit levels must be consecutive, the new guidance states "with the expansion to ten audit levels and the reduction of the concentration span within each audit level, it is appropriate to allow an audit level to be skipped while still auditing a minimum of three levels. Even with this increased flexibility, audit levels should still be chosen so that at least two levels bracket 80 percent of the ambient data. The goal is to choose levels that best reflect the concentrations at your monitoring sites". This means that an auditor may choose two consecutive levels and skip one level for the third required audit level.

Table 4.1: NO and NO2 Target Audit Concentration Level Ranges.

Audit Level	Concentration Range NO	GPT Range NO_2 (ppm)
1	~0.1000	0.0003-0.0029
2	~0.1000	0.0030-0.0049
3	~0.1000	0.0050-0.0079
4	0.1080 - 0.1200	0.0080-0.0199
5	00.1200 - 0.1500	0.0200-0.0499
6	0.1500 - 0.2000	0.0500-0.0999
7	0.2000 - 0 .4000	0.1000-0.2999
8	0.4000 - 0.6250	0.3000-0.4999
9	0.6250 - 1.000	0.5000-0.7999
10	1.000 - 1.250	0.8000-1.000

In addition to these audit levels, another NO audit level concentration (~0.700 – 0.750 ppm) is used to assess the performance of the analyzer NO and NO_x channels. Every year a data review of the network's past three years of ambient data levels is evaluated to determine where 80% of the ambient concentration data is collected. The boxes highlighted in yellow represent APCD's current target concentrations. These levels are chosen to comply with the EPA's wishes to have at least two audit concentrations performed where the majority of the data is found and to test the monitors throughout at least the lower half of their calibration ranges to assure the critical "higher" values that are occasionally collected are accurate as well.

The audit test NO concentrations are obtained by diluting a nitric oxide (NO) gas cylinder of known concentration with scrubbed ambient air (also called zero air). Nitrogen dioxide (NO_2) concentrations are obtained by gas phase titration (GPT) of NO with ozone. The NO cylinder is directly traceable to a NIST NO standard and follows EPA Protocol gas requirements. Gas from the cylinder is delivered to a mixing chamber at various flow rates and then diluted with the zero air to obtain different audit level concentrations. Audit standards, personnel, and equipment used in NO_2 accuracy audits are always different than those used during instrument calibration and site quality control and site calibration.

The audit is carried out by allowing the analyzer to analyze the audit test atmosphere in its normal sampling mode such that the test atmosphere passes through all filters, scrubbers, conditioners, and other sample inlet components used during normal ambient sampling, and as much of the ambient air inlet system as is practicable.

The APCD audit staff employs calibrators with independently verified mass flow controllers. These mass flow controllers are compared to APCD's NIST traceable primary laboratory flow standard on a semi-annual basis. This mass flow controller verification procedure can be found in APCD's QAPP, Appendix QA3 "Standards Verification and Calibration Standard Operating Procedures". Calibrators with verified mass flow controllers are simple to operate and are typically microprocessor controlled. Detailed procedures for the operation of each type of calibrator are beyond the scope of this SOP. To obtain operating procedures for any calibrator in particular, please refer to the appropriate operator manual.

The primary method (chemiluminescence) for the determination of oxides of nitrogen has been widely used for almost 30 years. Teledyne API (TAPI) oxide of nitrogen analyzers which operate on a gas phase chemiluminescence principle initially attained federal equivalency designation in 1994, and the new trace level model designations were attained in 2012. The cavity attenuated phase shift technology is a new in production type NO_2 analyzer and attained federal equivalency designation in 2014. Production of these analyzers by TAPI began in early 2014. The lower detection limit (LDL) for the CAPS T500U analyzer reported by TAPI is 0.04 parts-per-billion (ppb). Auditing the CAPS analyzer is the same as auditing the chemiluminescence sampler and is accomplished by introducing the sampler to titrated NO_2 during the gas phase titration levels of the audit. If both types of samplers are at the same site, the audits can be conducted simultaneously by introducing each type of analyzer the titrated NO_2 levels one after the other. The APCD also utilizes the Teledyne 200EU NO_y analyzer at a few of its sites. The 200EU monitor is a close derivative of the Model 200E NO_x analyzer. The 200EU is a low level NO/NO_y analyzer (0-0.20 ppm range), which operates in virtually the same manner as the Model 200E, with the exception of the 501Y module. This 501Y module contains a molybdenum catalytic converter. The module is mounted outside the shelter on a 10-meter height tower so that catalytic reaction to convert NO_y species to NO occurs very close to the point where ambient air is sampled. This configuration allows the immediate conversion of approximately 30 nitroxyl compounds (collectively known as NO_y) to NO. The NO_y compounds are too unstable to be measured when taken in through the entire length of the typical ambient air sampling inlet system. The audit procedure for the Teledyne 200EU NO_y sampler is virtually the same as the audit procedure for the Teledyne 200E NO_x sampler and is detailed below. Please use the correct audit form within the QA Audits database to store and archive the audit data. A copy of the NO_y audit form is pictured below.

The APCD uses NO gas cylinders for the audit of NO_x analyzers. The APCD does not use NO_2 cylinders because the stability of NO_2 in cylinders is very poor. Instead, NO cylinders are used and a gas phase titration (GPT) is performed in which NO is reacted with ozone to produce NO_2. The stoichiometric equation for this reaction is as follows:

$$NO + O_3 \leftrightarrow NO_2 + O_2$$

All calibrators used by the APCD auditing and calibration staff are equipped with ozone generators and are capable of performing the GPT process. The quantification of NO_2 is achieved by calculating the difference between the NO concentration pre GPT and the NO concentration post GPT on a verified NO channel. The verified NO channel is usually part of the NO_x analyzer being audited and is verified by first performing an audit on the NO channel of the analyzer. After completion of the NO audit, stoichiometric mixtures of NO_2 in combination with NO are generated by adding O_3 to known amounts of NO. For example: if the production of 0.400 ppm NO_2 is desired, then enough O_3 would have to be introduced in the GPT reaction as to reduce 0.500 ppm NO to 0.100 ppm NO (as observed on an NO analyzer).

No matter what calibrator is used, the procedure for performing the audit is essentially the same. The main difference occurs in the data reduction step where; the NO_2 audit concentrations are based on the reduction of the NO concentration when ozone titration occurs at the same NO concentration as the direct NO measurement was made.

The APCD utilizes an Access Database to enter and process audit results. The database used for all continuous gaseous and particulate instruments within APCD's network is called the "QA Audits Database". A printout of the Nitrogen Dioxide Analyzer Audit form is used as a field datasheet in which raw data is hand entered (see Figure 4.2). Information from the hand written datasheet is then input into the laptop Access Database. The hand written datasheets are archived incase the electronic copy is lost or damaged. A copy of the Access Database is stored on the auditor's notebook computer and used for uploading all the audit information to a table linked, master copy of the database located on the J: Drive within APCD's local area network. Additionally, a back-up copy of any data entered in the field is backed up onto a thumb drive.

The location of the master database within APCD's network is J: \ QA Audit Programs \ P&A Database \ QA Audits Database.mdb. Throughout each calendar quarter the auditors within TSP program perform the required number of audits for each parameter and store the electronic copy of each audit on their personal notebook computer. At the end of each quarter the audits are reviewed for completeness and accuracy and then uploaded to the master audits archive database located on the J: Drive for archival and subsequent upload to EPA's AQS database. Prior to upload to the AQS database, the QA data is verified and validated. Hand written audit forms are also archived and stored in case the electronic copy is lost or damaged. For Nitrogen Dioxide, the form used for storing audit data can be located by opening the QA Audits Database and clicking the "Enter/Edit New Audits" from the main page of the database and selecting the desired pollutant.

4.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on any style NO_x analyzer:

- Dilution gas calibrator instrument with current verified Mass Flow Controllers (annual certification).
- Clean air source/pack.
- Audit sample delivery line set up and additional Teflon sample line with fittings (see Figure 4.1).
- Calculator.
- Personal Laptop for data entry and audit verification.
- NIST-traceable thermometer.
- A printout of the Nitrogen Dioxide Analyzer Audit Form (see Figure 4.2) to be used as a Nitrogen Dioxide Analyzer Audit Field Form.
- NIST-traceable EPA Protocol NO gas cylinder with regulator.
- Clipboard with Nitrogen Dioxide Analyzer Audit Worksheet.
- Tools and spare Teflon sample lines and fittings.

Sample Line Note: When possible and practical it is best to audit all gaseous instrumentation through the complete sample line inlet. This practice is best because the auditor can test the condition of the sample line. Over time, sample lines can build up dust and various forms of debris or become scratched. When this occurs the sample lines can actually interfere with the true ambient readings. It is best practice to replace or clean sample lines on an annual basis unless it is proven through various testing procedures that the sample line is not effecting the actual ambient concentrations being analyzed for. The GMM unit has procedures set in place to replace sample lines annually, and to trim the sample inlet end of these lines periodically throughout the year (see the NO_2 SOP for more detail on site maintenance) and most of the gaseous sites in the network are set up to run the station zero, span and precision nightly checks through the sample line inlet, giving the GMM unit information on the condition of the sample inlet.

4.4. NO_2 Audit Procedure

4.4.1. Collect Analyzer Information, Disable Data logger and Perform Leak Check

1. Collect required information from the NO_x analyzer being audited by scrolling through parameters on the front panel of the analyzer. Tracked parameters should be

recorded on the site log located in the sample shelter. This information is compared to the instrument operation specifications and to the last set of parameters the operator recorded to assure the analyzer is functioning properly before starting an audit.

2. Enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field;

   - The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
     - Hit "ESC" key twice.
     - Logger ID is usually written on the upper left corner of the monitor.
     - Input "logger ID" + "AQM"
     - Password for the ESC Systems is "go vols"

   - The second type of logger system is the Agilaire. This is a windows based system and the password to log into this system is "Agilaire".

3. Before an audit can be performed, the NO, NO_2, CAPS NO_2 and NO_x channels must be disabled on the data logger so that all data collected during the time the audit was performed is flagged as invalid. To disable the Oxides of Nitrogen channels for each type of data logging system, follow the procedures listed below;

   - ESC System:
     i. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter".
     ii. From this menu select "Configure Data Channels".
     iii. Next go into "Disable/Mark Channel Offline".
     iv. From here you will see a list of enabled reporting channels. Highlight the desired channel and press "enter". This process will take the channels offline so the audit data is not reported as ambient concentrations.
     v. Repeat task iii and iv as necessary to flag all affected channels as offline.

   - Agilaire System:
     i. From the Home page of **AV-Trend**, go to the " Utilities" drop down menu and choose "Site Node Logger Toolbox"

ii. You will find a list of all the channels at the station. All channels which are active should be "False". To mark the channel as offline, under the "Disabled Flag" click "False" for the NO_x channels, and it should change to "True" which indicates that it is now offline.

4. Read the data logger's current time. Record the time on the station analyzer log and on the Nitrogen Dioxide Analyzer Audit Field Form.

5. Record calibration information on the Nitrogen Dioxide Analyzer Audit Field Form (Figure 4.2). Information about the most recent calibration is obtained from the calibration sticker. This information includes analyzer serial number, calibration date, prior sampler flow setting, and zero and gain settings at the time of the calibration. Verify that the slope from the calibration sticker is the same as the slope recorded for the instrument parameters on the site log. Verify the NO and NO_x channels have similar slopes. Verify the slopes are both between 0.70 and 1.30 for NO and NO_x.

6. Record current analyzer information obtained directly from the analyzer.

7. If working at a station where there is a manifold, confirm that the station manifold fan is operating and that the fan motor housing is not hot to the touch if one is present. Currently APCD does not utilize manifolds. If a manifold is being used, remove sample line from the station manifold. Cap off the open port at the manifold to prevent shelter air from entering the manifold.

Perform a leak check if needed. Remove the sample line from the back of the analyzer, and follow the operator manual directions for conducting a leak check. Record leak check results on the Nitrogen Dioxide Analyzer Audit Field Form and on the station log.

4.4.2. Analyzer Quality Control and Audit Equipment Set up

1. First, run the analyzer through the nightly station zero and span tests to ensure the analyzer is functioning properly and that all station Quality Control (QC) checks are passing specifications. Record stabilized readings on the Nitrogen Dioxide Audit Analyzer Form (Figure 4.2). Wait to perform the precision test until after the audit has been performed to verify station analyzer is left in operable condition.

2. Connect the "diluent in" port of the auditing dynamic dilution calibrator (audit calibrator) to the output end of the audit clean air system (zero-air) with quarter-inch Teflon tubing. Make sure the supplied zero-air source does not exceed 35 PSI delivery to prevent damage to internal O-rings and gaskets of the audit calibrator. (It is best to start with a low pressure delivery from the zero air source and ramp it up when the audit calibrator is in operation). Verify the pressure reading on the audit calibrator system for the dilution "DIL Pressure" is between 25-35 psi. It is ideal to keep this pressure approximately 30 psi for the entire audit process. Be aware that changes in output concentrations and ambient conditions can affect "DIL Pressure" so adjustments to the calibration regulator may be necessary throughout the audit process.

4. Evaluate the station plumbing to determine if you will be performing a Through the Probe (TTP) or a Back of Analyzer (BOA) audit. A "T" is used in the audit gas delivery line to act as a vent and prevent over pressurizing the site analyzer which could cause damage to the system. A TTP system already has a "T" or vent at the inlet, so an additional "T" is not required, while performing a BOA audit the "T" setup is required:

   - If the station analyzer is set up to perform Through The Probe (TTP) nightly precision, span and zero testing, then disconnect the sample delivery line from the STATION calibration system (or from the back side of the solenoid that delivers the nightly checks to the NO_2 inlet), and place the sample delivery line on the AUDITING calibration system sample output port (cap any unused sample outlet ports with stainless steel caps only).

   - If the NO_2 analyzer is not set up to run TTP nightly checks, then the following set up is required;
     i. Place a Teflon audit sample delivery line on the auditing calibrator's sample outlet port (cap any unused sample outlet ports with stainless steel caps only).
     ii. The analyzer sample line is then connected to one side of a T-fitting. Attach a long piece (~5-8 ft.) of Teflon tubing to the other side of the T fitting for venting purposes to maintain ambient pressure in the analyzer being tested.
     iii. The third piece of Teflon is connected to the remaining opening on the "T" fitting while the other end is attached to either the sample inlet (if doing a TTP audit, which in most cases is the preferred audit type) or the back of the analyzer sample inlet port (the BOA is only

used when a TTP audit could not be performed due to safety issues). For operator safety the excess sample flow should be vented to the outside of the station (See Figure 4.1).

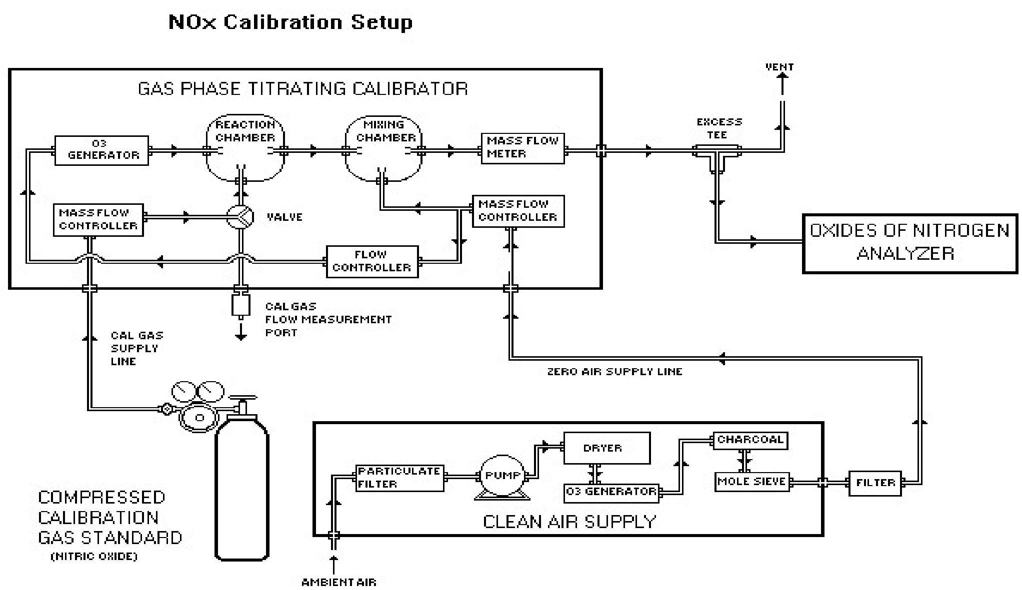


Figure 4.1: NOx Audit Sample Train Setup

5. Connect the audit NO gas cylinder to one of the input ports of the audit calibrator Cal port with 1/8" Teflon tubing and a stainless steel fitting. Make sure to triple purge the gas line and cylinder regulator to ensure no oxygen is present in the line that could potentially react with the nitrogen from the audit cylinder. Adjust cylinder regulator to a delivery pressure of 25-35 psi (Again, if in doubt it is always better to start with a lower pressure and turn the delivery pressure up after connecting to assure excess pressure will not damage the calibrator). Verify the pressure reading on the audit calibrator system given from the tank to the calibrator as "CAL Pressure". It is ideal to keep this pressure approximately 30 psi for the entire audit process. Be aware that changes in output concentration can affect "CAL Pressure" so adjustments to the calibration regulator may be necessary throughout the audit process.

Note: each port on the back of the audit calibrator is specific for each type of audit gas. This must be verified by checking the program in the audit calibrator when the calibrator is in "standby" by going to Setup>Gas>Cyl mode and then checking each port. Also, confirm that the concentration of the audit gas is input correctly for that particular gas cylinder.

6. Turn on the clean air source and dilution calibrator.

7. Record the clean air source information (vacuum and gauge pressure, as well as serial number), the gas cylinder identification number, gas cylinder NO concentration, and the regulator pressures on the Nitrogen Dioxide Analyzer Audit Field Form.

4.4.3. Level 4, 3, 2 and 1 Accuracy Audit

1. To ensure the readings in question are stable, it is helpful to use a graphical display to better visualize when a reading have stabilized:

- For the Windows based Agilaire data logging system, utilize the *AV-Trend* program which offers a graphical display:
  - i. Go to the "Status Displays" drop down menu and choose "Realtime Data Trending".
  - ii. Highlight parameter you wish to monitor and number of hours you would like to look back, typically "1" will do.
  - iii. Make sure the Average Interval is "1 minute".
  - iv. Highlight "Realtime Data Trending" on the top menu and choose "Auto Refresh". This should bring up graphical display which is updated every minute.

  It typically takes at least ten minutes of stable operation to get good quality readings. Recorded readings are determined by which type of data system is being utilized;
- For the ESC data system, record the:
  - ➢ Concentration from data logger (ppm)
  - ➢ Analyzer display (ppm).
  - ➢ Output concentration from the audit calibrator (ppm).

- Actual Dilution (A Dil) and Actual Cal (A Cal) flow readings from the audit calibrator.

  The procedure for taking real-time concentration readings from the ESC data logger system:

- From the main menu, go into the "Real – Time Display Menu" by hitting the letter "D" on the logger keyboard.
- From this menu type "F" to "Display Readings w/flags". This will continuously display the data logger NO_x concentration response with flags. If the analyzer has been correctly taken offline there will be a "D" displayed in parentheses after the NO_2 concentration.
- .

- For the Agilaire data system:
  - Record the data logger response (ppm).
  - Record analyzer display response (ppm).
  - Output concentration from the audit calibrator (ppm).
  - Actual Dilution (A Dil) and Actual Cal (A Cal) flow readings from audit calibrator.

  After the NO_2 concentration has stabilized, record ten values and average these readings as the analyzer response (ppm). Record observed readings on the *Nitrogen Dioxide Analyzer Audit Field Form*.

2. Next, verify that the audit calibrator is providing approximately 3-4 L/min of zero air to the analyzer, in "ZERO" mode, and verify that no source gas is being introduced to the analyzer at this time. Observe the real time display, if one is available, to determine when the instrument response to the zero air test concentration has stabilized; this can take up to 30 minutes. Also make sure the stability reading on the NO_2 analyzer being audited is below 1.0 when taking "indicated" sampler values during the audit. After about ten minutes of stable operation, record 1 minute averages of the analyzer display response (ppm) for all three channels (NO, NO_2 and NO_x) and averages of any additional required readings on the Nitrogen Dioxide Analyzer Audit Field Form. An example of this datasheet is presented as Figure 4.2. Again, required readings are determined by which type of onsite data logger is utilized and is summarized above.
   Note: Part of making sure the zero air system is producing a clean zero air is to perform yearly maintenance to the machine. This includes replacing all the associated scrubber materials within the zero air generator see Appendix GM4 for this procedure or consult the ZAG operator's manual.

3. Next, adjust the calibrator so that clean zero air and audit cylinder NO are mixed in the calibrator to a gas concentration appropriate for the first audit gas concentration which is selected from the 10-tiered audit level bins in table 4.1. The first audit level should be the highest chosen concentration and is referred to as the **Level 4 Audit Concentration**, not to be mistaken with the 10-tiered audit level bins that the four Concentrations are chosen from. Because it is necessary to condition sample lines and fittings to these high NO concentrations, this high concentration audit point can take up to 60 minutes or more to stabilize.
Note: When adjusting the audit gas flow on the audit calibrator, it must be taken into consideration that there are two Mass Flow Controllers (MFCs) dedicated for the audit gas flow located within the audit calibrator. It is important to try to only use one MFC at a time to eliminate an additional margin of error. The MFCs are rated for approximately 5-50cc/min and 20-200cc/min. However, the primary standard being used to verify the flow rates on the low end of the 0-50cc/min mass flow controller is only calibrated by the manufacturer down to 13cc/min and generally flow rates at the very low end tend to be inaccurate. When selecting gas flows, try to keep the audit gas flows between 10-49cc and 52-199cc to eliminate the possibility of two mass flow controllers functioning at the same time and to avoid problems associated with the use of flow rates outside the range of traceability.

4. From the audit calibrator, enter the known concentration being produced by the calibrator on the Nitrogen Dioxide Analyzer Audit field form.

5. Watch the NO graphical display or stability reading of the analyzer to determine when the instrument response to the **Level 4** test concentration has stabilized. After about ten minutes of stable operation, take 1 minute averages of all the required readings and record the required readings on the Nitrogen Dioxide Analyzer Audit field form. Also, record the dynamic dilution calibrator's indicated readings for both the cal gas and dilution flow rates (A Dil and A Cal) on the Nitrogen Dioxide AnalyzerAudit field form.

6. Adjust the audit calibrator so that clean zero air and audit cylinder NO are mixed in the calibrator to a gas concentration appropriate for the **Level 3** audit point from the 10-tiered audit level bins in table 4.1. From the audit calibrator, enter the known concentration being produced by the calibrator on the Nitrogen Dioxide Analyzer Audit field form for Level 3.

7. Observe the graphical display or site analyzer stability to determine when the instrument response to the **Level 3** test concentration has stabilized. After about ten minutes of stable operation, record 1 minute averages of all required readings on the Nitrogen Dioxide Analyzer Audit field form. Also, record the dynamic dilution

calibrator's indicated readings for both the cal gas and dilution flow rates on the Nitrogen Dioxide Analyzer Audit field form.

8. Perform a gas phase titration on the **Level 3** NO flows. While maintaining the same flow rate as the Level 3 NO audit point adjust the amount of ozone entering the gas phase reaction chamber so that NO_2 production is within the **Level 3** allowable range. This is accomplished by entering into the calibrator's software the concentration of ozone needed to approximately achieve the desired amount of NO to NO_2conversion (adjustments may have to be made to the ozone concentration during this part of the audit to obtain the desired NO_2 levels). In most cases 100 ppb of ozone introduced creates approximately 100 ppb of NO_2. If you are auditing a CAPS analyzer this would be the first audit level where introducing the NO_2 titration audit gas is appropriate. There is no need to introduce the CAPS analyzer direct NO concentrations as these samplers do not measure NO.

9. Watch the graphical display, or site analyzer stability value to determine when the instrument's response to the **Level 3 GPT** test concentration has stabilized. After about ten minutes of stable operation, record 1 minute averages of all required readings on the Nitrogen Dioxide Analyzer Audit field form.

10. Repeat steps 9 through 12 for **Levels 2** and **1**.

11. If needed, perform a second end of audit zero point on the site analyzer. Make sure the audit calibrator is placed in "ZERO" mode, not set to a concentration of 0.00, to perform this function.

12. Enter any remaining pertinent information on to the Nitrogen Dioxide Analyzer Audit field form. Enter the data from the field form into the database and save the audit record to the archive by selecting the button titled "Save to Archive" at the bottom of the data sheet. To verify the audit was saved and archived, click the "View Audit Archive" button from the main menu of the data base.

Figures 4.2: Nitrogen Dioxide, CAPS and NO_y Analyzer Audit Forms

Nitrogen Dioxide Analyzer Audit

CDPHE CO
COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site: 080310027
Site Name: I-25
Monitor: 42602

POC	1	Method Code	99	AQS Units	8 (ppb)
Auditor	Sharp, Clyde	Initial NO2	34.3	Calibrator SN	105
Audit Type	Quarterly	Time Offline	7:59	Zero Air SN	698
Audit Date	9/3/2019	Final NO2		Station Temp.	
Audit Time	8:00	Time Online	13:47	Audit Temp.	

Analyzer Information

Serial #	5627	Slope	-1.1	Intercept	0.8	Full Scale	

Do you want to zero correct the analyzer? ☐

Upload to AQS? ☑

Pre-Audit Precision and Span Evaluation

Audit Set Point	NO Conc. Out (ppb)	NO Display Value (ppb)	NO Zero Corr. (ppb)	NO % Relative Error	NO2 Display Value (ppb)	NOx Display Value (ppb)	NOx % Relative Error
Zero	0.000	1.300			-0.300	0.800	
Span	600.000	590.900	590.900	-1.5%	0.100	591.100	-1.5%
Precision	100.000	94.800	94.800	-5.2%	0.200	95.700	-4.3%

Audit Calibrator Flow Rates

Audit Set Point	Target (ppb)	Cylinder	Source NO (ppm)	Source NOx (ppm)	Dilution Flow (l/min)	Cal. Flow (l/min)	NO Conc. Out (ppb)	NOx Conc. Out (ppb)	NO Indicated (ppb)
Zero	0.000				4.5000	0.0000	0.000	0.000	0.000
Level 6	700.000	FB03971	10.0300	10.19	2.8570	0.2052	672.117	682.838	670.200
Level 5	400.000	FB03971	10.0300	10.19	3.9060	0.1606	396.109	402.428	395.000
Level 4	250.000	FB03971	10.0300	10.19	4.4490	0.1131	248.656	252.622	247.900
Level 3	150.000	FB03971	10.0300	10.19	4.4970	0.0681	149.623	152.010	146.600
Level 2	75.000	FB03971	10.0300	10.19	4.5290	0.0343	75.390	76.593	75.300
Level 1	15.000	FB03971	10.0300	10.19	5.5590	0.0082	14.773	15.009	14.900

Nitric Oxide (NO) Audit Data

Audit Set Point	NO Display Value (ppb)	NO Zero Corr. (ppb)	NO % Relative Error	NO2 Display Value (ppb)	NOx Display Value (ppb)	NOx % Relative Error
Zero	0.500			-0.400	0.000	
Level 6	682.900	682.900	1.6%	-11.200	671.600	-1.6%
Level 5	400.800	400.800	1.2%	-7.700	393.100	-2.3%
Level 4	249.900	249.900	0.5%	-3.500	246.300	-2.5%
Level 3	149.400	149.400	-0.1%	-2.700	146.600	-3.6%
Level 2	75.100	75.100	-0.4%	-1.700	73.300	-4.3%
Level 1	14.500	14.500	-1.9%	-0.700	13.800	-8.1%

Regression Results

NO

Slope	1.016171
Intercept	-1.24873
R-Squared	0.999974

NOx

Slope	0.999751
Intercept	-1.65437
R-Squared	0.999975

NO Results

Zero	PASS
Level 6	PASS
Level 5	PASS
Level 4	PASS
Level 3	PASS
Level 2	PASS
Level 1	PASS

Gas-Phase Titration Data

Audit Set Point	Ozone Conc. Out (ppb)	NO Indicated (ppb)	NO Remaining (ppb)	NOx Indicated (ppb)	NOx Remaining (ppb)	NO2 Indicated (ppb)	NO2 Actual (ppb)
Level 6							
Level 5	320.000	78.600	78.578	391.200	392.952	312.600	316.275
Level 4	170.000	84.100	83.991	244.100	245.816	160.000	164.026
Level 3	70.000	69.400	69.524	146.200	147.891	76.800	78.767
Level 2	15.000	56.100	56.436	73.500	75.173	17.400	18.537
Level 1	4.000	9.400	10.479	13.700	15.358	4.300	4.979

NO2 Relative Error

Level 6	
Level 5	-1.2%
Level 4	-2.5%
Level 3	-2.5%
Level 2	-6.1%
Level 1	-13.6%

NO Conv. Efficiency

Level 6	
Level 5	100.6%
Level 4	101.4%
Level 3	100.5%
Level 2	98.9%
Level 1	102.1%

Internal Temp.

Station	
Audit	
Difference	

Regression Results

Slope	0.989883
Intercept	-1.11784
R-Squared	0.999965

Comments

TTP audit done. The low level actually passes with less than 1.5ppb difference.

CAPS Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080310026				
Site Name	LA CASA				
Monitor	42602				
POC	1	Method Code	212	AQS Units	8 (ppb)
Auditor	Sharp, Clyde	Initial NO2	24.7	Calibrator SN	105
Audit Type	Quarterly	Time Offline	8:27	Zero Air SN	698
Audit Date	2/20/2020	Final NO2	21.6	Station Temp.	20.8
Audit Time	8:27	Time Online	15:25	Audit Temp.	20.8

Analyzer Information

Serial #	80	Slope	1.028	Intercept	0.1	Full Scale	500

Do you want to zero correct the analyzer? ☐ Upload to AQS? ☑

Audit Set Point	Conc. Out (ppb)	DAS Value (ppb)	Zero Corr. (ppb)	% Relative Error	Display Value (ppb)	% Relative Error
Pre-Audit Precision and Span Evaluation						
Zero	0.000	0.100			0.100	
Span	400.000	428.000	428.000	7.0%	428.000	7.0%
Precision	50.000	51.500	51.500	3.0%	51.500	3.0%
Audit Summary						
Zero	0.000	0.400			0.400	
Level 5	312.708	308.200	308.200	-1.4%	308.200	-1.4%
Level 4	165.212	162.000	162.000	-1.9%	162.000	-1.9%
Level 3	80.397	79.300	79.300	-1.4%	79.300	-1.4%
Level 2	15.057	15.100	15.100	0.3%	15.100	0.3%
Level 1	5.300	5.500	5.500	3.8%	5.500	3.8%

Audit Results

DAS Results		Display Results		Internal Temp.		Regression Results	
Zero	PASS	Zero	PASS	Station	PASS	Slope	0.983908
Level 5	PASS	Level 5	PASS	Audit	PASS	Intercept	0.162566
Level 4	PASS	Level 4	PASS	Difference	PASS	R-Squared	0.999991
Level 3	PASS	Level 3	PASS				
Level 2	PASS	Level 2	PASS				
Level 1	PASS	Level 1	PASS				

NOy Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080310026				
Site Name	LA CASA				
Monitor	42600				
POC	1	Method Code	699	AQS Units	8 (ppb)
Auditor	Sharp, Clyde	Initial NO2	27.6	Calibrator SN	105
Audit Type	Quarterly	Time Offline	7:26	Zero Air SN	698
Audit Date	2/20/2020	Final NO2		Station Temp.	20.8
Audit Time	7:00	Time Online	15:15	Audit Temp.	20.8

Analyzer Information

Serial #	155	Slope	1.028	Intercept	0.1	Full Scale	1000

Do you want to zero correct the analyzer? ☐

Upload to AQS? ☑

Pre-Audit Precision and Span Evaluation

Audit Set Point	NO Conc. Out (ppb)	NO Display Value (ppb)	NO Zero Corr. (ppb)	NO % Relative Error	NO2 Display Value (ppb)	NOy Display Value (ppb)	NOy % Relative Error
Zero	0.000	0.000			0.000	0.500	
Span	600.000	574.000	574.000	-4.3%	19.000	593.900	-1.0%
Precision	100.000	96.000	96.000	-4.0%	2.000	98.800	-1.2%

Audit Calibrator Flow Rates

Audit Set Point	Target (ppb)	Cylinder	Source NO (ppm)	Source NOx (ppm)	Dilution Flow (l/min)	Cal. Flow (l/min)	NO Conc. Out (ppb)	NOx Conc. Out (ppb)	NO Indicated (ppb)
Zero	0.000				4.0000	0.0000	0.000	0.000	0.000
Level 6	700.000	FF42876	9.8760	9.891001	2.8530	0.2073	668.985	670.001	671.900
Level 5	400.000	FF42876	9.8760	9.891001	3.8930	0.1622	395.021	395.621	396.100
Level 4	250.000	FF42876	9.8760	9.891001	3.9550	0.1016	247.350	247.726	247.700
Level 3	150.000	FF42876	9.8760	9.891001	3.9920	0.0612	149.120	149.346	149.100
Level 2	75.000	FF42876	9.8760	9.891001	4.0300	0.0308	74.907	75.020	75.200
Level 1	15.000	FF42876	9.8760	9.891001	5.0540	0.0076	14.829	14.851	14.900

Nitric Oxide (NO) Audit Data

Audit Set Point	NO Display Value (ppb)	NO Zero Corr. (ppb)	NO % Relative Error	NO2 Display Value (ppb)	NOy Display Value (ppb)	NOy % Relative Error
Zero	0.000			1.000	1.400	
Level 6	669.000	669.000	0.0%	0.000	670.000	0.0%
Level 5	392.000	392.000	-0.8%	0.000	391.900	-0.9%
Level 4	243.000	243.000	-1.8%	1.000	244.900	-1.1%
Level 3	146.000	146.000	-2.1%	1.000	148.400	-0.6%
Level 2	74.000	74.000	-1.2%	1.000	75.300	0.4%
Level 1	15.000	15.000	1.2%	0.000	15.700	5.7%

Regression Results

NO

Slope	0.999122
Intercept	-1.40702
R-Squared	0.999942

NOy

Slope	0.998150
Intercept	0.036621
R-Squared	0.999948

NO Results

Zero	PASS
Level 6	PASS
Level 5	PASS
Level 4	PASS
Level 3	PASS
Level 2	PASS
Level 1	PASS

Gas-Phase Titration Data

Audit Set Point	Ozone Conc. Out (ppb)	NO Indicated (ppb)	NO Remaining (ppb)	NOy Indicated	NOy Remaining	NO2 Indicated (ppb)	NO2 Actual (ppb)
Level 6							
Level 5	320.000	79.000	80.478	391.700	392.389	312.700	312.112
Level 4	170.000	79.000	80.478	244.500	244.916	165.500	164.839
Level 3	70.000	67.000	68.467	146.600	146.835	79.600	80.171
Level 2	15.000	59.000	60.460	74.400	74.501	15.400	14.943
Level 1	4.000	9.000	10.416	15.300	15.292	6.300	5.276

NOy Relative Error

Level 6	
Level 5	-0.2%
Level 4	-0.2%
Level 3	-0.2%
Level 2	-0.1%
Level 1	0.1%

NO Conv. Efficiency

Level 6	
Level 5	100.1%
Level 4	100.2%
Level 3	102.3%
Level 2	106.4%
Level 1	108.2%

Internal Temp.

Station	PASS
Audit	PASS
Difference	PASS

Regression Results

Slope	1.00015
Intercept	0.414481
R-Squared	0.999978

Comments

TTP audit done.

4.4.4. Calculate Analyzer Error

4.4.4.1. Calculate NO and NO_x Channel Errors

1. The raw data logger response (ppm) is used to assess the analyzer performance.

2. Each of the Level 1 through 4 data logger responses is zero-corrected using the data logger response from both the zero air testing (this is done only if the ambient data is zero corrected for the same time period).

3. A percent relative error at each of the audit points is calculated using the data logger response that was recorded on the Nitrogen Dioxide Analyzer Audit field form.

4. Calculate a least-squares linear regression using the NO actual audit concentrations $[NO]_A$ calculated from the cylinder concentration and dilution set up as the abscissa (x values) and using the data logger NO channel indicated response as the ordinate (y values). The regression slope, intercept, and correlation coefficient are recorded on the audit form.

5. Repeat calculations for NO_x channel using $[NO]_A$ concentration plus $[NO_2]_{IMP}$. Where $[NO_2]_{IMP}$ is the cylinder certified NO_2 impurity.

4.4.4.2. Calculate NO_2 Channel Errors

1. The data logger NO_2 response (ppm) is used to assess the analyzer performance.

2. Each of the Level 1 through Level 3 data logger NO_2 channel responses is zero-corrected using the data logger response from the zero air testing (zero correction is done only if the site analyzer ambient data is zero corrected for the same time period).

3. At each level 1 through 3, determine the $[NO]_{ORIG}$ concentrations during titrations using the following formula:

$$[NO]_{ORIG} = \frac{[NO]_R - intercept}{slope}$$

   where:
   $[NO]_{ORIG}$ = Actual NO audit concentration corrected for NO channel error.

$[NO]_R$ = NO indicated channel response
intercept = Regression intercept calculated in Step 4 above.
slope = Regression slope calculated in Step 4 above.

4. The $[NO_2]_A$ concentration at each of the Level 1, 2, and 3 audit concentrations is determined using the following formula:

$$[NO_2]_A = [NO]_{ORIG} - [NO]_{REM}$$

where:
$[NO_2]_A$ = NO_2 concentration of audit (ppm)
$[NO]_{ORIG}$ = NO concentration of audit (ppm) response point before titration,, and corrected for NO channel error
$[NO]_{REM}$ = Actual NO audit concentration response for the titration point, , and corrected for NO channel error

5. A percent relative error at each of the audit points is calculated using the $[NO_2]_A$ value and the NO_2 data logger response and recorded on the audit sheet.

6. Least-squares linear regressions are performed using the $[NO_2]_A$ audit concentrations as the ordinate (y-coordinate) and the data logger NO_2 channel response as the abscissa (x-coordinate). The regression slope, intercept, and correlation coefficient are recorded on the Nitrogen Dioxide Analyzer Audit field form.

4.4.4.3. Assessment of Audit Results

1. The raw data logger response (ppb) is used to assess the analyzer performance.

2. Each of the Level 1 through 4 data logger responses is zero-corrected using the averaged data logger response from both the pre and post audit zero testing levels (this is done only if the site analyzer ambient data is zero corrected for the same time period).

3. A percent relative error at each of the audit points is calculated using the data logger response.

4. For bin levels 3-10 in table 4.1, the percent difference for each tested “indicated” analyzer value must fall within ±15% of the “true/actual” audit concentration to pass the criteria for regulatory auditing. For audit bin levels 1 & 2 from the table 4.1, the tested “indicated” analyzer value must be within ±1.5 ppb or ±15% of the

"true/actual" audit concentration. However, APCD considers anything over 10% difference to be in the warning range, and the GMM group would like to be notified immediately of audits that appear to be out more than 7%.

5. At the end of each quarter the supervisor of the APCD's GMM Unit receives a digital copy of all Nitrogen Dioxide audits performed for the previous quarter. Additionally, a summary of all failed audits, for all pollutants, is reported to the appropriate Technical Services Program Supervisor(s) immediately after a failed audit has occurred. It is also important to store failing audits in a folder on the network drive and follow up with monitoring supervisors during quarterly data review to make sure data was flagged if appropriate or other action was taken.

   Note: All the above calculations are performed by the Access Database (QA Audits Database) when the data recovered is correctly entered into each audit form.

6. Calculate the converter efficiency of the analyzer for each titrated point using:

$$[NO]_{CONV} = [NO_2]_A – ([NO_x]_{ORIG} – [NO_x]_{REM}) + [NO_2]_{IMP}$$

   where:
   $[NO]_{CONV}$ = Converter efficiency
   $[NO_2]_{IMP}$ = NO_2 impurity listed on gas cylinder
   $[NO_x]_{ORIG}$ = NO_x concentration of audit (ppm) response point before titration, and corrected for NO_x channel error
   $[NO_x]_{REM}$ = Actual NO_x audit concentration response for the titration point, and corrected for NO_x channel error
   $[NO_x]_{ORIG}$ and $[NO_x]_{REM}$ are calculated the same way the $[NO]_{ORIG}$ and $[NO]_{REM}$ using the total cylinder gas NO_x concentration

   Plot Converter Efficiency:

   $[NO_2]_{CONV}$ on x-axis and $[NO_2]_A$ on y-axis

   Determine slope and multiply slope by 100% to determine converter efficiency. Converter efficiency must be between 96% and 104%

   Note: All the above calculations are performed by the Access Database (QA Audits Database) when the data recovered is correctly entered into each audit form.

4.4.5. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the station is left in the condition it was found or better. The following is a checklist of items to be completed before exit:

1. Remove all audit equipment and tubing from the sample train.

2. Connect sample lines to the correct ports on analyzer or manifold and verify, by checking concentration readings on the front panel of the analyzer, that the readings are reasonable for conditions observed.

3. Run the site analyzer through a site *precision/zero check* to ensure the analyzer is running as-per-design and record stabilized readings on the Nitrogen Dioxide Accuracy Analyzer field form.

4. Once the analyzer is in ambient sampling condition, it is time to place the parameters back online following the procedure discussed above in section 4.4.1 #3.

5. Place comments of activities performed on the site hardcopy logs located inside the station.
6. A note of activities performed must be placed on the site electronic logs by following the procedures below for each type of data logger:
    - For the ESC data system, starting at the main page:
        - Select “S” (Status Menu)
        - Select “M” (Message Menu)
        - Select “C” (Leave a Message for Central)
        - Input Message of activities performed and hit enter.

    - For the Agilaire data system, starting at the home menu:
        - Select the “Data Editors” drop down menu.
        - Select “LogBook Enty Editor”.
        - Highlight “LogBook Enty Editor” on the top menu bar and select “New Log Entry”.
        - Input Message of activities performed then hit arrow on left side of screen, next to new message, to save message.
7. Remove all equipment from site and double check site for any irregularities.

4.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years. A detailed description of the accuracy data processing procedures is located in Appendix D4 of this QAPP.

Within 90 days of the end of a calendar quarter, all Nitrogen Dioxide accuracy data are verified and validated, then downloaded to an ASCII-format data file and then uploaded into the AQS database. These data processing operations are performed by Quality Assurance Unit staff.

5. Sulfur Dioxide Audit Procedure

5.1. Introduction

Sulfur dioxide (SO_2) gases are formed in the atmosphere when fuel containing sulfur is burned, when gasoline is extracted from oil, or when metals are extracted from ore. The main source of SO_2 in the atmosphere is the combustion of fossil fuels, such as coal or oil, where most of the sulfur contained in the fuel is converted to SO_2. SO_2 dissolves in water vapor to form acid and interacts with other gases and particles in the air to form sulfates and other products that can be harmful. SO_2 in the atmosphere can have detrimental effects on vegetation and cause corrosion of metals and building materials. Oxidation of atmospheric SO_2 contributes to loss of visibility and acidic precipitation. High concentrations of sulfur dioxide can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated sulfur dioxide levels during moderate activity may result in breathing difficulties that can be accompanied by symptoms such as wheezing, chest tightness or shortness of breath.

5.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true (expected) or accepted value. Quantitative comparisons are made between these two values during audits. Generally, three upscale points and a zero point are utilized for comparison.

The APCD is required to perform accuracy audits on at least 25% of the sulfur dioxide (SO_2) monitoring network each quarter, such that each SO_2 analyzer is audited at least once per year. The APCD goal is to exceed this requirement by auditing each analyzer twice per year. The audit is made by challenging the analyzer with an audit gas of known concentration from at least three of the following ranges that fall within the measurement range of the analyzer being audited. Two of the audit points should fall within the range of where 80% of the ambient data values occur. One point should be performed at either the highest concentration level seen over the past three years or at the NAAQS, whichever is higher. A zero air level should be audited. Additional audit concentrations can be taken if it is needed to better characterize analyzer performance. The lowest concentration range in the table below are intended for trace gas analyzers.

The Environmental Protection Agency (EPA) and Office of Air Quality Planning and Standards (OAQPS) has put out a memorandum dated Nov. 10, 2010, giving guidance to monitoring organizations on new expanded audit levels (bins) (detailed in the Table 5.1 below). Also in the memorandum, is guidance allowing an auditor to skip one bin. While the CFR states that the audit levels must be consecutive, the new guidance states "with the expansion to ten audit levels and the reduction of the concentration span within each audit level, it is appropriate to allow an audit level to be skipped while still auditing a minimum of three levels. Even with this increased flexibility, at least two audit levels should still be chosen to bracket 80 percent of the ambient data. The goal is to choose levels that best reflect the concentrations at your monitoring sites". The boxes highlighted in yellow represent APCD's current target concentrations.

The standards from which audit gas concentrations are obtained are directly traceable to Certified Reference Materials (CRM) using analysis procedures specified by the EPA and detailed in the EPA Traceability Protocol for Assay and Certification of Gasesou Calibration Standards, 2012. When audit gas cylinders arrive at APCD they are then tested against the APCD in-house standards using the Standards Verification/Calibration SOP found in the appendicies of the APCD QAPP. Personnel, audit standards and equipment used in sulfur dioxide accuracy audits are always different than those used in instrument calibration and site precision tests.

Table 5.1: SO_2 Target Audit Concentration Ranges

Audit Level	Concentration Range (ppm)
1	0.0003 – 0.0029
2	0.0030-0.0049
3	0.0050-0.0079
4	0.0080-0.0199
5	0.0200-0.0499
6	0.0500-0.0999
7	0.1000-0.1499
8	0.1500-0.2599
9	0.2600-0.7999
10	0.8000-1.000

An audit is performed by introducing an audit test atmosphere into the station analyzer in its normal sampling mode, such that the test atmosphere passes through all filters, scrubbers and as much of the ambient air inlet system as is practical.

The APCD audit staff employs calibrators with verified NIST traceable mass flow controllers. These mass flow controllers are compared to APCD's NIST traceable primary laboratory flow standard on a semi-annual basis. This mass flow controller verification procedure can be found in APCD's QAPP, Appendix QA2 "Standards Verifications and Calibrations". Calibrators with verified mass flow controllers are simple to operate and are typically microprocessor controlled. To obtain standard operating procedures for a particular type of calibrator, please refer to the appropriate operations manual.

The APCD utilizes an Access Database to enter and process audit results. The database used for all continuous gaseous and particulate instruments within APCD's network is called the "QA Audits Database". A printout of the SO_2 Audit form is used as a datasheet in which raw data is hand entered (Figure 5.2). Information from the datasheet is then input into the Access Database. The hand written datasheets are archived incase the electronic copy is lost or damaged. A copy of the Access Database is stored on the auditor's notebook computer and used for uploading all the audit information to a, master archive copy of the database located on the J: Drive within APCD's local area network.

The location of the master database within APCD's network is J:\QA Audit Programs\P&A Database\QA Audits Database.mdb. Throughout each calendar quarter the auditors within APCD perform the required number of audits for each parameter and store the electronic copy of each audit on their personal notebook computer. After each audit is entered the auditor should also store a copy of the audit on a back-up drive in case the laptop is damaged. At the end of each quarter the audits are reviewed for accuracy and uploaded to the master database located on the J: Drive for archival and upload to EPA's AQS database. The hand written copies are also archived and stored in case the electronic copy is lost or damaged. For sulfur dioxide, the form used for storing audit data can be located by opening the QA Audits Database and clicking the "Enter New Audit" from the main form of the database and choosing Sulfur Dioxide.

5.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on a SO_2 analyzer:

- Dilution gas calibrator with current verified Mass Flow Controllers (annual certification).
- Clean air source/pack.
- Audit sample delivery line set up and additional Teflon sample line with fittings (Figure 5.1).
- Calculator.
- Personal Laptop for data entry and audit verification. Loaded with Instrument manuals file.
- NIST-traceable thermometer.
- Copy of the Sulfur Dioxide Audit Accuracy Form (Figure 5.2) for use as the Sulfur Dioxide Analyzer Audit Field Form.
- NIST-traceable SO_2 cylinder with regulator.
- Tools and spare Teflon sample lines and fittings.

Sample Line Note: When possible and practical it is best to audit all gaseous instrumentation through the complete sample line inlet. This practice is preferred because the auditor can test the condition of the sample line. Over time, sample lines can build up dust and various forms of debris, or they can degrade from extreme weather conditions causing leaks. Build-up of debris can create interferences in the analyzer concentration measurements (see GM1 SOP for more details on positive and negative analyzer interferences). It is best practice to replace or clean sample lines on an annual basis unless it is proven through various testing procedures that the sample line is not effecting the actual ambient concentrations being analyzed for. The GMM unit has procedures set in place to address this problem with most of the gaseous sites in the network set up to run the nightly zero, span and precision QC checks through the sample line inlet, giving the GMM unit information on the condition of the sample inlet.

5.4. SO_2 Audit Procedure

5.4.1. Collect Analyzer Information, Disable Data Logger and Perform Leak Check

1. Collect required information from the SO_2 analyzer being audited by scrolling through parameters on the front panel of the analyzer. Tracked parameters should be recorded on the station SO_2 analyzer site log located in the sample shelter. This information is compared to the instrument operation specifications and to the last set of parameters the operator recorded to assure the analyzer is functioning properly before starting an audit.

2. Enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field:
   - The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
     i. Logger ID # is usually written on the upper left corner of the monitor in two digit form. If not, hit "ESC ESC . . AQM" and logger ID number should appear on screen. Hit "Escape" key twice
     ii. Input "logger ID" + "AQM"
     iii. Password for the ESC Systems is "GO VOLS"

   - The second type of logger system is the Agilaire. This is a windows based system and the password to log into this system is "Agilaire".

3. Before an audit can be performed, the SO_2 channels must be disabled on the data logger so that all data collected during the time the audit was performed is flagged as invalid. To disable the SO_2 channels for each type of data logging system, follow the procedures listed below:

   - ESC System:
     i. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter".
     ii. From this menu select "Configure Data Channels".

iii. Next go into “Disable/Mark Channel Offline”. To put channels back online, choose “Enable/Mark Channel Online”
iv. From here you will see a list of enabled reporting channels. Highlight the desired channel and press “enter”. This process will take the channels offline so the audit data is not reported as ambient concentrations.
v. Repeat task iii and iv as necessary to flag all affected channels as offline.

- Agilaire System:
  i. From the Home page of the **AV-Trend**, go to the “ Utilities” drop down menu and choose “Site Node Logger Toolbox”
  ii. You will find a list of all the channels at the station. All channels which are active should be “False”. To mark the channel as offline, click “False” under the “Disabled Flag” column for the SO_2 channel, and it should change to “True” which indicates that it is now offline.

4. Read the data logger’s current time. Record the time on the station analyzer log and on the Sulfur Dioxide Analyzer Audit Field Form.

5. Record calibration information on the Sulfur Dioxide Analyzer Audit Field Form (see Figure 5.2). Information about the most recent calibration is obtained from the calibration sticker. This information includes analyzer serial number, calibration date, prior sampler flow setting, and zero and gain settings at the time of the calibration. Verify that the zero and gain from the calibration sticker is the same as the zero and gain recorded for the instrument parameters and on the SO_2 analyzer site log form.

6. If working at a station where there is a manifold, confirm that the station manifold fan is operating and that the fan motor housing is not hot to the touch if one is present. Currently APCD does not utilize manifolds. If a manifold is being used, remove sample line from the station manifold. Cap off the open port at the manifold to prevent shelter air from entering the manifold.

7. Perform a leak check if needed. Remove the sample line from the back of the analyzer, and follow the operator manual directions for conducting a leak check. Record leak check results on the Sulfur Dioxide Analyzer Audit Field Form and on the station SO_2 analyzer site log form.

5.4.2. Analyzer Quality Control and Audit Equipment Set up

1. First, run the analyzer through the nightly station zero and span tests to ensure the analyzer is functioning properly and that all station nightly QC checks are passing specifications. Record stabilized readings on the Sulfur Dioxide Audit Accuracy Form (Figure 5.2). Wait to perform the precision test until after the audit has been performed to verify station analyzer is left in operable condition.

2. Connect the "diluent in" port of the auditing dynamic dilution calibrator (audit calibrator) to the output end of the audit clean air system (zero-air) with quarter-inch Teflon tubing. Make sure the supplied zero-air source does not exceed 35 PSI delivery to prevent damage to internal O-rings and gaskets of the audit calibrator. (It is best to start with a low pressure delivery from the zero air source and ramp it up when the audit calibrator is in operation.) Verify the pressure reading on the audit calibrator system for the dilution "DIL Pressure" is between 25-35 psi. It is ideal to keep this pressure approximately 30 psi for the entire audit process. Be aware that changes in output concentrations and ambient conditions can affect "DIL Pressure" so adjustments to the zero air regulator may be necessary throughout the audit process.

4. Evaluate the station plumbing to determine if you will be performing a Through the Probe (TTP) or a Back of Analyzer (BOA) audit:

   - If the station analyzer is set up to perform Through The Probe (TTP) nightly precision, span and zero testing, then disconnect the sample delivery line from the STATION calibration system (or from the back side of the solenoid that delivers the nightly checks to the SO_2 inlet), and place the sample delivery line on the AUDITING calibration system sample output port.

   - If the SO_2 analyzer is not set up to run TTP nightly checks, then the following set up is required;
     i. Place a Teflon audit sample delivery line on the audit calibrator's sample outlet port (cap any unused sample outlet ports with stainless steel caps only).
     ii. The analyzer sample line is then connected to one side of a T-fitting. Attach a long piece (~5-8 ft.) of Teflon tubing to the other side of the T fitting for venting purposes to maintain ambient pressure in the analyzer being tested.

iii. The third piece of Teflon is connected to the remaining opening on the "T" fitting while the other end is attached to either the sample inlet (if doing a TTP audit, which in most cases is the preferred audit type) or the back of the analyzer sample inlet port (the BOA is only used when a TTP audit could not be performed due to safety issues). For operator safety the excess sample flow should be vented to the outside of the station (See Figure 5.1).

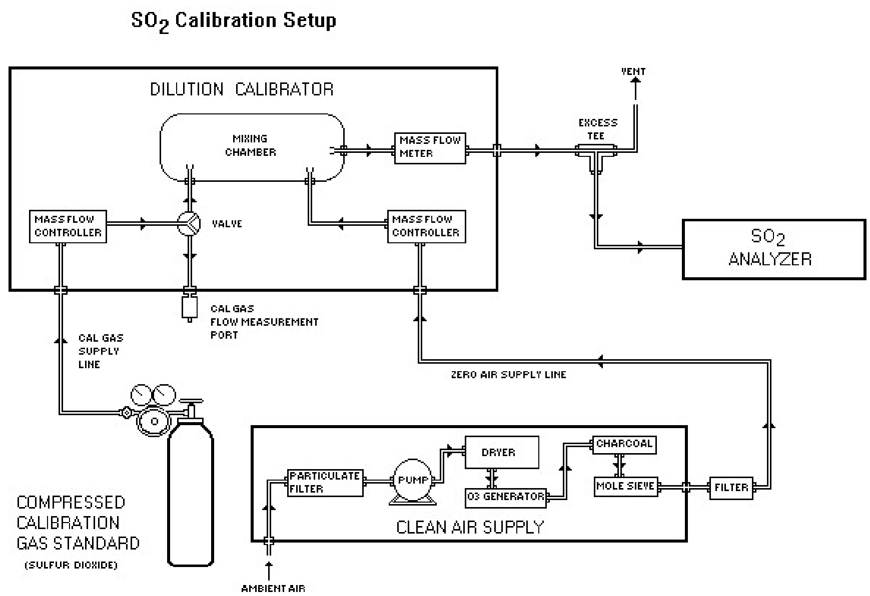


Figure 5.1: SO_2 Audit Sample Train Setup

5. Connect the audit SO_2 cylinder to the input port of the audit calibrator Cal with 1/8" Teflon tubing and a stainless steel fitting. Adjust cylinder regulator to a delivery pressure of 25-35 psi (Again, if in doubt it is always better to start with a lower pressure and turn the delivery pressure up after connecting to assure excess pressure will not damage the calibrator). Verify the pressure reading on the audit calibrator system given from the tank to the calibrator as "CAL Pressure". It is ideal to keep this pressure approximately 30 psi for the entire audit process. Be aware that changes in output concentration can affect "CAL Pressure" so adjustments to the calibration regulator may be necessary throughout the audit process.

Note: each port on the back of the audit calibrator is specific for each type of audit gas. This must be verified by checking the program in the audit calibrator when the calibrator is in “standby” by going to *Setup>Gas>Cyl* mode and then checking each port. Also, confirm that the concentration of the audit gas is input correctly for that particular gas cylinder.

6. Turn on the clean air source and dilution calibrator and allow to warm up for approximately 15 minutes.

7. Record the clean air source information (vacuum and gauge pressure), gas cylinder identification number, gas cylinder SO_2 concentration, and regulator pressures on the Sulfur Dioxide Analyzer Audit Field Form.

5.4.3. Level 3, Level 2 and Level 1 Accuracy Audit

1. To ensure the readings in question are stable, it is helpful to use a graphical display to better visualize when a reading have stabilized;
   - For the Windows based Agilaire data logging system, utilize the *AV-Trend* program which offers a graphical display:
     i. Go to the “Status Displays” drop down menu and choose “Realtime Data Trending”.
     ii. Highlight parameter you wish to monitor and number of hours you would like to look back, typically “1” will do.
     iii. Make sure the Average Interval is “1 minute”.
     iv. Highlight “Realtime Data Trending” on the top menu and choose “Auto Refresh”. This should bring up a graphical display which is updated every minute.

     It typically takes at least ten minutes of stable operation to get good quality readings. Recorded readings are determined by which type of data system is being utilized;
   - For the ESC data system, record the:
     - Concentration from data logger (ppm)
     - Analyzer display (ppm).
     - Output concentration from the audit calibrator (ppm).

       The procedure for taking real-time concentration readings from the ESC data logger system:
     - From the main menu, go into the “Real – Time Display Menu” by hitting the letter “D” on the logger keyboard.
     - From this menu type “F” to “Display Readings w/flags”. This will continuously display the data logger NO_x concentration response

with flags. If the analyzer has been correctly taken offline there will be a "D" displayed in parentheses after the NO_2 concentration.
- A Dil and A Cal flow readings from the audit calibrator.

- For the Agilaire data system:
  - Record the data logger response (ppm).
  - Record analyzer display response (ppm).
  - Output concentration from the audit calibrator (ppm).
  - A Dil and A Cal flow readings from the audit calibrator.

After the SO_2 concentration has stabilized, record ten values and average these readings as the analyzer response (ppm). Record observed readings on the *Sulfur Dioxide Analyzer Audit Field Form*.

2. Next, verify that the audit calibrator is providing approximately 3-4 L/min of zero air to the analyzer and verify that no source gas is being presented to the analyzer at this time. After the zero reading has stabilized for 10 minutes, record the required readings on the Sulfur Dioxide Analyzer Audit Field Form. Again, readings that are recorded are determined by the type of data logger being utilized.
Note: Part of making sure the zero air system is producing a clean zero air is to perform yearly maintenance to the machine. This includes replacing all the associated scrubber materials within the zero air generator.

3. Next, adjust the calibrator so that clean zero air and Audit cylinder SO_2 are mixed in the calibrator to a gas concentration appropriate for the **Level 3** audit point from the 10-tiered audit level bins in table 5.1. Because it is necessary to condition sample lines and fittings to these high SO_2 concentrations, this high concentration audit point often takes about 60 to 90 minutes to stabilize.
Note: When adjusting the audit gas flow on the audit calibrator, it must be taken into consideration that there are two Mass Flow Controllers (MFCs) dedicated for the audit gas flow located within the audit calibrator. It is important to try to only use one MFC at a time to eliminate an additional margin of error. The MFCs are rated for use between 5-50cc/min and 20-200cc/min. However, the primary standard being used to verify the flow rates on the low end of the 0-50cc/min mass flow controller is only calibrated by the manufacturer down to 13cc/min. When selecting gas flows try to keep the audit gas flows between 10-49cc and 52-199cc to eliminate the possibility of two mass flow controllers functioning at the same time and to avoid problems associated with use of flow rates outside the range of traceability.

4. From the audit calibrator, enter the known concentration being produced by the calibrator on the Sulfur Dioxide Analyzer Audit Field Form.

5. Watch the SO_2 graphical display and stability reading from the analyzer to determine when the instrument response to the **Level 3** test concentration has stabilized. After about ten minutes of stable operation, record the required readings on the Sulfur Dioxide Analyzer Audit Datasheet. Also record the dynamic dilution calibrator's indicated readings for both the cal gas and dilution flow rates on the Sulfur Dioxide Analyzer Audit Field Form.

6. Adjust the calibrator so that clean zero air and cylinder SO_2 are mixed in the calibrator to a gas concentration appropriate for the **Level 2** audit point from the 10-tiered audit level bins in table 3.1. From the calibrator, enter the known concentration being produced by the calibrator on the Sulfur Dioxide Analyzer Audit field form.

7. Watch the SO_2 graphical display and stability reading from the analyzer to determine when the instrument response to the **Level 2** test concentration has stabilized. After about ten minutes of stable operation, record the required readings on the Sulfur Dioxide Analyzer Audit Datasheet. Also record the dynamic dilution calibrator's indicated readings for both the cal gas and dilution flow rates on the Sulfur Dioxide Analyzer Audit field form.

8. Adjust the calibrator so that clean zero air and cylinder SO_2 are mixed in the calibrator to a gas concentration appropriate for the **Level 1** audit point from the 10-tiered audit level bins in table 3.1. From the audit calibrator, enter the known concentration being produced by the calibrator on the Sulfur Dioxide Analyzer Audit field form.

9. Watch the SO_2 graphical display or stability reading of the analyzer to determine when the instrument response to the **Level 1** test concentration has stabilized. After about ten minutes of stable operation, record the required readings on the Sulfur Dioxide Analyzer Audit field form. Also record the dynamic dilution calibrator's indicated readings for both the cal gas and dilution flow rates on the Sulfur Dioxide Analyzer Audit Datasheet.

10. If needed, perform a second end of audit zero point on the site analyzer. Make sure the audit calibrator is placed in "ZERO" mode to perform this function.

11. Enter any remaining pertinent data onto the Sulfur Dioxide Analyzer Audit field form. Enter the data from the field form into the database and save the audit record to the archive by selecting the button titled "Save to Archive" at the bottom of the

data sheet. To verify the audit was saved and archived, click the “View Audit Archive” button from the main form of the database.

Figure 5.2: Sulfur Dioxide Accuracy Audit Form

Sulfur Dioxide Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080310002
Site Name	DENVER - CAMP
Monitor	42401

POC	1	Method Code	100	AQS Units	8 (ppb)
Auditor	Sharp, Clyde	Initial SO2	2	Calibrator SN	105
Audit Type	Semiannual	Time Offline	6:34	Zero Air SN	698
Audit Date	8/7/2019	Final SO2	1.2	Station Temp.	24.1
Audit Time	6:30	Time Online	10:51	Audit Temp.	23.1

Analyzer Information

Serial #	748	Slope	0.986	Intercept	47.6	Full Scale	200

Audit Set Point	Target (ppb)	Cylinder	Cylinder Conc. (ppm)	Dilution Flow (l/min)	Cal. Flow (l/min)	Indicated (ppb)
Zero	0.000			4.5000	0.0000	0.000
Level 5	35.000	FF57061	5.019	4.5210	0.0320	35.200
Level 4	15.000	FF57061	5.019	4.5450	0.0136	14.900
Level 3	7.500	FF57061	5.019	6.5530	0.0098	7.500
Level 2	2.000	FF57061	5.019	12.0640	0.0049	2.000
Level 1	1.000	FF57061	5.019	13.0660	0.0026	1.000

Do you want to zero correct the analyzer? ☐ Upload to AQS? ☑

Audit Set Point	Conc. Out (ppb)	DAS Value (ppb)	Zero Corr. (ppb)	% Relative Error	Display Value (ppb)	% Relative Error
Pre-Audit Precision and Span Evaluation						
Zero	0.000	0.400			0.400	
Span	80.000	78.200	78.200	-2.3%	78.200	-2.3%
Precision	20.000	20.700	20.700	3.5%	20.700	3.5%
Audit Summary						
Zero	0.000	0.400			0.400	
Level 5	35.275	32.200	32.200	-8.7%	32.200	-8.7%
Level 4	14.974	13.700	13.700	-8.5%	13.700	-8.5%
Level 3	7.495	7.100	7.100	-5.3%	7.100	-5.3%
Level 2	2.038	2.150	2.150	5.5%	2.150	5.5%
Level 1	0.999	1.200	1.200	20.2%	1.200	20.2%

Audit Results

DAS Results

Zero	PASS
Level 5	PASS
Level 4	PASS
Level 3	PASS
Level 2	PASS
Level 1	PASS

Display Results

Zero	PASS
Level 5	PASS
Level 4	PASS
Level 3	PASS
Level 2	PASS
Level 1	PASS

Internal Temp.

Station	PASS
Audit	PASS
Difference	PASS

Regression Results

Slope	0.905115
Intercept	0.248197
R-Squared	0.999871

Comments

TTP audit done.

5.4.4. Calculate Analyzer Error

1. The data logger response (ppb) is used to assess the analyzer performance.

2. A percent relative error at each of the audit points is calculated using the data logger response. Data logger responses are only zero corrected if the ambient data has been zero corrected for the same time period as the audit occurred.

3. For bin levels 3-10 in table 5.1, the percent difference for each tested “indicated” analyzer value must fall within ±15% of the “true/actual” audit concentration to pass the criteria for regulatory auditing. For audit bin levels 1 & 2 from the table 5.1, the tested “indicated” analyzer value must be within ±1.5 ppb or ±15% of the “true/actual” audit concentration. However, APCD considers anything over 10% difference to be in the warning range, and the GMM group would like to be notified immediately of audits that appear to be out more than 7%.

4. At the end of each quarter the supervisor of the APCD’s GMM Unit receives a digital copy of all Sulfur Dioxide audits performed for the previous quarter. Additionally, a summary of all failed audits, for all pollutants, is reported to the appropriate Technical Services Program Supervisor(s) immediately after a failed audit has occurred.
   Note: All the above calculations are performed by the Access Database (QA Audits Database) when the data recovered is correctly entered into each audit form.

5.4.5. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the station is left in the condition it was found or better. The following is a checklist of items to be completed before exit:

1. Remove all audit equipment and tubing from the sample train.

2. Connect sample lines to the correct ports on the analyzer and verify, by checking concentration readings on the front panel of the analyzer, that the readings are reasonable for conditions observed.

3. Run the site analyzer through a site *precision/zero check* to ensure the analyzer is running as-per-design and record stabilized readings on the Sulfur Dioxide Analyzer Audit Field Form.

4. Once the analyzer is in ambient sampling condition, it is time to place the parameters back online following the procedure discussed above in section 5.4.1 #3.

5. Place comments of activities performed on the site hardcopy logs located inside the station complete with dates, the times samplers were offline and auditor initials.

6. A note of activities performed must be placed on the site electronic logs by following the procedures below for each type of data logger:

    - For the ESC data system, starting at the main page;

        - Select “S” (Status Menu)
        - Select “M” (Message Menu)
        - Select “C” (Leave a Message for Central)
        - Input Message of activities performed and hit enter.

    - For the Agilaire data system, starting at the home menu;

        - Select the “Data Editors” drop down menu.
        - Select “LogBook Enty Editor”.
        - Highlight “LogBook Enty Editor” on the top menu bar and select “New Log Entry”.
        - Input Message of activities (time channels were taken offline and put back online, reason why and who performed audit)performed then hit arrow on left side of screen, next to new message, to save message.

        Note: Be mindful of what information you are sharing on these electronic messages, as after they are saved they are permanent record and cannot be edited or removed.

7. Remove all equipment from site and double check site for any irregularities.

5.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

Within 90 days of the end of a calendar quarter, all Sulfur Dioxide accuracy data are downloaded to an ASCII-format data file and then uploaded into the AQS database. These data processing operations are performed by Quality Assurance Unit staff.

5.6. Ozone Audit Procedure

5.7. Introduction

Ozone (O_3), a colorless gas, has both beneficial and detrimental effects on human health and the environment. Ozone naturally occurring in the upper atmosphere protects humankind against skin cancer caused by ultraviolet radiation from the sun. But ozone at or near ground level is the principal constituent of smog, which adversely affects respiratory health, agricultural crops, and forests. The formation of O_3 in smog is formed by sunlight reacting with oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) which are discharged into the air from gasoline vapors, solvents, fuel combustion by-products, and consumer products. Atmospheric conditions frequently transport precursor gases emitted in one area to another where the ozone-producing reactions actually occur.

5.8. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true (expected) or accepted value. Quantitative comparisons are made between these two values during audits. Generally, three *upscale points* and a *zero point* are utilized for comparison.

The APCD is required to perform accuracy audits on at least 25% of the Ozone (O_3) monitoring network each quarter, such that each O_3 analyzer is audited at least once per year. The APCD goal is to exceed this requirement by auditing each analyzer twice per year. The audit is made by challenging the analyzer with an audit gas of known concentration from at least three of the ranges (see Table 6.1) that fall within the measurement range of the analyzer being audited. Two of the audit points should fall within the range of where 80% of the ambient data values occur. One point should be performed at either the highest concentration level seen over the past three years or at the NAAQS, whichever is higher. A zero air level should be audited. Additional audit concentrations can be taken if it is needed to better characterize analyzer performance. The lowest concentration ranges in the table below are intended for trace gas analyzers.

The Environmental Protection Agency (EPA) and Office of Air Quality Planning and Standards (OAQPS) has put out a memorandum dated Nov. 10, 2010, giving guidance to monitoring organizations on new expanded audit levels (bins) (detailed in *Table 1* below). Also in the memorandum, is guidance allowing an auditor to skip one bin. While the CFR states that the audit levels must be consecutive, the new guidance states “with the expansion to ten audit levels and the reduction of the concentration span within each audit level, it is appropriate to allow an audit level to be skipped while still auditing a minimum of three levels. Even with this increased flexibility, at least two audit levels should still be chosen to bracket 80% of the ambient data. The goal is to choose levels that best reflect the concentrations at your monitoring sites". This means that an auditor may choose two consecutive levels and skip one level for the third required audit level.

Every year, a data review of the network's past three years of ambient data levels is evaluated to determine where 80% of the ambient concentration data is collected. The boxes highlighted in yellow in Table 6.1 represent APCD's current target concentrations. These levels are chosen to comply with the EPA's wishes to have audits performed where the majority of the data is found, and to test the monitors throughout at least the lower half of their calibration ranges to assure the critical "higher" values that are often collected are accurate as well.

Table 6.1: Ozone Target Audit Concentration Ranges.

Audit Level	Concentration Range (ppm)
1	0.004 – 0.0059
2	0.006 – 0.019
3	0.020 – 0.039
4	0.040 – 0.069
5	0.070 – 0.089
6	0.090 – 0.119
7	0.120 – 0.139
8	0.140 – 0.169
9	0.169 – 0.189
10	0.189 – 0.259

The audit test ozone concentrations are obtained using an ultraviolet (UV) ozone generator, in conjunction with a photometer placed in a feedback loop. That photometer regulates the light intensity of the UV lamp so as to provide an accurate and stable ozone output. The photometer is certified quarterly against the response of the APCD in-house laboratory standard. This adjustment, performed on both calibration and audit ozone generating systems, ensures the traceability of all ozone test concentrations back to a common standard. Personnel, audit standards and equipment used in ozone accuracy audits are always different than those used in instrument calibration.

The audit is carried out by allowing the analyzer to analyze the audit test atmosphere in its normal sampling mode such that the test atmosphere passes through all filters, scrubbers, conditions, and other sample inlet components used during normal ambient sampling, and as much of the ambient air inlet system as is practicable.

The APCD audit staff currently employs two types of auditing field transfer standards. The TAPI 700EU and T703 calibrators consist of an ozone generating device and a photometer. The TAPI 700 series has verified NIST traceable mass flow controllers in addition to the ozone generator and photometer feedback loop. These mass flow controllers are compared to APCD's NIST traceable primary laboratory flow standard on a semiannual basis. This mass flow controller verification procedure can be found in

APCD's QAPP, Appendix QA2 "Standards Verification and Calibration Standard Operating Procedures". Calibrators with verified mass flow controllers are simple to operate and are typically microprocessor controlled. Detailed procedures for the operation of each type of calibrator are beyond the scope of this SOP. To obtain operating procedures for any calibrator in particular, please refer to the appropriate operations manual.

The APCD utilizes an Access Database to enter and process audit results. The database used for all continuous gaseous and particulate instruments within APCD's network is called the "QA Audits Database". A printout of a blank Ozone Analyzer Audit Form is used as the Ozone Analyzer Audit Field Form in which raw data is hand entered, this hand written data is used for review and archived (see Figure 6.2). Information from the Ozone Analyzer Audit Field Form is then input into the Access Database. The hand written Ozone Analyzer Audit Field Form is archived incase the electronic copy is lost or damaged. A copy of the Access Database is stored on the auditor's notebook computer and backed up on a thumb drive while in the field after each audit entry in completed. After returning to the office the laptop computer is used for uploading all the audit information to a table linked, master copy of the database located on the J: Drive within APCD's local area network. The location of the master database within APCD's network is J: \ QA Audit Programs \ P&A Database \ QA Audits Database \ Archive.mdb.

At the end of each quarter the audits are reviewed for accuracy and completeness, and accuracy strings are generated and uploaded to the EPA's AQS database. Hard copy printouts are also archived and stored in case the electronic copy is lost or damaged. For ozone, the form used for storing audit data can be located by opening the QA Audits Database and clicking the "Enter New Audit" from the main form of the database and choosing Ozone from the menu.

5.9. Audit Equipment Checklist

The equipment listed below is required to perform an audit on an O_3 analyzer:

- Photometric calibrator; TAPI 700EU Dynamic Dilution Calibrator or the TAPI 703 O_3 Calibrator.
- Zero air source with external pump if using the TAPI 700EU Dynamic Dilution Calibrator.
- Water trap filter and hydrocarbon filter set up if using the TAPI 703 O_3 Calibrator equipped with internal pump system.
- Additional Teflon sample line with fittings (Figure 6.1).
- Calculator.
- Personal Laptop for data entry and audit verification.
- NIST-traceable thermometer.
- Copy of the Ozone Analyzer Audit Field Form (Figure 6.2).
- Tools and spare Teflon sample lines and fittings.

<u>*Sample Line Note*</u>: When possible and practical it is best to audit all gaseous instrumentation through the complete sample line inlet. This practice is best because the auditor can test the condition of the sample

line. Over time, sample lines can build up dust and various forms of debris or get scratched. When this occurs the sample lines can actually interfere with the true ambient readings. It is best practice to replace or clean sample lines on an annual basis unless it is proven through various testing procedures that the sample line is not effecting the actual ambient concentrations being analyzed for. The Gaseous and Meteorology Monitoring (GMM) unit has procedures set in place to address this problem and most of the gaseous sites in the network are set up to run a station zero, span and precision QC check through the sample line inlet, giving the GMM unit information on the condition of the sample inlet.

5.10. O_3 Audit Procedure

5.10.1. Collect Analyzer Information, Disable Data Logger and Perform Leak Check

1. Collect required information from the ozone (O_3) analyzer being audited by scrolling through parameters on the front panel of the analyzer. Tracked parameters should be recorded on the station O_3 analyzer site log located in the sample shelter. This information is compared to the instrument operation specifications and to the last set of parameters the operator recorded to assure the analyzer is functioning properly before starting an audit.

2. Enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field:

    - The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
        i. Logger ID # is usually written on the upper left corner of the monitor in two digit form. If not, hit “ESC ESC. AQM” and logger ID number should appear on screen. Hit “Escape” key twice
        ii. Input “logger ID” + “AQM”
        iii. Password for the ESC Systems is “go vols”

    - The second type of logger system is the Agilaire. This is a windows based system and the password to log into this system is “Agilaire”.

3. Before an audit can be performed, the O_3 channels must be disabled on the datalogger so that all data collected during the time the audit was performed is flagged as invalid. To disable the O_3 channels for each type of data logging system, follow the procedures listed below:

    - ESC System:

i. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter".
ii. From this menu select "Configure Data Channels".
iii. Next go into "Disable/Mark Channel Offline". To put channels back online, choose "Enable/Mark Channel Online"
iv. From here you will see a list of enabled reporting channels. Highlight the desired channel and press "enter". This process will take the channels offline so the audit data is not reported as ambient concentrations.
v. Repeat task iii and iv as necessary to flag all affected channels as offline.

- Agilaire System:
  i. From the Home page of the **AV-Trend**, go to the " Utilities" drop down menu and choose "Site Node Logger Toolbox"
  ii. You will find a list of all the channels at the station. All channels which are active should be "False". To mark the channel as offline, click "False" under the "Disabled Flag" column for the O_3 channel, and it should change to "True" which indicates that it is now offline.

4. Read the data logger's current time. Record the time on the station analyzer log and on the Ozone Analyzer Audit Field Form.

5. Record calibration information on the Ozone Analyzer Audit Field Form (see Figure 6.2). Information about the most recent calibration is obtained from the calibration sticker. This information includes analyzer serial number, calibration date, prior sampler flow setting, and zero and gain settings at the time of the calibration. Verify that the gain from the calibration sticker is the same as the gain recorded for the instrument parameters and on the O_3 analyzer site log form.

6. If working at a station where there is a manifold, confirm that the station manifold fan is operating and that the fan motor housing is not hot to the touch if one is present. Currently, the APCD does not utilize manifolds at any of its ambient air monitoring stations. If a manifold is being used, remove sample line from the station manifold. Cap off the open port at the manifold to prevent shelter air from entering the manifold.

7. Perform a leak check if needed. Remove the sample line from the back of the analyzer, and follow the operator manual directions for conducting a leak check. Record leak check results on the Ozone Analyzer Audit Field Form and on the station O_3 analyzer site log form.

5.10.2. Analyzer Quality Control and Audit Equipment Setup

1. First, run the analyzer through the nightly station zero and span tests to ensure the analyzer is functioning properly and that all station Quality Control (QC) checks are passing specifications. Record stabilized readings on the Ozone Analyzer Audit Field Form. Wait to perform the precision test until after the audit has been performed to verify the station analyzer is left in operable condition.

2. If utilizing the TAPI 700 series dynamic dilution calibrator, connect the "diluent in" port of the audit dynamic dilution calibrator (audit calibrator) to the output end of the audit clean air system (zero-air) with quarter-inch tubing. Make sure the supplied zero-air source does not exceed 35 PSI delivery to prevent damage to internal O-rings and gaskets of the audit calibrator (It is best to start with a low pressure delivery from the zero air source and ramp it up when the audit calibrator is in operation). If utilizing the TAPI 703 O_3 calibrator, connect the water trap filter set up to the "DRY AIR IN" port, making sure the "ZERO AIR IN" port is capped. The TAPI 703 O_3 calibrator uses an internal pump for the supply of zero air for the audit process**.**

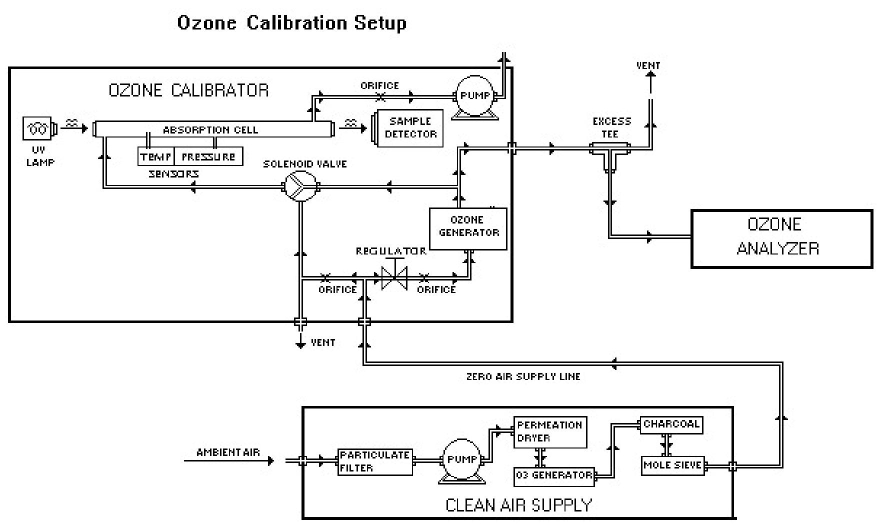
3. Evaluate the station plumbing to determine if you will be performing a Through the Probe (TTP) or a Back of Analyzer (BOA) audit:

    - If the station analyzer is set up to perform Through The Probe (TTP) nightly precision, span and zero testing, then disconnect the sample delivery line from the STATION calibration system (or from the back side of the solenoid that delivers the nightly checks to the O_3 inlet), and place the sample delivery line on the AUDITING calibration system sample output port.

    - If the O_3 analyzer is not set up to run TTP nightly checks, then the following set up is required;
        i. Place a Teflon audit sample delivery line on the auditing calibrator's sample outlet port (cap any unused sample outlet ports with stainless steel caps only).
        ii. The analyzer sample line is then connected to one side of a T-fitting. Attach a long piece (~5-8 ft.) of Teflon tubing to the other side of the

T fitting for venting purposes to maintain ambient pressure in the analyzer being tested.

iii. The third piece of Teflon is connected to the remaining opening on the "T" fitting while the other end is attached to either the sample inlet (if doing a TTP audit, which in most cases is the preferred audit type) or the back of the analyzer sample inlet port (the BOA is only



used when a TTP audit could not be performed due to safety issues). For operator safety the excess sample flow should be vented to the outside of the station (See Figure 6.1).

Figure 6.1: O_3 Audit Sample Train Setup

4. If utilizing the TAPI 700 series dynamic dilution calibrator, turn on the clean air source and audit dilution calibrator. If utilizing the TAPI 703 O_3 Calibrator, simply turn on the audit dilution calibrator which is equipped with drierite in line before the dry air inlet. Allow audit system to warm up for approximately 30 minutes.

5. Record the clean air source information (vacuum and gauge pressure) on the back page of the Ozone Analyzer Audit Field Form, if applicable.

5.10.3. Perform Accuracy Audit

1. To ensure the readings in question are stable, it is helpful to use a graphical display to better visualize when a reading has stabilized;

   - For the Windows based Agilaire data logging system, utilize the *AV-Trend* program which offers a graphical display.
     i. Go to the "Status Displays" drop down menu and choose "Realtime Data Trending".
     ii. Highlight parameter you wish to monitor and number of hours you would like to look back, typically "1" will do.
     iii. Make sure the Average Interval is "1 minute".
     iv. Highlight "Realtime Data Trending" on the top menu and choose "Auto Refresh". This should bring up graphical display which is updated every minute.

     It typically takes at least ten minutes of stable operation to get good quality readings. Recorded readings are determined by which type of data system is being utilized;

   - For the ESC data system, record the:
     - Concentration from data logger (ppm)
     - Analyzer display (ppm).
     - Output concentration from the audit calibrator (ppm).

     The procedure for taking real-time concentration readings from the ESC data logger system:

     - From the main menu, go into the "Real – Time Display Menu" by hitting the letter "D" on the logger keyboard.
     - From this menu type "F" to "Display Readings w/flags". This will continuously display the data logger Ozone concentration response with flags. If the analyzer has been correctly taken offline there will be a "D" displayed in parentheses after the Ozone concentration.

   - For the Agilaire data system:

     - Record the data logger response (ppm) from the "Site Node Logger Toolbox" concentration or "Value" display.
     - Record analyzer front panel display response (ppm).
     - Output concentration from the audit calibrator (ppm).

After the O_3 concentration has stabilized, record ten values as the analyzer response (ppm). Record these readings on the Ozone Analyzer Audit Field Form.

2. Next, verify that the audit calibrator is providing approximately 3-4 L/min of zero air to the analyzer by setting the output concentration from the audit calibrator to 0.000 ppm O_3 (do not use "zero" mode). After the zero reading has stabilized, record the required readings on the *Ozone Analyzer Audit Field Form*. Again, recorded readings are determined by the type of data logger being utilized.

3. To obtain the required readings for the Ozone Analyzer Audit Field Form, adjust the station data logger to continuously display the ozone concentration response. At regular intervals of approximately every 15-20 seconds, note the audit calibrator ozone output display concentration from the front panel of the audit calibrator, and the ozone concentration displayed on the computer terminal display from the station O_3 analyzer. These values are recorded on the audit sheet under the "Audit Raw Data" section in the appropriate rows labeled "Standard" and "Analyzer". Repeat this step until all 10 observations have been recorded. This completes the data collection for this audit test concentration.

4. Set the audit calibrator output appropriate for the **Level 3** audit concentration. This high concentration audit point may take several minutes to stabilize.

5. After the site O3 analyzer has stabilized for several minutes at this **Level 3** audit concentration, record required readings on the Ozone Analyzer Audit Field Form.

6. Repeat steps 4 and 5 for the appropriate **Level 2** and **Level 1** concentrations.

7. If needed, perform a second end of audit zero point on the site analyzer to ensure site O_3 analyzer is functioning properly. Make sure the audit calibrator is placed in "Generate 0.0 ppb ozone" mode to perform this function.

8. Enter any remaining pertinent data into the *Ozone Analyzer Audit Field Form*. Enter the data from the field form into the database by clicking "Enter New Audit" and selecting Ozone from the list. Save the audit record to the archive by selecting the button titled "Save to Archive" at the bottom of the data sheet. To verify the audit was saved and archived, click the "View Audit Archive" button and select the audit you are looking for.

Note: The audit calibrator must give consistent concentrations that do not deviate from the set point by more than 3 ppb while the auditor is recording the audit data. If this occurs, discontinue the audit and consult the operator's manual for troubleshooting solutions to set point drift.

Figure 6.2: Ozone Analyzer Audit Form

Ozone Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080590011
Site Name	NATIONAL RENEWABLE ENERGY LABS - NREL
Monitor	44201

POC	1	Method Code	87	AQS Units	7 (ppm)
Auditor	Sharp, Clyde	Initial O3	50.5	Calibrator SN	160
Audit Type	Performance	Time Offline	11:20	Cal. Slope	1.003459
Audit Date	9/18/2019	Final O3	49	Cal. Intercept	-3.696285E-04
Audit Time	11:30	Time Online	13:13		
Station Temp.	25.0	Audit Temp.	26.1		

Analyzer Information

Serial #	4670	Slope	1.009	Intercept	-3.6	Full Scale	0.25

Do you want to zero correct the analyzer? ☐ Upload to AQS? ☑

Audit Set Point	Conc. Out (ppm)	DAS Value (ppm)	Zero Corr. (ppm)	% Relative Error	Display Value (ppm)	% Relative Error
Pre-Audit Precision and Span Evaluation						
Zero	0.3000	0.0000			0.0000	
Span	0.2408	0.2387	0.2387	-0.9%	0.2387	-0.9%
Precision	0.0604	0.0603	0.0603	-0.2%	0.0603	-0.2%

Raw Audit Data

	1	2	3	4	5	6	7	8	9	10	Average
Zero											
Standard	-0.0010	-0.0010	-0.0010	-0.0010	-0.0010	-0.0020	-0.0010	-0.0010	-0.0010	-0.0010	-0.0011
Analyzer	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0010	0.0000	0.0000	0.0002
Level 5											
Standard	0.1304	0.1305	0.1304	0.1305	0.1305	0.1298	0.1297	0.1296	0.1294	0.1297	0.1301
Analyzer	0.1287	0.1291	0.1293	0.1293	0.1289	0.1288	0.1289	0.1277	0.1277	0.1284	0.1287
Level 4											
Standard	0.0749	0.0751	0.0751	0.0751	0.0748	0.0747	0.0750	0.0747	0.0750	0.0752	0.0750
Analyzer	0.0763	0.0758	0.0750	0.0740	0.0749	0.0737	0.0740	0.0752	0.0759	0.0760	0.0751
Level 3											
Standard	0.0355	0.0352	0.0354	0.0350	0.0349	0.0351	0.0347	0.0349	0.0349	0.0346	0.0350
Analyzer	0.0374	0.0368	0.0365	0.0355	0.0353	0.0361	0.0367	0.0359	0.0358	0.0355	0.0361
Level 2											
Standard	0.0154	0.0154	0.0152	0.0149	0.0149	0.0147	0.0151	0.0151	0.0152	0.0147	0.0151
Analyzer	0.0157	0.0158	0.0157	0.0159	0.0166	0.0167	0.0164	0.0163	0.0166	0.0164	0.0162
Level 1											
Standard											
Analyzer											

5.10.4. Calculate Ozone Test Concentrations

1. Average the ten calibrator observations recorded for each of the three audit levels plus the zero test concentration.

2. Zero-correct the average calibrator output at each audit level by subtracting the average zero test concentration (zero correcting the audit data is only done if the ambient data was also zero corrected during the time frame the audit was conducted).

3. Although the UV photometer used to generate ozone test concentrations is a primary standard, the output of this device is corrected back to the response of the APCD in-house laboratory standard. This adjustment is performed for each of the ozone test concentrations using the following equation:

$$[O_3]_{corrected} = \frac{[O_3]_{raw} - intercept}{slope}$$

Where:

$[O_3]_{raw}$ =	calibrator output concentration (ppm)
$[O_3]_{corrected}$ =	calibrator output concentration corrected to response of the APCD laboratory standard (ppm)
slope =	Average regression slope of the most recent six certification comparisons
intercept =	Average regression intercept of the most recent six certification comparisons

5.10.5. Calculate Analyzer Error

1. The raw data logger response (ppm) is used to assess the analyzer performance.

2. Each of the Level 1 through 3 data logger responses is zero-corrected using the averaged data logger response from both the pre and post audit zero testing levels. Zero correction is only performed if the ambient data from the station analyzer was also zero corrected during the time of the audit.

3. A percent relative error at each of the audit points is calculated using the data logger response.

4. For bin levels 3-10 in table 6.1, the percent difference for each tested "indicated" analyzer value must fall within ±15% of the "true/actual" audit concentration to pass the criteria for regulatory auditing. For audit bin levels 1 & 2 from the table 6.1, the tested "indicated" analyzer value must be within ±1.5 ppb or ±15% of the "true/actual" audit concentration. However, APCD considers anything over 10% difference to be in the warning range, and the GMM group would like to be notified immediately of audits that appear to be out more than 7%.

5. At the end of each quarter the supervisor of the APCD's GMM Unit receives a hardcopy of all Ozone audits performed for the previous quarter. Additionally, a summary of all failed audits, for all pollutants, is reported to the appropriate Technical Services Program Supervisor(s) immediately after a failed audit has occurred. It is also important to store failing audits in a folder on the network drive and follow up with monitoring supervisors during quarterly data review to make sure data was flagged if appropriate or other action was taken.
Note: All the above calculations are performed by the Access Database (QA Audits Database) when the data recovered is correctly entered into each audit form.

5.10.6. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the station is left in the condition it was found or better. The following is a checklist of items to be completed before exit:

1. Remove all audit equipment and tubing from the sample train.

2. Connect sample lines to the correct ports on analyzer and verify, by checking concentration readings on front panel of analyzer, that the readings are reasonable for conditions observed.

3. Run the site analyzer through a site *precision/zero check* to ensure analyzer is operating as-per-design and record stabilized readings on the Ozone Analyzer Audit Field Form.

4. Once the analyzer is in ambient sampling condition, it is time to place parameters back online following the procedure discussed above in section 6.4.1 #3.

5. Place comments of activities performed on the site hardcopy logs located inside the station, including date and times of analyzer off and online, an audit was performed and initials of auditor.

6. A note of activities performed must be placed on the site electronic logs by following the procedures below for each type of data logger:
   - For the ESC data system, starting at the main page:
     - Select “S” (Status Menu)
     - Select “M” (Message Menu)
     - Select “C” (Leave a Message for Central)
     - Input Message of activities performed and hit enter.

   - For the Agilaire data system, starting at the home menu:
     - Select the “Data Editors” drop down menu.
     - Select “LogBook Enty Editor”.
     - Highlight “LogBook Enty Editor” on the top menu bar and select “New Log Entry”.
     - Input Message of activities performed (time analyzer was off and online, an audit was performed and auditor initials) then hit arrow on left side of screen, next to new message, to save message.

     Note: Be mindful of what information you are sharing on these electronic messages, as after they are saved they are permanent record and cannot be edited or removed.

7. Read the data logger time. Record the time on the station analyzer log and on the Ozone Analyzer Audit Field Form.

8. Remove all equipment from site and double check site for any irregularities.

5.11. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

Within 90 days of the end of a calendar quarter, all Ozone accuracy data are verified and validated, then downloaded to an ASCII-format data file and then uploaded into the AQS database. These data processing operations are performed by Quality Assurance Unit staff.

6. PM_{10}/TSP High Volume Sampler Audit Procedure

6.1. Introduction

PM_{10} is the designation of particulate matter in the atmosphere that has an aerodynamic diameter of 10 µm or less. PM_{10} sampling is designated as a method in the *Code of Federal Regulations* (CFR) (40 CFR Part 50, Appendix M) (EPA 2006). PM_{10} includes two general size categories of particles, fine and coarse. This compounds the problem associated with particle pollution and makes it more difficult to describe the health effects from PM_{10}. Fine particles, known as $PM_{2.5}$ (particles smaller than 2.5 microns in aerodynamic diameter) penetrate more deeply into the lungs and are more difficult for the body to remove than coarse particles (2.5 - 10 microns). Several recent health studies indicate a link between fine particle concentrations in the outdoor air and certain health effects (40 CFR Part 58, EPA 2004a and EPA 2004b). Fine particles are generally emitted from combustion activities (such as industrial and residential fuel burning and motor vehicles) while coarse particles mainly come from dust emitted during activities such as re-entrained road dust from vehicular travel, construction and agricultural activities. Some of the health effects that have been linked to fine particulate matter pollution include: premature death and increased hospital admissions and emergency room visits, primarily by the elderly and individuals with cardiopulmonary disease. Fine particles or $PM_{2.5}$ is more fully described in the, "Standard Operating Procedures for Monitoring $PM_{2.5}$ in Ambient Air Using the Rupprecht & Patashnick Partisol Plus 2025 FRM Sampler", elsewhere in the Quality Assurance Project Plan, and in 40 CFR Part 58.

Total suspended particulates (TSP) were first monitored in Colorado in 1960 at 414 14th Street in Denver. Since that time, TSP monitoring was expanded throughout the state until the late 1980's. On July 1, 1987, with the promulgation of the PM_{10} standards, the old TSP standards were eliminated. With the elimination of these standards, the number of state operated TSP samplers dropped significantly. Currently, APCD operates no TSP samplers. TSP samplers are mainly used to determine compliance with lead standards.

6.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between the measured value and the true, standard value during audits.

Persons independent of the particulate program conduct field audits quarterly on all PM_{10} samplers. The APCD Quality Assurance staff typically performs the field audits. The field audit is performed by measuring flow, temperature, pressure and time of the sampler with standards that are independent of those used in the calibration of the sampler. Audit standards must be certified against a NIST traceable standard and be of equal or of higher quality than of those being certified. To ensure a quality audit, it is important that the audit is performed during a period of good weather and stable conditions. If the weather and/or conditions are not suitable, the audit should be rescheduled.

Quality control (QC) refers to procedures established for collecting data within pre-specified tolerance limits. Quality control procedures include any maintenance that benefits the PM_{10}/TSP operations and verification performed by the PM_{10}/TSP program staff, that ensure all equipment are operating under pre-specified tolerances.

The APCD utilizes an Access database to enter and process audit results. A printout of the data entry form may be utilized as a field datasheet in which raw data is hand entered (see **Figure 7.1**) or any field form which allows for all required audit information to be documented may be used. Data from the datasheet is then input into the QA Audits Access Database and the raw field datasheets are archived incase the electronic copy is lost or damaged. A copy of the Access Database is stored on the auditor's notebook computer and used for uploading all the audit information to a master copy of the database located on the J: Drive within APCD's local area network. The location of the master database within APCD's network is J:\QA Audit Programs\P&A Database\QA Audits Database\Archive.mdb. The QA Audits Database is used to store audits for several particulate and gaseous monitoring networks. The main screen will be displayed once the database is opened. Select the button "Enter New Audit" and then select the parameter that pertains to the audit being performed. There is only one version of the Access data input form of each audit type.. Upon opening the appropriate form, the data entry form is displayed and a new audit record can be entered into the form. Data from the form can be saved to an archive table as an audit record by pressing the button <Save to Archive>. To view archive records press the <View Audit Archive> button. The form will be reconfigured to display archive records. To select an archive record, select a record from the main drop down box located at the top of the form. For each monitoring network there exists a table that contains a current list of all site and monitoring information. Procedures to transfer accuracy audits to the J:Drive and then to AQS are performed on a quarterly basis.

6.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on High Volume PM_{10} and TSP samplers:

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- Certified NIST-traceable flow transfer standard or certified flow orifice.
- Manometer with extra tubing to connect from the flow orifice to the monometer.
- Audit filter (Quartz) and audit plate.
- PM_{10}/TSP Hi-Vol audit field datasheet (**Figure 7.1**)
- Calculator.
- Personal Laptop for data entry and audit verification.
- Tools and extra parts.

6.4. PM_{10}/TSP High Volume Audit Procedure

The PM_{10} and TSP MFC audit procedure presented in this section relates known flow rates to the pressure in the exit orifice plenum. The known flow rates are determined by an orifice transfer standard that has previously been certified or calibrated against a *National Institute of Standards and Technology* (NIST) traceable standard. This orifice transfer standard must also be independent of those used for calibration. The individual performing the audit cannot be the operator or the person who performed the calibration. No adjustments may be made to the sampler system before the audit is performed. The PM_{10} sampler inlet is designed to operate at an actual volumetric flow rate of 1.132m^3/min, and the acceptable flow rate range is ±10% of this value. The TSP sampler inlet is designed to operate at an actual volumetric flow rate of 1.4 m^3/min., and the acceptable flow rate range is ±10% of this value.

6.4.1. Collect Analyzer Information and Perform One-Point Flow Rate Audit

1. Collect required information from the PM_{10} and/or TSP high volume sampler which is being audited and collect current ambient conditions. Information collected includes:
   - Current date and time (Mountain Standard Time(mst))
   - Sampler location
   - Sampler number
   - Motor number
   - Current sampler set point
   - Current ambient temperature
   - Current ambient pressure

2. Turn on sampler and let run for 5 – 10 minutes to warm up motor.

3. After the sampler warm up period is complete, record the initial ΔP_{ex} (sampler) monometer reading with the sampler in normal sample condition (i.e. with sample head down and secure over sample media).

4. Turn sampler off. Open sampler head and place metal cover over sample media cassette to protect from particulates settling on the media and damaging the filter while the audit is being performed. Loosen and remove thumb screws. Remove the sample filter cassette and set it aside in a clean location while the audit is being performed.

5. Set up audit system as follows:
   i. Place the audit quartz filter on sampler inlet screen and cover with audit plate. Ensure the filter does not shift and covers the entire sample surface.
   ii. Secure audit plate with the supplied wing nuts, making sure to secure all four corners evenly to prevent leaks.
   iii. Place audit orifice on audit plate and secure snugly to prevent leaks.

iv. Ensure the audit monometer is level and the monometer is zeroed.
v. Ensure audit monometer is not connected to the orifice pressure port at this time.

6. Perform sampler leak check as follows:
   i. Block the flow orifice openings with large-diameter rubber stoppers, or other means, to block the air flow from entering the orifice ports. Additionally, seal the pressure port with cap or some other device to prevent air flow.
   ii. Turn on the sampler for a short period of time.
   Note: avoid running the sampler for longer than 30 seconds at a time with the orifice blocked. This precaution will reduce the chance that the motor will overheat due to lack of cooling air and in turn reduce the lifespan of the motor.
   iii. Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. Observe sampler manometer, a leak-free system will not produce an upscale response in the sampler's exit orifice manometer. All leaks must be eliminated before proceeding with the audit.
   iv. When the sampler is determined to be leak-free, turn off the sampler and unblock the orifice.
   v. Connect audit monometer tubing to the audit orifice.

7. Perform one-point flow rate audit:
   i. Turn on the sampler and allow sampler flow controller to stabilize for 2 to 5 minutes.
   ii. Ensure audit orifice is in the wide-open position. Briefly inspect auditing and field equipment for leaks or damage. Take ΔH_2O (orifice) monometer reading from auditing orifice transfer standard and take ΔP_{ex} (sampler) monometer reading.
   iii. Turn off sampler. Remove audit orifice transfer standard, audit faceplate and audit filter.
   iv. Reinstall sample filter cassette and secure snuggly/evenly with the provided thumb screws. Remove cover plate from cassette. Lower inlet (sampler) head back on top of sampler and secure in place.
   v. Turn sampler on and allow unit flow to stabilize. Take final ΔP_{ex} (sampler) monometer reading. Compare this reading to initial ΔP_{ex} (sampler) monometer reading from Step 3. This will assure equipment is being left in as good or better operating condition than when auditor arrived. Note any discrepancies. If the initial and final ΔP_{ex} (sampler) values are not similar, then a possible cassette leak or cassette installation problem might exist.
   It is important to note that the High Volume Transfer Standard Orifice plate and manometer must be maintained. On a yearly basis, at least the rubber seal on the bottom of the orifice plate should be

replaced and the manometer oil inside the manometer should also be replaced. The audit manometer must also be checked for leaks by carefully drawing oil up the manometer and blocking the air. A leak free manometer will hold this oil in place after the air flow is blocked on one end of the manometer.

8. Using the auditor's field laptop, open the QA Audits Database located on the auditor laptop. Select the "Enter New Audit" button from the Main Menu form. Select the PM (Hi-Vol) to enter a new audit into the database (**Figure 7.1**).

9. On the electronic audit form, enter all the requested Site Information, Orifice Information, Temperature/Pressure Information and Calibration Information. Enter ΔP_{ex} (sampler) manometer value from Step 3. Enter the ΔH_2O(orifice) monometer reading measured in Step 7. Enter ΔP_{ex} (sampler) manometer value from Step 7. Enter the final ΔP_{ex} (sampler) monometer value from step 7. The program will calculate if the one-point audit passes or fails, if actual/design flow-rate passes or fails, and if any corrective measures (such as recalibration or MFC adjustment) need to be performed. If any corrective measures need to be performed, a member of the PM_{10}/TSP Particulate Monitoring group must be notified as soon as is reasonably possible.

10. The Audit database software program performs the following calculations:

Equation: 7.A

$$Audit\ Qa\ (orifice) = A(\Delta H_2O)^B \times \sqrt{\left(\frac{760}{Pa}\right) \times \left(\frac{Ta}{298.15}\right)}$$

Audit Qa(orifice) = Actual flow rate as indicated by the monometer reading affiliated with the audit orifice flow transfer standard
A = Orifice transfer standard calibration factor
B = Orifice transfer standard calibration exponent
ΔH_2O = Pressure drop (in inches H_2O) across the orifice transfer standard
Pa = Ambient pressure (in mm Hg)
Ta = Ambient temperature (in K)
760 represents standard pressure (in mm Hg)
298.15 represents standard temperature (in K)

Equation: 7.B

$$Qa(sampler) = \frac{\left(\left(\sqrt{\Delta P_{ex}(sampler) \times (T_a + 30) \times P_a}\right) - b\right)}{m}$$

ΔP_{ex} (sampler) = Reading taken from the sampler monometer which measures the pressure drop across the motor plenum exit
Pa and Ta are defined above
30 represent the estimated temperature increase as air flows through the sampler motor
b = y- intercept from most recent sampler calibration
m = Slope from most recent sampler calibration

Equation: 7.C

$$Audit\ Flow\ \%\ Difference = \left(\frac{Qa(sampler) - Audit\ Qa(orifice)}{Audit\ Qa(orifice)}\right) \times 100$$

Equation: 7.D

$$Qa(corrected) = Qa(sampler)\left(\frac{100 - Audit\ Flow\ \%\ Diff.}{100}\right)$$

Equation: 7.E

$$Design\ Flow\ \%\ Difference = \left(\frac{(Qa(corrected) - 1.132)}{1.132}\right) \times 100$$

Press the <Capture Data> key to store the audit record to the archive data table.

6.4.2. Audit Failure

The acceptance criteria for accuracy audits are reported in Appendix MQO within the main body of the APCD QAPP. If any of the calculated audit values exceed the accuracy thresholds listed in Appendix MQO, then the auditor will notify the supervisor of the APCD Particulate Monitoring Unit in a timely manner, typically within one working day.

Before the audit is recognized as failing, steps must be performed to verify:

1. Perform a second audit (either single-point or multi-point) to verify results, preferably with a second set of “back-up” audit equipment.

2. If second audit fails criteria, the following actions must be taken:

i. If the calibration verification fails, the sampler must be calibrated (see Section 9 of Appendix F within this QAPP) to provide a temporary calibration until the Particulate Monitoring Group can get out to the site. The Work Lead of the Particulate Monitoring Group must be notified as soon as is reasonably possible. Upon returning to the office, the failed audit information is emailed to the Particulate Monitoring Group Supervisor informing them of the failed audit. It is the Particulate Monitoring Groups Supervisor's responsibility to ensure that all corrective actions are performed and that those corrective actions are recorded and saved by the end of the subsequent calendar quarter.

ii. If the design flow check fails and the instrument is equipped with a Variac or a Mass Flow Controller, these devices can be adjusted to bring the flow rate back within optimal design flow rate parameters. If the sampler does not have one of these devices, the PM_{10}/TSP Particulate Monitoring Group must be notified as soon as is reasonable possible so they can troubleshoot the problem. Upon returning to the office, the failed audit information is emailed to the Particulate Monitoring Group Supervisor informing them of the failed audit. It is the Particulate Monitoring Groups Supervisor's responsibility to ensure that all corrective actions are performed and that those corrective actions are recorded and saved by the end of the subsequent calendar quarter.

6.4.3. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the station is left in the condition it was found and or better. The following is a checklist of items to be completed before exit:

- Ensure the PM_{10}/TSP head is closed/secured.
- Close and secure the front access door to the sampler.
- Return the sampler to its original operational mode (pre-audit).
- Close and secure the timer box.
- Remove all equipment from site and double check site for any irregularities.

6.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The Technical Services Program maintains an Access Database on the Air Pollution Control Division (ACPD) Local Access Network (LAN). This program records the results of all PM_{10} and TSP particulate accuracy audits conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the accuracy data before they are submitted to AQS. A detailed description of the accuracy data processing procedures is located in Appendix D4 or in the main body of the APCD QAPP.

A summary of these procedures is as follows. At the end of the calendar quarter, individual audit records contained on the auditor's laptop are uploaded to the QA Audits Archive database. Within 90 days of the end of a calendar quarter, all particulate accuracy data from the previous quarter are downloaded to an ASCII-format data file and then uploaded into the AQS database. Quality Assurance staff performs these data processing operations.

Figure 7.1: High Volume Particulate Analyzer Audit Form

Hi-Vol PM Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080990002				
Site Name	LAMAR MUNICIPAL BLDG				
Method	HI-VOL SA/GMW-1200 - GRAVIMETRIC				
Parameter	81102	POC	2	Method Code	63
Auditor	Sharp, Clyde	Audit Date	6/6/2019	Audit Time	12:45
Audit Orifice	BG3-PM10				
Cal. Date	10/10/2018	"A" Factor	0.62246	"B" Factor	0.4905157

Ambient Pressure		
(inches Hg)	(atm)	(mm Hg)
	0.8776	667

Ambient Temperature		
(Farenheit)	(Celsius)	(Kelvin)
	28.9	302.1

Upload to AQS? ☑

Sampler Info						Manometer Readings (inches H2O)			
Sampler Number	Cal. Date	Motor Number	Motor Type	Slope	Int.	Pre-Audit Manometer	Audit Manometer	Sampler Manometer	Post-Audit Manometer
PM10-1	4/15/2019	17475	MFC	1.1526	-0.1171	2.6	2.6	2.6	2.7
PM10-2	4/15/2019	15861	MFC	1.1342	-0.1210	2.9	3.25	3	2.9
PM10-3	4/15/2019	17233	MFC	0.9870	0.1197	3	3.1	3.1	3
PM10-4	4/15/2019	14726	MFC	1.0681	-0.0792	2.5	2.9	2.4	2.5

Audit Flow Rate Verification Results (cubic meters/min)									
Sampler Number	Audit Flow	Audit Flow @ STP	Sample Flow	Sample Flow @ STP	% Relative Error	Pre-Audit Flow	Post-Audit Flow	Bias Corr. Flow	Design Flow % Rel. Error
PM10-1	1.069	0.926	1.089	0.943	1.9%	1.089	1.108	1.087	-4.0%
PM10-2	1.192	1.033	1.184	1.026	-0.7%	1.166	1.166	1.174	3.7%
PM10-3	1.165	1.009	1.137	0.985	-2.4%	1.117	1.117	1.144	1.1%
PM10-4	1.127	0.976	1.098	0.951	-2.6%	1.119	1.119	1.148	1.4%

Comments

7. R&P Partisol 2000 PM FRM Single Sampler Audit Procedure

7.1. Introduction

Fine particles (smaller than 2.5 microns) penetrate more deeply into the lungs than coarse particles (2.5 - 10 microns). Recent health studies indicate a link between fine particle concentrations in the outdoor air and certain health effects (40 CFR Part 58). Fine particles are generally emitted from combustion activities (such as industrial and residential fuel burning and motor vehicles) while coarse particles mainly come from dust emitted during activities such as construction and agricultural tilling.

Some of the health effects that have been linked to fine particulate matter pollution include:

- Premature death and increased hospital admissions and emergency room visits, primarily by the elderly and individuals with cardiopulmonary disease.
- Acute respiratory symptoms, including aggravated coughing and difficult or painful breathing.
- Decreased lung function and alterations in lung tissue and structure occur, particularly in children and people with asthma.

Note: The Low-Volume 2000 and 2025 R&P Partisol samplers can be set up to measure particle sizes of either PM_{10} or $PM_{2.5}$. Both samplers are equipped with an initial PM_{10} inlet head; installation of a Sharp Cut Cyclone below the PM_{10} head converts the unit to a $PM_{2.5}$ sampler.

7.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between the measured value and the true, standard value during audits.

Persons independent of the particulate program conduct field audits quarterly on all manual filter based samplers. The APCD Quality Assurance staff typically performs the field audits. The field audit is performed by measuring flow, temperature and pressure of the sampler with standards that are independent of those used in the calibration of the sampler. Audit standards must be certified against a NIST traceable standard and be of the same or of high quality than of those being certified.

To ensure a quality audit, it is important that the audit is performed during a period of good weather and stable conditions. If the weather and/or conditions are not suitable, the audit should be rescheduled.

The APCD utilizes an Access database to enter and process audit results. A printout of the PM Analyzer Audit Datasheet can be used as a field datasheet in which raw data is hand entered (see **Figure 8.1**). Data from the datasheet is then input into the Access database via the use of a data input form. The datasheets are archived incase the electronic copy is lost or damaged. The auditor's field laptop typically has a copy (satellite version) of the database. The QA Audits Database is used to store audits for several particulate monitoring networks. The main screen will be displayed once the database is opened. Select the button that pertains to the audit being performed. There is only one version of the Access data input form of each audit type, however it can be configured to input new audit records or to view old archive records.

Upon opening the appropriate form, the data entry form is displayed and a new audit record can be entered into the form. Data from the form can be saved to an archive table as an audit record by pressing the button <Save to Archive>. To view archive records press the <View Audit Archive> button from the main screen and select the parameter you would like to enter. This archive is used to store audit records and to create text strings to be loaded to EPA's AQS system on a quarterly basis.

The general order of the field audit is as follows:

a) Set up audit standards and record sampler information.
b) Evaluate date and time.
c) Evaluate if samples have been loaded correctly.
d) Document any status codes.
e) Test sampler for leak.
f) Evaluate ambient temperature criteria.
g) Evaluate ambient barometric pressure criteria.
h) Evaluate sampler flow criteria.

7.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on FRM samplers:

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- Certified NIST-traceable Flow Transfer Standard (FTS) and leak tested/zeroed manometer.
- Certified time piece.
- Leak check audit adapter equipped with vacuum gauge.
- Audit filter cassette.
- PM Analyzer Audit Field Datasheet (**Figure 8.1**).
- Personal Laptop for data entry and audit verification.
- Tools, spare parts, and backup audit standards.

7.4. Federal Reference Monitor (FRM) Audit Procedure

7.4.1. Pre-Audit

1. Place the temperature probe for the audit thermometer in the louvered gill screen of the sampler's ambient temperature probe. If possible, affix the audit temperature probe so that the top one inch of the probe is in close proximity to the sampler's ambient temperature probe. Verify that both the audit and sampler temperature probes are out of direct sunlight. Allow the audit thermometer to equilibrate for approximately 10 minutes prior to making temperature readings.

2. Remove the audit barometer form its carrying case and place the barometer out of direct sunlight (if possible) and allow the barometer to equilibrate for approximately 10 minutes prior to any barometric pressure readings.

3. Remove the flow transfer standard (FTS) and stage it on top of the sampler. If a manometer is utilized, try to orientate it so that it is level, zeroed and will be in the same position throughout the flow audit.

4. Unlock the sampler and a fill in all requested information in the Site Information and Standards Information portions of the PM Analyzer Audit Field Datasheet.

5. Perform Date and Time Audit - The time and date audit is done to verify that the sampler is operating in accordance with the EPA sample day and run-time schedule of midnight to midnight Mountain Standard Time (MST). Samplers that operate outside these schedules must be adjusted and/or reprogrammed so that compliance with these schedules is met. From the main screen of the sampler, note the sampler's date and time on the PM Analyzer Audit Field Datasheet. Additionally, note the date and time from the auditors timepiece onto the audit field datasheet. If the instrument's time has a difference of more than 15 minutes as compared to the audit standard or if the date is incorrect as compared to the audit standard, contact the appropriate APCD particulate personnel. Continue with the rest of the audit.

   Note: All RP2000's and 2025's in the Colorado network are set to Mountain Standard Time (MST) all year. On the Main Screen, note the sampler time. Site operators may use their watch as a standard if it has been set accurately. There is a web site to the atomic clock in Boulder, Colorado where operators may set their watches; the URL is http://www.time.gov/. It is preferable to use a cell phone as a standard because cell phones are updated to the atomic clock automatically.

6. Perform Sampler Leak Check:
   The leak check procedure is used to verify that the air handling system in the sampler is adequately free from leakage that could cause either the flow rate to be measured incorrectly or filtration artifacts to be introduced into the system. The R&P sampler automatically determines leakage by pulling a vacuum on the internal air volume of the sampler, sealing the volume by closing valves and monitoring the internal pressure of a set period of time. If the internal vacuum decreases too rapidly, a leak is indicated, and troubleshooting procedures must be followed to stop the leak.

   Note: Some RP2000's in the Colorado network are fitted with an automatic leak check procedure. The following description of the External Leak Check procedure can be performed on all the RP2000's in the Colorado network. Refer to Rupprecht & Patashnick Partisol FRM Model 2000 Operating Manual for a complete description of the automatic external leak check procedure.

The procedure for performing the **External Leak Check** is as follows:

i. Remove the sample filter in the filter chamber and install the audit filter cassette. While the audit is occurring, store the sample filter in an environment that is secure and free from contamination.

ii. Remove the PM_{10} inlet and place the flow audit adapter (with vacuum gauge if available) on the sample down tube, as in the picture below, and close the valve (open is vertical, closed is horizontal).

iii. From the Main Screen, press <F5: Setup> to access the Setup Screen.

iv. When in the Setup Screen press <F5: Audit> to access the Audit Screen.

v. Ensure an External Leak Check Cassette has been installed in the exchange assembly.

vi. Turn on the flow by pressing <F2: Valve>, and then press <F3: Pump>.

vii. Shut off the flow to the flow controller assembly by turning the manual shut off valve (attached to the large air filter on the left side of the manifold in the hub).

viii. Once the vacuum gauge is stable, shut off the flow to the pump by turning the other manual shut off valve located on the bottom of the manifold in the hub.

ix. Turn off the pump by pressing <F3: Pump>.

x. Note the <u>initial</u> vacuum (in. Hg), recorded from the vacuum gauge located on the leak check device, immediately after the pump is turned off.

xi. Note the final vacuum (in.Hg) reading on the vacuum gauge one minute after the pump valve is closed. Subtract the final vacuum from the initial vacuum noted from above.

xii. Multiply this value by 25.4 mm/in; this is the leak rate, **this value should not exceed 25mmHg/min.**

xiii. If the leak rate is greater than 25 mmHg/min place a different audit filter into the chamber, check the Sharp Cut Cyclone for tightness if one is installed, make sure the flow audit adapter is closed, and the Sharp Cut Cyclone and all its' fittings are tight.

xiv. Attempt another external leak check.

xv. If the external leak rate continues to exceed the leak check criteria perform an Internal Leak Check (procedure below) and contact the appropriate APCD particulate personnel.

xvi. If the leak rate passes note the external leak rate in the appropriate space on the PM Analyzer Audit Field Datasheet.

xvii. Slowly open the valve to the flow controller assembly and the valve on the flow audit adapter.

xviii. Turn on the flow to the pump by turning the other manual shut off valve located on the bottom of the manifold in the hub.

The procedure for performing the **Internal Leak Check** is as follows:

Note: an internal leak check is not typically necessary as part of the normal audit procedure. An internal leak check is only performed if the external leak check fails

i. Remove the sample filter in the filter chamber and install the *Internal Leak Check* cassette (solid backing screen). While the audit is occurring, store the sample filter in an environment that is secure and free from contamination.

ii. From the Main Screen, press <F5: Setup> to access the Setup Screen.

iii. Press <F3: Audit> for the Audit Screen.

iv. Press <F2: Valve>, turn on the pump by pressing <F3: Pump>.

v. Shut off the flow to the flow controller assembly by turning the manual shut off valve (attached to the large air filter on the left side of the manifold in the hub).

vi. Once the vacuum gauge is stable shut off the flow to the pump by turning the other manual shut off valve located on the bottom of the manifold in the hub.

vii. Turn off the pump by pressing <F3: Pump>. Note the initial vacuum (in. Hg), recorded from the vacuum gauge located on the flow audit adapter, immediately after the pump is turned off.

viii. Note the final vacuum (in.Hg) reading on the vacuum gauge one minute after the pump valve is closed. Subtract the final vacuum from the initial vacuum noted from above.

ix. Multiply this value by 25.4 mm/in; this is the leak rate, **this value should not exceed 140mmHg/min.**

x. If the leak rate is greater than 140 mmHg/min, check the seals in the exchange assembly and ensure that the cassette with the Internal Leak Check disk is tight and secure.

xi. Repeat the above procedure. If the leak rate is still above 140 mmHg/min, then contact the appropriate APCD particulate personnel.

xii. If the leak rate passes note the internal leak rate in the appropriate space on the PM Analyzer Audit Field Datasheet. Slowly open the valve to the flow controller assembly and the valve on the flow audit adapter (**very slowly so as not to damage the audit filter)**.

xiii. Turn on the flow to the pump by turning the other manual shut off valve located on the bottom of the manifold in the hub.

7. Perform Temperature Audit:
The mass flow controllers used in the samplers utilize temperature and barometric pressure feedbacks to maintain a flow of 16.67 L/min at LTP. Incorrect ambient temperature readings will yield incorrect flow rates. The temperature audit is used to verify that the sampler's ambient temperature sensor is operating correctly so that flow rate adjustments can be performed accurately. The temperature audit procedure is as follows:
   i. From the Main Screen note the current Ambient Temperature in the appropriate space on the PM Analyzer Audit Field Datasheet.
   ii. Determine the current temperature (°C) at the ambient temperature sensor using the certified audit thermometer. Note the audit temperature on the PM Analyzer Audit Field Datasheet.
   iii. Verify that the value of ambient temperature displayed on the Main Screen is within ±2°C of the measured temperature. If this is not the case, notify the appropriate APCD particulate personnel. Continue with the remainder of the verification procedures.

8. Perform Barometric Pressure Audit:
The barometric pressure audit procedure is as follows:
   i. From the Main Screen note the current ambient barometric pressure in the appropriate space on the PM Analyzer Audit Field Datasheet.
   ii. Determine the current barometric pressure (inHg) at the ambient barometric pressure sensor using the certified audit barometer. Note the audit pressure on the PM Analyzer Audit Field Datasheet. This value can be converted to millimeters of Mercury (mmHg) by multiplying the value given by 25.4 in/mm.
   iii. Verify that the value of barometric pressure displayed on the Main Screen is within ± 10 mmHg of the audit standard. If this is not the case, notify the

appropriate APCD particulate personnel. Continue with the rest of the verification procedures.

7.4.2. Flow Rate Audit

Each reference PM sampler includes a specially designed sample air inlet, a size fractionation impactor/cyclone, and a sample flow rate control system. The particle size discrimination characteristics of both the inlet and the impactor/cyclone are critically dependent on specific internal air velocities; a change in velocity will result in a change in the nominal particle size collected. These velocities are determined by the actual volumetric flow rate of the sampler. Therefore, in order to control the size-fractionating cut-points and to measure the total volume correctly, the sampler's flow rate must be maintained at a constant value that is within +/- 5% of the design flow rate of 16.67 L/min. After completing the Leak Check, the flow rate audit procedure is as follows:

1. Remove the flow audit adapter and install the audit FTS on the sample down tube making sure the FTS is snug and completely attached. Verify that the manometer is properly connected to the flow transfer standard with no leaks and zero the manometer.

2. (Optional) From the Main Screen press <F5: Setup>. Each FTS is calibrated to accurately quantify flow. The RP2000 will perform the FTS calculation if it has the proper FTS "m" and "b" calibration constants.

3. (Optional) Verify that the constants printed on the side of the FTS are entered in the Setup screen.

4. (Optional) If changes are required press <EDIT>, enter the appropriate changes, and then press <ENTER> to accept the changes.

5. From the Main Screen press<F5: Setup> to access the Setup Screen.

6. Confirm that the desired flow rate (16.67 L/min) is set in the Set Flow field. If the Set Flow field is incorrect, use the arrow key to scroll down the Set Flow field and press the <F1 Edit>key to enter the edit mode. Using the key pad enter the correct flow rate and press the <Enter> button on the key pad.

7. Press the <F5: Audit> key to get to the Audit Screen.

8. Press <F3: Pump> and then <F2: Valve1>. Wait for the flow rate displayed in the Cur Flow column to stabilize.

9. Observe the manometer and take an average of the pressure readings.

10. (Optional) Press <EDIT>, enter the pressure drop average (inches H_2O) from the manometer in the appropriate field, and then press <ENTER>.

11. (Optional) The sampler will calculate and display the FTS volumetric flow (FTS Flow).

12. Press the <esc> key to return to the setup menu.

13. Repeat Steps 6–12 for the following additional flow rates; 16.0 L/min, 17.3 L/min and 16.67 L/min once again.

14. If multiple flow rate audits are performed at the 16.67 Lpm flow rate, then based upon the sequential order in which they were performed, the median run will be used to evaluate the sampler's flow rate. The flow rate audit criterion is evaluated on the Current Flow. The measured audit flow should be within ± 4% of the displayed Current Flow. At a Set Flow rate of 16.67 L/min the flow verification is acceptable if the FTS flow is between 16.0 and 17.3 L/min.

15. Record flow information for each flow level along with a temperature reading for each flow level on the PM Analyzer Audit Field Datasheet.

7.4.3. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the station is left in the condition it was found and or better. The following is a checklist of items to be completed before exit:

1. Remove the manometer, flow transfer standard, and thermometer from the instrument.
2. Replace the PM_{10} inlet head on the sampler's downtube.
3. Replace the audit filter cassette in the filter chamber with the sample filter.
4. Repeatedly press the <esc> key until the sampler returns to its main menu.
5. Press the <Run/Stop> button to return the sampler to its original sample status.
6. Close and lock the instrument enclosure.
7. Double check the site for any irregularities.

7.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The Technical Services Program maintains an Access Database on the Air Pollution Control Division (ACPD) Local Access Network (LAN). This program records the results of all PM and TSP particulate accuracy audits conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the accuracy data before they are submitted to AQS. A detailed description of the accuracy data processing procedures is located in Appendix D4 within the main body of the APCD QAPP.

A summary of these procedures is as follows. At the end of the calendar quarter, individual audit records contained on the auditor's laptop are uploaded to the QA Audits database Archive. Within 90 days of the end of a calendar quarter, all particulate accuracy data from the previous quarter are downloaded to an ASCII-format data file and then uploaded into the AQS database. Quality Assurance staff performs these data processing operations.

i. Enter all the information collected on the PM Analyzer Audit Field Datasheet into the PM Analyzer Data Entry Form within the QA Audits Database located on the auditor's notebook computer (Figure 8.1).

ii. Press the <Save To Archive> key to store the audit record to the archive data table. The acceptance criteria for accuracy audits are reported in Appendix MQO within the main body of the APCD QAPP. If any of the calculated audit values exceed the accuracy thresholds listed in Appendix MQO, then the auditor will notify the supervisor of the APCD Particulate Monitoring Unit in a timely manner, typically within one working day.

iii. At the end of each quarter the supervisor of the APCD's Particulate Monitoring Unit receives a summary report of all failed audits identified for the previous quarter.

Figure 8.1: Low Volume R&P Partisol 2000 PM FRM Analyzer Audit Form

Lo-Vol / Continuous PM Analyzer Audit

COLORADO
Air Pollution Control Division

Site	080410017				
Site Name	COLORADO SPRINGS - COLLEGE COLLEGE				
Method	R - P Co Partisol Model 2000 - Gravimetric				
Parameter	81102	POC	1	Method Code	127
Auditor	Brett	Audit Date	8/17/2022	Audit Time	11:13
Serial #	20258217990506				
FTS	JD260H				
Cal. Date	1/25/2022	Slope	0.2131	Intercept	0.1164

	Ambient Pressure			Ambient Temperature		
	(mm Hg)	(atm)	(inches Hg)	(Farenheit)	(Celsius)	(Kelvin)
Audit Standard		0.8145	24		23.2	296.4
Sampler		0.8092	24		22.8	296.0

Leack Check Verification ☑ *Upload to AQS?* ☑

Flow Rate Verification

Assessment Number	Audit Set Point (lpm)	Sampler Flow (lpm)	Audit Flow (lpm)	Delta H2O	Temp. (C)	Audit Rel. Error (%)	Design Rel. Error (%)
	16.00	15.98	15.78	14.840	23.3	1.3%	1.4%
1	16.67	16.67	16.45	16.160	23.0	1.3%	1.3%
	17.30	17.28	17.03	17.300	23.4	1.5%	1.6%

Audit Results

Pressure		Temperature		Audit Flow		Design Flow	
-0.005	PASS	-0.4	PASS	1.4%	PASS	1.4%	PASS
+/- 0.013 atm		*+/- 2 degrees C*		*+/- 4%*		*+/- 5%*	

Comments

8. Low Volume R&P Partisol Plus 2025 FRM PM Sampler Audit Procedure

8.1. Introduction

Fine particles (smaller than 2.5 microns) penetrate more deeply into the lungs than coarse particles (2.5 - 10 microns). Recent health studies indicate a link between fine particle concentrations in the outdoor air and certain health effects (40 CFR Part 58). Fine particles are generally emitted from combustion activities (such as industrial and residential fuel burning and motor vehicles) while coarse particles mainly come from dust emitted during activities such as construction and agricultural tilling.

Some of the health effects that have been linked to fine particulate matter pollution include:

- Premature death and increased hospital admissions and emergency room visits, primarily by the elderly and individuals with cardiopulmonary disease.
- Acute respiratory symptoms, including aggravated coughing and difficult or painful breathing.
- Decreased lung function and alterations in lung tissue and structure occur, particularly in children and people with asthma.

Note: The Low-Volume 2000 and 2025 R&P Partisol samplers can be set up to measure particle sizes of either PM_{10} or $PM_{2.5}$. Both samplers are equipped with an initial PM_{10} inlet head; installation of a Sharp Cut Cyclone below the PM_{10} head converts the unit to a $PM_{2.5}$ sampler.

8.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between the measured value and the true, standard value during audits.

Persons independent of the APCD particulate program conduct field audits quarterly on all manual samplers. The APCD Quality Assurance staff typically performs the field audits. The field audit is performed by measuring flow, temperature, pressure and time of the sampler with standards that are independent of those used in the calibration of the sampler. Audit standards must be certified against a NIST traceable standard and be of the same or of higher quality than of those being certified.

To ensure a quality audit, it is important that the audit is performed during a period of good weather and stable conditions. If the weather and/or conditions are not suitable, the audit should be rescheduled.

The APCD utilizes an Access database to enter and process audit results. A printout of the data entry form is used as a datasheet in which raw data is hand entered (see **Figure 9.1**). Data from the datasheet is then input into the Access database via the use of a data input form. The datasheets are archived incase the electronic copy is lost or damaged. A copy (satellite version) of the Access database is typically located on the auditor's laptop computer. The QA Audits Database is used to store audits for several particulate monitoring networks. The main screen will be displayed once the database is opened. Select the <Enter New Audit> button. Select the parameter that pertains to the audit being performed.. Upon opening the appropriate form, the data entry form is displayed and a new audit record can be entered into the form. Data from the form can be saved to an archive table as an audit record by pressing the button <Save To Archive>. To view archive records press the <View Audit Archive> button. The form will be reconfigured to display archive records. For each monitoring network there exists a table that contains a current list of all site and monitoring information. Procedures to transfer accuracy audits to the J:Drive archive database are performed on a quarterly basis and are covered in the Precision and Accuracy Data Handling SOP located within APCD's QAPP.

The general order of the field audit is as follows:

a) Set up audit standards and record sampler information.
b) Evaluate date and time.
c) Evaluate if samples have been loaded correctly.
d) Document any status codes.
e) Test sampler for leak.
f) Evaluate ambient temperature criteria.
g) Evaluate ambient barometric pressure criteria.
h) Evaluate sampler flow criteria.

8.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on Federal Reference Method (FRM) samplers:

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- Certified NIST-traceable Flow Transfer Standard (FTS) and leak tested/zeroed manometer.
- Certified time piece.
- Leak check audit adapter equipped with vacuum gauge.
- Audit filter cassette.
- PM Analyzer Audit Field Datasheet (**Figure 8.1**).
- Personal Laptop for data entry and audit verification.
- Tools, spare parts, and backup audit standards.

8.4. Federal Reference Method (FRM) Audit Procedure

8.4.1. Pre-Audit

1. Place the temperature probe for the audit thermometer in the louvered gill screen of the sampler's ambient temperature probe. If possible, affix the audit temperature probe so that the top one inch of the probe is in close proximity of the sampler's ambient temperature probe. Verify that both the audit and sampler temperature

probes are out of direct sunlight. Allow the audit thermometer to equilibrate for approximately 10 minutes prior to making temperature readings.

2. Remove the audit barometer from its carrying case and place the barometer out of direct sunlight (if possible) and allow the barometer to equilibrate for approximately 10 minutes prior to any barometric pressure readings.

3. Remove the flow transfer standard (FTS) and stage it on top of the sampler. If a manometer is utilized, try to orientate it so that it is level, zeroed and will be in the same position throughout the flow audit.

4. Unlock the sampler and a fill in all requested information in the Site Information and Standards Information portions of the field datasheet.

5. Perform Date and Time Audit - The time and date audit is done to verify that the sampler is operating in accordance with the EPA sample day and run-time schedule of midnight to midnight Mountain Standard Time (MST). Samplers that operate outside these schedules must be adjusted and/or reprogrammed so that compliance with these schedules is met. From the main screen of the sampler, note the sampler's date and time on the PM Analyzer Audit Field Datasheet. Additionally, note the date and time from the auditors timepiece onto the audit field datasheet. If the instrument's time has a difference of more than 15 minutes as compared to the audit standard or if the date is incorrect as compared to the audit standard, contact the appropriate APCD particulate personnel. Continue with the rest of the audit.

   Note: All RP2000's and 2025's in the Colorado network are set to Mountain Standard Time (MST) all year. On the Main Screen, note the sampler time. Site operators may use their watch as a standard if it has been set accurately. Using a cell phone as a standard is the preferred option as cell phones automatically update based on the atomic clock. There is a web site to the atomic clock in Boulder, Colorado where operators may set their watches and or double check their cell phone time accuracy; the URL is http://www.time.gov/.

6. Perform Sampler Leak Check:
   The leak check procedure is used to verify that the air handling system in the sampler is adequately free from leakage that could cause either the flow rate to be measured incorrectly or filtration artifacts to be introduced into the system. The R&P sampler automatically determines leakage by pulling a vacuum on the internal air volume of the totally assembled sampler, sealing the volume by closing valves and monitoring the internal pressure of a set period of time. If the internal pressure increases too rapidly, a leak is indicated, and troubleshooting procedures must be followed to stop the leak. The steps in performing a Leak Check are as follows;

i. From the Main Screen press 'RUN/STOP' once. Select <F1: Audit> and press 'MENU' twice.
ii. Select 'Leak Check' using the down arrow (↓) key and press <ENTER>. Remove the sample supply magazine from the left side of the sample compartment (when changing out magazines, take note of the condition of the o-rings, looking for wear and tear, on the bottom manifold where the pneumatic tubing attaches to the magazine, notify the appropriate APCD personnel if condition is unsatisfactory), cover the sample magazine with a clean cap and set the magazine aside. Also remove the sample collection magazine from the right side, cover magazine with clean cap and set aside.
iii. Install an audit magazine containing a prepared audit cassette on the left side and an empty magazine on the right side.
iv. Press <F4: FiltAdv> to move the sample filter in the sample chamber into the storage magazine and advance the audit cassette into the sample chamber.
v. After the filter advance has been completed, swap the audit storage magazines so that the sample filter can be placed back into the sample chamber and the audit cassette is returned to an audit magazine at the conclusion of the audit.
vi. Remove the sample head from the down tube and set aside.
vii. Place the flow audit adapter on the sample down tube and turn the valve handle to the horizontal position to close the value (open is vertical).
viii. While in 'Audit' mode from the Main Screen press 'MENU', select 'Leak Check', press <F2: Start>, press <F1: External>, and follow the prompts. The external leak check will start automatically. A Pass/Fail message will be displayed at the end of the leak check cycle.
ix. If a 'Fail' message is displayed, first check the filter cassette for possible leaks. Then check the WINS or the VSCC for tightness, make sure the flow audit adapter is closed, and the WINS adapter (the aluminum cup that fits on top of the WINS is on tightly. If needed, advance another audit cassette into the sample chamber. Attempt another external leak check.
x. If a 'Fail'message, is displayed once again, contact the appropriate APCD particulate personnel.
xi. If a 'Pass' message is displayed, **<u>slowly</u> open the valve on the flow audit adapter** to avoid damaging the filter or sampler and press any key to view the External Leak Check Results Screen, a pressure drop of 25 mmHg or less is the external leak check pass criterion. Note the external leak rate in the appropriate space on the PM Analyzer Audit Field Datasheet.

7. Perform Temperature Audit:
The mass flow controllers used in the samplers utilize temperature and barometric pressure feedbacks to maintain a flow of 16.67 Lpm at LTP. Incorrect ambient temperature readings will yield incorrect flow rates. The temperature audit is used to verify that the sampler's ambient temperature sensor is operating correctly so that flow rate adjustments can be performed accurately.

   i. From the Main Screen (while in 'AUDT' mode) press <MENU>, select 'Audit', this will bring up the Audit Screen.
   ii. Determine the current temperature (°C) at the ambient temperature sensor using the certified audit thermometer. Note the audit temperature on the audit field datasheet.
   iii. Verify that the value of ambient temperature displayed on the Audit Screen is within ± 2°C of the measured temperature. If this is not the case, notify the appropriate APCD particulate personnel. Continue with the rest of the verification procedures.

8. Perform Barometric Pressure Audit:
The mass flow controllers used in the samplers utilize temperature and barometric pressure feedbacks to maintain a flow of 16.67 Lpm at LTP. Incorrect barometric pressure readings will yield incorrect flow rates. The barometric pressure audit is used to verify that the sampler's ambient barometric pressure sensor is operating correctly so that flow rate adjustments can be performed accurately.

   i. From the Main Screen (while in 'AUDT' mode) press <MENU>, select 'Audit', this will bring up the Audit Screen. Note the current ambient barometric pressure in the appropriate space on the audit field datasheet (Figure 12).
   ii. Determine the current barometric pressure (inHg) at the ambient barometric pressure sensor using the certified audit barometer. Note the audit pressure on the audit field datasheet. This value can be converted to millimeters of Mercury (mmHg) by multiplying the value given by 25.4 in/mm.
   iii. Verify that the value of barometric pressure displayed on the Audit Screen is within ± 10 mmHg of the audit standard. If this is not the case, notify the appropriate APCD particulate personnel. Continue with the rest of the verification procedures.

8.4.2. Flow Rate Audit

Each reference method PM sampler includes a specially designed sample air inlet, a size fractionation impactor/cyclone, and a sample flow rate control system. The particle size discrimination characteristics of both the inlet and the impactor/cyclone are critically dependent on specific internal air velocities; a change in velocity will result in a change in the nominal particle size collected. These velocities are determined by the actual volumetric flow rate of the sampler. Therefore, in order to control the size-fractionating cut-points and to measure the total volume correctly, the sampler's flow rate must be maintained at a constant value that is within +/- 5% of the design flow rate of 16.67 L/min. After completing the Leak Check, the flow rate audit procedure is as follows:

1. Remove the flow audit adapter and install the audit FTS on the sample down tube making sure the FTS is snug and completely attached. Verify that the manometer is properly connected to the flow transfer with no leaks and zero the manometer.

2. (Optional) From the Main Screen press <F5: Setup>. Each FTS is calibrated to accurately quantify flow. The RP2025 will perform the FTS calculation if it has the proper FTS "m" and "b" calibration constants.
3. (Optional) Verify that the constants printed on the side of the FTS are entered in the Setup screen.

4. (Optional) If changes are required press <EDIT>, enter the appropriate changes, and then press <ENTER> to accept the changes.

5. From the Main Screen press<F5: Setup> to access the Setup Screen.

6. Confirm that the desired flow rate (16.67 L/min) is set in the Set Flow field. If the Set Flow field is incorrect, use the arrow key to scroll down the Set Flow field and press the <F1 Edit>key to enter the edit mode. Using the key pad enter the correct flow rate and press the <Enter> button on the key pad.

7. Press the <F5: Audit> key to get to the Audit Screen.

8. Press <F3: Pump> and then <F2: Valve 1>. Wait for the flow rate displayed in the Cur Flow column to stabilize.

9. Observe the manometer and take an average of the pressure readings.

10. (Optional) Press <EDIT>, enter the pressure drop average (inches H_2O) from the manometer in the appropriate field, and then press <ENTER>.

11. (Optional) The sampler will calculate and display the FTS volumetric flow (FTS Flow).

12. Press the <esc> key to return to the setup menu.

13. Repeat Steps 6–12 for the following additional flow rates; 16.0 L/min, 17.3 L/min and 16.67 L/min once again.

14. If multiple flow rate audits are performed at the 16.67 Lpm flow rate, then based upon the sequential order in which they were performed, the median run will be used to evaluate the sampler's flow rate. The flow rate audit criterion is evaluated on the Current Flow. The measured audit flow should be within ± 4% of the displayed Current Flow. At a Set Flow rate of 16.67 L/min the flow verification is acceptable if the FTS flow is between 16.0 and 17.3 L/min.

15. Record flow information for each flow level along with a temperature reading for each flow level on the PM Analyzer Audit Field Datasheet.

8.4.3. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the sampler is left in the condition it was found and or better. The following is a checklist of items to be completed before exit:

1. Remove the manometer, flow transfer standard, and thermometer from the instrument.
2. Replace the PM_{10} inlet head on the sampler's downtube.
3. From the Audit Screen press <F4: FiltAdv>. After advancing the sample filter into the sample chamber, remove the **audit** magazines from the *supply* and *storage* sides of the sampler and replace them with the **sample** *supply* and *storage* magazines.
4. Press the 'Run/Stop' key to return the instrument from 'Audit' to 'WAIT' or 'SAMP' mode.
5. Close the sampler door and lock the instrument enclosure.
6. Double check the site for any irregularities.

8.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The Technical Services Program maintains an Access Database on the Air Pollution Control Division (ACPD) Local Access Network (LAN). This program records the results of all PM and TSP particulate accuracy audits conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the accuracy data before they are submitted to AQS. A detailed description of the accuracy data processing procedures is located in Appendix D4 within the main body of the APCD QAPP.

A summary of these procedures is as follows. At the end of the calendar quarter, individual audit records contained on the auditor's laptop are uploaded to the PMT database. Within 90 days of the end of a calendar quarter, all particulate accuracy data from the previous quarter are downloaded to an ASCII-format data file and then uploaded into the AQS database. Quality Assurance staff performs these data processing operations.

iv. Enter all the information collected on the PM Analyzer Audit Field Datasheet into the PM Analyzer Data Entry Form within the QA Audits Database located on the auditor's notebook computer (Figure 9.1).

v. Press the <Save to Archive> key to store the audit record to the archive data table. The acceptance criteria for accuracy audits are reported in Appendix MQO within the main body of the APCD QAPP. If any of the calculated audit values exceed the accuracy thresholds listed in Appendix MQO, then the auditor will notify the supervisor of the APCD Particulate Monitoring Unit in a timely manner, typically within one working day.

i. At the end of each quarter the supervisor of the APCD's Particulate Monitoring Unit receives a summary report of all failed audits identified for the previous quarter.

Figure 9.1: Low Volume / ContinuousPM Analyzer Audit Form

Lo-Vol / Continuous PM Analyzer Audit

CDPHE CO
COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080350004				
Site Name	CHATFIELD STATE PARK				
Method	R & P Model 2025 PM-2.5 Sequential Air Sampler w/VSCC - Gravimetric				
Parameter	88101	POC	1	Method Code	145
Auditor	Harkwell, Brett	Audit Date	5/3/2019	Audit Time	11:47
Serial #	2025B21807050б				
FTS	JD260H				
Cal. Date	1/22/2019	Slope	0.2130	Intercept	0.1022

	Ambient Pressure			Ambient Temperature		
	(mm Hg)	(atm)	(inches Hg)	(Farenheit)	(Celsius)	(Kelvin)
Audit Standard		0.8202	25		17.3	290.5
Sampler		0.8276	25		16.9	290.1

Leack Check Verification ☑ *Upload to AQS?* ☑

Flow Rate Verification							
Assessment Number	Audit Set Point (lpm)	Sampler Flow (lpm)	Audit Flow (lpm)	Delta H2O	Temp. (C)	Audit Rel. Error (%)	Design Rel. Error (%)
	16.00	15.98	16.12	16.010	16.7	-0.9%	-0.8%
1	16.67	16.67	16.85	17.480	17.0	-1.1%	-1.1%
	17.30	17.29	17.49	18.790	17.6	-1.1%	-1.1%

Audit Results							
Pressure		Temperature		Audit Flow		Design Flow	
0.007	PASS	-0.4	PASS	-1.0%	PASS	-1.0%	PASS
+/- 0.013 atm		*+/- 2 degrees C*		*+/- 4%*		*+/- 5%*	

Comments

9. Audit Procedure for the MetOne SASS and Super SASS

9.1. Introduction

The Speciation Air Sampler System (SASS) chemical sampler was developed under contract with the United States Environmental Protection Agency (EPA) by Met One Instruments. The SASS collects samples for the chemical and gravimetric analysis of $PM_{2.5}$ particles (particles smaller than 2.5 µm) in ambient air. These particles are comprised of sulfates, nitrates, organic carbon, soot like carbon and metals. With the fine particle standard for $PM_{2.5}$, the EPA has mandated a sampling network for determining the concentration of each of these species. The SASS has been specifically designed to meet these needs. After the instrument pulls ambient air through its sampler filters for 24 hour sample runs on designated sample days, the filters are sent to EPA's contract laboratory for analysis. The analysis determines what $PM_{2.5}$ species are captured on the filter and the concentration of each species.

9.2. Quality Assurance

Quality Assurance (QA) refers to procedures established for collecting quality data within pre-specified tolerance limits. Almost all QA procedures have already been covered under specific topics within this SOP. Documentation and audit procedures for the SASS and Super SASS, are discussed below.

The general order of the field audit is as follows:

a) Set up audit standards and record sampler information.
b) Evaluate date and time.
c) Test sampler for leaks.
d) Evaluate ambient temperature criteria.
e) Evaluate ambient barometric pressure criteria.
f) Evaluate sampler flow criteria.

9.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on the SASS and Super SASS samplers:

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- Certified NIST-traceable Flow Transfer Standard (FTS) with digital manometer or typically a BGI Trical is utilized.
- Certified time piece.
- SASS Audit filter cassette.
- Chemical Speciation Network Performance Audit Worksheet (**Figure 10.13**).
- Personal Laptop for data entry and audit verification.

- Tools, extra tubing and spare parts.

9.3.1. Audit Procedure

When the Audit Filter canisters are in place, open the weather shield on the control box and power up the screen on the MetOne sampler. The control module display will become illuminated. Through a series of keystrokes listed later in this section, the Clock Test, Leak Test, Flow Test, Temperature Test and Pressure Test can be obtained from the Main Menu (**Figure 10.1**) of the Control Box. The data that is obtained will be entered manually on the Chemical Speciation Network Performance Audit Worksheet (**Figure 10.13**). The Chemical Speciation Network Performance Audit Worksheet is an excel spreadsheet that is maintained by the EPA and performs all calculations for passing or failing the respective tests.

Note: It is recommended that the auditor key in the data in the field as well as write it on a printed audit form for cross verification.

1. Time Audit procedure is as follows;
   i. From the Main Menu screen (**Figure 10.1**) select the Setup menu (**Figure 10.2**), then select clock (or F3).
   ii. From the clock screen (**Figure 10.3**) record the air sampler's displayed time as the SASS time on the Chemical Speciation Network Performance Audit Worksheet (**Figure 10.13**).
   iii. Record the NIST traceable reference clock time on the Chemical Speciation Network Performance Audit Worksheet, this is another external device such as a cell phone or an atomic wristwatch/clock.
   iv. The time difference shall be calculated (<5.0 minutes difference), on the worksheet, and determined to be either a Pass/Fail status.

   Recall that the Speciation Network samples on the same schedule as the National $PM_{2.5}$ FRM network which is constrained to Local Standard Time all year long. The Speciation network is also on the 3-day and 6-day EPA sampling schedule. It is important that no audits occur on scheduled Speciation Network sample days so as not to interrupt a sample and lose ambient data.

Figure 10.1 MetOne Control Box Displaying Main Menu

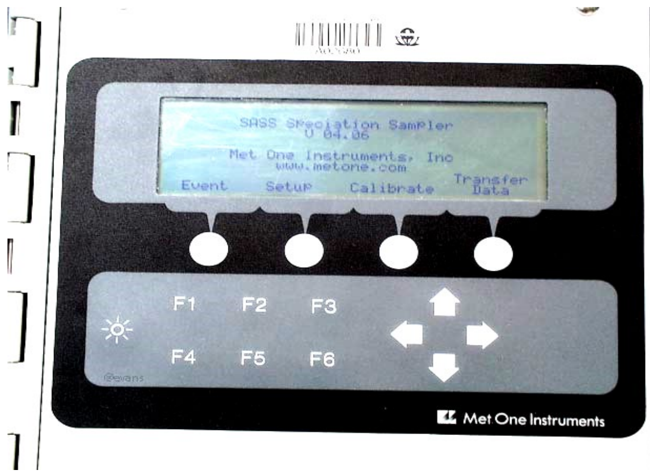


Figure 10.2 Setup Menu

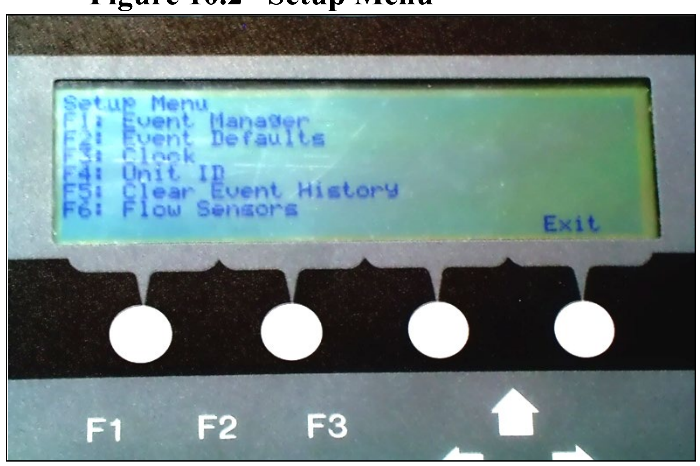
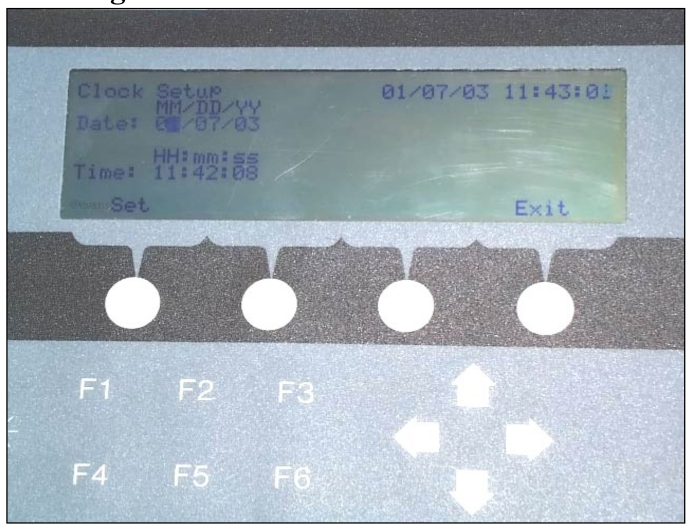


Figure 10.3 Clock screen



2. Perform Sampler Leak Check:
The leak check procedure is used to verify that the air handling system in the sampler is adequately free from leakage that could cause either the flow rate to be measured incorrectly or filtration artifacts to be introduced into the system.

   i. From the Main Menu (**Figure 10.1**) select the *Calibration Menu*;
   ii. At the Calibration menu (**Figure 10.4**), select the *System Test* Menu (F1). (**Figure 10.5**) ***Do not press "Flow Calibration."*** From the System Test Menu, the user is able to turn on the pump by selecting the Pump key.
   iii. When the pump key has been chosen, a warning will come up and ask if you want to continue or cancel the run; push "Continue" and the pump will start (**Figure 10.6**).
   iv. The user must press *Continue* to perform the leak test and flow checks. Once this is done, the screen reverts back to the System Test Menu that allows the user to view the flow rates for each system channel.
   v. Ensure that the leak option is selected by pressing the *Leak key*, from the System Test Menu. The user is now prepared to perform leak test.

Figure 10.4 Calibration Menu

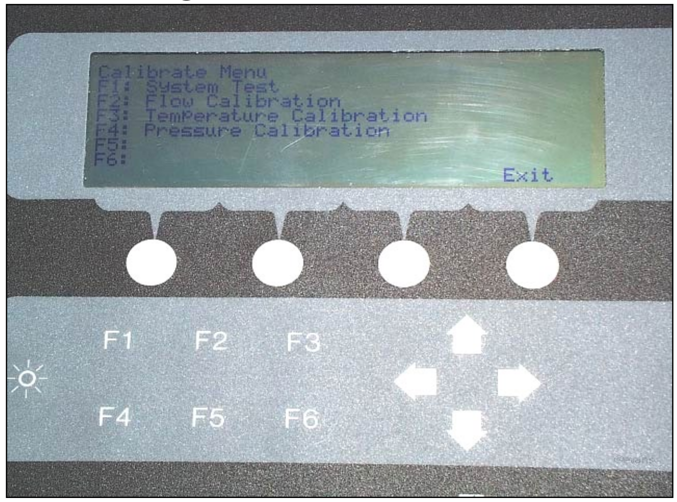


Figure 10.5 System Test Menu

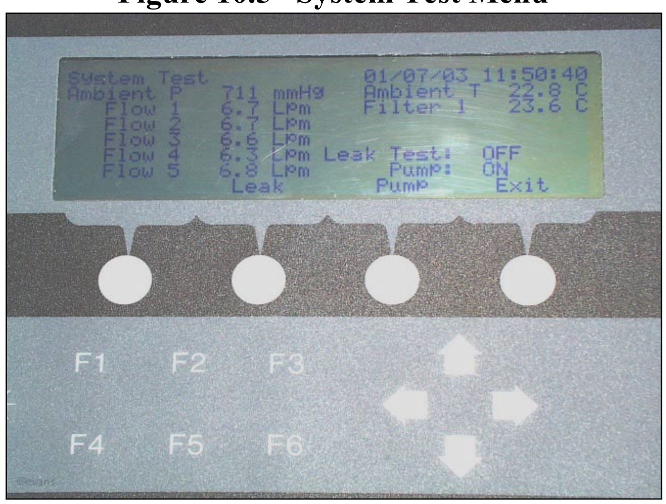


Figure 10.6 Pump Screen

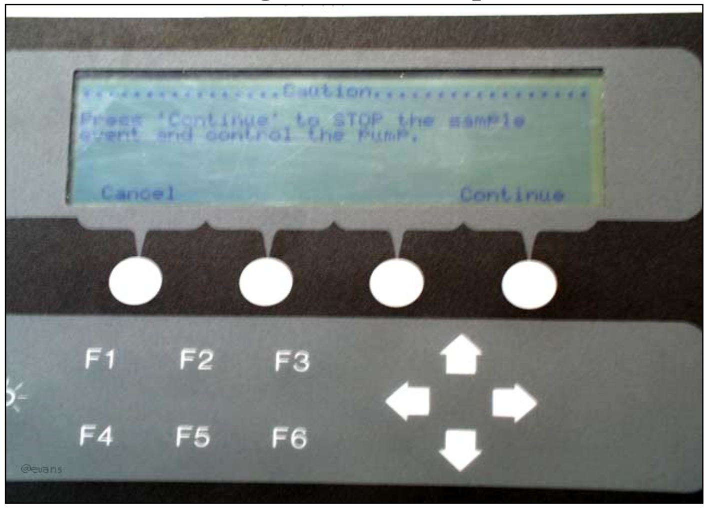


Figure 10.7: Leak check by capping inlet

vi. Use either a finger or a cap, to tightly seal the inlet of the SCC so that no air can pass up through the nozzle (**Figure 10.7**).

vii. Allow the system to stabilize at a constant flow rate for several minutes.

viii. The flow rate indicated should be 0.0 L/min, which indicates that there is no leak in the flow system.

ix. Record the leak flow rate for channel #1, from the *System Test Menu* on the Chemical Speciation Network Performance Audit Worksheet. A leak of up to 0.10 L/min will pass the acceptance criteria.

x. **Slowly** release the vacuum on the Channel #1 inlet, and move to the next two consecutive channel positions (channels 2 & 3) in succession to perform leak checks.

xi. Record the leak flow rate for each channel on the Chemical Speciation Network Performance Audit Worksheet.

Note: It is not necessary to stop the pump or change the menus to conduct leak and flow checks between each channel.

3. Perform Flow Audit:

Following the Leak test, with the pump still running, begin the flow checks. Remember the TriCal requires 60 minutes to equilibrate prior to use and should be cycled off and on after equilibration and before use.

i. Attach the opposite end of the hose that is connected to the TriCal via the venturi #1 tube adapter to the filter canister SCC inlet (**Figure 10.8**), or any other NIST traceable flow measurement device.

ii. Allow the flow to stabilize and record the displayed MetOne sample flow rate for channel #1, and the flow rate displayed on the TriCal on the Chemical Speciation Network Performance Audit Worksheet.

iii. Without stopping the pump, repeat the above procedures for channels 2 and 3. Record the sampler and audit device flow rates for each channel on the Chemical Speciation Network Performance Audit Worksheet.

Figure 10.8 Flow audit device connected to SCC inlet.

iv. When the flow audit is completed, select *Exit* from the System Test menu to shut off the pump. The screen will then default back to the *Calibration Menu*.
v. At the *Calibration Menu*, press the *Exit* key the screen defaults back to the Main Menu.
vi. Remove the audit canister assembly from the air sampler.

4. Filter Temperature Audit is performed as follows:
   i. Ensure that the temperature probe is attached to the TriCAL and that it has been allowed to equilibrate.
   ii. From the Main Menu on the MetOne SASS, press the *Event key*; this will take the user into the *Event Menu* (**Figure 10.9**).
   iii. At the *Event Menu*, press the *Current Event Status* key (F1), this takes the user into the *Current Event Menu* (**Figure 10.10**).
   iv. Insert the TriCAL temperature probe into the open sample orifice of channel #1 and allow enough time for the temperature reading on the TriCal display to stabilize (**Figure 10.11**), or any other NIST traceable field thermometer.

v. Record the filter temperature for channel #1, which is located at the upper right hand corner of the screen, and the displayed temperature reading,"Tfil," from the TriCAL.

Note: For the MetOne SASS the filter temperature audit only requires temperature readings for channel #1. The Super SASS has a temperature sensor at every channel so each will be tested.

Figure 10.9: Event Menu

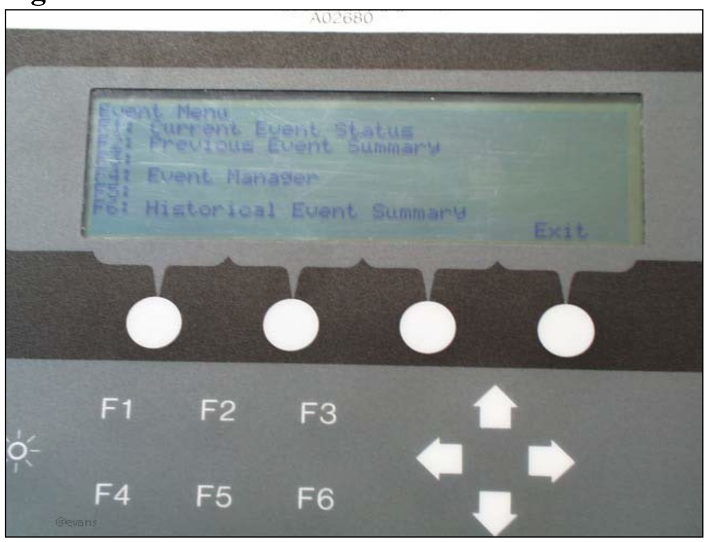


Figure 10.10: Current Event Menu

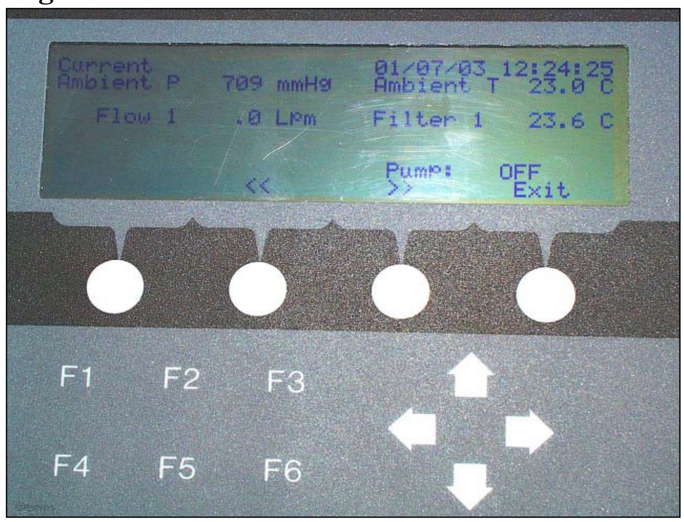
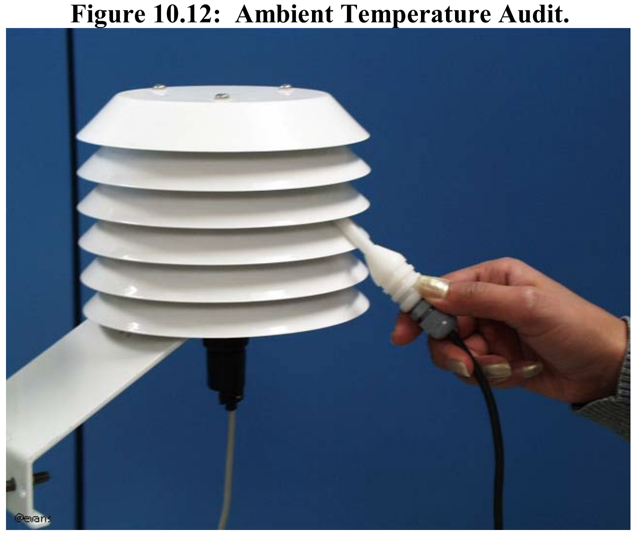


Figure 10.11: Filter temperature audit.

5. Ambient Temperature Audit is performed as follows:
Even though we are taking the ambient temperature from the SASS Sampler we use the "Tfil" probe to make the measurement; therefore we must record the "Tfil" reading from the TriCal as our ambient temperature measurement reading.
   i. Carefully insert the temperature probe into the gill screen of the SASS ambient temperature sensor, avoiding contact with the sides of the gill screen, and direct sunlight (**Figure 10.12**).
   Note: Contact with a gill screen that has been exposed to direct sunlight may result in non-representative/erroneous readings due to possible elevated temperatures of the gill screen.
   ii. Allow the TriCAL temperature reading to stabilize.
   iii. Record the air sampler ambient temperature, from the *Current Event Menu*, and the TriCAL ambient temperature.

Figure 10.12: Ambient Temperature Audit.



6. Ambient Pressure Audit is performed as follows:
   i. Record the ambient barometric pressures from the TriCAL, or any other NIST traceable barometer and the SASS, which is found in the upper right hand corner of the Current Event screen.
   ii. Once the ambient pressures have been recorded the audit procedure is completed, restore the air sampler to its original condition ensuring that the Control Box is returned to the Main Menu.
   iii. Replace any routine filter canisters to their original positions.
   iv. Return all the audit instrumentation to their cases.

7. Other Observations:
   Record any applicable observations on the comments section of the Chemical Speciation Network Performance Audit Worksheet. This may include information such as the following:
   - Obvious Vandalism.
   - Known power outages/failures.
   - Any interrupted sample events.
   - Inclement weather conditions.
   - Any other pertinent information that might have adverse impacts on data generation/collection.

8. Follow Up Actions:
   i. The auditor should prepare a completed Performance Audit Worksheet including any findings recorded during the TSA interview and inspection in the "Findings" text box. The findings should be divided into "Significant" and "General."
   ii. Within two weeks following a site audit, a draft audit report should be submitted to the QA team within APCD for submittal to AQS..
   iii. The site operator will be given two weeks to respond for the purpose of ensuring there are no erroneously recorded data that led to a false significant finding. Erroneous data entry should be corrected if there is a high level of confidence that accurate audit data can be recovered from the written versions of the Chemical Speciation Network Performance Audit Worksheet and TSA form.
   iv. Disputed findings of any parameter or condition that were not the result of erroneous data entry should be identified for the interim final report.
   v. Within 6 weeks after an audit has concluded and two weeks after the operator's response period, an interim final report will be prepared and forwarded to the Site operator, the SLT's monitoring program manager, the EPA Chemical Speciation Network Program Manager, and the appropriate Regional Monitoring Program contact and QA Contact.
   vi. Monitoring site owners are expected to correct significant findings within 60 days following issuance of the interim final report. Safety findings should be corrected immediately. Remedies for significant findings should be patterned after those stated in the National $PM_{2.5}$ Chemical Speciation Network guidance document and Field QAPP.

vii. If necessary, a final actions update will be added to the interim final 90 days following the 60 day remediation period, and the resulting report will stand as the "Final Audit Report"

Audit Reports for the Speciation Network will be summarized and loaded to AQS by APCD QA personnel.

9.4. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The auditor should keep a hand written copy of the audit findings for archival and storage just in case the electronic copy is lost or damaged. Results are tabulated and stored in an Excel spreadsheet for CSN and SASS audits. The electronic copy of the Excel spreadsheet should have the handwritten data entered into it and stored for archival and submittal to AQS by the APCD QA staff. The electronic copies of the audit spreadsheet (**Figure 10.13**) should be stored on the APCD LAN at J:/QA Audit Programs/CSN SASS audits.

Figure 10.13: Chemical Speciation Network Performance Audit Worksheet – MetOne SASS

Chemical Speciation Network Performance Audit Worksheet MetOne SASS - Primary Sampler		**Colorado Department of Public Health and Envi**	
Note - Cyan fields are entered from TSA worksheet or calculated - yellow fields are to be filled in here			
Location	Denver Municipal Animal Shelter	Date	8/14/2012
AQS Site ID	80310025		
AQS Sampler POC	5		
Audit Information			
Sampler Type (Model)	SASS		
Auditor(s)	Clyde W. Sharp	Affiliation	Colorado Department of Public He
Audit Type	PQAO		
		Sampler S/N	A4031
		Head S/N	A4886
		Pump S/N	F4179
Last Calibration Date			
Audit Reference Standards			
Flow Reference Std Model	Select From Dropdown List	Standard S/N	JD263
Specify if "Other"	InFlow	Calibration Date	3/27/2012
Temperature Ref Std Model	NIST TRACEABLE THERMOMETER	Standard S/N	341803
Specify if "Other"		Calibration Date	Jan-12
BP Std Model	OTHER	Standard S/N	27263
Specify if "Other"	Pretel Digi Barometer	Calibration Date	Jan-12
Significant Findings:			
General Findings:			

MetOne SASS - Primary Sampler									
Clock Audit									
If Local Time is under daylight savings, convert Ref Std to Local Standard Time. Daylight Saving Time begins for most of the United States at 2:00 a.m. on the first Sunday of April. Time reverts to standard time at 2:00 a.m. on the last Sunday of Octobe									
	Time (hh:mm)				Difference		5 minutes or less?		
	Ref Std		SASS		Minutes		Pass	Fail	
Audit Time	03:44		03:41		-3.0		X		
Date	8/14/2012		8/14/2012						
Recalib Time									
Date	8/14/2012								

Leak Test								
	Initial Audit		After Correction		Greater than 0.10 L/min fails		
	A L/min		B L/min		Pass	Fail A	Fail B
Channel 1	0.000	Channel 1			X		
Channel 2	0.000	Channel 2			X		
Channel 3		Channel 3					
Channel 4		Channel 4					
Channel 5		Channel 5					
Channel 6		Channel 6					
Channel 7		Channel 7					
Channel 8		Channel 8					

Flow Audit								
For the reference standard, enter "UR" for under range and "OR" for over range flow readings.								
	L/min				% Difference		Within ± 10%?	
	Lower Limit	Ref Std	Upper Limit	SASS	SASS - Ref		Pass	Fail
Channel 1	6.39	7.10	7.81	6.7	-5.633802817		X	
Channel 2	6.39	7.10	7.81	6.7	-5.633802817		X	
Channel 3	NA		NA					
Channel 4	NA		NA					
Channel 5	NA		NA					
Channel 6	NA		NA					
Channel 7	NA		NA					
Channel 8	NA		NA					
Retest after Calibration								
	L/min				% Difference		Within ± 10%?	
	Lower Limit	Ref Std	Upper Limit	SASS	SASS - Ref		Pass	Fail
Channel 1	NA		NA					
Channel 2	NA		NA					
Channel 3	NA		NA					
Channel 4	NA		NA					
Channel 5	NA		NA					
Channel 6	NA		NA					
Channel 7	NA		NA					
Channel 8	NA		NA					

10. URG 3000N Chemical Speciation Sampler Audit Procedure

10.1. Introduction

The URG 3000N Carbon Sampler is part of EPA's chemical speciation network, which also utilizes the above described SASS and SuperSass samplers. The URG 3000N is designed to collect organic and elemental carbon as part of that program in ambient $PM_{2.5}$ concentrations. The sampler collects $PM_{2.5}$ particles on quartz filters, which are then sent to a lab and analyzed for carbon using the Thermal Optical Reflective analysis method. The audit data is handled in exactly the same fashion as the SASS audit data with the same Excel spreadsheet and is described at the end of this SOP under the Data Processing section.

10.2. URG 3000N Audit Procedure

Prior to the first use of the sampler and on a quarterly basis thereafter, conduct audits of ambient temperature, barometric pressure, and flow rate according to the schedule provided by APCD. ***Always use verification standards provided by APCD. Allow the pump and MFC ample time to warm up.*** Use the Carbon Speciation Network Performance Audit Worksheet (**Figure 11.2**) to record and report results of the verification. Also, always have a copy of the URG 3000N Operations Manual on hand.

10.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on URG samplers:

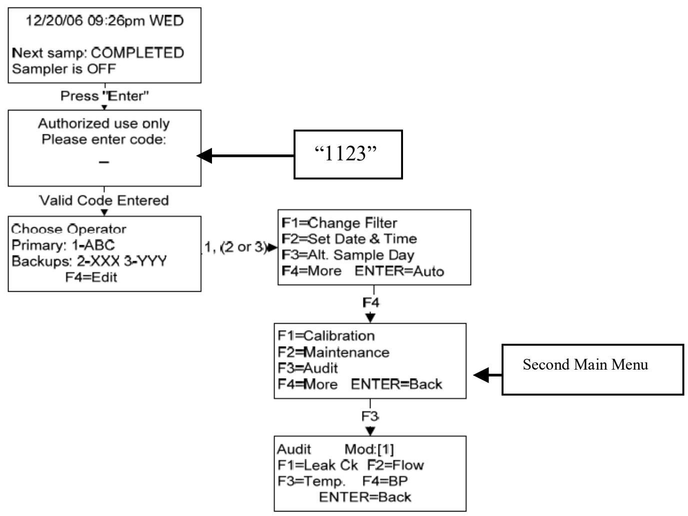
- Carbon Speciation Network Performance Audit Worksheet (**Figure 11.2**).
- URG-3000N sampler operations manual.
- Audit cartridge for the leak check and verification.
- Temperature, pressure and flow standards.
- Leak check assembly provided by URG, specifically:
  - Downtube reducer (1.5"ID to 1.25"OD),
  - Leak check adaptor (1.25" to brass hose barb with shutoff valve)
  - Pump shutoff valve assembly (This assembly will be hard-plumbed into later models of the URG 3000N)

10.4. URG Audit Procedure

10.4.1. AUTO MODE To Audit Menu Screens

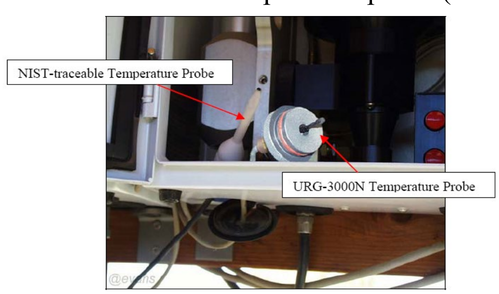
The image below (**Figure 11.1**) displays the menu screens from the AUTO MODE screen to the Audit Menu. The first menu screen displayed is the AUTO MODE screen. From this screen, press the "**ENTER**" key to move to the Authentication screen. Then enter "**1123**" to proceed to Choose Operator screen. Select the appropriate operator by their initials; the primary operator is "**1**", the backup operator is "**2**", and the auditor is "**3**". These values will be set up when the sampler is installed. Selecting "**1**, **2**, or **3**" keys will forward the instrument to the next screen. Select the "**F4**" key to proceed to the next screen, the second Main Menu. At the second Main Menu, press the "**F3**" key for the Audit Menu.

Figure 11.1: Menu Tree from AUTO MODE Screen to Audit Menu Screen



10.4.2. Ambient Temperature Audit

At the base of the inlet tee, locate the ambient temperature probe (see image below).



While holding the ambient temperature probe cable, gently push the black plastic disc through the bottom of the Sample Module.

With one hand reach into the sample module box and carefully wiggle the probe plug free from the inlet tee and lay in the bottom side of the sample module box away from direct sunlight.

Place the verification temperature probe adjacent to the sampler's ambient temperature probe and allow both temperature probes to equilibrate, making sure to protect the probes from sunlight and wind.

```
Audit Temperature
Temperature(C)= 25.4
F1:+/-      F2:C/F
Ref. Temp(C):?
```

After the two probes equilibrate, enter in the reference standard temperature value in degrees Celsius. Press the "**F1"** key to toggle between positive and negative values; press the "**F2"** key to toggle between Celsius and Fahrenheit. The decimal place is fixed to one place, so entering "254" will represent 25.4 ºC.

Record the sampler and reference standard values in degrees Celsius to the Carbon Speciation Network Performance Audit Worksheet. **The agreement should be within ±2 ºC**. If values do not agree within the acceptance criteria then verify the readings and notify the appropriate PM staff within APCD.

After entering the reference standard's temperature, the next screen shows the sampler's temperature, reference standard's temperature, and the difference between the two values in Fahrenheit and Celsius (see screen below).

```
C/F Samp. Ref. Diff.
C  25.4  25.0  0.4
F  77.7  77.0  0.7
              ENTER=Next
```

Press the "**ENTER**" key to proceed to the next screen. Press the "**YES**" key to save audit results to the memory card. If the operator selects the "**NO**" key, no data will be saved and the sampler software and the sampler will return to the Audit Menu screen. By selecting "**YES**", the next screen appears (this screen could take a few moments to appear).

```
Save audit results to
memory card?

YES=Save   NO=Cancel
```

↓

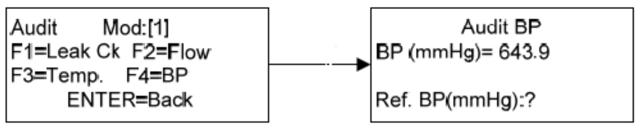
```
Audit results saved to
memory card.

              ENTER=Next
```

Press the "**ENTER**" key to return to the Audit Menu.

Remove the temperature standard and securely replace the sampler's temperature probe in the bottom of the inlet tee. Replace the black plastic disc and the temperature probe back to its' original location. Be careful not to damage the temperature sensor and make sure it is seated properly. If the temperature sensor is not seated properly a leak in the sampler flow will occur.

10.4.3. Barometric Pressure Verification

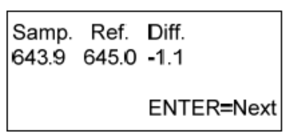
At the Audit Menu, press the "**F4**" key to proceed to the barometric pressure verification (audit) screen (see below).



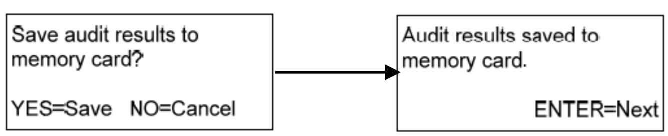
Enter the barometric pressure (in mm Hg) of an equilibrated NIST-traceable reference standard using the keypad. The decimal point is fixed to one place so entering '6245' will represent 624.5.

Record the sampler and verification standard values in mm Hg on the Carbon Speciation Network Performance Audit Worksheet. ***The agreement should be within ±10 mm Hg*****.** If values do not agree within acceptance criteria verify the values and notify the appropriate PM staff within APCD.

After entering the reference standard's barometric pressure, the next screen shows the sampler's barometric pressure, the reference standard's barometric pressure, and the difference between the two values in mm Hg (see below).



Press the "**ENTER**" key and select "**YES**" to save the results to the memory card. There will be a pause after you select 'YES' as the sampler writes the results to the card.

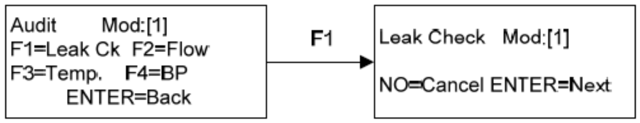


Press the "**ENTER**" key to return to the Audit Menu.

If the auditor wishes to return to the AUTO MODE, press the "**ENTER**" key twice. To continue with a leak check and flow rate verification.

10.4.4. Leak Check Verification

At the Audit Menu, press “**F1**” and “**ENTER**” keys to begin the *leak check* (see below).

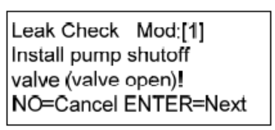


Remove the inlet cap from the top of the downtube, place the reducer on the downtube and install the flow audit adapter, make sure it’s in the open position, demonstrated here.



Press the “**ENTER**” key to continue with the leak check. The screen requests that the operator install the pump shutoff valve in the open position (see below).

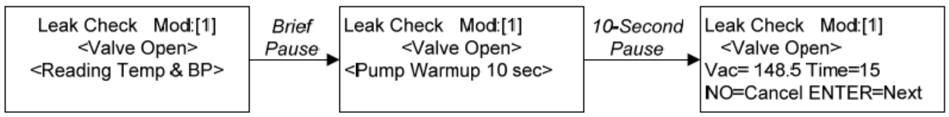
NOTE: Samplers produced post-2006 have the pump shut-off valve plumbed into the instrument, consequently this step is automatically performed for the operators.



Inspect and assure the pump shutoff valve is in the open position. Disconnect the vacuum line from the side of the pump enclosure. Connect the pump shutoff valve to the vacuum (air) line and reconnect to the side of the pump enclosure (see below).



Press the "**ENTER**" key to continue with the leak check. The software screen will now display that both valves are open, the pump is warming up, and a vacuum and time value, which will count down from 15 to 0 seconds (see below).



Press the "**ENTER**" key to continue to the next screen. This screen requests the operator to close the flow audit adapter at the top of the downtube (see below).

Rotate the lever on the flow audit adapter 90º to close the **flow audit adapter.** This will begin creating a vacuum in the downtube, through the sampler, to the pump.

Press the "**ENTER**" key to continue to the next screen. The vacuum will begin to increase and at a point near 680 mm Hg, the time will begin to count down from 15 to 0.

```
Leak Check   Mod:[1]
   <Valve Closed>
Vac=655  Time=15
NO=Cancel ENTER=Next
```

After countdown reaches zero, press the "**ENTER**" key and close the pump shutoff valve (see below).

```
Leak Check   Mod:[1]
        Close pump
       shutoff valve!
NO=Cancel ENTER=Next
```

Press the "**ENTER**" key, the pump will stop and the leak check will begin. The vacuum will begin to drop and when it reaches 380 mm Hg, a timer will count for a maximum of 35 seconds.

After the 35 second count, the leak check result will be displayed as either PASSED or FAILED. The acceptance criterion is a vacuum drop of less than 225 mmHg in 35 seconds. The timer will stop if the leak is large enough for the vacuum pressure to drop more than 225 mm Hg within 35 seconds (see below).

PASSED

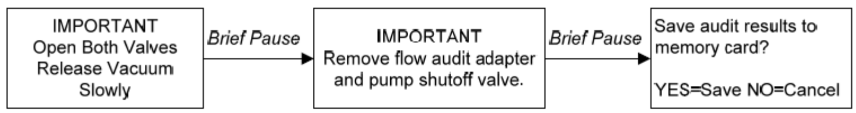
```
Leak Check   Mod:[1]
Max  Min  Diff  Time
380  250  130   35
PASSED    ENTER=Done
```

FAILED

```
Leak Check   Mod:[1]
Max  Min  Diff  Time
380  81   299   15
FAILED    ENTER=Done
```

Record the pressure drop in mmHg on the Carbon Speciation Network Performance Audit Worksheet. If the sampler fails the leak check, attempt another leak check. If the sampler fails both times notify the appropriate Particulate staff within APCD.

Press the "**ENTER**" key to advance to the next screen, shown here.



Slowly release the pressure in the sampler by slowly turning the lever on the flow audit adapter. **(*NOTE: Releasing the vacuum quickly may rupture the filter or pop it loose from the cassette.)*** The next screen (see above) will request the operator to remove the flow audit adapter and pump shutoff valve, reconnect the vacuum line. If the operator is going to perform a flow rate verification, the reducer can remain in place.

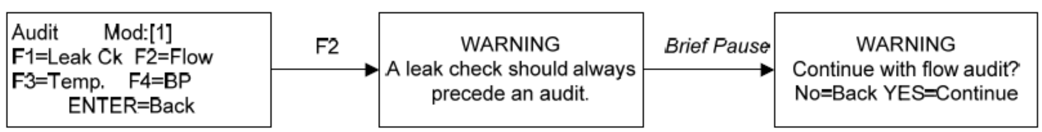
Press the "**YES**" key to save the audit results to the memory card and press "**ENTER**" to return to the Audit Menu.

If the operator wishes to return to the AUTO MODE, press the "**ENTER**" key twice. To continue with a flow rate verification, see below.

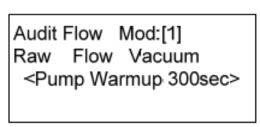
10.4.5. Flow Rate Verification

Prior to conducting a flow rate verification, a successful leak check must be completed (see previous). The operator should use the flow transfer standard provided by APCD, equilibrated to ambient conditions. The flow rate verification should be conducted with the "AUDIT" cartridge in place.

At the Audit Menu, press the "**F2**" key to proceed to the flow rate verification (audit) screen and select "**YES**" to continue with the flow verification.



Check the connections to the flow transfer standard, and press the "**ENTER**" key to continue. The pump will turn on after a brief pause and the following screen appears:



The MFC will run for 5 minutes (300 seconds) at the samplers design flow rate of 22.0 L/min. At the end of the 5-minute warm up period, the screen below will appear showing the sampler's flow rate and vacuum at that time.

NOTE: At this point it may not be necessary to accommodate the entire 300 seconds of pump warm-up. If the operator wishes to proceed without the entire 300 seconds simply press "ENTER" at any point during the Pump Warmup.

Press the "**ENTER**" key to continue to the next screen. In the screen below, the operator is prompted to enter the reference standard's flow rate in L/min. Use the keypad to enter the reference standard's flow rate value. The decimal place is fixed at two decimal places, so for a flow rate of 21.95 L/min., enter “**2195**”.

```
Audit Flow   Mod:[1]
Raw    Flow   Vacuum
3052   21.95  147.9
Ref. Flow(LPM):?
```

The APCD uses the following equation to calculate flow rates measured with an FTS:

$$Q = m * \sqrt{\Delta H2O * (Ta + 273.15)/(\frac{Pa}{760})} + b$$

Where:
Q = flow, L/min
m = FTS slope, printed on side of flow transfer standard
b = FTS intercept, printed on side of flow transfer standard
Ta = current ambient temperature, Celsius
Pa = current ambient pressure, mmHg
ΔH_2O = manometer pressure drop, inches of H_2O.

After entering the calculated flow transfer standard flow rate, the screen below appears showing the sampler’s flow rate, the reference standard’s flow rate, and the difference (sampler – reference standard) between the two values (all in L/min).

Record the sampler and reference standard values in L/min on the Carbon Speciation Network Performance Audit Worksheet. The calculated flow should be 22.0 ± 2 L/min (i.e. from 24 to 20). If the flow rate falls outside of this range notify the appropriate particulate staff within the APCD.

Press the “**ENTER**” key to proceed to the next screen, select “**YES**” to save the audit results to the memory card, press “**ENTER**” to return to the Audit Menu, shown here.

```
Samp.  Ref.   Diff.
21.95  22.00  -0.05

ENTER=Next
```

```
Save audit results to
memory card?

YES=Save   NO=Cancel
```

```
Audit results saved to
memory card.

ENTER=Next
```

Note the pump will not shutdown until all the reference flow rates have been recorded.

Return the sampler to the AUTO MODE by pressing “ENTER”. The verification is now complete and the operator must make sure the sampler is back in the correct configuration. Remove the transfer standard and reducer from the downtube and reinstall the inlet cap. Make sure to remove the audit cartridge and install the proper sampling cartridge. Verify that the configuration of the next scheduled sampling event is correct.

10.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. The APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The auditor should keep a hand written copy of the audit findings for archival and storage just in case the electronic copy is lost or damaged. An Excel spreadsheet is used to tabulate and store CSN and SASS audits by APCD. The electronic copy of the Excel spreadsheet should have the handwritten data entered into it and stored for archival and submittal to AQS by the APCD QA staff. The electronic copies of the audit spreadsheet (**Figure 11.1**) should be stored on the APCD LAN at J:/QA Audit Programs/CSN SASS audits.

Figure 11.1: Carbon Speciation Network Performance Audit Worksheet - URG 3000N

Chemical Speciation Network Performance Audit Worksheet URG 3000N - Primary Sampler		**Colorado Department of Public Health and Env**	
Note - Cyan fields are entered from TSA worksheet or calculated - yellow fields are to be filled in here			
Location	Denver Municipal Animal Shelter	Date	8/14/2012
AQS Site ID	80310025		
AQS Sampler POC	5		
Audit Information			
Auditor(s)	Clyde W. Sharp	Affiliation	Colorado Department of Public H
Audit Type	PQAO		
Sampler Model	URG 3000 N	Controller S/N	3N B0211
		Pump S/N	3N B0165
		Sampler S/N	3N B0209
Last Calibration Date			
Audit Reference Standards			
Flow Reference Std Model	OTHER FLOW STANDARDS	Standard S/N	MJ387
Specify if "Other"	InFlow	Calibration Date	3/27/2012
Temperature Ref Std Mode	NIST TRACEABLE THERMOMETER	Standard S/N	341803
Specify if "Other"		Calibration Date	Jan-12
BP Std Model	Select From Dropdown List	Standard S/N	27263
Specify if "Other"	Pretel Digi Barometer	Calibration Date	Jan-12
Significant Findings:	Notified operator of clock failure. Site is being moved from DMAS to La Casa next week. The operator		
General Findings:			

URG 3000N - Primary Sampler

Clock Audit

If Local Time is under daylight savings, convert Ref Std to Local Standard Time. Daylight Saving Time begins for most of the United States at 2:00 a.m. on the first Sunday of April. Time reverts to standard time at 2:00 a.m. on the last Sunday of Octobe

	Time (hh:mm)				Difference	5 minutes or less?	
	Ref Std		URG		Minutes	Pass	Fail
Audit Time	03:23		03:15		-8.0		X
Date	8/14/2012		8/14/2012				
Recalib Time							
Date	8/14/2012						

Leak Test

	Initial Audit A mm Hg		After Correction B mm Hg	225 mm Hg drop or higher fails: Pass	Fail A	Fail B
Channel 1	96	Channel 1		X		

Flow Audit

For the reference standard, enter "UR" for under range and "OR" for over range flow readings.

	L/min					Less than 10%?	
	Lower Limit	Ref Std	Upper Limit	URG	% Difference	Pass	Fail
Channel 1	20.439	22.7	24.981	21.9	-3.6	X	

Retest after Calibration

	L/min					Less than 10%?	
	Lower Limit	Ref Std	Upper Limit	URG	% Difference	Pass	Fail
Channel 1	NA		NA				

Reference Standard vs Design Flow

	L/min					Less than 10%?	
	Lower Limit	URG	Upper Limit	Ref Std	% Difference	Pass	Fail
Channel 1	19.8	22.0	24.2	22.7	3.227272727	X	

Retest after Calibration

	L/min					Less than 10%?	
	Lower Limit	URG	Upper Limit	Ref Std	% Difference	Pass	Fail
Channel 1	19.8	22.0	24.2				

Ambient Temperature Audit

Degrees C					Less than 2 degrees?	
Lower Limit	Ref Std	Upper Limit	URG	Difference	Pass	Fail
33	35.0	37	34.2	-0.8	X	
Retest After Recalibration						
NA		NA				

Pressure Audit

mm Hg					Less than 10 mm Hg?	
Lower Limit	Ref Std	Upper Limit	URG	Difference	Pass	Fail
626	628	630	628	0	X	
Retest after recalibration						
NA		NA				

10.5.1. Continuous Particulate Sampler (TEOM) Audit Procedure

10.6. Introduction

The Series 1400a Monitor incorporates the patented Tapered Element Oscillating Microbalance (TEOM) technology developed by Rupprecht & Patashnick Co., Inc. to measure particulate matter mass concentrations continuously. These monitors are now sold and developed by Thermo Electron Corporation. The TEOM's set up by the APCD to continuously monitor $PM_{2.5}$ have been configured with a standard PM_{10} sample inlet and a Sharp Cut Cyclone to establish the appropriate cut points. The APCD have deployed some TEOM's that monitor PM_{10} by simply removing the Sharp Cut Cyclone. The microprocessor-based unit accommodates all siting requirements and provides internal data storage and analog and serial data input/output capabilities. Filter-based, direct mass measurements are considered the standard technique for determining particulate matter mass concentration.

10.7. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between these two values during audits. The audit procedures described in this section outline the steps for implementing a performance audit for the Rupprecht and Patashnick Series 1400 TEOM monitor operated by the APCD. The primary objective of an auditing program is to identify system errors that may result in suspect or invalid data. Parameters evaluated include: time, leak rate, ambient temperature, ambient pressure, total flow, main flow, and mass verification (K_o).

For State and Local Air Monitoring Stations (SLAMS), audits shall be conducted on at least 25 percent of the operational samplers in the PM_{10} and $PM_{2.5}$ monitoring networks each quarter such that each sampler is audited at least once a year. If there are fewer than four TEOM monitors in the $PM_{2.5}$ or PM_{10} network, re-audit one or more randomly so that one is audited each calendar quarter. Mass verifications audits are performed once per calendar year on the entire network. APCD's goal is to perform an audit on every TEOM in its monitoring network on a quarterly basis.

An audit is performed by challenging each parameter against a known NIST traceable standard. The instrument's main and total flow rates are challenged with a calibrated volumetric flow transfer standard. The actual instrument flow rate (3 L/min) and total flow rate (16.67 L/min) are measured with the transfer standard and reported for accuracy. The instrument clock is checked to verify it is within ±15 minutes of Standard Time. The temperature sensor is challenged with a NIST traceable thermometer to verify it is within ±2 °C. The pressure sensor is challenged with a NIST traceable barometer to verify it is within ±10 mmHg of the audit measurement.

The APCD utilizes an Access Database to enter and process audit results. To access the database the auditor must open the "QA Audits" access database. A copy (satellite version) of the master database is typically stored on the auditors' field laptop. The master database is stored on APCD's network J:\QA

Audit Programs\P&A Database\QA Audits Database\Laptop Version.mdb. Once the database is opened, the auditor can click the button titled "Enter new Audit" from the main menu of the database. A printout of the PM (Lo-Vol/Continuous) Audit datasheet is used as the Field Audit Datasheet in which raw data is hand entered (**Figure 12.1**). Data from the Audit datasheet is then input into the QA Audits Access Database. The Audit Datasheets are archived in the event the electronic copy is lost or damaged. After all the audit data is entered into the form, it is transferred into an archive by pressing <Save To Arhcive>.

10.8. Audit Equipment Checklist

The equipment listed below is required to perform an audit on TEOM samplers:

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- Certified NIST-traceable flow transfer standard.
- Certified time piece.
- Leak check audit adapter.
- Audit filters.
- PM (Lo-Vol/Continuous) Datasheet (**Figure 12.1**).
- Pre Weighed Audit TEOM Filters (if K_o constant is being calculated).
- Personal Laptop for data entry and audit verification.

10.9. TEOM Audit Procedure

10.9.1. Collect Analyzer Information and Disable Data logger

Upon initiation of the audit, perform the following steps:

1. Place the reference thermometer in close proximity to the analyzers ambient temperature sensor. Make sure both sensors are in a shaded environment and the probes are not in contact with any surrounding materials. Turn on the reference thermometer and allow the thermometer to stabilize prior to performing the temperature audit.

2. Place the reference barometer in close proximity to the analyzers ambient barometric sensor. Make sure both sensors are in a shaded environment. Turn on the reference barometer and allow at least 5 minutes for the barometer to stabilize prior to performing the barometric pressure audit.

3. Place the flow transfer standard (FTS) near the analyzer and allow the device to equilibrate to ambient conditions.

4. Record on the Audit Datasheet all requested site and time/date information.

5. Record on the Audit Datasheet all requested information from the Main screen.

6. Record on the Audit Datasheet all requested information from the Set Temps/Flows screen.

7. Record on the Audit Datasheet all requested information from the Set Hardware screen.

8. If the site has computer access, the following procedures are applicable before continuing with audit. These procedures are necessary to disable/flag data logger communications, and also to ensure logger data output is comparable to the analyzer display.

   Enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field:

   - The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
     xi. Logger ID # is usually written on the upper left corner of the monitor in two digit form. If not, hit "ESC ESC . . AQM" and logger ID number should appear on screen. Hit "Escape" key twice
     xii. Input "logger ID" + "AQM"
     xiii. Password for the ESC Systems is "GO VOLS"

   - The second type of logger system is the Agilaire. This is a windows based system and the password to log into this system is "Agilaire".

9. Before an audit can be performed, the TEOM channels must be disabled on the data logger so that all data collected during the time the audit was performed is flagged as invalid. To disable the TEOM channels for each type of data logging system, follow the procedures listed below:
   - ECS System:
     i. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter", or by typing the letter associated with the command and hitting enter.
     ii. From this menu select "Configure Data Channels".
     iii. Next go into "Disable/Mark Channel Offline". To put channels back online at the end of the audit, choose "Enable/Mark Channel Online"

iv. From here you will see a list of enabled reporting channels. Highlight the desired channel and press "enter". This process will take the channels offline so the audit data is not reported as ambient concentrations.

v. Repeat task iii and iv as necessary to flag all affected channels as offline.

- Agilaire System:
  i. From the Home page of the **AV-Trend**, go to the " Utilities" drop down menu and choose "Site Node Logger Toolbox".
  ii. You will find a list of all the channels at the station. All channels which are active should be "False". To mark the channel as offline, under the "Disable Flag"column, click "False" for the PM fine, PM10 ltp, PM10 stp and PM course channels, and it should change to "True" which indicates that it is now offline.

  Note: Make sure to put all parameters back online after all auditing activities are complete.

10.9.2. Accuracy Leak Check

Perform the following steps for the Leak Check audit:

1. Remove the TEOM filter from the mass transducer and store it in the sensor unit on one of the provided tabs for later replacement.
   Note: if the sample filter is not removed from the TEOM sensor before a leak check, damage to the filter can occur. It is also important to be very careful when a TEOM filter is removed from the sensor unit. Be advised that damage to the sensor unit will occur if the TEOM filter is not pulled straight up off the glass post on which it is installed for sampling measurement.

2. From the Main screen, press (<↑>) and (<↓>) to scroll up and down through the parameters. Scroll to display the main flow and auxiliary flow values.

3. Remove the sample inlet from the flow splitter and replace it with the flow audit adapter equipped with a vacuum gauge.

4. Close the valve on the flow audit adapter and also close the auxiliary flow line valve.

5. From the Main screen, the main flow reading should read less than 0.15 L/min and the auxiliary flow reading should read less than 0.60 L/min. If the main flow reading is less than 0.15 L/min and the auxiliary flow reading is less than 0.60 L/min, continue to step 8. If the main flow reading is greater than 0.15 L/min and/or the

auxiliary flow reading is greater than 0. 60 L/min, check the hose fittings and other critical connections in the flow system for leaks. While the flow audit adapter is closed note the vacuum gauge reading. If it is less than 16in Hg then the pump most likely needs to be replaced.

6. After checking the hose fittings and other critical connections in the flow system for leaks, repeat the leak check, then check the main flow reading and the auxiliary flow reading from the Main screen. If the readings continue to exceed 0.15 L/min for the main flow and 0.60 L/min for the auxiliary flow, the leak check procedure must be repeated using an offset value to account for the characteristic non-linearity of the mass flow sensor for flow values near 0 L/min. To determine the non-linearity offset value (NOV), perform the following steps:

    i. **Slowly** open the valve on the flow audit adapter to release the vacuum.
    ii. Disconnect or unplug the power to the pump.
    iii. Wait 1 minute and observe the main flow and auxiliary flow readings. These are the NOVs (or zero's) for both the main flow and auxiliary flow; note these values.
    iv. Plug in or reconnect the vacuum pump, and wait 3-5 minutes to allow the main flow and auxiliary flow to stabilize.
    v. When both flow rates have stabilized, close the valve on the flow audit adapter. From in the Main screen, the main flow reading should read less than 0.15 L/min ***plus the main flow NOV***, and the auxiliary flow reading should read less than 0.60 L/min ***plus the auxiliary flow NOV***. For example, if the NOV for the main flow was recorded as 0.08 L/min, add 0.08 to 0.15 for a total of 0.23 (0.08 + 0.15 = 0.23). The main flow should be less than 0.23 L/min taking the NOV into consideration. Follow the same procedure for the auxiliary flow.

    Note: when entering leak check values into the FRM computer spreadsheet, leak values for the main and auxiliary are set. So SUBTRACT the NOV values from the observed leak check values to determine if the leak check passes (e.g.<0.15 L/min for the Main flow and <0.60 L/min for the auxiliary flow.

7. If the flow readings continue to exceed these calculated values (the NOVs plus 0.15 L/min for the main flow and 0.60 L/min for the auxiliary flow), Notify the appropriate APCD particulate personnel of findings and troubleshooting performed as soon as possible. If the flow readings do not exceed these calculated values, continue on with the following steps.

8. **Slowly** open the valve located on the flow audit adapter to gradually release the vacuum in the system.

9. Remove the flow audit adapter from the flow splitter.

10. Install the sample inlet onto the Sharp Cut Cyclone (if appropriate).

11. Replace the TEOM filter in the mass transducer.
Note: Please be very careful when reinstalling the TEOM sample filter. It is relatively easy to damage the sensor unit by not pressing the filter straight down onto the glass sensor tube. If the auditor does not push straight down and instead pushes the filter at an angle the glass tube where the sample filter is installed can be broken. After the sample filter is reinstalled and the flows and sensor unit has stabilized verify the noise in the sensor unit has stabilized to three digits before finishing the audit if the noise has not stabilized the TEOM filter is most likely not seated properly in the sensor unit.

12. Close the mass transducer and the sensor unit door.

13. Note the results on the Audit Datasheet.

10.9.3. Accuracy Ambient Temperature Audit

Compare the value for the ambient temperature displayed on the Main Screen with the value given by a NIST traceable temperature standard. Follow the steps below to perform the ambient temperature audit:

1. From the Main Screen, press the <1> and <9> keys, and then press the <ENTER> key to display the Set Temps/Flows screen.

2. When in the set Temps/Flows screen, locate the current ambient temperature reading in the “Amb Temp” field.

3. Determine the current ambient temperature (°C) at the ambient temperature sensor using an external NIST traceable audit thermometer, [°C = 5/9 * (°F - 32)].

4. Verify that the value of the “Amb Temp” field is within ± 2°C of the measured temperature.

5. Record the results on the audit datasheet.

10.9.4. Accuracy Ambient Pressure Audit

Compare the value for the ambient pressure displayed on the Main Screen with the value given by a NIST traceable pressure standard. Follow the steps below to perform the ambient pressure audit:

1. From the Main Screen, press the <1> and <9> keys, and then press the <ENTER> key to display the Set Temps/Flows screen.

2. When in the set Temps/Flows screen, locate the current ambient pressure reading in the “Amb Pres” field.

3. Determine the current ambient pressure in mm Hg (absolute pressure, not corrected to sea level).

4. Verify the monitor’s ambient pressure by measuring the current ambient station pressure with an external measurement device.
   - To convert from Atmospheres to mm Hg, multiply by 760.
   - To convert from millibars to mm Hg, multiply by 0.75012.
   - To convert from inches Hg to mm Hg, multiply by 25.4.

5. Verify that the value of the “Amb Pres” field is within ±10 mm Hg of the measured ambient pressure.

6. Record the results on the audit datasheet.

10.9.5. Accuracy Flow Audit

Accurate measurement of particulate mass concentration is dependent upon flow rates under actual conditions; the audit must also be conducted in terms of actual conditions.

Follow the steps below to perform the flow audit:

1. Reset the Series 1400a monitor by pressing the <F1> or <Data Stop> keys on the front panel of the control unit. Please note that any data generated by the instrument during this audit procedure are invalid.

2. Remove the PM_{10} sample inlet and replace it with an Audit FTS. This flow meter should have been recently (within one year) calibrated to a primary standard and must be capable of measuring 3.0 L/min and 16.7 L/min to an accuracy of ±1%, and having a pressure drop of less than 0.07 bar (1 psi).

3. Scroll the Main Screen using (<↑>) and (<↓>) until the Main Flow and Auxiliary Flow appear on the four-line display. These represent the actual volumetric flows as measured by the monitor's flow controllers. Confirm that these flows are within ±2% of their set points (3.0 L/min for the Main Flow and 16.7 L/min for the Main Flow

plus Auxiliary Flow). Any greater deviation may indicate plugged in-line filters or other blockages in the system.

4. Read the total flow (nominally 16.7 L/min) on the audit flow meter. If a non-volumetric flow meter is being used, make any corrections necessary to translate this reading to volumetric L/min at the current ambient temperature and barometric pressure. The volumetric flow measured by the audit flow meter must be 16.7 Lpm ±10% for PM_{10}, ±5% for $PM_{2.5}$ design and ±4% for actual audit to be acceptable. Record the total flow rate audit results on the PM (Lo-Vol/Continuous) Audit Field Datasheet.

5. Disconnect the Bypass Flow Line where it connects to the Flow Splitter with the Swagelok quick connect or close off the flow with the in-line valve depending on the site specific configuration.

6. Read the main flow (nominally 3.0 L/min) on the audit flow meter. If a non-volumetric audit flow meter is being used, make any corrections necessary to translate this reading to volumetric L/min at the current ambient temperature and barometric pressure. The volumetric flow indicated by the audit flow meter must be 3.0 Lpm ±10% for PM_{10}, ±5% for $PM_{2.5}$ design and ±4% for actual audit to be acceptable. Record the main flow rate audit results on the Audit Datasheet.

7. If either the Main or Auxiliary Flow is outside acceptable limits, contact the appropriate APCD particulate personnel so that calibration procedures can be performed.

8. Replace the Bypass flow line or open the valve to return the monitor to its original, normal operating condition.

9. Remove the FTS. Replace the PM_{10} Inlet on the top of the Flow Splitter. Double check to make sure the instrument is returned to its normal operating configuration.

10. Insert the TEOM filter onto the mass transducer. Verify the frequency displayed at the bottom of the main screen on the TEOM control unit is stable to three significant digits and the instrument is in "Ok" mode before leaving the site.

11. Reset the Series 1400a monitor by pressing <F1> or <Run>. The instrument will automatically begin data collection after temperatures and flow rates have remained stable at their set points for one-half hour.

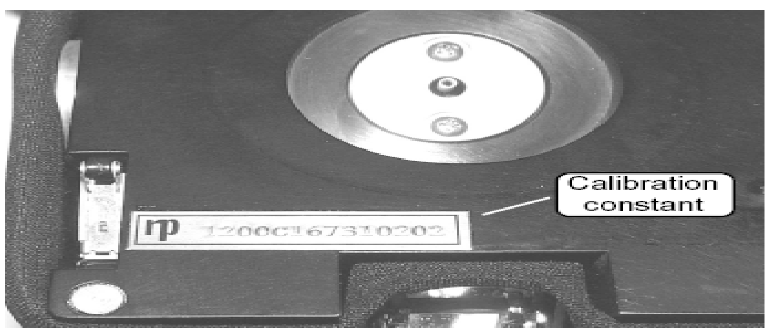
10.9.6. Accuracy Mass Transducer Verification

This procedure is performed annually on all APCD TEOMs. The calibration of the mass transducer in the Series 1400a monitor is determined by the mass transducer's physical mechanical properties. Under normal circumstances, the calibration does not change materially over the life of the instrument. Contact Thermo Electron Corp. (formerly R&P) if the results of the verification procedure indicate that the calibration constant has changed by more than 2.5% from the original R&P (now Thermo Electron Corp.) calibration constant. You can locate the original R&P (now Thermo Electron Corp.) calibration constant inside the mass transducer.

Follow the steps listed below to confirm the systems K_0 calibration:

1. When in the Main screen, press the <DATA STOP> key on the monitor's keypad.

2. Open the Mass Transducer and record the Calibration Constant (K_o). While the Mass Transducer is open, carefully remove the TEOM filter and store in safe protected place until it can be reinstalled, then close the Mass Transducer.



3. At the TEOM keypad press STEP SCREEN the "LISTING OF SCREENS" will appear, scroll down to "Set Hardware", press ENTER, the top line is "Cal Const>" (K_o).

4. Verify that the displayed K_o is the same as the K_o on the label in the Mass Transducer. If not, contact particulate group for resolution. If the same, proceed with the following steps.

5. Press the <STEP SCREEN> key. The Menu screen will display on the four-line display.

6. When in the Menu screen, press the up (<↑>) and down (<↓>) arrow keys to select "K_0 Confirmation."

7. Press the <ENTER> key. The "K_0 Confirmation" screen will display. You also can display the K_0 Confirmation screen by pressing <1>, <7> and then the <ENTER> key.

8. Press the <EDIT> key.

9. Press the up and down arrow keys to select the "Filt Wght" field.

10. Using the monitor's keypad, enter the weight of the pre-weighed calibration verification filter in the "Filt Wght" field in grams.

11. Press the <F1> or the <RUN> key to operate the system without a filter and wait for the oscillating frequency shown in the upper right-hand corner of the screen to reach a maximum, stable value. This can take up to 15 minutes for a stable value that is minimally oscillating.

12. When the frequency stabilizes, press the <FIRST/LAST> key to record the frequency, (f_0). Record the frequency reading on the PM (Lo-Vol/Continuous) Audit Field Datasheet.

13. Install the pre-weighed calibration filter on the mass transducer in the instrument and wait for the frequency to stabilize again (maximum value with minimal oscillation is reached).

14. When the frequency stabilizes, press the <FIRST/LAST> key to record the frequency (f_1). Record the frequency reading on the PM (Lo-Vol/Continuous) Audit Field Datasheet. The instrument will now automatically compute and display the audit value of the calibration constant (K_0) in the "Audit K_0" field.

15. Remove the calibration filter and reinstall the TEOM filter onto the mass transducer and verify the filter is seated properly by making sure the frequency reading at the bottom of the main screen on the TEOM control unit has stabilized down to three significant digits.

16. Reset the Series 1400a monitor by pressing <Data Stop> and then press <Run>. The instrument will automatically begin data collection after temperatures and flow rates have remained stable at their set points for one-half hour.

10.9.7. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the station is left in the condition it was found and or better. The following is a checklist of items to be completed before exit:

1. Ensure all audit equipment is removed from the analyzer.

2. Verify that all components of the analyzer are properly reconnected.

3. If applicable, enable data logger communications (refer to section 2.4.1 #9). Read the data logger time. Record the time the instrument was disabled and enabled on the station analyzer log and on the PM (Lo-Vol/Continuous) Audit Field Datasheet.

4. Remove all equipment from site and double check site for any irregularities.

10.10. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The Technical Services Program maintains an Access Database on the Air Pollution Control Division (ACPD) Local Access Network (LAN). This program records the results of all particulate accuracy audits conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the accuracy data before they are submitted to AQS. A detailed description of the accuracy data processing procedures is located in Appendix D4 in the main body of the APCD QAPP.

Within 90 days of the end of a calendar quarter, all particulate accuracy data are downloaded to an ASCII-format data file and then uploaded into the AQS database. These data processing operations are performed by Quality Assurance Unit staff.

Figure 12.1: PM (Lo-Vol/Continuous) Audit Form

Lo-Vol / Continuous PM Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080013001				
Site Name	WELBY				
Method	INSTRUMENTAL-R&P SA246B-INLET - TEOM-GRAVIMETRIC				
Parameter	81102	POC	3	Method Code	79
Auditor	Sharp, Clyde	Audit Date	12/3/2019	Audit Time	9:21
Serial #					
FTS	IA179H				
Cal. Date	1/22/2019	Slope	0.2174	Intercept	0.1341

	Ambient Pressure			Ambient Temperature		
	(mm Hg)	(atm)	(inches Hg)	(Farenheit)	(Celsius)	(Kelvin)
Audit Standard		0.8342	25		10.9	284.1
Sampler		0.8290	25		10.0	283.2

Leack Check Verification ☑ *Upload to AQS?* ☑

Flow Rate Verification							
Assessment Number	Audit Set Point (lpm)	Sampler Flow (lpm)	Audit Flow (lpm)	Delta H2O	Temp. (C)	Audit Rel. Error (%)	Design Rel. Error (%)
1	16.70	16.65	16.93	17.520	10.9	-1.6%	-1.3%

Audit Results

Pressure		Temperature		Audit Flow		Design Flow	
-0.005	PASS	-0.9	PASS	-1.6%	PASS	-1.3%	PASS
+/- 0.013 atm		*+/- 2 degrees C*		*+/- 4%*		*+/- 5%*	

Comments
Audit flow for Main was read at 2.95 LPM. Leak check was passing range.

11. Grimm EDM 146

11.1. Introduction

The GRIMM EDM 180 was developed by GRIMM AEROSOL Technik GmbH & Co. to measure particulate matter mass concentrations continuously and report PM_{10}, $PM_{2.5}$, and (where appropriate) PM_1. There are not cut points to maintain with the GRIMM, it counts particles in 31 different size bins, converts the counts to mass and utilizes controlled flow to report mass concentration in units of $\mu g/m^3$. The microprocessor-based unit accommodates all siting requirements and provides internal data storage and analog and serial data input/output capabilities. In March 2011 the United States Environmental Protection Agency (U.S. EPA) designated the GRIMM EDM 180 Monitors as an equivalent method for the determination of $PM_{2.5}$ concentrations in ambient air. The GRIMM EDM180 draws the sample through a stainless steel downtube (d_i=3mm) into the detection chamber. The particulate matter in the sample stream are classified by size and counted inside the detection chamber through scattering light measurement.

A laser collimator generates a homogeneous optical field; a light trap is used to assure low noise due to scattered light. An inlet on the sample chamber focus' particles into this optical field. Every particle scatters light; when the particulate-laden sample air is pulled through the sample chamber the scattered light is sent via a mirror to a detector where the light intensity is measured. The particle size is proportional to the intensity of the reflected light beam. The count rate is determined from the particle count and the volumetric flow rate. Having known particle diameters and an assumed density(s) the particle mass can be calculated from the particle count, the method assumes the particles are spherical. The intensity of the scattered light can be influenced by the particle shape and its refractive index. However, this influence is very small at typical atmospheric concentrations.

11.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between these two values during audits. The audit procedures described in this section outline the steps for implementing a performance audit for the GRIMM EDM180 monitor operated by the APCD. The primary objective of an auditing program is to identify system errors that may result in suspect or invalid data.

An audit is performed by challenging each parameter against a known NIST traceable standard. The GRIMM's flow rate is challenged with a calibrated volumetric Flow Transfer Standard (FTS). The actual instrument flow rate (1.20 L/min) is measured with the FTS and must fall within the acceptable range of 1.08 L/min to 1.32 L/min (or +/- 10% of 1.20 L/min). However, any flow greater than 1.26 L/min or less than 1.14 L/min is considered in the warning range, and the particulate group should be notified of the findings as soon as possible. The clock on the site data logger is checked to verify it is within ±15 minutes of Standard Time. The temperature sensor is challenged with a NIST traceable thermometer to verify it is within ±2 °C. The pressure sensor is challenged with a NIST traceable barometer to verify it is within ±10 mmHg of the audit measurement.

11.3. Audit Equipment Checklist

There are two (2) methods by which the GRIMM audit can be performed. Both methods will be covered in this procedure beginning with the method recommended by the vendor.

A) The equipment listed below is required to perform an audit on GRIMM samplers using the GRIMM EDM 186 Test Kit:

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- Certified NIST-traceable flow transfer standard (FTS).
- Certified NIST-traceable Digital Manometer.
- Certified time piece.
- Leak check audit adapter.
- 1.25" OD downtube.
- GRIMM EDM 186 leak check/flow verification kit.
- GRIMM audit field data form.
- Personal Laptop for data entry and audit verification.
- Tools, parts, and tubing.

B) The equipment listed below is required to perform an audit on GRIMM samplers using the CDPHE APCD designed Certified NIST-traceable flow transfer standard (FTS):

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- CDPHE APCD designed certified NIST FTS.
- Certified NIST-traceable Digital Manometer.
- Certified time piece.
- 0-test filter.
- Silicone Stuff.
- GRIMM audit field data form.
- Personal Laptop for data entry and audit verification.
- Tools, parts, and tubing.

11.4. GRIMM Audit Procedure

11.4.1. Pre-Audit

Upon initiation of the audit, perform the following steps:

1. Place the reference thermometer in close proximity (inside the thermometer radiation shield is ideal) to the analyzers ambient temperature sensor. Make sure both sensors are in a shaded environment and the probes are not in contact with any surrounding materials. Turn on the reference thermometer and allow for the thermometer to stabilize prior to performing the temperature audit.

2. Place the reference barometer in close proximity to the analyzers ambient barometric sensor. Make sure both sensors are in a shaded environment. Turn on the reference barometer and allow for the barometer to stabilize prior to performing the barometric pressure audit.

3. Place the FTS near the analyzer and allow the device to equilibrate to ambient conditions.

4. Record on the Grimm Audit field Datasheet all requested site and time/date information.

5. If applicable, enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field:

   - The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
     i. Logger ID # is usually written on the upper left corner of the monitor in two digit form. If not, hit "ESC ESC . . AQM" and logger ID number should appear on screen. Hit "Escape" key twice, then input "logger ID" + "AQM"
   - The password for the ESC System is "GO VOLS"

6. Before an audit can be performed, the GRIMM channels must be disabled on the data logger so that all data collected during the time the audit was performed is flagged as invalid. To disable the GRIMM channels for each type of data logging system, follow the procedures listed below:

   - ESC System:
     i. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter".
     ii. From this menu select "Configure Data Channels".
     iii. Next go into "Disable/Mark Channel Offline".

iv. From here you will see a list of enabled reporting channels. Highlight the desired channel and press "enter". This process will take the channels offline so the audit data is not reported as ambient concentrations. To put channels back online, choose "Enable/Mark Channel Online" and highlight the channels you would like to put online, and then press enter.

v. Repeat task iii and iv as necessary to flag all affected channels as offline.

- Agilaire System:

    i. From the Home page of the **AV-Trend**, go to the " Utilities" drop down menu and choose "Site Node Logger Toolbox"

    You will find a list of all the channels at the station. All channels which are active should be "False". To mark the channel as offline, click "False" under the "Disable Flag"column for the PM fine, PM10 ltp, PM10 stp and PM course channels, and it should change to "True" which indicates that it is now offline.

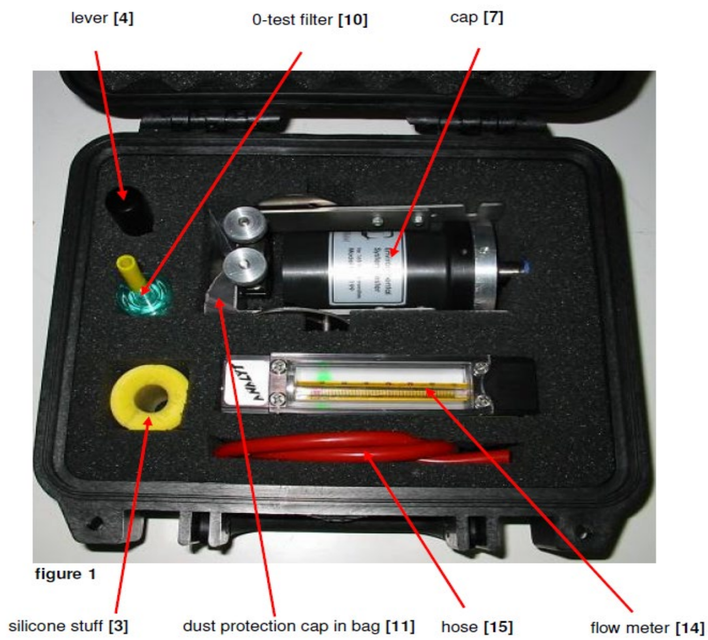
7. Record the analyzers current time on the station analyzer log and on the GRIMM Field Form. Compare the current audit time to the analyzer time. The analyzer time must not deviate by more than 20 minutes from the official audit time.

8. Record the analyzers current date on the station analyzer log and on the Audit Verification Form. Compare the current audit date to the analyzer date. The analyzer date must not deviate from the official audit date.

11.4.2. Zero/leak Check

A) Perform the following steps for the Zero/Leak Check audit using the GRIMM EDM 186 leak check/flow verification kit pictured below (**Figure 13.1**):

Figure 13.1 - GRIMM EDM 186 EDM Test Kit

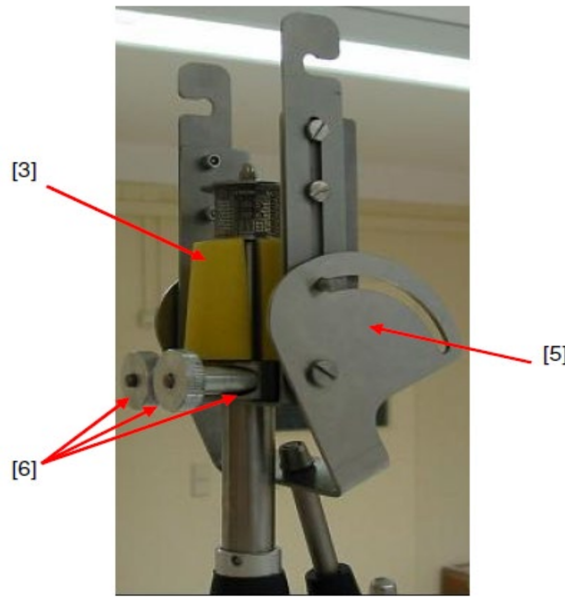


1. Place the silicone stuff around the pipe directly under the sample head with the smaller diameter towards the sample inlet.

2. Mount the lifting device directly below the silicone stuff (**Figure 13.2)**.

Figure 13.2 – Lifting Device Installation

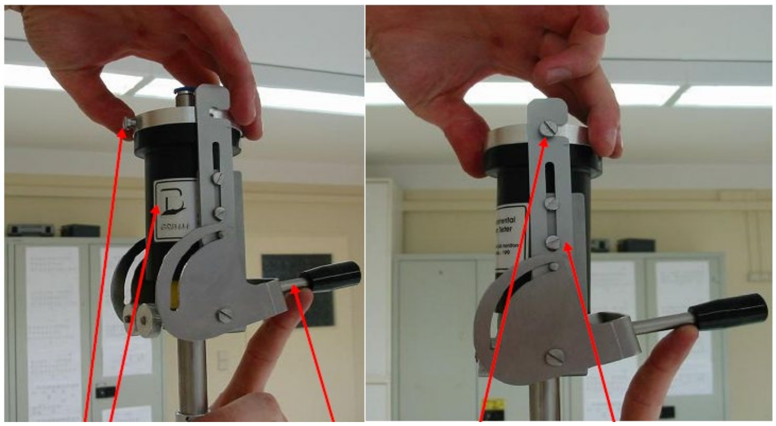
mount lifting device **[5]** with clip and nuts **[6]** under silicone stuff **[3]** at sample pipe



3. Place lever in the upward end position.

4. With the instrument running, place the cap around the sampler down tube and rotate until screws slide into lifting device (**Figure 13.3**).

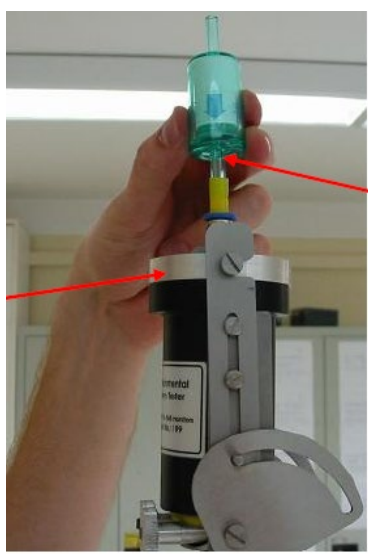
Figure 13.3 – Cap Installation



5. Now place lever in the downward end position ensuring a good seal around down tube.

6. Connect the 0-test filter with hose to the sample inlet of the cap. The arrow on the 0-test filter should point in the direction of flow (**Figure 13.4**).

Figure 13.4 – Test Filter Installation



7. After 1 minute, observe the instrument display. A particulate value of 0µg/m^3 should be observed for both PM_{10} and $PM_{2.5}$ if there are no leaks in the system.

B) Perform the following steps for the Zero/Leak Check procedure using the APCD designed Certified NIST-traceable FTS (**Figure 13.5**).

Figure 13.5 – APCD designed FTS Kit

1. Place the silicone stuff around the pipe directly under the sample head with the smaller diameter towards the sample inlet.

2. Mount the FTS over the stuff making sure to obtain a good seal. Ensure stuff does not slide down the inlet shaft by placing hand around inlet pipe directly under stuff. Rotate FTS slightly back and forth to ensure a proper seal on the stuff (**Figure 13.6**).

Figure 13.6 – FTS Installation over Stuff

3. Connect the 0-test filter with small piece of silicon tubing to the top port of the FTS with the arrow on the 0-test filter pointing in the direction of flow. Connect the digital monometer with Teflon tubing to the side port of the FTS to prevent leakage during zero/leak check (**Figure 13.7**).

Figure 13.7 – Setup for Zero / Leak Check

4. After 1 minute, observe the instrument display. A particulate value of 0µg/m^3 should be observed for both PM_{10} and $PM_{2.5}$ if there are no leaks in the system. Allow the instrument to stabilize with a concentration of 0µg/m^3 for about 5 minutes so the data logger records these values for both channels.

11.4.3. Ambient Temperature Verification

Follow the steps below to perform the ambient temperature audit for both audit procedures:

1. The instrument's ambient temperature can usually be viewed on the data logger. If this isn't the case then on the front panel press the **Temp./r.H.** key, the temperature reading is displayed in ºC.

2. Determine the current temperature (°C) at the ambient temperature sensor using an external thermometer, [°C = 5/9 x (°F - 32)].

3. Verify that the reported value of the current ambient temperature is within ± 2°C of the measured temperature. If this is not the case there may be a problem with the external temperature sensor, notify the appropriate APCD personnel.

4. Note the results on the Grimm audit data sheet.

11.4.4. Ambient Pressure Verification

Follow the steps below to perform the ambient pressure audit for both audit procedures:

1. The instrument's ambient pressure can usually be viewed on the data logger. If this isn't the case then on the front panel, while the instrument is running, press the '+' key to enable the cyclic display of the sensor values. Ambient pressure is displayed in hPa.

2. Determine the current ambient pressure in hPa.

3. Verify the monitor's ambient pressure by measuring the current ambient station pressure with an external measurement device.
   - To convert from hPa to atm divide by 1013.25.
   - To convert from hPa to mm Hg multiply by 0.75012.

4. Verify that the reported field value is within ±10 mm Hg or 0.013 atm of the measured ambient pressure. If this is not the case there may be a problem with the internal pressure sensor, notify the appropriate APCD personnel.

5. Note the results on the Grimm audit data sheet.

11.4.5. Flow Verification

A) Follow the steps below to perform the flow verification audit with use of the GRIMM EDM 186 leak check/flow verification kit (**Figure 13.8**) :

1. With the leak check verification kit still installed on the sampler inlet, place one end of the red tubing on the zero air filter making sure not to restrict the flow to the analyzer.

2. Connect the other end of the red hose to the flow audit adaptor. Make sure the valve is in the open position on the flow audit adapter.

3. Connect the 1.25" OD adapted downtube to the open end of the flow audit adapter.

4. Connect the FTS onto the open end of the adapted down tube.

5. Connect a monometer using the appropriate tubing to the flow transfer standard and record the monometer reading on the audit form (inH_2O). Calculate the flow reading with the following equation:

$$Q_{ltp} = m*((T_a/P_a)*\Delta H_2O)^{1/2} + b$$

Where;
Q_{ltp} = flow rate, actual conditions, liters per minute
m = FTS Slope
Ta = ambient temperature, degrees Kelvin
Pa = ambient pressure, atmospheres
ΔH_2O = manometer reading, inches water
b = FTS Intercept

6. The acceptable range for a successful flow verification is from 1.08 L/min to 1.32 L/min. However, any flow greater than 1.26 L/min or less than 1.14 L/min should be a possible reason to recalibrate the instrument.

7. Note the results on the Grimm audit data sheet.

B) Follow the steps below to perform the flow verification audit using the APCD designed Certified NIST-traceable FTS kit (**Figure 13.8**).

1. With the APCD designed Certified NIST-traceable FTS still installed on the sampler inlet, remove the 0-test filter from top port making sure not to restrict the flow to the analyzer.

2. With the digital monometer disconnected from the FTS tubing, ensure that the digital monometer is zeroed.

3. Connect a monometer using the appropriate tubing to the FTS side port and place your hand around the inlet shaft just below the stuff pushing slightly up on the stuff to help create a good seal and maintain headspace in the FTS (**Figure 13.8**). Record the monometer reading on the audit form (inH_2O). Calculate the flow reading with the following equation:

   $Q_{ltp} = m*((T_a/P_a)*\Delta H_2O)^{1/2} + b$

   Where;
   Q_{ltp} = flow rate, actual conditions, liters per minute
   m = FTS Slope
   Ta = ambient temperature, degrees Kelvin
   Pa = ambient pressure, atmospheres
   ΔH_2O = manometer reading, inches water
   b = FTS Intercept

4. The acceptable range for successful flow verification is from 1.08 L/min to 1.32 L/min. However, any flow greater than 1.26 L/min or less than 1.14 L/min should be reason to recalibrate the instrument.

5. Note the results on the Grimm audit data sheet.

Figure 13.8 – Flow Verification Setup for APCD Designed FTS

11.4.6. Completion of Audit

After the audit is complete and no adjustments or troubleshooting are required, it is VERY important that the station is left in the condition it was found. The following is a checklist of items to be completed before exit:

1. Remove all audit equipment from the analyzer.
2. Verify that all components of the analyzer are properly reconnected.
3. Double check analyzer display to ensure readings are reasonable and there are no error messages.

4. If unit was placed offline on the datalogger, it must be returned to on-line status.

11.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The Technical Services Program maintains an Access Database on the Air Pollution Control Division (ACPD) Local Access Network (LAN). The file path for this database can be found within the LAN at J:\QA Audit Programs\P&A Database\QA Audits Database.mdb. This program records the results of all particulate accuracy audits conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the accuracy data before they are submitted to AQS. A detailed description of the accuracy data processing procedures is located in Appendix D4 of this QAPP.

Within 90 days of the end of a calendar quarter, all particulate accuracy data are downloaded to an ASCII-format data file and then uploaded into the AQS database. These data processing operations are performed by Quality Assurance Unit staff.

Figure 13.9: Low Volume / Continuous Analyzer Audit Form

Lo-Vol / Continuous PM Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080310002				
Site Name	DENVER - CAMP				
Method	GRIMM EDM Model 180 with naphion dryer - Laser Light Scattering				
Parameter	88101	POC	3	Method Code	195
Auditor	Sharp, Clyde	Audit Date	5/23/2019	Audit Time	9:49
Serial #					
FTS	YL897				
Cal. Date	4/1/2019	Slope	0.0260	Intercept	0.0603

	Ambient Pressure			Ambient Temperature		
	(mm Hg)	(atm)	(inches Hg)	(Farenheit)	(Celsius)	(Kelvin)
Audit Standard		0.8299	25		7.2	280.4
Sampler		0.8232	25		7.7	280.9

Leack Check Verification ☑ *Upload to AQS?* ☑

Flow Rate Verification							
Assessment Number	Audit Set Point (lpm)	Sampler Flow (lpm)	Audit Flow (lpm)	Delta H2O	Temp. (C)	Audit Rel. Error (%)	Design Rel. Error (%)
1	1.20	1.20	1.25	6.200	6.8	-3.9%	-3.9%

Audit Results

Pressure		Temperature		Audit Flow		Design Flow	
-0.007	PASS	0.5	PASS	-3.9%	PASS	-3.9%	PASS
+/- 0.013 atm		*+/- 2 degrees C*		*+/- 4%*		*+/- 5%*	

Comments

passing grimm audit.

12.TAPI Model T640 PM Mass Monitor

12.1. Introduction

The Teledyne T640 PM Mass Monitor is an optical aerosol spectrometer that converts optical measurements to mass measurements by determining sampled particle size via scattered light at the single particle level, according to the Lorenz-Mie Theory. Light scattering in this regime occurs when the diameters of atmospheric particles are similar to the wavelengths of the scattered light. Dust, pollen, smoke and microscopic water droplets are common causes of Mie scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates in cloudy conditions. Mie scattering simply refers to the equations used to quantify the amount of light scattered.

The Inlet for the T640 allows complete transmission of all particle sizes. The air sample is drawn through the inlet at 5.0 LPM and is dried with the Aerosol Sample Conditioner (ASC). The sample is then moved into the optical particle sensor where scattered light intensity is measured to determine particle size diameter. The particles move separately through the analyzer via an optically differentiated measurement volume that is homogeneously illuminated with polychromatic light. The polychromatic light source, an LED, combined with a 90° scattered light detection achieves a precise and unambiguous calibration curve in the Mie range, resulting in a large size resolution. Each particle generates a scattered light impulse that is detected at an 85° to 95° angle where amplitude and signal length are measured; the amplitude (height) of the scattered light impulse is directly related to the particle size diameter. The T-aperture and simultaneous signal length measurements within the analyzer eliminate possible interference, which can be characterized by the partial illumination of particles at the border of the measurement range.

In July, 2016 the United States Environmental Protection Agency (U.S. EPA) designated the TAPI Model T640 Monitor as an equivalent method for the determination of $PM_{2.5}$ concentrations in ambient air.

12.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between these two values during audits. The audit procedures described in this section outline the steps for implementing a performance audit for the TAPI Model T640 PM mass monitor operated by the APCD. The primary objective of an auditing program is to identify system errors that may result in suspect or invalid data.

An audit is performed by challenging each parameter against a known NIST traceable standard. The T640's flow rate is challenged with a calibrated volumetric Flow Transfer Standard (FTS). The actual instrument flow rate (5.0 L/min) is measured with the FTS and must fall within the acceptable range of 5.5 L/min to 4.5 L/min (or +/- 10% of 5.0 L/min). However, any flow greater than 5.4 L/min or less than 4.6 L/min is considered in the warning range, and the particulate group should be notified of the findings as soon as possible. The instrument clock is checked to verify it is within +/-15 minutes of Standard

Time. The temperature sensor is challenged with a NIST traceable thermometer to verify it is within +/-2 °C. The pressure sensor is challenged with a NIST traceable barometer to verify it is within +/-10 mmHg of the audit measurement.

12.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on FEM samplers:

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- Certified NIST-traceable flow transfer standard (FTS).
- Certified NIST-traceable Manometer.
- T640 Flow Audit Adapter.
- T640 HEPA Filter for Zero Air Determination.
- Certified time piece.
- T640 Lo-Vol / Continuous PM Analyzer Datasheet.
- Personal Laptop for data entry and audit verification.

12.4. T640 Audit Procedure

12.4.1. Pre Audit

Upon initiation of the audit, perform the following steps:

1. Place the reference thermometer in close proximity to the analyzers ambient temperature sensor. Make sure both sensors are in a shaded environment and the probes are not in contact with any surrounding materials. Turn on the reference thermometer and allow for the thermometer to stabilize prior to performing the temperature audit.

2. Place the reference barometer in close proximity to the analyzers ambient barometric sensor. Make sure both sensors are in a shaded environment. Turn on the reference barometer and allow for the barometer to stabilize prior to performing the barometric pressure audit.

3. Place the FTS near the analyzer and allow the device to equilibrate to ambient conditions.

4. Record on the T640 Audit field Datasheet all requested site and time/date information.

5. If applicable, enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field:

- The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
  - ii. Logger ID # is usually written on the upper left corner of the monitor in two digit form. If not, hit "ESC ESC . . AQM" and logger ID number should appear on screen. Hit "Escape" key twice, then input "logger ID" + "AQM"
  - iii. The password for the ESC System is "GO VOLS"

- The second type of logger system is the Agilaire. This is a windows based system and the password to log into this system is "Agilaire".

6. Before an audit can be performed, the T640 PM fine, PM10 ltp, PM10 stp and PM course channels must be disabled on the data logger so that all data collected during the time the audit was performed is flagged as invalid. To disable the T640 channels for each type of data logging system, follow the procedures listed below:

- ESC System:
  - vi. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter".
  - vii. From this menu select "Configure Data Channels".
  - viii. Next go into "Disable/Mark Channel Offline".
  - ix. From here you will see a list of enabled reporting channels. Highlight the desired channel and press "enter". This process will take the channels offline so the audit data is not reported as ambient concentrations. To put channels back online, choose "Enable/Mark Channel Online" and highlight the channels you would like to put online, and then press enter.
  - x. Repeat task iii and iv as necessary to flag all affected channels as offline.

- Agilaire System:
  - ii. From the Home page of the **AV-Trend**, go to the " Utilities" drop down menu and choose "Site Node Logger Toolbox"

iii. You will find a list of all the channels at the station. All channels which are active should be “False”. To mark the channel as offline, click “False” under the “Disable Flag”column for PM fine, PM10 ltp, PM10 stp and PM course channels, and it should change to “True” which indicates that it is now offline.

7. Record the analyzers current time on the station analyzer log and on the T640 Field Form. Compare the current audit time to the analyzer time. The analyzer time must not deviate by more than 20 minutes from the official audit time.

8. Record the analyzers current date on the station analyzer log and on the Low Vol / Continuous Analyzer field form. Compare the current audit date to the analyzer date. The analyzer date must not deviate from the official audit date.

12.4.2. Leak Test / Zero Test

Never subject the T640 to a vacuum as would normally be the approach during a leak check on the low volume particulate samplers. Leak checking the T640 is accomplished by performing a Zero Test on the instrument as follows:

1. To enable a quicker zero response from the T640 analyzer during the Zero Test, change the setting on the analyzer as follows:
   - From the main screen tap “Setup”.
   - Then tap “Vars”.
   - The top option under Vars tap “Boxcar Filter Size”.
   - Tap “Edit” and change value from 60 to “1”.
   - Hit enter.

2. Remove the inlet by carefully rotating and pulling upward.

3. Install the flow audit adaptor fitted with a HEPA Filter.

4. Within a few minutes, the PM values should be recording zero on the display of the T640.

5. If the PM values are not reading zero, then there may be a leak in the system above the optical sensor (i.e. from the optical sensor nozzle up to where the HEPA filter is fitted. It is also possible that the HEPA filter being used is either bad or leaking. Always have a spare HEPA filter handy to check.

6. If the PM values are reading a steady zero, then there is not a leak above the optical sensor.

7. Note the results on the site verification form and on the Low Vol / Continuous Analyzer field form.

8. Make sure to change the “Boxcar Filter Size” setting back to “60” by following the procedure above.

12.4.3. Ambient Temperature Verification

Follow the steps below to perform the ambient temperature audit for both audit procedures:

1. The instrument’s ambient temperature can usually be viewed on the data logger. If this isn’t the case then on the front panel press the **Temp./r.H.** key, the temperature reading is displayed in ^{o}C.

2. Determine the current temperature (°C) at the ambient temperature sensor using an external thermometer, [°C = 5/9 x (°F - 32)].

3. Verify that the reported value of the current ambient temperature is within ± 2°C of the measured temperature. If this is not the case there may be a problem with the external temperature sensor, notify the appropriate APCD personnel.

4. Note the results on the Site Verification form and the T640 audit data sheet.
   Note: The ambient temperature sensor on the T640 does not have the capability to be calibrated. If there is a notable temperature difference, the operator must be notified so the sensor can be replaced or calibrated.

12.4.4. Ambient Pressure Verification

Follow the steps below to perform the ambient pressure audit for the T640:

1. Note the instrument’s ambient pressure displayed on the front panel.

2. Determine the current ambient pressure in mmHg.

3. Verify the monitor’s ambient pressure by measuring the current ambient station pressure with an external measurement device.

4. Verify that the reported field value is within ±10 mmHg of the measured ambient pressure. If this is not the case there may be a problem with the internal pressure sensor, notify the appropriate PM personnel.

5. Note the results on the Site Verification form and the T640 audit data sheet.

12.4.5. Flow Verification

Follow the steps below to perform the flow verification audit on the T640 PM Analyzer:

1. With the flow audit adaptor still installed from the leak check, remove the HEPA filter from the train.

2. Install an FTS that measures flow in the correct range (5.0 LPM)

3. Zero and install the digital manometer to the FTS using the appropriate tubing.

4. Record the pressure drop (ΔH_2O) through the FTS on the T640 Site Verification form and the T640 audit data sheet.

5. Calculate the flow reading with the following equation:

   $$Q_{ltp} = m*((T_a/P_a)*\Delta H_2O)^{1/2} + b$$

   Where;
   Q_{ltp} = flow rate, actual conditions, liters per minute
   m = FTS Slope
   Ta = ambient temperature, degrees Kelvin
   Pa = ambient pressure, atmospheres
   ΔH_2O = manometer reading, inches water
   b = FTS Intercept

6. The acceptable range for a successful flow verification is from 4.50 L/min to 5.50 L/min. However, any flow greater than 5.40 L/min or less than 4.40 L/min should be a possible reason to recalibrate the instrument. The PM supervisor and site operator must be notified ASAP.

7. Note the results on the Site Verification form and the Low Vol / Continuous Analyzer field form.

12.4.6. Completion of Audit

After the audit is complete and no adjustments or troubleshooting is required, it is VERY important that the station is left in the condition it was found. The following is a checklist of items to be completed before exit:

1. Remove all audit equipment from the analyzer.
2. Verify that all components of the analyzer are properly reconnected and head is reinstalled properly.
3. Double check analyzer display to ensure readings are reasonable and there are no error messages.
4. Ensure that the “Boxcar Filter Size” was reset to “60”.
5. If the unit was placed offline on the datalogger, it must be returned to on-line status.
6. Note the time on the Site Verification form and the Low Vol / Continuous Analyzer field formof when the audit was complete and analyzer was placed back online.

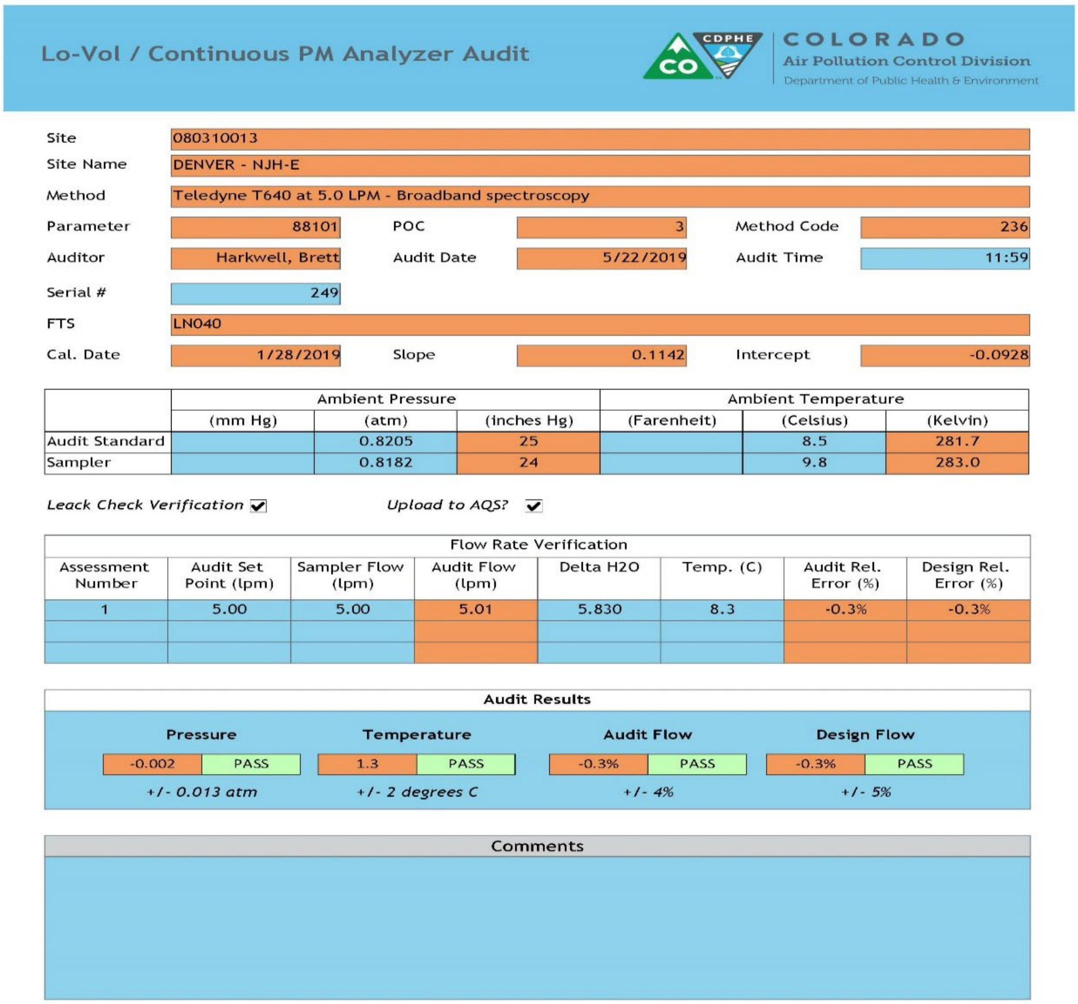
12.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The Technical Services Program maintains an Access Database on the Air Pollution Control Division (ACPD) Local Access Network (LAN). The file path for this database can be found within the LAN at J:\QA Audit Programs\P&A Database\QA Audits Database.mdb This program records the results of all particulate accuracy audits conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the accuracy data before they are submitted to AQS. A detailed description of the accuracy data processing procedures is located in Appendix D4 of this QAPP.

Within 90 days of the end of a calendar quarter, all particulate accuracy data are downloaded to an ASCII-format data file and then uploaded into the AQS database. These data processing operations are performed by Quality Assurance Unit staff.

Figure14.1: Low Volume / Continuous Analyzer Audit Form T640



Lo-Vol / Continuous PM Analyzer Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080310013				
Site Name	DENVER - NJH-E				
Method	Teledyne T640 at 5.0 LPM - Broadband spectroscopy				
Parameter	88101	POC	3	Method Code	236
Auditor	Harkwell, Brett	Audit Date	5/22/2019	Audit Time	11:59
Serial #	249				
FTS	LN040				
Cal. Date	1/28/2019	Slope	0.1142	Intercept	-0.0928

	Ambient Pressure			Ambient Temperature		
	(mm Hg)	(atm)	(inches Hg)	(Farenheit)	(Celsius)	(Kelvin)
Audit Standard		0.8205	25		8.5	281.7
Sampler		0.8182	24		9.8	283.0

Leack Check Verification ☑ *Upload to AQS?* ☑

Flow Rate Verification							
Assessment Number	Audit Set Point (lpm)	Sampler Flow (lpm)	Audit Flow (lpm)	Delta H2O	Temp. (C)	Audit Rel. Error (%)	Design Rel. Error (%)
1	5.00	5.00	5.01	5.830	8.3	-0.3%	-0.3%

Audit Results							
Pressure		Temperature		Audit Flow		Design Flow	
-0.002	PASS	1.3	PASS	-0.3%	PASS	-0.3%	PASS
+/- 0.013 atm		*+/- 2 degrees C*		*+/- 4%*		*+/- 5%*	

Comments

13. TAPI Model 633 Aethalometer®

13.1. Introduction

An Aethalometer is an instrument for measuring the concentration of optically absorbed (black) suspended particles in a gas colloid stream; commonly visualized as smoke or haze. The Model 633 Aethalometer® instrument uses the principles of aerosol light absorption to measure Black Carbon (light absorbing) mass concentration.

The measurement is done using an assumed aerosol cross sectional absorption coefficient from the raw light absorption measurements. The aerosol light absorption coefficient that is applied in the Aethalometer® instrument is a function of the filter media being used to collect the sample, and is dependent on the incident LED wavelength (λ). The Model 633 Aethalometer® uses a 7-wavelength (370, 470, 525, 590, 660, 880, and 940nm) light source, internal mass flow meters, and Teflon coated glass fiber filter tape to perform measurements. The Model 633 measures the attenuation of light at different wavelengths on two parallel spots drawn from the same input stream, but collected at different rates of accumulation. By combining the data from the two spots the Model 633 yields the value of BC extrapolated back to 'zero loading'; as well as a real-time output of the 'loading compensation parameter' (k) which provides insights into the aerosol nature and composition.

13.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between the measured value and the true, standard value during audits.

Persons independent of the APCD particulate program conduct field audits quarterly on field samplers. The APCD Quality Assurance staff typically performs the field audits. The field audit is performed by measuring flow, leak rate, temperature, pressure and time of the sampler with standards that are independent of those used in the calibration of the sampler. Audit standards must be certified against a NIST traceable standard and be of the same or of higher quality than of those being certified.

The general order of the field audit is as follows:

a) Set up audit standards and record sampler information.
b) Evaluate date and time.
c) Document any status codes.
d) Test sampler for leaks.
e) Evaluate ambient temperature criteria.
f) Evaluate ambient barometric pressure criteria.
g) Evaluate sampler flow criteria.
h) Leave site in same or better condition than it was found.

13.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on the TAPI Model 633 Aethalometer®

- Certified NIST-traceable thermometer.
- Certified NIST-traceable barometer.
- Certified NIST-traceable BGI Trical.
- Aethalometer Flow Calibration Pad.
- Certified time piece.
- Personal Laptop for data entry and audit verification.
- Audit Verification Form.
- Tools, extra tubing and spare parts.

13.4. Aetholometer Audit Procedure

13.4.1. Collect Analyzer Information and Disable Data Logger

1. Collect required information from the Model 633 Aethalometer® analyzer being audited by scrolling through parameters on the front panel of the analyzer. Tracked parameters should be recorded on the station analyzer site log located in the sample shelter. This information is compared to the instrument operation specifications and to the last set of parameters the operator recorded to assure the analyzer is functioning properly before starting an audit.

2. If applicable, enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field:
   - The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
     i. Logger ID # is usually written on the upper left corner of the monitor in two digit form. If not, hit "ESC ESC . . AQM" and logger ID number should appear on screen. Hit "Escape" key twice, then input "logger ID" + "AQM"
     ii. The password for the ESC System is "GO VOLS"

   - The second type of logger system is the Agilaire. This is a windows based system and the password to log into this system is "Agilaire".

3. Before an audit can be performed, the Aethalometer channels must be disabled on the data logger so that all data collected during the time the audit was performed is flagged as invalid. To disable

the Aethalometer channels for each type of data logging system, follow the procedures listed below:

- ESC System:
    - i. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter".
    - ii. From this menu select "Configure Data Channels".
    - iii. Next go into "Disable/Mark Channel Offline".
    - iv. From here you will see a list of enabled reporting channels. Highlight the desired channel and press "enter". This process will take the channels offline so the audit data is not reported as ambient concentrations. To put channels back online, choose "Enable/Mark Channel Online" and highlight the channels you would like to put online, and then press enter.
    - v. Repeat task iii and iv as necessary to flag all affected channels as offline.

- Agilaire System:
    - i. From the Home page of the **AV-Trend**, go to the " Utilities" drop down menu and choose "Site Node Logger Toolbox"
    - ii. You will find a list of all the channels at the station. All channels which are active should be "False". To mark the channel as offline, click "False" under the "Disable Flag" for the BC and UVPM channels, and it should change to "True" which indicates that it is now offline.

4. Record the analyzers current time on the station analyzer log and on the Aetholometer Field Form. Compare the current audit time to the analyzer time. The analyzer time must not deviate by more than 20 minutes from the official audit time.

5. Record the analyzers current date on the station analyzer log and on the Aetholometer Field Form. Compare the current audit date to the analyzer date. The analyzer date must not deviate from the official audit date.

13.4.2. Accuracy Ambient Temperature Audit

Compare the value for the ambient temperature displayed on the Main Screen with the value given by a NIST traceable audit temperature standard. Follow the steps below to perform the ambient temperature audit:

1. Place the audit thermometer in close proximity to the analyzer temperature sensor making sure not to place in direct sunlight. Allow the sensors to stabilize before recording readings.

2. Record the analyzers current temperature on the station analyzer log and on the Aetholometer Field Form. Compare the current audit temperature to the analyzer temperature. The analyzer temperature must not deviate more than +/- two (2) degrees Celsius (°C) from the official audit temperature.

13.4.3. Accuracy Ambient Pressure Audit

Compare the value for the ambient pressure displayed on the Main Screen with the value given by a NIST traceable audit pressure standard. Follow the steps below to perform the ambient pressure audit:

1. Place the audit pressure sensor in close proximity to the analyzer pressure sensor making sure not to place in direct sunlight. Allow the sensors to stabilize before recording readings.

2. Record the analyzers current atmospheric pressure on the station analyzer log and on the Aetholometer Field Form. Compare the current audit atmospheric pressure to the analyzer atmospheric pressure. The analyzer atmospheric pressure must not deviate more than +/- 0.013 atmosphere (atm) from the official audit atmospheric pressure.

13.4.4. Leak Check

Always conduct a leak test prior to running a flow check to ensure analyzer is operating within parameters. While performing the leak check procedure, the instrument will be lifting and lowering the sample chamber multiple times. The QA technician must wait to perform each step of the procedure until the sample chamber stopped moving or until prompted by the display. The steps to perform a leak check are as follows:

1. From the OPERATION Menu on the GENERAL tab, press STOP to pause sampling of the analyzer.

2. From the OPERATION Menu on the GENERAL tab, press ‘Leakage Test’, then press ‘Manual”. The tape will advance automatically.

3. Install a Certified NIST-traceable BGI Trical flowmeter equipped with tubing to the inlet of the analyzer.

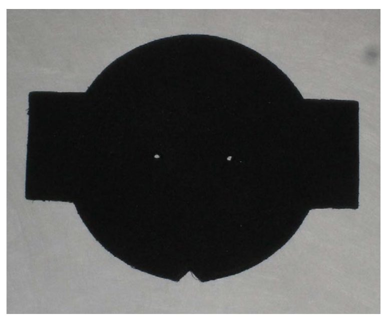
4. Select flowrate of 4 liters/min on the control panel of the aetholometer, press ok, the pump will start.

5. Allow the flow to stabilize.

6. Press the flow field on the control panel (the box adjacent to the word "flow"). Using the key pad on the control panel, enter the actual flow rate in milliliters per minute. Press "Enter", then press "OK".

7. The pump will shut off and the chamber will lift. Remove filter tape carefully from the sample chamber. Install the calibration pad (Figure 1), tabs of the pad parallel to the direction of the tape with the notch of the pad aligned with the center line of the sample chamber, press "OK" when pad is in place. The pump will turn on.

Figure 1 – Aethalometer Calibration Pad



8. Allow the flow to stabilize. Once again press the flow field, using the key pad on the control panel, enter the actual flow rate in milliliters per minute. Press "Enter", then press "OK".

9. On the audit form and site check sheet, record F_{tape}, F_{pad}, and leakage percentage (%), then Press "OK".
   Note: If the auditor will be performing a flow verification, leave the calibrating pad and flow meter in place. Otherwise, remove the pad and replace the tape, then press "OK".

10. After completion of the leak check, and if not performing a flow check, remove calibration pad from sample chamber and replace filter strip, press “OK”. Wait for chamber to return to home sample position and the pump to initiate. Ensure the sample unit is left in good operating condition.

11. Leakage (ζ) is measured during instrument operation. It is calculated from the flow in (F_{in}) and flow out (F_{out}) by the following equation:

$$\zeta = 1 - (F_{in} / F_{out})$$

Average leakage is approximately 7% at 4 LPM.

13.4.5. Flow Verification Procedure

While performing the flow verification procedure, the instrument will be lifting and lowering the sample chamber multiple times. The QA technician must ensure the sampler is given ample time to complete this transition before moving on to each step. The technician will be informed on the display when it is ok to continue to the next step. The steps to performing the flow verification is as follows:

1. After having performed the Leak Check with the Calibration Pad still in place; from the OPERATION menu on the general tab press “Verify flow”, then press “Manual”.

2. Since the Calibration Pad is still in place, press “skip”, the chamber will now move into the operating position.

3. If the audit flowmeter is not connected to the analyzer sample inlet, connect the flow meter and then press “OK”.

4. Tap the Temp field and enter actual ambient temperature in degrees Celsius (°C), press “Enter”. Note this value on the verification form and on the site check sheet.

5. Tap the Pressure field, enter actual ambient pressure in pascals (note: to convert from mmHg to pascals, divide by 760 and then multiply by 101325), press “Enter”. Note this value on the verification form and on the site check sheet.

6. Allow the flow to stabilize then tap the flow field. Enter first actual flow rate, press “Enter”, then press “OK”. Note the value on the Audit Verification Form for “F_{act}” level 1.
   Note: The first flow verification check point is near 1.2 LPM, make sure to use a flow verification standard that can measure flow accurately at this level.

7. Allow the flow to stabilize then tap the flow field. Enter first actual flow rate, press "Enter", then press "OK". Note the value on the Audit Verification Form for "F_{act}" level 2.
   Note: The second flow verification check point is near 4.0 LPM, make sure to use a flow verification standard that can measure flow accurately at this level.

8. Allow the flow to stabilize then tap the flow field. Enter first actual flow rate, press "Enter", then press "OK". Note the value on the Audit Verification Form for "F_{act}" level 3.
   Note: The third and final flow verification check point is near 6.0 LPM, make sure to use a flow verification standard that can measure flow accurately at this level.

9. Record the flow results (where Fact is the reading from the external flowmeter), then press "OK":

F_{act}	F_{in}	F_1	%	F_c	%
1148	1157	1145	99	1145	100
3690	3770	3730	100	3775	100
6230	6280	6299	100	6284	100

Where:
Fact = flow rate at actual ambient conditions measured by an external flowmeter
Fin = F_{act} adjusted to instrument reported conditions
F_1 = flow at mass flowmeter 1
Fc = flow at mass flow meter C
% = F_1/F_{in}
% = F_c/F_{in}

10. Also displayed on the results screen are the instrument ambient temperature and pressure, note these values on the Audit Verification Form and the site QC check sheet.

11. Remove the calibration pad, carefully reinstall the filter tape, then press "OK". The chamber will move to the home position, wait until prompted

12. When the 633 prompts “Flow Verification Finished”, press “OK”. If returning instrument to normal operation, press “Start”. Analyzer pump should initiate and return to normal operation.

13.4.6. Completion of Audit

After the audit is complete and no adjustments or troubleshooting are required, it is VERY important that the station is left in the condition it was found. The following is a checklist of items to be completed before exit:

1. Remove all audit equipment from the analyzer.

2. Verify that all components of the analyzer are properly reconnected.

3. Double check analyzer display to ensure readings are reasonable and there are no error messages.

4. If analyzer was placed offline on the datalogger, it must be returned to on-line status. The site analyzer data sheet should be noted of the times the analyzer was taken offline and what action was taken.

13.5. Data Processing

Documentation is important for all measurements. Certification paperwork for all quality control and quality assurance practices are rigorously maintained for each standard and analyzer. APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

The Technical Services Program maintains an Access Database on the Air Pollution Control Division (ACPD) Local Access Network (LAN). This program records the results of all particulate accuracy audits conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the accuracy data before they are submitted to AQS. A detailed description of the accuracy data processing procedures is located in Appendix D4 of this QAPP.

14. Meteorological Audit Procedures

14.1. Introduction

The APCD has a goal of conducting performance audits at each meteorological monitoring site at a minimum frequency of once per calendar year. Even though meteorological parameters are not considered criteria pollutants by the EPA, the APCD still loads all meteorological data up to the EPA's AQS database, with the exception of audit data, which is not loaded to the AQS database. The meteorological data produced by APCD is important for the modeling group within APCD to help determine stationary source permitting and for the forecasting group to notify the public of high pollution days or smoke advisories.

Audit standards and the personnel performing audits are different than those used in meteorological equipment calibrations. The performance of three components of the meteorological monitoring system (wind direction, wind speed, and temperature) is evaluated during the audit procedure.

14.2. Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between these two values during audits.

The steps of the meteorological audit are as follows

- Check the initial cross-arm orientation with a surveyor's transit.
- Disable the data logger channels of the applicable meteorological parameters.
- Lower the tower.
- Perform wind speed, wind direction, and temperature sensor audits.
- Perform translator diagnostic checks.
- Raise and secure the tower.
- Enable the applicable data logger channels.
- Check the final cross-arm orientation.
- Perform calculations and evaluate performance relative to the APCD data quality objectives.
- Tools.

14.3. Audit Equipment Checklist

The equipment listed below is required to perform an audit on a meteorological tower:

- Surveyor's Transit.
- Synchronous Motors for Wind Speed.
- Certified NIST-traceable thermometer.
- Wind Direction Disk Template for MetOne sensors, and a Vane Angle Bench stand for RM Young sensors.

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- APCD Meteorological Tower Audit Form (**Figure 14.1**).
- Calculator.
- Vacuum grease.
- Electrical Tape.
- 100 ft extension cord.
- Step ladder to rest tower on while performing audit on sensors.
- Tools (Allen Wrenches, adjustable wrenches, screw drivers, etc).
- Personal Laptop for data entry and audit verification (not required).

14.4. Meteorological Tower Audit Procedure

14.4.1. Initial Cross-arm Orientation Audit Procedure

Cross-arm orientation is determined by use of a surveyor's transit (Schneider Model DB-3). The goal is to place the transit so that it is sighting directly along the length of the cross-arm. Parallax is avoided by making sure that both the anemometer and the wind vane, which are on opposite ends of the cross-arm, overlap in the telescopic field of view. The orientation of the cross-arm is then read from the transit. From the ground, inspect the condition of the wind vane, anemometer, and temperature probe radiation shield. Note any apparent damage or abnormal conditions on the Meteorological Tower Field Audit Form (**Figure 14.1**).

14.4.1.1. Transit Setup

The following procedure is used as a guide to setting up the transit:

1. Set up the transit in direct alignment with the cross-arm. Typically, the transit should be set up at a minimum distance of about 20 meters from the meteorological tower in order to get a good view of the cross-arm alignment.
   Note: Take special care when placing the transit not to locate around metal objects and remove keys and cell phones from area, as this may interfere with the magnetic compass in the transit and provide skewed results in the cross-arm alignment.

2. Sight the boom through the transit telescope. The wind vane and anemometer should directly overlap in the field of view and the view should align with the length of the cross-arm. If necessary, move the transit a few feet laterally in order to ensure direct alignment of the sensors/cross-arm to the horizontal line in the transit view finder.

3. Level the surveyor's transit using the three large black knurled leveling screws at the base of the transit. Check the transit level by rotating the transit 180^{O} and ensuring that the transit level bubbles are still centered.

4. Line up the inner and outer vernier plates on the transit so that both are zero. Lock them into position using the upper plate clamp screw.

5. Unclamp the compass needle by releasing tension on the small tensioning screw at the top of the transit. Align the compass needle with the local magnetic declination. For example, for Denver monitoring sites, the compass needle will point ~9^{o} east of north. The continuous database used to enter and store meteorological audits should be updated on a yearly basis with respect to any change in magnetic declination at each site. The continuous analyzer staff updates a spread sheet that calculates the magnetic declination at each site using the website www.ngdc.noaa.gov. The spread sheet is stored on APCD's LAN J:\zsfiles\MET Declination. The database used to enter audits should also be updated yearly by the same staff. Double check that the magnetic declination automatically populated in the database form, after the site name is picked, matches that in the MET Declination spreadsheet stored on the J: Drive.

6. Lock the outer vernier ring in position using the lower plate clamp screw. At the completion of this step, the transit is level, and the out vernier scale (which reads 0-360^{o}) is aligned with true direction.

14.4.1.2. Transit Measurement

The following procedure is used as a guide to performing a transit measurement:

1. Release tension on the upper plate clamp screw. Rotate the telescope as necessary in order to sight the wind sensors mounted on the cross-arm assembly. With the sensors in the telescope crosshairs, lock the transit in position using the upper plate clamp screw.

2. The zero on the inner vernier (which shows the true orientation of the cross-arm assembly) will be aligned with some value on the other vernier. Read the outer vernier scale to the nearest degree and minute and record this value under "Pre-Audit Crossarm Alignment Check" in the "Normal" field of the audit data sheet.

3. Invert the telescope so that the telescope is now pointing away from the meteorological tower boom. Loosen the upper clamp screw and rotate the telescope approximately 180^{o}. Again sight the sensors through the telescope. With the sensors in the telescope crosshairs, lock the transit in position using the upper plate clamp screw.

4. Read the outer vernier scale to the nearest degree and minute and record this value in the "Pre-Audit Crossarm Alignment Check, Inverted" field. This procedure, called inverting the telescope, acts as a check on the first reading. The difference in the transit normal and inverted readings should be exactly 180°.
   Note: At most APCD monitoring sites, it will be necessary to take down the transit and move it to a secure location during the next phases of the audit to prevent theft or damage.

14.4.2. Login to Site Computer and Disable Data Logger Channels

Perform the following steps to log on to the site computer and disable the data logger channels. This is dependent on which type of data logger is utilized.

Enter the appropriate login information into the site computer to gain access. There are two types of data systems that could be encountered in the field:

- The first type of logger system is the ESC logger, which is a DOS based system. Log in procedures are as follows:
  i. Hit "ESC" key twice.
  ii. Logger ID is usually written on the upper left corner of the monitor.
  iii. Input "logger ID" + "AQM"
  iv. Password for the ESC Systems is "go vols"

- The second type of logger system is the Agilaire. This is a windows based system and the password to log into this system is "Agilaire".

Before an audit can be performed, the meteorological channels must be disabled on the data logger so that all data collected during the time the audit was performed is flagged as invalid. To disable the Meteorological channels for each type of data logging system, follow the procedures listed below:

- ESC System:
  i. From the main menu, go into the "Configuration Menu" by scrolling down with the arrow key highlighting the desired option and then hit "enter".
  ii. From this menu select "Configure Data Channels".
  iii. Next go into "Disable/Mark Channel Offline". To put channels back online, choose "Enable/Mark Channel Online".
  iv. From here you will see a list of enabled reporting channels. Highlight the desired channel and press "enter". This process will take the channels offline so the audit data is not reported as ambient readings.
  v. Repeat task iii and iv as necessary to flag all affected channels as offline.

- Agilaire System:

i. From the Home page of the **AV-Trend**, go to the “Utilities” drop down menu and choose “Site Node Logger Toolbox”.
ii. You will find a list of all the channels at the station. All channels which are active should be “False”. To mark the channel as offline, click “False” under the “Disable Flag”column for all the meteorological channels, and all should change to “True” which indicates that they are now offline.

Read the data logger’s current time. Record the time the parameters were taken offline on the station log and on the meteorological audit datasheet.

14.4.3. Lower Meteorological Tower

Perform the following steps to lower meteorological towers:

1. Most of the stations have locked tower guards, which are designed to prevent unauthorized access to the equipment. These are locked using combination padlocks, and use the same combination of 4180.

2. In most cases the towers are secured to concrete footers by three bolts. The towers are designed so that one bolt can be removed, and the remaining two bolts loosened and act as pivots for lowering the tower. At some sites the towers are mounted to the walls of portable shelters. The auditor must remove several mounting bolts, and the tower pivots on a mounting bracket.

3. Most of the meteorological towers in the APCD network are equipped with hand winches which enable the tower to be safely lowered by one person. The remaining towers have to be dropped by hand and require a minimum of two people to assist in lowering the tower safely.

4. When the tower is lowered, rest the frame of the tower on a support, usually a stepladder, to prevent the cross-arm from hitting and resting on the ground. In addition, the tower must be elevated on a support so that the sensors are above ground level and at a convenient working height.

14.4.4. Wind Speed Translator and Diagnostic Checks

Follow the steps below to perform the wind speed audit:

1. Attach the voltmeter leads to TP1 (ground) and TP3 (voltage output) locations on the wind speed translator card (ID#1180-1) (**Figure 14.2**).

2. Record the wind speed sensor type and identification number on the audit form. Take note of the condition of the anemometer cups for the *MetOne* sensors, and the propeller for the *RM Young* sensors.

3. For the MetOne sensor, use an Allen wrench to loosen the set screw and remove the anemometer cups. For the RM Young sensor, loosen and remove the set screw on front of the propeller and then remove the propeller. Spin the shaft, observing how well the bearings operate. If the wind speed bearings do not spin freely promptly notify the Meteorological Calibration staff.

4. Immobilize the wind speed shaft either with tape or mounted to a synchronous motor which is switched off. After response has stabilized, record voltage and data acquisition system readings. This is the zero wind speed response on the Meteorological Tower Audit Field Datasheet.

5. Attach the anemometer shaft to a variable or 300-rpm synchronous motor. Turn on synchronous motor (clockwise direction). Allow at least 30 seconds for the speed to stabilize. Record DVM voltage, data acquisition system voltage, and wind speed responses on the Meteorological Tower Audit Field Datasheet. The variable motors allow all the speed and rotation settings to be run consecutively without changing motors and allow for more data points.

6. Turn off synchronous motor. Shift the switch to the counterclockwise position. Turn motor back on. Record response to counterclockwise rotation.

7. Repeat steps 5 and 6 for all designated rotational speed settings. For the MetOne sensors, the APCD-QA Unit uses either two fixed speed motors, which provide checks of two rotation speeds (300 rpm, and 600 rpm) or a variable speed synchronous motor. This assesses sensor response over a range of audit inputs from zero to 36 mph for the fixed and up to 90 mph for the variable motor units. For the RM Young sensor, the APCD-QA Unit utilizes a variable speed synchronous motor which can verify wind speeds from 0 to 90 mph and higher. Typically for the RM Young sensor, rotational speeds of 0, 600, 1700, 3300 and 5400 are utilized and the corresponding wind speeds are 0, 6.87, 19.47, 37.79 and 61.83 mph respectively. For the Met One sensor 0, 300, 600, 900 and 1200 rotations per minute are utilized and the corresponding wind speeds are 0, 18.5, 36.4, 54.3 and 72.1 mph respectively.

8. The true wind speed value associated with each motor speed is dependent on the sensor type. The sensor types and the true wind speed for each motor speed are

printed on the audit form. For example, a MetOne 010B sensor rotating at 300 rpm should show an indicated wind speed of 18.49 miles per hour. When entering the wind speed model into the Meteorological Tower Audit database form, the form will automatically update with the correct sensor settings.

9. The APCD data quality objective is that wind speed response should be within ±5% of the audit input.

10. Turn off and remove the wind speed motor.

11. Turn on zero switch S1 on translator card, and record voltage from voltmeter. Do the same with the span switch S2.

12. Replace anemometer cups or propeller and tighten set screw or replace nut and tighten securely.

14.4.5. Wind Direction Translator Output and Diagnostic Checks

Follow the steps below to perform the wind direction audit:

1. Attach voltmeter leads to TP1 (ground) and TP3 (voltage output) locations on the wind direction translator card (ID#1190-1) (**Figure 14.2**).

2. Record the wind direction sensor type and identification number on the audit form.

3. Check the wind vane for physical damage. Rotate it gently to determine whether there are any problems with the bearings. Note the results on the audit data sheet.

4. For the MetOne Sensor, use a fine Allen wrench to loosen the set screw and remove the wind vane. For the RM Young sensor, loosen the hose clamp which secures the sensor in place and remove the sensor from the post.
   Note: make sure not to loosen the orientation ring hose clamp on the RM Young unit as this ***will alter the orientation of the sensor****. There is a notch located below the control/circuit board box which should align to true south on the notch of the alignment clamp.*

5. For the MetOne wind direction sensor, the sensor has two sections, one is fixed and the other is free to rotate. Each section has a scribed mark machined into the side of the sensor. When the scribed marks are aligned the wind sensor response should indicate south or 180°.

6. For the MetOne wind direction sensor, place the direction template disk on the shaft of the sensor so that when the scribed marks are aligned the indicator is pointing to 180^o. For the RM Young sensor, once the sensor has been removed from the tower, place sensor on the Vane Angle Bench stand with the notch oriented towards the 180^o.

7. Rotate the sensor clockwise a full turn and bring the indicator back to 180^o.

8. After the data logger response has stabilized, record the translator card voltage, the data acquisition system voltage and wind direction readings on the Meteorological Tower Audit Form.

9. Rotate the direction clockwise to 270^o, 360^o and 90^o. Record voltage and data logger responses for each position on the Meteorological Tower Audit Form.

10. Rotate the sensor counter-clockwise a full turn and bring the indicator back to 180^o.

11. After the data logger response has stabilized, record the voltage, the data acquisition system voltage and wind direction readings on the Meteorological Tower Audit Form.

12. Rotate the direction counter-clockwise to 90^o, 360^o and 270^o. Record voltage and data logger response for each position on the Meteorological Tower Audit Form.

13. Calculate the degree differences between data acquisition response, and vane setting. The audit database will automatically do these calculations after all the audit data is correctly entered into the form and display this difference in the "DCN Error (deg)" column. The APCD data quality objective is that wind direction response should be within 5^o totaled with the crossarm composite error of the audit input.

14. Turn on zero switch S1 on translator card, and record voltage from voltmeter. Do the same for the span switch S2.

15. Remove the MetOne wind direction audit plate from the wind direction sensor. For the RM Young wind direction sensor, remove sensor from the Vane Angle Bench Stand and replace the sensor on the meteorological tower post with the orientation notch oriented to the south. Secure the hose clamp.

16. Replace the wind vane on the MetOne sensor making sure it is secure.

14.4.6. Temperature Sensor Translator Output and Diagnostic Checks

Follow the steps listed below to perform a temperature sensor audit:

1. Attach voltmeter leads to TP1 (ground) and TP3 (voltage output) locations on the temperature translator card (ID#1230-1) (**Figure 14.2**).

2. Place the probe of a NIST-traceable thermometer near the probe of the temperature monitor and allow the thermometer to equilibrate for approximately ½ hour. Make an effort to keep both thermometer probes out of direct sunlight so as not to create erroneous temperature readings due to solar radiation.

3. Note the audit thermometer ambient temperature value and the DCN ambient temperature value on the Meteorological Tower Audit Form. Wait at least 15 minutes and perform this task once again and record on the Meteorological Tower Audit Form.

4. Calculate the difference between the data logger response and the true temperature. The Meteorological Tower Audit form will automatically calculate and display this difference in the "Error F" column for the auditor after the audit data is entered into the form correctly. The APCD data quality objective is that temperature response should be within $\pm 2^{o}$ F of the audit input.

5. Turn on the zero switch S1 on translator card, then record voltage from voltmeter. Do the same for the span switch S2.

14.4.7. Raise and Secure the Tower

1. Check that the wind vane and anemometer are securely mounted, the dust caps are in the upright positions and the sensors are able to rotate freely.

2. Raise the tower into position and securely replace the mounting bolts. Make sure to tighten all 3 mounting bolts snugly.

3. Replace and secure the tower guard, if applicable.

14.4.8. Enable Data Logger Channels

1. Enable the data logger channels associated with the meteorological tower using the appropriate data logger commands discussed above in section 14.3.2.

2. Confirm that the appropriate channels have been enabled within the station data logger.

3. Read the data logger time. Record the time on the audit form and on the station's meteorological equipment log.

14.4.9. Final Cross-Arm Orientation Audit

The final cross-arm orientation is determined by use of a surveyor's transit in a procedure identical to that used to make the initial cross-arm orientation check. This check is made to confirm that the cross-arm orientation and tower position wasn't changed appreciably during the course of the audit. Refer to section 14.5.1 for the procedure of performing the final cross-arm orientation.

Note: When putting the transit into its carrying case for transport, make sure to lock down the compass needle with the compass needle tightening screw. This will keep the needle secure during transport and create less possibility of damage. Also loosen all other screws as to not cause undue stress to the transit during transport.

14.5. Calculations and Reports to Management

The data quality objectives for the APCD meteorological monitoring network are wind direction measurements within ±5° (cumulative between the transit error and sensor error), wind speed measurements within ±5%, and temperature measurements within ±2°F. The data logger output value is used as the indicated value in making the audit error calculations. Listed below is the criterion for the audits performed on the meteorological equipment:

1. For the temperature audit, the difference between the known input and the sensor response is calculated and compared to the ±2°F criterion.

2. For wind speed and wind direction, the difference between the known and the sensor response is calculated at each audit point. Wind direction measurements within ±5° (cumulative between the transit/crossarm error and the sensor error), wind speed measurements within ±5%.

3. A memorandum presenting the results of the performance audit is submitted to the APCD Technical Services Program Manager within three working days of the audit date. The original audit form is kept on file at APCD offices as a permanent record of the performance audit.

4. At the end of each quarter the supervisor of the APCD's Gaseous and Meteorological Monitoring Unit (GM) receives a hardcopy of all meteorological audits performed for the previous quarter. Additionally, a summary of all failed audits, for all pollutants, is reported in internal memoranda to four key Technical Services Program managers quarterly. Managers on the meteorological audit memoranda distribution list include

the supervisors of GM Unit, the Particulate Monitoring Unit, the QA Unit, and the TSP Program Manager.

14.6. Data Processing

The APCD utilizes an Access database to enter and process audit results. A printout of the data entry form is used as a datasheet in which raw data is hand entered (**Figure 14.1**). Data from the datasheet is then input into the Access database via the use of a data input form. The field datasheets are archived in case the electronic copy is lost or damaged. The Access database is typically located on the auditor's laptop computer. The QA Audits Database is used to store audits for several continuous monitoring networks. The main screen will be displayed once the database is opened. Select the <Enter New Audit> button and select the parameter that pertains to the audit being performed. There is only one version of the Access data input form for each audit type, however it can be configured to input new audit records or to view old archive records. Upon opening the appropriate form, the data entry form is displayed and a new audit record can be entered into the form. Data from the form can be saved to an archive table as an audit record by pressing the button <Save to Archive>. To view archive records press the <View Audit Archive> button from the home screen. The form will be reconfigured to display archive records.

The Technical Services Program maintains the above described Access database called the QA Audits database on the Air Pollution Control Division (ACPD) Local Access Network (LAN). The file path for this database can be found within the LAN at J:\QA Audit Programs\P&A Database\QA Audits Database.mdb. This database records the results of all continuous audits conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the accuracy data before they are finalized. There is currently no provision for submittal of meteorological quality assurance information to the EPA's Air Quality Subsystems AQS database.

Figure14.1: Meteorological Tower Audit Form

Meteorological Tower Audit

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Site	080350004
Site Name	CHATFIELD STATE PARK

Auditor	Sharp, Clyde	Time Offline	11:17
Audit Date	7/25/2019	Time Online	11:55

Sensor Information			
Sensor	Serial Number	Make	Model
Wind Speed	J1075	Met One	10B
Wind Direction	N10133	Met One	
Temp (Upper)			
Temp (Lower)			
Hygrometer			
Barometer			

Span/Zero Voltages		
Sensor	Zero	Span
Wind Speed		
Wind Direction		
Temp (Upper)		
Temp (Lower)		
Hygrometer		
Barometer		

Magnetic Declination	8.12406	Distance to Tower (ft)	100
Crossarm Orientation	N-S	Correction (ft)	0.6

Subtract magnetic declination? ☐

Pre-Audit Crossarm Alignment Check				
	Degrees	Minutes	Offset	Error
Normal	0	20	-360	0.3
Inverted	180	20	0	0.3

Post-Audit Crossarm Alignment Check				
	Degrees	Minutes	Offset	Error
Normal	0	20	-360	0.3
Inverted	180	20	0	0.3

Wind Speed Sensor Audit (+/- 5%)										
Audit Set Point (RPM)		Wind Speed (mph)	DVM (volts)	DVM (mph)	Error (%)	DCN Actual (volts)	DCN Actual (mph)	Error (%)	DCN Res. (mph)	Error (%)
Zero	0	0.0					0.6		0.6	
CW	300	18.5					18.5	0.0%	18.5	0.0%
CCW	300	18.5					18.6	0.5%	18.6	0.5%
CW	600	36.4					36.5	0.3%	36.5	0.3%
CCW	600	36.4					36.5	0.3%	36.5	0.3%
CW	900	54.3					54.3	0.0%	54.3	0.0%
CCW	900	54.3					54.4	0.2%	54.4	0.2%
CW	1200	72.1					72.3	0.3%	72.3	0.3%
CCW	1200	72.1					72.3	0.3%	72.3	0.3%

Wind Direction Sensor Audit (+/- 5 Degrees)										
Audit Set Point	Wind Dir. (degrees)	DVM (volts)	DVM (degrees)	DCN Act. (volts)	DCN Act. (degrees)	Offset	DCN Act. Error	DCN Res. (degrees)	DCN Res. Error	Composite Error
South	180				181.7	0.0	1.7	181.7	1.7	2.0
CW West	270				271.4	0.0	1.4	271.4	1.4	1.7
CW North	360				2.2	-360.0	2.2	2.2	2.2	2.5
CW East	90				92.9	0.0	2.9	92.9	2.9	3.2
CCW South	180				181.4	0.0	1.4	181.4	1.4	1.7
CCW East	90				92.2	0.0	2.2	92.2	2.2	2.5
CCW North	360				2.6	-360.0	2.6	2.6	2.6	2.9
CCW West	270				270.1	0.0	0.1	270.1	0.1	0.4

	Temperature (+/- 2 Degrees C)									
Reading	Upper Temp. Sensor					Lower Temp. Sensor				
	DVM (volts)	DCN (volts)	Audit (F)	DCN (F)	Error	DVM (volts)	DCN (volts)	Audit (F)	DCN (F)	Error
Point 1			87.0	87.7	0.7					
Point 2			86.1	87.0	0.9					
Avg.			86.6	87.3	0.8					

	Humidity (+/- 5%)					Pressure (+/- 10 mm Hg)				
Reading	DVM (volts)	DCN (volts)	Audit (%)	DCN (%)	Error	DVM (volts)	DCN (volts)	Audit (mmHg)	DCN (mmHg)	Error
Point 1										
Point 2										
Avg.										

Audit Results

Wind Speed

CW 300 RPM	PASS
CCW 300 RPM	PASS
CW 600 RPM	PASS
CCW 600 RPM	PASS
CW 900 RPM	PASS
CCW 900 RPM	PASS
CW 1200 RPM	PASS
CCW 1200 RPM	PASS

Wind Direction

South	PASS
CW West	PASS
CW North	PASS
CW East	PASS
CCW South	PASS
CCW East	PASS
CCW North	PASS
CCW West	PASS

Temperature

Upper Avg.	PASS
Lower Avg.	

Humidity

Avg.	

Pressure

Avg.	

Comments