

QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	OPTEC NGN-2 NEPHELOMETER AUDIT PROCEDURES (IMPROVE PROTOCOL)
TYPE	STANDARD OPERATING PROCEDURE
NUMBER	4700
DATE	JANUARY 1995

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REVISION HISTORY			
REVISION NO.	CHANGE DESCRIPTION	DATE	AUTHORIZATIONS
1.0	Up-scale calibration using upgraded valve.	March 1995	
2.0	Changes to span gas settings / add type 2 system.	April 2004	

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1.0 PURPOSE AND APPLICABILITY

This standard operating procedure (SOP) describes the procedures for conducting a performance audit of an Optec NGN-2 nephelometer. The purpose of the audit is to assess the measurement process under normal operating conditions without any special preparation or adjustment of the system. The audit is used to:

- Ensure the integrity of the data, and
- Assess the data for accuracy.

The audit of an Optec NGN-2 nephelometer includes:

- Performing a zero and upscale calibration:
 - Using the existing station calibration system.
 - Using the audit calibration system.
- Comparing the audit calibration to the station calibration:
 - To assess the validity of operator-performed calibrations.
 - To assess how the instrument has changed since installation.

Nephelometers are typically audited at least once a year, but can be audited at any time. This standard operating procedure is intended for use by independent auditors who understand general instrument audit concepts and have their own audit equipment and audit documentation form(s).

2.0 RESPONSIBILITIES

2.1 PROJECT MANAGER

The project manager shall:

- Coordinate with the independent auditor regarding audit schedules, procedures, calibration constants, and required supplies.
- Review all audit results.
- Direct appropriate corrective action if indicated by the audit results.
- Review and approve any changes to audit procedures.

2.2 INDEPENDENT AUDITOR

The independent auditor shall:

- Perform all required audits.
- Document the audit results on the appropriate form(s).
- Forward audit results to the ARS data coordinator and other identified project personnel.

2.3 DATA COORDINATOR

The data coordinator shall:

- Enter the audit results into the quality assurance database.
- Coordinate and/or perform any corrective actions as indicated by the audit results.

2.4 SITE OPERATOR

The site operator shall assist the auditor.

3.0 REQUIRED EQUIPMENT AND MATERIALS

Two configurations of the internal span gas valve exist in operational Optec NGN-2 nephelometers: small orifice valve and large orifice valve. Span gas flow rates during calibrations or audits will vary depending on the valve configuration. Note that the nephelometers with the large orifice valve can be distinguished by a circular brass fitting with Allen screws attached at the span gas entry port. The large orifice system is the preferred configuration and nephelometers should be upgraded with this configuration if possible.

The following materials are required for audit upscale and zero calibrations:

- Audit Upscale Calibration System:
 - Calibration span gas (typically a 30 lb. non-refillable tank of DuPont SUVA-134a refrigerant)
 - A pressure regulator capable of providing tight regulation at low pressure (2 psi) and an adjustable flowmeter compatible and calibrated for use with the span gas. (Suggested regulator – Air Products MN E11-N510B). (Suggested flowmeter – Cole Parmer rotameter MN N014-96ST).
 - Calibration gas hoses and fittings to connect the tank, regulator, flowmeter, and nephelometer (Refer to Figure 3-1 for Type 1 systems and Figure 3-2 for Type 2 systems).

- Audit Zero Calibration System (2 options):

Option 1: Zero value determined with an independent zero air supply (preferred option)

- Zero air supply capable of providing at least 4 lpm of particle-free air at 2 psi
- Zero air supply hose (approximately 15 feet long)
- Nephelometer zero air filter assembly without the filter cartridge installed

Option 2: Zero value determined using the nephelometer's internal zero air system pump and tubing with an independent audit filter

- Nephelometer zero air filter assembly with audit filter cartridge (0.3 micron filter)

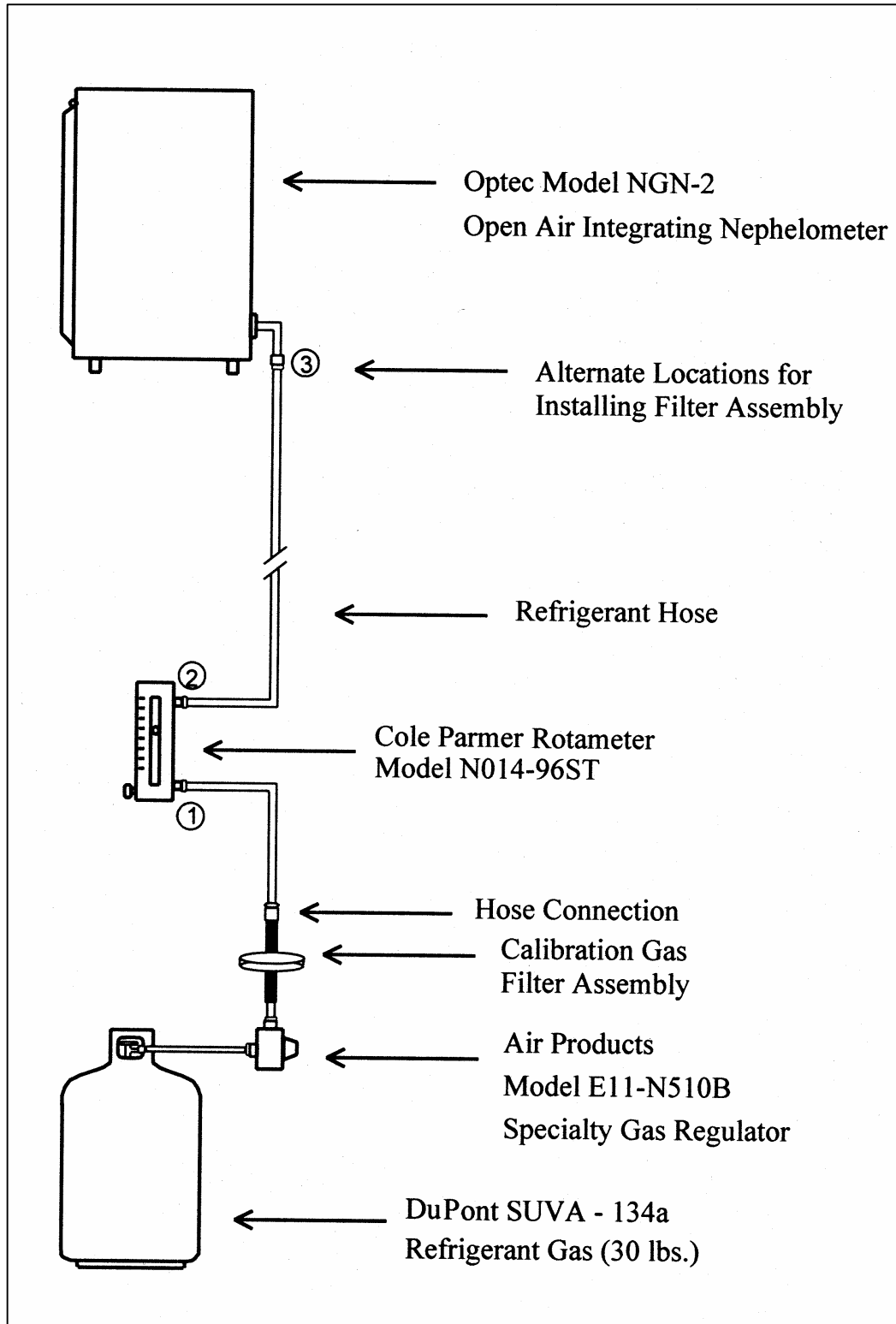


Figure 3-1. Manual Span Gas Calibration/Audit Configuration for the Optec NGN-2 Nephelometer – Type 1.

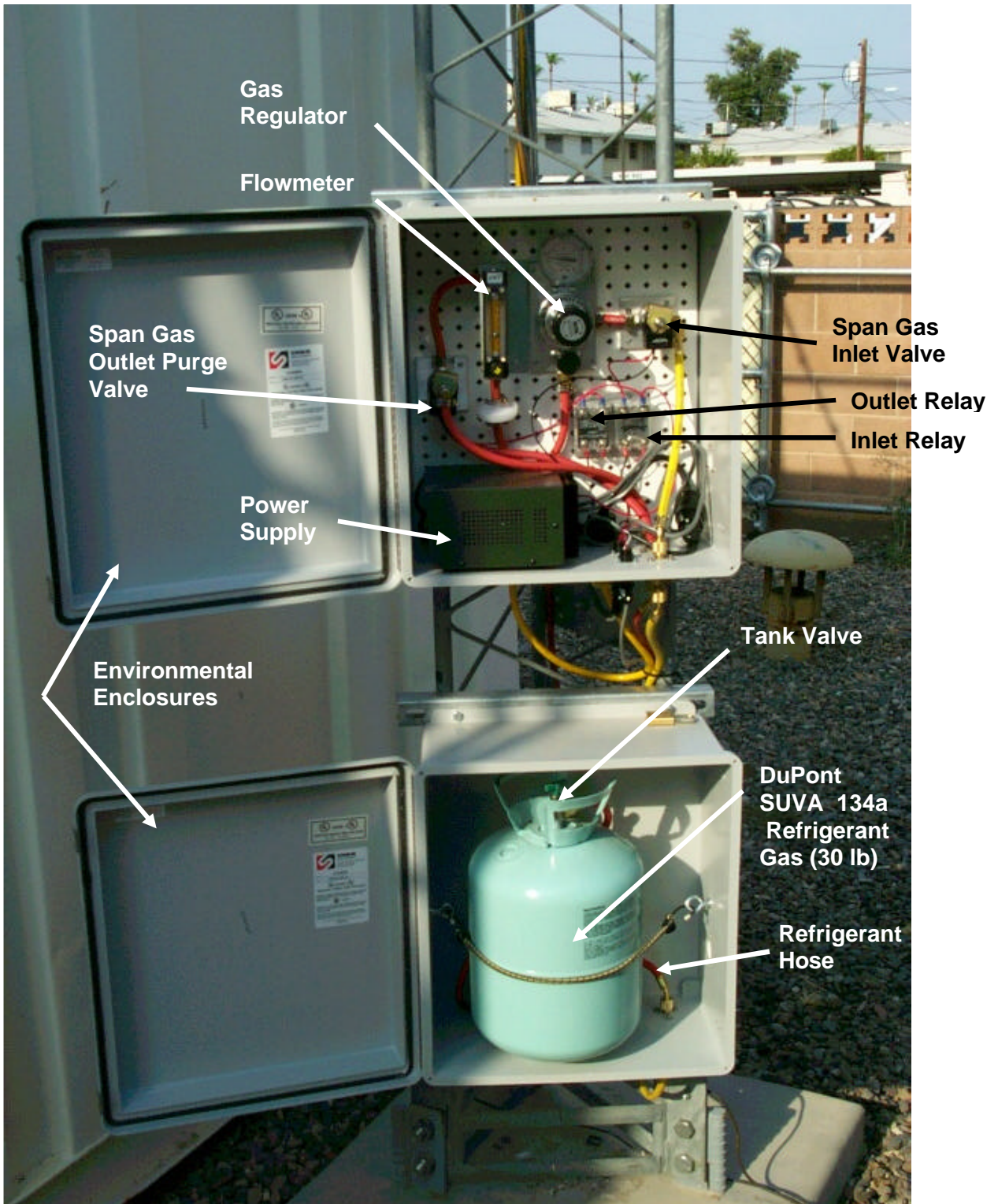


Figure 3-2. Automatic Span Gas Calibration System for the Optec NGN-2 Nephelometer – Type 2.

- TI 4200-2000, *Calibration of Optec NGN-2 Nephelometers – Type 1 (IMPROVE Protocol)*
- or -
- TI 4200-2005, *Calibration of Optec NGN-2 Nephelometers – Type 2 (IMPROVE Protocol)*
- Audit forms and pen or pencil
- Flat-blade screwdriver and pliers for removing the station calibration gas hose from the nephelometer calibration inlet.
- Lint-free cloth for use during the nephelometer inspection.

4.0 METHODS

This section describes the nephelometer audit, and includes five (5) major subsections:

- 4.1 Pre-Inspection Audit Calibration
- 4.2 Nephelometer Inspection
- 4.3 Post-Inspection Audit Calibration
- 4.4 Operational Configuration Verification
- 4.5 Audit Results Report

Information regarding datalogger access for viewing nephelometer outputs is included in TI 4200-2000, *Calibration of Optec NGN-2 Nephelometers – Type 1 (IMPROVE Protocol)*, and TI 4200-2005, *Calibration of Optec NGN-2 Nephelometers – Type 2 (IMPROVE Protocol)*.

4.1 PRE-INSPECTION AUDIT CALIBRATION

The pre-inspection audit calibration is performed before physical examinations of the nephelometer clean air filter and light trap are performed. The pre-inspection calibration represents the state of the instrument upon arrival and includes the following:

- Nephelometer physical condition check.
- Nephelometer calibration using station calibration system.
- Nephelometer calibration using audit calibration system.

4.1.1 Physical Condition Check

Verify that the nephelometer is in good physical condition before attempting to check the calibration. Verify the following:

- Proper operation of the power supply.
- Unobstructed nephelometer door (i.e., free of obstructions such as ice or packed snow).

4.1.2 Calibration Using Station Calibration System

The calibration procedures using the station calibration system (nephelometer zero air filter and station calibration gas) are identical to those performed at regular intervals by the site operator as described in TI 4200-2000, *Calibration of Optec NGN-2 Nephelometers – Type 1 (IMPROVE Protocol)* and TI 4200-2005, *Calibration of Optec NGN-2 Nephelometers – Type 2 (IMPROVE Protocol)*. The procedures include:

POWER-ON SELF TEST (POST) The nephelometer performs a Power-On Self Test (POST) followed by an automatic zero and span check when it is powered up. The POST sequence is as follows:

- Door closes
- Door opens
- Lamp turns on
- Fan turns on and off
- Internal solenoid turns on and off
- Clean air pump turns on and off
- Internal span gas valve turns on and off
- Fan turns on, solenoid turns on
- One-minute sample reading is taken
- Fan and solenoid turn off
- Pump turns on and door closes

UPSCALE CALIBRATION Following the POST, the upscale/zero calibration sequence begins with a 20-minute upscale calibration. The upscale calibration requires that a source of regulated calibration gas (typically SUVA 134a) be supplied to the nephelometer during the calibration process. The following procedures are used to perform the upscale calibration:

- Connect the calibration gas hose from the nephelometer to the output connector (top) of the flowmeter.
- Connect the flowmeter input hose (bottom) to the calibration gas regulator output connector.
- Open the calibration gas tank valve fully, then turn the valve back 1/4 to 1/2 turn.
- Reset the nephelometer by interrupting power to the nephelometer for five seconds.
- Observe the Power-On Self Test (POST). Document the results of the POST. Approximately 30 seconds after the door closes, the span gas valve will open. The flowmeter settings can only be adjusted while the valve is open.
- Adjust the pressure regulator control valve to provide 4 psi to the nephelometer.
- Adjust the flowmeter as follows:

UPSCALE CALIBRATION (continued)

For large orifice valves, adjust the flowmeter to 2 lpm (corrected) of span gas. Use settings of approximately 20 mm when using the suggested Cole Parmer rotameter. Check the individual flowmeter calibration for the actual value.

For small orifice valves, adjust the flowmeter to greater than 2 lpm (4 lpm optimal). If the flow cannot be adjusted to greater than 2 lpm, the valve is suspect and should be replaced or upgraded to a larger orifice configuration.

- Wait 20 minutes for the upscale calibration to complete. At the end of the upscale calibration, the nephelometer door will open. Record the results of the upscale calibration from the following nephelometer outputs:
 - Upscale calibration (counts) and related parameters on the serial channel
 - Upscale calibration value (1 mVDC = 1 count) on analog channel 1
- TURN THE CALIBRATION GAS TANK VALVE COMPLETELY OFF.
- Disconnect the calibration gas hose from the flowmeter. Place hose caps or plugs on the open ends of the hose and flowmeter.
- The nephelometer door will stay open for one minute to exhaust the calibration gas. After the minute, the door will close and the zero calibration will begin.

ZERO CALIBRATION

Following the one-minute calibration gas purge, the 15-minute zero calibration begins. The nephelometer circulates air in the measurement chamber through the 0.3 micron filter to perform the zero calibration. The following procedures describe the zero calibration:

- Wait 15 minutes for the zero check to complete. At the end of the zero calibration, the nephelometer door will open and the nephelometer will begin taking ambient readings. Record the results of the zero calibration from the following nephelometer outputs:
 - Zero calibration (counts) and related parameters on the serial channel
 - Zero calibration (1 mVDC = 1 count) on analog channel 1

The nephelometer will begin operating in ambient mode upon completion of the zero and span check.

4.1.3 Calibration Using Audit Calibration System

The audit calibrations should be performed with an independent source of calibration gas to yield an upscale value and one of two options to yield a zero air value:

- Option 1: Zero value determined with an independent zero air supply using the complete calibration method (preferred option) (refer to TI 4200-2000, *Calibration of Optec NGN-2 Nephelometers – Type 1* or TI 4200-2005, *Calibration of Optec NGN-2 Nephelometers – Type 2 (IMPROVE Protocol)*).
- Option 2: Zero value determined using the nephelometer's internal zero air system pump and tubing with an independent audit filter.

The audit procedures are the same as those detailed in Section 4.1.2, Calibration Using Station Calibration System, except for the following:

- OPTION 1 The zero value is determined with an independent zero air supply.
- Replace the nephelometer zero air filter assembly with the empty audit assembly.
 - Disconnect the station upscale calibration system from the nephelometer calibration gas inlet.
 - Attach the audit upscale calibration system to the nephelometer calibration gas inlet.
 - Perform the upscale calibration as detailed above using the audit upscale calibration system.
 - Record the results of the upscale calibration.
 - Disconnect the audit upscale calibration system from the nephelometer calibration gas inlet.
 - Connect the audit zero air calibration system to the nephelometer calibration gas inlet by resetting the nephelometer. This will allow the valve to open, letting the zero air into the chamber.
 - Perform the zero calibration as detailed above using the audit zero air system.
 - Record the results of the audit zero calibration.
 - Disconnect the audit zero calibration system from the nephelometer calibration gas inlet.
- OPTION 2 The zero value is determined using the nephelometer's internal zero air system pump and tubing with an independent audit filter. Note that this option only isolates the zero air filter. Problems with the nephelometer zero air pump or tubing may not be detected using this approach.

- OPTION 2 (continued)
- Replace the nephelometer zero air filter assembly with an audit filter assembly.
 - Disconnect the station upscale calibration system from the nephelometer calibration gas inlet.
 - Attach the audit upscale calibration system to the nephelometer calibration gas inlet.
 - Perform the upscale calibration as detailed above using the audit upscale calibration system.
 - Record the results of the upscale calibration.
 - Perform the zero calibration as detailed above using the audit zero air system.
 - Record the results of the audit zero calibration.
 - Disconnect the audit upscale calibration system from the nephelometer calibration gas inlet.

4.2 NEPHELOMETER INSPECTION

The nephelometer inspection verifies that the instrument is capable of making an ambient reading and that the nephelometer components necessary for correct operation are not contaminated. Most of the nephelometer mechanical functions are tested during the Power-On Self Test (POST) described above. The nephelometer calibration can be affected by contamination in the light trap and clean air filter. The nephelometer inspection includes the following procedures:

- CHECK INLET SCREEN Check the nephelometer inlet screen for dirt and debris that can impede the flow of air into the sample chamber.
- CHECK FAN OUTLET Check the sample fan outlet screen for debris that can impede the flow of sample air through the nephelometer.
- CHECK LIGHT TRAP The light trap can collect water and other debris that can affect the nephelometer. Check the light trap for contamination as follows:
- Remove the light trap by unscrewing it from the bottom of the nephelometer.
 - Examine the light trap for water or other contamination. Note any contamination.
 - If necessary, remove water and other debris and gently clean and dry the inside of the light trap with a lint-free cloth.
 - Replace the light trap.
- CHECK CLEAN AIR FILTER The clean air filter assembly can collect water during severe weather. The filter cartridge can be contaminated by water trapped in the assembly. Check the clean air filter assembly as follows:

**CHECK CLEAN AIR
FILTER (continued)**

- Remove the clean air filter assembly from the nephelometer by turning the entire assembly counter-clockwise.
- Remove the cover from the assembly by turning the cover counter-clockwise, or by loosening the knurled knobs (depending upon the style of assembly).
- Remove the filter cartridge from the assembly by turning the cartridge counter-clockwise, or by removing the paper filter.
- Examine the clean air assembly and filter cartridge for water or other contamination. Note any contamination.
- If necessary, remove water and other debris and gently clean the inside of the clean air assembly with a lint-free cloth. Replace the filter cartridge or paper filter if it is contaminated.
- Replace the clean air assembly in the reverse order it was removed.

4.3 POST-INSPECTION AUDIT CALIBRATION

The nephelometer post-inspection audit calibration is performed following inspection of the nephelometer clean air filter or light trap. The post-inspection audit calibration represents the state of the instrument after the audit is complete. The calibration is identical to the pre-inspection audit calibration described in Section 4.1.2, Calibration Using Station Calibration System.

4.4 OPERATIONAL CONFIGURATION VERIFICATION

Following the audit, verify that all nephelometer components are in their operational configuration and that the nephelometer is in ambient mode. Specifically:

- Reconnect the station span gas hose to the nephelometer span gas port.
- Verify that the station span gas tank valve is turned completely off.
- Verify that the span gas hoses are disconnected at the flowmeter.
- Verify that the operational clean air filter assembly is in place.
- Verify that the nephelometer is operating in the correct ambient mode.
- Verify that all datalogging systems are in their standard configuration.

4.5 AUDIT RESULTS REPORT

Nephelometer audit results are reported by:

- Comparing the nephelometer's audit zero and upscale calibrations to the station zero and upscale calibrations to verify correct instrument operation.

- Comparing the nephelometer’s audit zero and span (span = upscale – zero) calibration to the installation zero and span calibration values to quantify how the instrument has changed since installation.
- Fully describing any inconsistencies noted during physical inspection of the system.

4.5.1 Nephelometer Audit Calibration vs. Station Calibration

The nephelometer audit and station zero and upscale calibration values are compared to verify correct instrument operation. Tables 4-1 and 4-2 show examples of nephelometer audit and station calibration results. The nephelometer audit results indicate the instrument is operating correctly when:

- The percent difference between the audit and station calibration values is less than 15%.
- The absolute difference between the audit and station calibration values is less than 5 counts.
- Span gas flow rates are greater than 2 lpm (4 lpm optimal). If the span gas flow is less than 2 lpm the audit results are suspect because the nephelometer chamber may not have filled properly with span gas.

Table 4-1

Example Nephelometer Audit Zero Calibration vs.
Station Zero Calibration Comparison

Calibration	Station Zero Calibration (counts)	Audit Zero Calibration (counts)	Absolute Difference (counts)	Percent Difference [Audit-Station] Station
Pre-inspection	55	54	1	1.8%
Post-inspection	55	53	2	3.6%

Table 4-2

Example Nephelometer Audit Upscale Calibration vs.
Station Upscale Calibration Comparison

Calibration	Station Reference Upscale Span (counts)	Audit Reference Upscale Span (counts)	Absolute Difference (counts)	Percent Difference [Audit-Station] Station
Pre-inspection	130	131	1	0.7%
Post-inspection	126	127	1	0.8%

4.5.2 Nephelometer Audit Calibration vs. Installation Calibration

The nephelometer audit span calibration (difference between the audit upscale and zero calibrations) is compared to the installation span calibration to quantify how the instrument has changed since installation. The installation calibration values may be obtained from Air Resource Specialists, Inc. Table 4-3 shows an example nephelometer audit and installation calibration comparison. The comparison indicates the instrument is operating correctly when the percent difference between the audit and initial span calibrations is less than 15%.

Table 4-3

Example Nephelometer Audit Span Calibration vs.
Installation Span Calibration

Calibration	Audit Span Calibration (Upscale-Zero) (counts)	Installation Span Calibration (Upscale-Zero) (counts)	Percent Difference [Audit-Installation] Installation
Initial	131-54=77	107-34=73	5.5%
Final	127-53=74	107-34=73	1.4%

4.5.3 Description of Physical Conditions

The audit report should include a complete description of any inconsistencies notes during physical inspection of the nephelometer that could affect the performance of the system.

4.5.4 Distribution of Audit Results

One copy of the audit results should be mailed or faxed to ARS and a second copy should be mailed to the project sponsors or other contract designated project personnel. If major problems are noted, the auditor should call ARS as soon after the audit as possible so that corrective actions can be initiated. The distribution of additional audit reports will depend on individual network monitoring plans.