Air Pollution Control Division

Technical Services Program

APPENDIX GM8

Standard Operating Procedure for the OPTEC NGN-2 Nephelometer

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1 SCOPE AND APPLICABILITY

1.1 Introduction

Visibility is unique among air pollution effects in that it involves human perception and judgment. It has been described as the maximum distance that an object can be perceived against the background sky. Visibility also refers to the clarity with which the form and texture of distant, middle and near details can be seen as well as the sense of the trueness of their apparent coloration. As a result, measures of visibility serve as surrogates of human perception. There are several ways to measure visibility but none of them tell the whole story or completely measure visibility as human beings experience it.

The Colorado Air Quality Control Commission established a visibility standard in 1990 for the Front Range cities from Fort Collins to Colorado Springs. The standard, an atmospheric extinction of 0.076 per kilometer (using a transmissometer), was based on the public's definition of unacceptable amounts of haze as judged from slides of different haze levels taken in the Denver area. At the standard, 7.6 percent of the light in a kilometer of air is blocked. The standard applies from 8 a.m. to 4 p.m. each day, during those hours when the relative humidity is less than 70 percent. The standard is evaluated from 12:00 p.m. to 4:00 p.m. with the first four hour average accounting for the time period 8:00 a.m. to 12:00p.m.. Visibility, along with meteorology and concentrations of other pollutants for which National Ambient Air Quality Standards exist, is used to determine the need for mandatory wood burning restrictions and voluntary driving restrictions.

There is no quantitative visibility standard for Colorado's pristine and scenic rural areas. However, in the 1977 amendments to the Federal Clean Air Act, Congress added Section 169a and established a national visibility goal that created a qualitative standard of "the prevention of any future and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from manmade air pollution". The implementation of Section 169a has led to federal requirements to protect visual air quality in large national parks and wilderness areas. Colorado has 12 Class I areas. Federal and state law prohibits visibility impairment in national parks and wildernesses due to large stationary sources of air pollution.

Visual air quality is an element of public welfare. Specifically, it is an important aesthetic, natural and economic resource of the state of Colorado. The worth of visibility is difficult to measure; yet good visibility is something that people undeniably value. Impaired visibility can affect the enjoyment of a recreational visit to a scenic mountain area. Similarly, people prefer to have clear views from their homes and offices. These concerns are often reflected in residential property values and office rents. Any loss in visual air quality may contribute to corresponding losses in tourism and usually make an area less attractive to residents, potential newcomers and industry.

There is increasing information that shows a correlation between ambient concentrations of particulate matter and respiratory illnesses. Some researchers believe this link may be strongest with concentrations of fine particles, which also contribute to visibility impairment. In July 1997, the EPA developed a National Ambient Air Quality Standard for particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). Any control strategies to lower ambient concentrations of fine particulate matter for health reasons will also improve visibility.

The cause of visibility impairment in Colorado is most often fine particles in the 0.1 to 2.5 micrometer size range (one micrometer is a millionth of a meter). Light passing from a vista to an observer is either scattered away from the sight path or absorbed by the atmospheric fine particulate. Sunlight entering the pollution cloud may be scattered into the sight path adding brightness to the view and making it difficult to see elements of the vista. Sulfate, nitrate, elemental carbon and organic carbon are the types of particulate matter most effective at scattering and/or absorbing light. The man-made sources of these particulates include wood burning, electric power generation, industrial combustion of coal or oil, and emissions from cars, trucks and buses.

There are several ways to measure visibility. Currently, the Division uses camera systems to provide qualitative visual documentation of a view. Transmissometers and nephelometers are used to measure the atmosphere's ability to attenuate light quantitatively.

A visibility site was installed in Denver in late 1990 using a long path transmissometer. Visibility in the downtown area is monitored using a receiver located near Cheesman Park and a transmitter located on the roof of a downtown building. This instrument directly measures light extinction, which is proportional to the ability of atmospheric particles and gases to attenuate image-forming light as it travels from an object to an observer. The visibility standard is stated in units of atmospheric extinction. Days when visibility is affected by rain, snow or high relative humidity are termed "excluded" and are not counted as violations of the visibility standard. A nephelometer was installed at the transmissometer receiver location in late 2000 to examine correlations between instrument types for future visibility studies. In September 1993, a transmissometer and nephelometer were purchased by the city of Fort Collins to monitor visibility.

1.2 Method Overview

The Optec NGN-2 uses a unique integrating open-air design that allows accurate measurement of the scattering extinction coefficient of ambient air. Because of the open-air design, relative humidity and temperature of the air sample are essentially unchanged, thus the aerosol is negligibly modified when brought into the optical measuring chamber. Extinction due to scatter can be accurately measured from Rayleigh to 100% saturated fog conditions.

1.3 Format and Purpose

The sequence of topics covered in this method follows 2007 EPA guidance on preparing standard operating procedures (SOPs). This method was also written to help field operators understand why, not just how, key procedures are performed (US EPA, 2007).

2 SUMMARY OF METHOD

Integrating nephelometers estimate the atmospheric scattering coefficient by directly measuring the light scattered by aerosols and gases in a sampled air volume. Scattered radiation from an illumination source is integrated over a large range of scattering angles, in a defined band of visible wavelengths. Because the total light scattered out of a path is the same as the reduction of light along a path due to scattering, the integrating nephelometer gives a direct estimate of back scatter.

The Optec NGN-2 is a self-contained unit that is mounted external to a shelter or building. An environmentally-sealed compartment in the Optec NGN-2 contains the singleboard computer, lamp assembly, motors, pumps, and electronics. The singleboard computer controls all operating functions of the NGN-2 which include: scattered light measurement, clean-air zero calibration, span gas calibration, moisture detection to close the optical chamber door during rain or snow conditions, optical chamber temperature measurement, initial data reduction, various error detection schemes, and diagnostic tests.

3 DEFINITIONS

The CDPHE/APCD/TSP QAPP contains an appendix of acronyms and definitions. Any commonly used shorthand designations for items such as the sponsoring organization, monitoring site, and the geographical area will be defined and included in this SOP or in the QAPP Appendix P2.

4 HEALTH AND SAFETY WARNINGS

<u>Electrical Hazards</u>

1. Always use a ground wire on all instruments.

2. 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 110 volt AC power supply. Refer to the manufacturer's instruction manual and know the precise locations of these components before working on the instrument

3. Avoid electrical contact with jewelry. Remove rings, watches, bracelets, and necklaces to prevent electrical burns.

4. Always unplug the analyzer whenever possible when servicing or replacing parts.

5 CAUTIONS

To prevent damage to the equipment, the following precautions should be taken:

1. Inspect the system regularly for structural integrity and weather tightness.

2. Keep the interior of the shelters/enclosures clean.

6 INTERFERENCES

The only known gaseous interference for this method is water vapor. Physical interferences can be caused by dirt on the optical window inside the instrument or contamination of the light trap.

7 PERSONNEL QUALIFICATIONS

General Personnel Qualifications are discussed in the CDPHE/APCD/TSP QAPP main body.

8 APPARATUS AND MATERIALS

8.1 Optec NGN-2 Integrating Nephelometer

"The NGN-2 contains nearly all of the equipment needed for an integrating nephelometer in one environmentally sealed enclosure which measures 10.7 x 8.2 x 16.5 inches and weighs 27 lbs. Only a source of low voltage DC power, span gas cylinder and data logging means are needed to complete a working instrument. Usually, the NGN-2 mounts from the top under some sort of protective roof such as a building overhang. The clean air filter module, access door for lamp changing, data/power cable connector and span gas inlet are mounted on one side of the unit for easy accessibility and maintenance.

The interior of the instrument is separated into three areas - measuring chamber, exhaust/pump chamber and the electronics/computer chamber.

Separated by a double wall, the optical measuring chamber is completely sealed from the rest of the enclosure to prevent either air or heat from the internal parts of the instrument from contaminating the measuring process. A large air inlet with motorized door allows ambient air to flow unmodified a short distance to the viewing volume. To prevent unwanted insects and large floating masses from entering the chamber, a 24 mesh (24 wires to the inch) stainless screen covers the inlet window. One side of the measuring chamber wall is easily removed to allow access to the chamber for cleaning and service. The exhaust fan mounted in the exhaust/pump chamber creates a strong negative pressure behind the rear wall of the measuring chamber which is perforated. This causes the ambient air to flow through the measuring chamber without much turbulence.

To allow the span gas to fill the chamber and the overflow to vent outside, a small plastic tube is coupled from the top of the chamber to the exhaust/pump chamber. The heavier than air span gas will fill the bottom of the chamber first and force air out through the top vent tube.

Separate and sealed from the electronics/computer chamber, the exhaust/pump chamber houses the lamp cooling heat sink, clean air pump, exhaust port door, exhaust fan and span gas solenoid activated inlet valve. The exhaust air from the measuring chamber passes through the exhaust/pump chamber before being expelled. In the process, this air passes through a finned heat sink which helps to reduce the internal heat of the instrument. A low voltage diaphragm pump is used to circulate the measuring chamber air at a rate of approximately 2 liters/minute. On the positive pressure side of the pump, tubing directs the air flow to the externally mounted clean air filter which mounts on the outside rear panel much like an automobile oil filter. A solenoid activated door allows the measuring chamber exhaust port to be completely sealed during calibration measurements. The span gas inlet uses a 1/8" barbed tubing insert for coupling to the compressed gas cylinder which should be pressure regulated to 10 psi. A solenoid activated valve allows the span gas to fill the measuring chamber on computer command.

The electronics/computer chamber contains the LED lamp, scattered light detector/electrometer, computer, interface board and door open/close motor." (Optec, Inc, 1998)

In June 2009, the Colorado's NGN-2 analyzer was upgraded from an incandescent light source to an LED light source. This modification was to reduce the maintenance required with incandescent bulbs and to decrease the temperature of the analyzing chamber that is produced by an incandescent bulb. "Even though the NGN-2 was designed to minimally heat the ambient aerosol as it passed through the optical scattering chamber, the use of an incandescent light source results in a slight heating of approximately 1-2 ºC. At high ambient relative humidity (>80%), an increase in temperature in the chamber as small as 1ºC will result in an 8-10% lowering of the relative humidity in the chamber. If highly hydroscopic aerosols are present (Ammonium Sulfate or Nitrate) and ambient relative humidity is high, the aerosol scattering measured by the nephelometer can be nearly 100% less than the actual ambient scattering. In addition the use of an incandescent light requires a mechanical chopping system to modulate the light source and the light source has a short life span resulting in frequent operator site visits to change out the lamp." (Molenar & Persha)

"A geared 12 volt DC motor is used to open and shut the inlet port. The torque of this motor is governed to close the door securely without providing too much torque which could be dangerous to trapped fingers. About 4 seconds is required for the motor to close or open the door. The door is opened to an approximate 30° angle from the front panel of the NGN-2. To conserve power and prevent internal heat from building up, the voltage to the motor is turned off after 10 seconds of operation.

Connected to the computer board, the interface control circuit board provides the necessary interface between the computer and the various control/ measurement functions of the NGN-2.

The 13.8 volt DC input power is first routed to the interface board where current, voltage and transient protection devices provide safe power for the rest of the instrument. On board regulators provide +5, +15 and -15 volt power to the various digital and analog circuits. Maximum continuous current required during operation is approximately 4.5 amps.

Either solid state HEXFET devices, or mechanical relay switch is connected to the I/O ports of the computer control the electromechanical devices within the instrument. All devices are connected to the 13.8 volt DC input power and are turned on when the circuit is completed to the power return through the switch." (Optec, Inc, 1998)

8.2 Data Acquisition System

The APCD employs four different models of onsite, data acquisition system equipment (DAS) in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, ESC 8864 data logger and the Agilaire 8872 data logger. The 8816 model is the oldest type of data logger in the network and is a predecessor to the 8832, 8864 and 8872 data loggers. The following are descriptions of these data loggers.

ESC 8816 Data Logger

The ESC Model 8816 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8816 is designed around an expansion bus that gives the user great flexibility in configuring the unit with a combination of analog and serial input and output (I/O) types.

For more details, refer to APCD's QAPP Appnedix D1, Datalogger and Central SOP or the individual operator manuals (Environmental Systems Corporation, 2001).

ESC 8832 Data Logger

The ESC Model 8832 data logger is currently used for CDPHE's sole nephelometer, however, other models may be used as deemed appropriate. The ESC Model 8832 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8832 is designed around an expansion bus that gives the user great flexibility in configuring the unit with almost any combination of input and output types. It is the successor to the 8816 data logger and is more robust in numerous areas. Of significance is expanded memory, faster processing speeds, faster communication speeds, remote Ethernet communications and polling and Modbus enabled communications with peripheral devices.

For more details, refer to APCD's QAPP Appendix D1, Datalogger and Central SOP or the individual operator manuals (Environmental Systems Corporation, 2006).

ESC 8864 Data Logger

To Be Developed

Agilaire 8872 Data Logger

The Model 8872 is a Windows-based data logger, a departure from the earlier 8816 / 8832 embedded systems designs. The 8872 includes a number of hardware and software features to ensure that the device matches the field reliability of the 8832, while offering the convenience of a Windows-based platform and integration with Agilaire's AirVision software.

The core of the 8872 is a fan-less PC, typically 2 GB of RAM. The device can be equipped with a 160 GB standard hard drive or, more commonly, a 64 GB solid state flash drive (SSD). For all digital versions of the 8872, the remainder of the enclosure simply provides convenient universal serial bus (USB), serial, and VGA I/O connections in a standard 3U rack mount enclosure, a form factor similar to the 8816 / 8832 family. However, the 8872 also supports traditional analog/discrete I/O via a variety of internal I/O modules and a protection / connector board to provide familiar detachable terminal block connections to the back. The layout of the connections is designed to make the unit easy to use as a 'drop in' replacement for an 8816 or 8832. (Agilaire, 2013)

For more details, refer to APCD's QAPP Appendix D1, Data Logger and Central SOP or the individual operator manuals.

8.3 Wiring, Tubing and Fittings

The nephelometer uses a span gas system to perform automatic span and zero calibration checks and manual span and zero calibration checks during scheduled site visits. The system, illustrated in Figure 1 includes the following components:

- Span gas regulator
- Span gas rotameter
- Span gas inlet and outlet valves
- Span inlet and outlet Relays

- Span gas hoses
- SUVA 134A span gas tank (not shown)

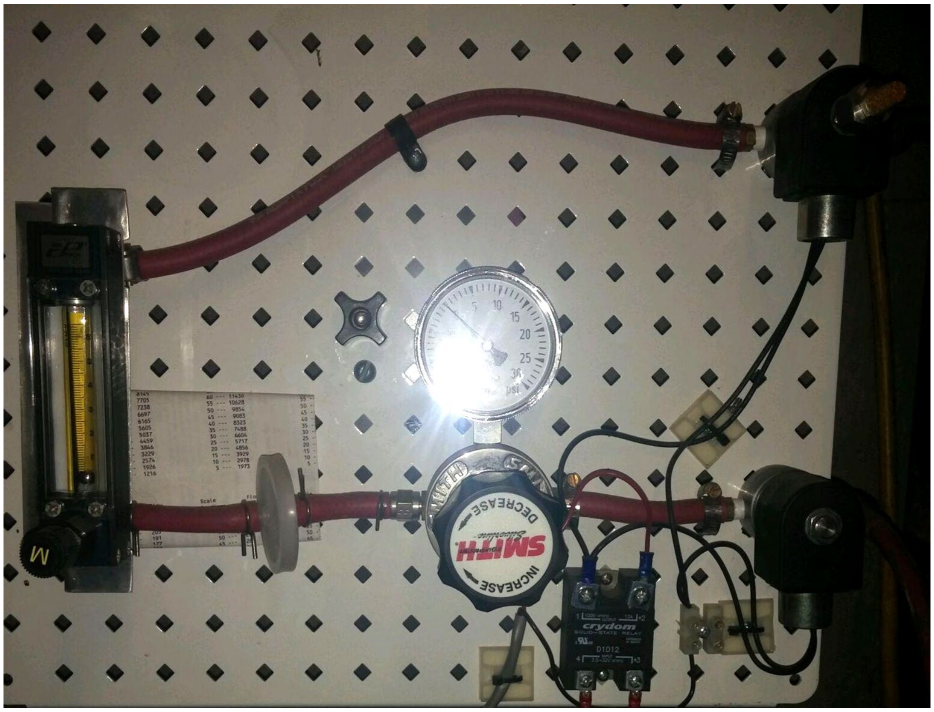

Figure 1. Nephelometer Span Gas System

Using a relay, power to the nephelometer is disconnected. After several seconds it is restored and by default the nephelometer will enter a span / zero mode. Span gas is introduced to the nephelometer during the span mode. The result from both the span and zero modes are stored in the data logger and used to calculate real-time backscatter.

The relay (not shown in Figure 1) is wired to wall power and the data logger. It uses a standard electrical wall power outlet to connect to the nephelometer. Additional wiring runs between the data logger control output (DO) board and the inlet and outlet solenoids.

Refrigerant tubing is used between the standard bottle and all solenoids up to the nephelometer.

8.4 Reagents and Standards

The span gas for the nephelometer is SUVA 134a refrigerant. When the span gas is connected to the span gas system the valve should be open to approximately half a full turn away from full open. Field experience has shown that a fully open valve on a Suva canister is prone to leaking so care should be taken to close the valve slightly back from fully opened.

8.5 Spare Parts and Incidental Supplies

SUVA 134a refrigerant is light and prone to leaking from the bottle. A spare bottle should be kept available. The nephelometer is the only system operated by the APCD that uses refrigerant tubing. All other components in the span gas system are common to other systems used by the APCD.

Since Air Resource Specialists is currently contracted to maintain calibration and non-routine maintenance on the nephelometer, they also maintain spare parts.

9 CALIBRATION

The Optec NGN-2 nephelometer requires an annual calibration. The APCD does not directly perform the calibration, but contracts this function out to ARS who has the facilities to ensure all operational and documentation elements are up to specifications. ARS will remove the nephelometer during the annual audit of the transmissometer and advise APCD when the nephelometer can be picked up and installed at the DESCI location. Once installed the data logger math constants will have to be updated with the new numbers from the audit sheet. Audit documentation regarding calibrations are available upon request from ARS.

ARS will initially set up a date to conduct an audit based on a forecast of weather and visibility. The clearest visibility conditions, calm winds, and moderate temperatures are best for equipment and personnel.

To enter constants into the data logger, from the main screen select C>K. K01 is the offset value and K02 is the span value. Edit the values as appropriate, pressing enter saves the value. Escape back to the main screen.

10 OPERATION AND MAINTENANCE

10.1 Introduction and Description of Monitoring

In late 2000 the Colorado Department of Health, Air Pollution Control Division, Technical Services Program (TSP) installed an Optec NGN-2 nephelometer in Denver on the roof of the DESCI building near Cheesman Park. A nephelometer is also located in Fort Collins, but is operated by an independent contractor.

Environmental Systems Corporation (ESC) data loggers 8816 and 8832 are used for data collection and as operator/instrument control interface. All nephelometer data are collected from the ESC loggers and collected by a central computer conforming to EPA guidance for automated continuous data collection.

One technical manual and one set of contractor-written SOP’s, in addition to this SOP, give the operational details and requirements for the system. The Optec NGN-2 manufacturer's instruction manual covers all necessary procedures and controls for successful operation (Optec, Inc, 1998). This manual is available at the receiver location and at the central offices of TSP. The contractor-written SOP’s for the Optec NGN-2 for the IMPROVE network are available for reference at the central offices of TSP (Air Resource Specialist, Inc, 1993 - 2004). For the ESC 8816 or 8832, the manufacturer's technical manual provides all operating instructions and system keyboard command descriptions. This manual is also available at each site and at the central offices of TSP. Refer to these manuals regarding any aspect of operation of these systems.

The nephelometer site is assigned to a specific TSP employee (electronic specialist) qualified by formal training, experience, TSP on-the-job training, and contractor training. This employee is responsible for all aspects of assigned site monitoring operation, including but not limited to maintenance, repair, documentation updates, logs, etc. In addition to keeping the site operational with a minimum of downtime, any of the senior level electronic specialists may be called upon to accept the responsibility for training of new TSP employees and contracted operators.

Experience with the ESC data logging and retrieval system since 1988 has shown a level of accuracy and reliability far superior to the mechanical strip chart recorders in use at the time. Digital data chart recorders provide a backup of data by storing it on memory cartridges similar to the primary ESC data acquisition system. As a result TSP considers the data acquired by the ESC system when properly validated to be the primary data source with the previous paper strip charts and current data charts as an emergency data backup system and only one of several data validation and trouble-shooting tools.

10.2 Equipment and Supplies

For a complete listing of supplies and equipment please see Section 8 of this standard operating procedure.

10.3 Logs and Forms

All actions at the site, scheduled and non-scheduled, are logged on forms. These forms are collected monthly, reviewed and filed together in monthly folders in a maintenance files cabinet. Three complete calendar years of forms are readily available on site. The intent of these forms is to be able to recreate events and actions taken well after the fact. Examples of these forms can be found at the end of this SOP. In addition to hand entered forms, field operators are required to enter abbreviated field notes into the data logger as a "Message to Central"

The forms in routine use are:

- Figure 3. Nephelometer Log Form
- Figure 4. Maintenance Report Form

10.4 General Operations

This section provides an overview of scheduled inspection and preventive maintenance procedures. To minimize downtime and ensure data quality, preventive maintenance is to be performed on all gaseous monitors in the network according to a schedule established by TSP, using the inspection criteria documented in this chapter. Below is a general summary of the types of maintenance check performed.

Data from each site is evaluated daily. There is a daily morning review of overnight Quality Control checks, data validity flags, data completeness, data representativeness, logger messages, and shelter environmental status to determine if an immediate site visit is needed. Data loggers are contacted as needed to evaluate and configure instrument systems.

The Weekly inspection is performed once each calendar week and as needed.

The Zero/Span cycles are automated and controlled by the data logger, but may be done manually at any time, and are required to be performed once every two weeks.

The Monthly inspection is performed at the beginning of each calendar month.

Upon completion of an inspection, log entries onto the MONTHLY VISIBILITY NEPHELOMETER LOG and into a "message to central" are required. Enter all tasks performed, any malfunctions, or other actions needed, discovered during the inspection.

All scheduled checks are minimum requirements. Individual site circumstances may dictate a more frequent preventative maintenance schedule. Monthly, quarterly, and semi-annual inspections are always conducted by TSP-approved staff that has the training or experience to reliably perform the required checks or maintenance.

By contract agreement, it is the responsibility of all contracted site operators to notify TSP of any unusual instrument/equipment performance, possible malfunction, or outright malfunction, and action taken, if any. TSP in turn will take the appropriate action as soon as workload and priorities permit. TSP maintenance personnel will summarize work performed in a "message to central" for all non-scheduled maintenance activities.

10.5 Routine Preventative Maintenance and Scheduled Activities

Preventive maintenance inspections and services should follow the recommended intervals by the EPA, the manufacturer, or as determined by actual experience. If preventive maintenance services are not being done according to the minimum guidelines of the manufacturer as set forth in this standard operating procedure, the TSP may jeopardize any claim to a manufacturer's warranty and may jeopardize the validity of the data collected. The preventive maintenance inspections are scheduled to provide an opportunity to detect and repair damage or wear conditions before major repairs are necessary and the loss of data occurs. The documentation of these activities is essential for quality control tracking and for compliance with EPA's Quality Systems methods. Site and analyzer log sheets along with "messages to central" are part of the official record and the documentation of maintenance or observations are to be written clearly and concisely and in accordance of good laboratory practices.

Table 1. Routine Preventative Maintenance and Schedule Activities

Procedure or Resource	Description
Every Onsite Visit	
	Check station for general condition and proper operation of heating, air conditioning, lighting, and sample pumps.
	Remove trash when waste receptacles are full. Remove from shelter all odorous trash, such as leftover food and food packaging.
10.6.7	Leave a "message to central" and a site log entry summarizing purpose of visit and a summary of all maintenance performed
Weekly Inspection / Maintenance	
	Perform Every Onsite Visit inspections as defined above.
	Perform general housekeeping as necessary. Includes sweeping station as necessary. Dispose of trash as necessary. Clean up trash and remove weeds/vegetation from surrounding property.
Figure 3	Enter notes and initial analyzer log sheet
10.6.2	Carry out weekly maintenance on the nephelometer
Figure 3	Log all bottle gas supply pressures on station log sheet
Figure 3	Enter notes and initial station log sheet
10.6.7	Leave a "message to central" summarizing purpose of visit and a summary of all maintenance performed
Every Two Week Period	
10.6.8	Perform Manual Quality Control Span Test – Performed by APCD staff
Monthly Inspection / Maintenance	
	Perform Weekly Inspection/Maintenance as defined above.
	Check associated wiring, power cables, and plumbing (lines and fittings) for wear, damage and proper installation.
	Inspect analyzer fan filters and clean as necessary (if equipped).
10.6.3	Carry out monthly maintenance on the nephelometer
Figure 3	Fill out new monthly station, analyzer, and calibrator (if equipped) log sheets for the upcoming

Procedure or Resource	Description
	month. Include the following key elements: • Analyzer log sheet – site name, month, year, analyzer SN and other appropriate info required by log sheet
10.6.6	Verify and adjust time on data logger.
	Upon completion of the Monthly Maintenance site visit, all previous months log sheets are collected and placed in the monthly forms data collection box within 2 business days of being collected.
10.6.7	Leave a "message to central" summarizing purpose of visit and a summary of all maintenance performed.
Quarterly Inspections / Maintenance	
	None Required
Six Month Inspections / Maintenance	
	None Required
Annual Inspections / Maintenance	
	Annual Audit – Assist contractor in the performance of an annual audit. Guidance and procedures are to be obtained from the contractor.
	Inspect and clean Heating, Ventilation and Air Conditioners (HVAC) units at site. Inspect for water access holes in the shelter, roof, and sides.

10.6 Maintenance Procedures

10.6.1 Disable/Enable Analyzer in Data Logger

<u>ESC 8816/ 8832</u>

Disable analyzer data channel:

From the top level menu, to disable a data channel from reporting to the data logger, the user must:

1. Choose menu options **CDM** (**C Configuration Menu** > **D Configure (Data) Channels** > **M Disable/Mark Channel Offline)** to view the list of available channels.

2. From the keyboard, using the down arrow button, scroll to the target channel name and hit the **Enter** or **Return** key.

3. Next, hit the **Esc** (Escape) key twice to get back to top level menu.

4. Select menu option **DF** (**D Real-Time Display Menu** > **F Display Readings w/flags**) to ensure the proper machine was disabled. You should see the letter "D" within parenthesis and adjacent to the targeted channel indicating it has been disabled.

Enable analyzer data channel:

From the top level menu to enable the data channel to resume reporting to the data logger, the user must:

1. Choose menu options **CDE** (**C Configuration Menu** > **D Configure (Data) Channels** > **E Enable /Mark Channel Online)** to view the list of available channels.

2. From the keyboard, using the down arrow button, scroll to the target channel name, and hit the **Enter** or **Return** key.

3. If all machines/instruments and/or channels are already on line, the user will receive a message stating "No channels are offline" at the bottom left screen. Otherwise a list of channel names will appear.

4. Next, hit the **Esc** key twice to get back to the top level menu.

5. Select menu option **DF** (**D Real-Time Display Menu** > **F Display Readings w/flags**) to ensure the proper channel was enabled. You should see parenthesis adjacent to the targeted channel without the letter "D" inside indicating the machine/instrument channel is enabled and reporting to the data logger.

<u>Agilaire 8872</u>

Disable analyzer data channel:

1. After logging in to AirVision™, if the Site Node Logger Toolbox is not open, from the top level menu select the **Home** tab > **Utilities** > **Site Node Logger Toolbox** > then select the **Channels** tab.

2. Identify the channel to be disabled. At the right side of the form, under the "Disabled" heading, click on the row with the target channel name. This action will change the channel state from "False" to "True" indicating that it is now disabled and not reporting to the data logger.

Enable analyzer data channel:

1. After logging in to AirVision™, if the Site Node Logger Toolbox is not open, from the top level menu select the **Home** tab > **Utilities** > **Site Node Logger Toolbox** > then select the **Channels** tab.

2. Identify the channel name to be enabled. At the right side of the form, under the "Disabled" heading, click on the row with the target channel name. This action will change the channel state from "True" to "False" indicating that it is now enabled and will now report to the data logger.

10.6.2 Weekly Nephelometer Maintenance

Record the following data on the nephelometer log sheet (Figure 3): Reading (BSCAT), STATUS, Span (when performed) and ZERO (when performed).

10.6.3 Monthly Nephelometer Maintenance

1. Unplug the nephelometer from the wall outlet

2. Disable the BSCAT channel

3. Change the filter on the nephelometer (Section 10.6.4)

4. Inspect and replace (if necessary) the water wick drain

5. Inspect the mounting of the nephelometer and adjust as necessary

6. Re-plug the nephelometer to the wall outlet

7. Observe the nephelometer during self-test for the opening of the door and the operation of the LED

8. After the self-test is complete, enable the BSCAT channel

10.6.4 Filter Change Procedure

1. Disable the BSCAT channel on the data logger (10.6.1)

2. Remove the old filter from the filter housing off the bottom of the analyzer.

3. Place new filter into the filter housing using tweezers to handle the filter.

4. Tighten the filter housing.

5. Enable BSCAT channel on data logger (10.6.1).

10.6.5 Bottle Change Procedure

1. Make note of the pressure left in the old bottle (psi).

2. Close the old gas bottle valve (clockwise turn).

3. Remove the refrigerant gas line from the SUVA bottle.

4. Inspect the line and fittings and replace as necessary.

5. Connect the refrigerant line to the new gas bottle.

6. Purge the refrigerant gas line:

    a. Activate the appropriate DO (Digital Output) control on the data logger to open both inlet and outlet solenoids for five seconds, then deactivate the DO control to close the solenoids.

7. Set the regulator pressure to 10psi and ensure that the gas bottle valve and regulator valve are open, if connected to a calibrator verify that the gas pressure is within the required range.

8. Make note of the bottle change on the station log and record the new bottle number, gas type, and pressure.

9. Send two messages to central through the data logger (see 10.6.11)

    a. The first message will consist of the designation of "old", **old** bottle number, and current bottle pressure.

    b. The second message will consist of the designation of "new", **new** bottle number, and current bottle pressure.

10.6.6 Time Change Procedure

<u>Data logger</u>

If the clock on a data logger is incorrect, there may be more serious issues to consider including data validity and proper operation of the data logger. Contact the Data Manager.

10.6.7 Message to Central Procedure

ESC 8816 or 8832

1. Log in to the data logger.

2. From the top level menu Type **SMC** (**S Status Menu** > **M Message Menu** > **C Leave a Message for Central**) followed by hitting the **Enter** or **Return** key.

3. When the text entry display appears, type in up to 80 characters of text explaining the site visit, followed by your initials, example, "Weekly completed. No problems noted. – JJ" then hit the **Enter** or **Return** key on the keyboard to accept the log entry.

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1. Log in to the data logger using the AirVision™ application.

2. Select the **Home** tab > then **Data Editors** drop down menu.

3. From the drop-down menu select, **LogBook Entry Editor**, and click the round green icon with white "plus" symbol, entitled, **New Log Entry**.

4. Next, click on the **Category**: drop-drop down menu and choose **Logger Message**.

5. Select the drop-down menu item, **Site** and choose the appropriate site, for example, **Welby**.

6. Enter text explaining the purpose of the site visit, followed by your initials. Example, "Weekly completed. No problems noted. – JJ" hit the **Save** button at the top left to save your comments. The application will allow more characters than 80, but they are truncated for the Central computer.

10.6.8 Perform Manual Span

ESC 8816 or 8832

1. Login to the data logger.

2. From the top level menu type **CCS** (**C Configuration Menu** > **C Configure Calibrations** > **S Start a Calibration Program**.)

3. A list of calibration options appears. Select the backscatter calibration and press enter.

4. Hit the Esc (escape) key twice to get back to the top level menu, then type, DF to verify the Precision Calibration was initiated. You should see the letter C next to the gaseous reading indicating it is in the calibration mode. It will run for about an hour. After a Manual Span has run to completion, the new precision value will appear in the RL list.

5. During the calibration, the value for "Span" and for "Zero" should change, even marginally, see note below.

6. Hit the **Esc** key twice to get to the top level menu then type **RL** to view, shown below.

7. Note the resultant zero and span values.

8. Hit the Esc key twice to get to the top level menu and type CK to Configure math K(c)onstants

9. Enter the zero value in Constant K1, and enter the span value in Constant K2. Constant K3 is the calibration span and Constant K4 is the calibration zero.

Please note, manual spans are of particular importance for the nephelometer. While other systems use manual precisions to validate the data being produced by the analyzer, the manual spans on the nephelometer generates the slope and offset needed to calculate the backscatter in inverse kilometers from the raw counts supplied by the nephelometer.

The slope between the factory span and the current span is calculated as (K2-K1)/(K3-1). This value is stored in the M channel. The offset is calculated as K1-M and stored in the B channel. Finally, the backscatter value in inverse kilometers is calculated as (6.25*0.0095*((BSCAT-K1)/(K3-K4))) for the X channel. Against this, be sure that the channels called "Span" and "Zero" reflect the recorded numbers seen during the precision. If they do not, contact the data administrator. See Section 17.2.1 for more information.

10.7 Calibration Standards

R134a is a commercial refrigerant also known as tetrafluoroethane, which is most commonly found in refrigerators and automobile air conditioners. According to the EPA, the chemical has low acute toxicity levels and presents a low risk to humans exposed to it in small amounts. The majority of hazards associated with this inert gas arise through inhalation over time or in large amounts.

11 Handling and Preservation

Atmospheric visibility readings are monitored continuously; no discrete samples are collected, handled, or preserved. Therefore this SOP for transmissometer monitoring of visibility does not need a section on Handling and Preservation.

12 Sample Preservation and Analysis

No samples of air are collected. Therefore this SOP for nephelometer monitoring of visibility does not need a section on Sample Preparation and Analysis.

13 Troubleshooting

13.1 Environmental Factors

Environmental conditions can play a role in the operational characteristics of analyzers. Some external factors may be constant while others are sporadic in nature. External factors to check include:

- Is the enclosure temperature stable throughout the day?
- Is vibration from other equipment causing an effect?
- Is the enclosure sealed to prevent moisture from entering the electronics or the clean air sample stream.

13.2 General Factors

Other factors linked to the shelter and manifold design can contribute to data loss. The shelters/enclosures should be checked on a regular basis to ensure integrity and weather tightness.

Power to the site is another factor that can contribute to data loss. Incoming power needs to be stable and have a good waveform.

13.3 Instrument Troubleshooting

Troubleshooting of problems with analyzers is specific to each analyzer and its design. Common problems with instruments include:

- Erratic or noisy readings
- No readings or off-scale readings
- Instrument locked up at a constant reading
- No output
- Analyzer completely inoperative

Troubleshooting sections in specific analyzer operation and service manuals, located at each site or in the APCD office, should be consulted to assist in resolving instrument problems. Equipment used in troubleshooting includes digital voltmeters.

14 DATA ACQUISITION, CALCULATIONS, AND DATA REDUCTION

Originally, ink-pen strip chart recorders were used by the APCD as a primary record of data from air monitoring instruments. Hourly averages were then hand-interpreted from these charts. Today, due to advances in data storage and retrieval systems, these ink-pen strip chart recorders are no longer in use. Instead, all data are now collected, stored, and retrieved digitally from data loggers. The terms data logger and onsite data acquisition system are used interchangeably throughout this SOP.

14.1 Data Acquisition

The APCD/TSP data acquisition system (DAS) is comprised of three components: an onsite primary data acquisition system that collects data from all continuous monitoring equipment, an onsite secondary data acquisition system, or back-up system that collects data from the continuous monitoring equipment, and a centralized central polling system that routinely collects data from the primary data acquisition system and stores it in a SQL database for processing and validation.

14.1.1 Primary Onsite Data Acquisition Systems

The APCD employs three different models of onsite DAS in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, and the Agilaire 8872 data logger. The 8816 data logger is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. See Section 8.1.4 for a more detailed description of these data loggers.

14.1.2 Secondary Onsite Data Acquisition Systems

The APCD uses two different data acquisition systems to provide backup data in case of failure of the primary systems. The backup data acquisitions systems are the analyzer based on-board data acquisition systems that are unique to each manufacturer. In the event an on-board data acquisition system is not available (as with the OPTEC), a digital strip chart recorder is used. The second data acquisition system is a Monarch DC1250 DataChart digital data recorder. This logger system is used almost exclusively for the older carbon monoxide Thermo 48C analyzers that have limited internal data logging capabilities.

The APCD does not maintain a secondary onsite data acquisition system for non-criteria pollutants such as meteorology and visibility; this includes the transmissometer and nephelometer at the DESCI site.

14.1.3 Central Polling System

The APCD uses the AirVision software package for its central data management system. "AirVision is a centralized data management and polling software system that is used to acquire, edit, validate, analyze, and report air quality data. AirVision supports open data acquisition and data imports thru modular drivers that can be added to provide connectivity to a data source. The system has combined data editing and quality control tools that can be utilized in evaluating and validating data in the post-processing environment. The post-processing environment allows user control of the data from the management of raw data within the server environment through the exporting of validated data through built in reports or for external statistical evaluations and reporting. A more detailed description of this application can be found in APCD's Data Logger and Central Polling Standard Operating Procedure, Appendix D1 of this QAPP." (Agilaire, 2009)

<u>Central Polling Daily Tasks</u>

1. Task managers within Air Vision polls data from remote air quality monitoring sites at the top of each hour, at a minimum. Some sites may be polled at a greater frequency depending upon data needs. Data from each site is stored in a SQL database and made available for review and analysis after polling has been completed.

2. Ambient data on the AirVision Central polling computer is reviewed every business day in the morning, the previous 24 hours (or 3 days on Mondays) worth of data is reviewed for completeness and accuracy. This data review is used to determine if a physical site visit is required.

3. Span and clean air zero sequences are run on a fixed schedule. The span tests are followed by a zero test and a recovery period. The results are reviewed each morning. It is the responsibility of one individual within TSP to review the daily Zero/Span results and notify the technician responsible of any out-of-control condition.

14.2 Calculations and Data Reduction

As mentioned above, data collected on a DAS are available as soon as the averaging period is complete. Data are polled automatically via modems (analog phone, wireless cellular, or DSL) by the Central polling computer hourly. If needed, sub-hourly polls or remote checks can also be performed.

Data from the continuous air monitoring equipment are generally stored at hourly and minute resolution averages. The software on the Central polling computer stores the downloaded minute and hourly averages and is capable of aggregating these averaging intervals into larger averaging intervals such as 8-hour or 24-hour averages.

A more detailed description of the DAS is given in the CDPHE/APCD/TSP QAPP Appendix D1, and in the manufacturers' manual.

15 COMPUTER HARDWARE AND SOFTWARE

The data acquisition system (DAS) used by the APCD/TSP for collecting data from continuous air monitors is generally described in Section 14 and in the CDPHE/APCD/TSP QAPP.

The primary DAS Central polling computer is a Windows based server. The Airvision data system on this server provides for polling the sites using dial-up modems and broadband access for data. A printer is attached to the system for printing out reports. The primary repository for data, and the engine for information assembly, is the Microsoft SQL Server operated and maintained by the Governor's Office of Information Technology. The CDPHE/APCD/TSP maintains a database owner position responsible for logical maintenance of the data system.

The 8872 is a Windows based PC with attached monitor, keyboard, and mouse. The 8832 and 8816 are proprietary hard-circuit systems that may or may not have attached screens and keyboards. Sites usually include other computer hardware and software such as switches, RS232 cables, Ethernet cables, and analog cables.

16 DATA MANAGEMENT AND RECORDS MANAGEMENT

16.1 Data Management

Data are generated from the analyzer at intervals internally set, ranging from an averaging time of 20 seconds to 5 minutes. The data is collected by the on-site data logger as near-real-time data (often every 3 to 10 seconds) and is aggregated into 1-minute averages, which are in turn aggregated into 1-hour averages. Some data streams may be stored at a third averaging interval, meteorological data can be stored as a 15-minute average and SO_2 data can be stored in a 5-minute average. Note the capacity of the on-site data logger is limited to three time-base averaging intervals and that the 5-minute SO_2 average supersedes the 15-minute meteorological average. The Central polling computer collects these averages routinely.

For reporting purposes, other averaging intervals are derived, such as an 8-hour moving average for ozone. In these cases, the data is aggregated by the Central polling computer for the purpose of the report and are often not stored independently. The Central polling computer connects to a SQL server, which is maintained, and backed up, by the Office of Information Technology.

Data are sent to the EPA centralized Air Quality System (AQS) database for long-term storage. Additionally, the data are stored and archived by the APCD/TSP in both electronic and hard copy formats. Monthly electronic data files and related printed material packets (maintenance forms, etc.) are produced.

A more detailed description of the data management is given in the Data Processing and Central SOP in the CDPHE/APCD/TSP QAPP Appendix D1.

16.2 Records Management

Continuous ambient air monitoring data are archived both in electronic and hard-copy formats. Electronic data and calibration files from the primary DAS are archived. Data from the backup electronic strip chart recorders, where used, are downloaded annually and archived on a computer hard drive. Hard copy printouts of the data are kept at the APCD office for a minimum of three calendar years before being sent to an off-site archive/storage facility.

17 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control are two terms commonly discussed, but often confused. Quality assurance refers to the overall process of ensuring that the data collected meet previously stated Data Quality Indicators (DQI) and associated measurement quality objectives (MQOs). The principal DQIs are precision, bias, representativeness, completeness, comparability, and sensitivity. The principal MQO's are parameter specific and are listed in CDPHE's QAPP, Appendix MQO. Guidance for developing DQI's and MQO's is given in EPA's Quality Assurance Handbook (US EPA, 2013). The nephelometer does not have any regulatory DQIs or MQOs developed. Quality control covers specific procedures established for obtaining and maintaining data collection within those limits.

17.1 Quality Assurance

The goal of the quality assurance program is to control measurement uncertainty to an acceptable level through the use of various quality control and evaluation techniques. The entire Quality Assurance effort put forward by the APCD is too large to include here. The scope of this SOP will describe efforts taken by site operators and data validation personnel to ensure the quality of the data collected meets standards set forth in various sections of the *Code of Federal Regulations*. For a complete description of the Quality Assurance and Quality Control process undertaken by the APCD, see the appropriate quality assurance appendices in the QAPP. Two of the most significant Quality Assurance procedures are described below.

17.2 Quality Control

Quality Control is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the EPA. Quality control includes establishing specifications or acceptance criteria for each quality characteristic of the monitoring/analytical process, assessing procedures used in the monitoring/analytical process to determine conformance to these specifications, and taking any necessary corrective actions to bring them into conformance.

Quality control refers to procedures established for collecting data within pre-specified tolerance limits. These pre-specified tolerances are defined in the Measurement Quality Objectives as defined in APCD's QAPP, Appendix MQO. While all Quality Control procedures are important, the most significant procedure employed by the APCD is the routine measurement of a known test gas by gaseous analyzers. All procedure documented in this SOP are Quality Control procedures because they allow the analytical systems to continue running in exceptional condition and serves to minimize out-of-control conditions as defined by APCD MQO's. By definition, the creation and use of this SOP is a Quality Control function. All Quality Control procedures are described in Sections 9 and 10 of this SOP. Three of the most significant Quality Control procedures are described below.

17.2.1 Clean Air Zero and Span Tests/Calibrations

"Periodic clean air and span gas calibrations are performed in order to monitor and correct for instrument gain and zero intercept drift due to temperature changes and/or dirt accumulating on the measurement chamber optics. Clean air calibrations are usually performed more often since they are easy to do and use no source of expendable gas. Span gas calibrations with a dense gas such as Freon-22 ($CHClF_2$), Sulfur Hexafluoride (SF_6) or HFC-134a are usually done on power up or computer reset with an operator present. However, the operating program can be easily modified to accomplish this periodically and without an operator.

The scattering value for clean air reading is considered equal to one Rayleigh or 0.01 km^{-1} if temperature and pressure values are compensated for. A span gas such as SUA-HFC 134A would have a scattering coefficient equal to 7.25 times the clean air value. Knowing these two values allows a solution to be found for the following linear equation

$$y = ax + b$$

where,

y = scattered light due to molecular and aerosol scatter in user selected units

a = scaling factor

x = normalized scattered light output for clean air or span gas

b = scattered light from the measurement chamber walls.

Clean Rayleigh quality air is obtained by recirculating the measuring chamber air through a 0.3 μm glass microfiber filter with the inlet door closed. This filter retains 99.97% of all particles larger than 0.3 μm. The clean air pumping requires approximately 5 minutes to completely filter all particles from the measuring chamber before a 10 integration is commenced. During the clean air cycle, a 7.0 volt Status signal is held on D/A channel-2 to indicate that a clean air calibration is in process. When the clean air calibration is completed, a 2.0 volt Status signal is sent to D/A channel-2 to indicate that the output on D/A channel-1 is a clean air reading. Simultaneously, the clean air value is sent to the serial and D/A channel-1 lines.

A cylinder of compressed span gas pressure regulated to approximately 10 psi is connected to the solenoid activated gas inlet valve. When a span gas calibration is started, this inlet is opened for 10 minutes to allow the span gas to completely fill the measuring chamber before a 10 minute integration is commenced. During the span gas cycle, a 7.0 volt Status signal is held on D/A channel-2 to indicate that a span gas calibration is in process. The measured scattered light value is transmitted to the serial port along with a status code indicating a span gas calibration value. This value is also converted to an analog voltage and passed to the D/A channel-1 output. A 3.0 volt Status signal is held on D/A channel-2 to indicate a span gas reading." (Optec, Inc, 1998)

For instructions on performing a manual precision Quality Control check, see Section 10.6.12.

17.2.2 Calibrations

Calibration of an analyzer or instrument establishes the quantitative relationship between the actual value of a standard, be it a pollutant concentration, a temperature, or a measure of extinction, and the analyzer's response (chart recorder reading, output volts, digital output, etc.). This relationship is used to convert subsequent analyzer response values to corresponding concentrations. Once an instrument's calibration relationship is established, it is checked at reasonable frequencies to verify that it remains in calibration. It is the goal of APCD to perform calibrations on the nephelometer annually. The most opportune time to do so is when the transmissometer is removed after its annual audit for maintenance. Periodic checks are performed against the transmissometer during clean air episodes. Extinction values from the transmissometer and the nephelometer should be similar during clean air episodes.

For instructions on performing a calibration, see Section 9.

17.2.3 Documentation

Documentation is an important component of the quality control system. Extensive certification paperwork and log sheet must be rigorously maintained for procedures, standards and analyzers. APCD takes special care to prepare and preserve backup copies of all data, especially calibration data. All data and supporting documentation should be held on-site for a minimum of three calendar years then sent for offsite archive. See Section 16 for additional information.

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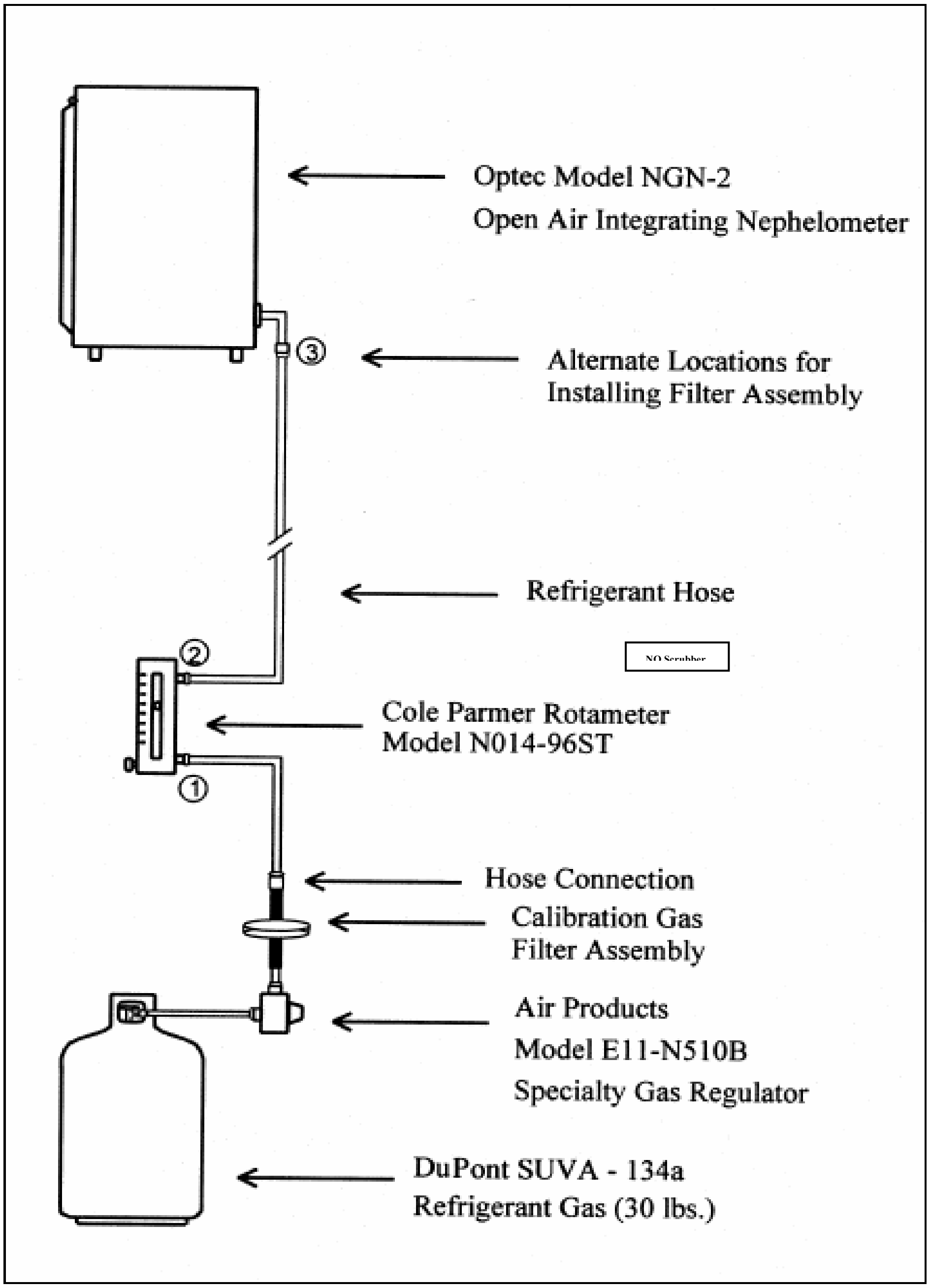

Figure 2. Nephelometer Calibration / Audit Setup

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT
Air Pollution Control Division - Technical Services Program

MONTHLY STATION ACTIVITIES LOG

VISIBILITY OPTEC NEPHELOMETER MONTH: ___________ YEAR: ___________ STATION: ______________________________________

S/N: _________________________

DATE																								
READING (BSCAT)																								
STATUS																								
SPAN (IF PERFORMED)																								
ZERO																								
OPERATOR																								

INSPECTIONS	WEEKLY:											MONTHLY:			ANNUAL:		
		DAY	BY	DAY	BY	DAY	BY	DAY	BY	DAY	BY		DAY	BY		DAY	BY

DAY	TIME OFF	ACTION DUE	BY	ACTION TAKEN	TIME ON	DAY	BY

USE REVERSE SIDE FOR ADDITIONAL INFORMATION 03-Jan-2005 j:\zsfiles\forms\MaintLogs.xls : viz-neph

Figure 3. Nephelometer Log Form

MAINTENANCE REPORT

DATE_______________________________________

STATION_______________________________________

ASSIGNED TO_______________________________________

ORIGINATED BY_______________________________________

ANALYZER or EQUIPMENT_______________________________________ S/N______________

MALFUNCTION DESCRIPTION OR COMPLAINT

ACTION TAKEN

DATA TO BE DELETED (IF ANY)

ENTER EXACT DATES AND DATA HOURS

COMPLETED BY_______________________________

COMPLETION DATE_______________________________

J:\zsfiles\forms\forms.xls:MaintRpt

Figure 4. Maintenance Report Form