Chapter 4

Continuous Monitoring of Carbon Monoxide

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1.0 Introduction

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by the incomplete combustion of hydrocarbons. Automobile emissions are the largest source of CO. CO is also present in large quantities in the emissions from industrial processes, such as coke plants and power stations.

It is the intent of this chapter to outline the monitoring, calibration, quality assurance, and data reporting requirements to be followed by all agencies (state, local, and independent) that conduct ambient CO monitoring within the State of Indiana.

2.0 Probe Sitting Criteria

Additional information can be found in Chapter 1 and in 40 CFR Part 58 Appendices, D and E.

2.1 Horizontal and Vertical Probe Placement

1. The inlet probe (for microscale sites) must be 3 meters above ground level ±0.5 meters.

2. The inlet probe (for neighborhood and middle scale sites) must be 2-15 meters above ground level.

3. The inlet probe must be located more than 1 meter in the vertical and horizontal direction from any supporting structure.

2.2 Spacing from Obstructions

1. Air flow must be unrestricted in an arc of at least 270° around the probe, and the predominant wind direction for the season of greatest pollutant concentration must be included in that arc.

2. There must be 180° clearance for any probe located on the side of a building.

2.3 Spacing from Roads

1. Microscale inlet probes must be between 2-10 meters from the nearest traffic lane.

2. Microscale inlet probes must be at least 10 meters from an intersection and preferably at mid-block.

3. See Table 1 for minimum separation distances between CO stations and roadways for neighborhood scale inlet probes.

2.4 Spacing from Trees

1. Microscale stations should have no trees or shrubs between the inlet probe and the road.

2. There must be no trees located between the major sources of CO and the sampler for middle and neighborhood stations.

3. For middle and neighborhood scales, the sample inlet must be at least 10 meters from the drip line of a tree that is between the sampler and the road.

3.0 Monitoring Methodology

3.1 Non-Dispersive Infrared Photometry (NDIR)

CO absorbs infrared radiation (IR) at known frequencies. This fact allows for accurate measurement of CO. When IR passes through a sample cell, CO absorbs a portion of the IR. This measurement method compares the amount of IR passing through the sample cell with the amount of IR passing through a CO free reference cell. Next, the method converts this difference in IR absorption passing through the two cells to an output signal.

CO analyzers must be reference or equivalent as described in the Code of Federal Regulations (CFR) 40 Part 50.1. A list of equivalent analyzers is available by writing to:

U.S. EPA Environmental Monitoring Systems Laboratory
Department E, MD-77
Research Triangle Park, NC 27711

or online on the Technology Transfer Network (TTN) Air Monitoring Technology Information Center (AMTIC) Web Page at "http://www.epa.gov/ttn/amtic/criteria.html".

3.2 Requirements for monitoring CO (include but are not limited to):

1. Incoming sample air must not be pressurized

2. Air flow to the sampler from the inlet sample probe must be unrestricted

3. Shelter or room temperature between 15-33 °C

4. Reference or equivalent CO analyzer

5. Location within guidelines found in CFR 40 Part 58 Appendices D, E

4.0 Calibration Methodology

Dynamic calibration involves introducing gas samples of known concentration to an instrument in order to adjust the instrument to a predetermined measurement range and to derive a calibration relationship.

There are currently two methods used to calibrate CO analyzers, multiple cylinder calibration and dilution system-gas blender calibration. Always refer to the manufacturer's instruction Manual for analyzer-specific directions, that may be unique to the calibration of a particular instrument.

4.1 Safety Precautions

CAUTION: Carbon monoxide gas is lethal in high concentrations, and can cause adverse health effects with prolonged exposures to lower concentrations (faintness, dizziness, nausea, vomiting, and even brain damage). Because it is colorless, odorless, and tasteless, extreme care should be taken to leak test all fittings and shut-off valves whenever using, transporting, or storing CO cylinders. Calibration systems exhaust air into the room, so it is necessary to vent the exhaust port to the outside whenever possible or use with adequate ventilation.

4.2 Multiple Cylinder Calibration

The multiple cylinder method of calibration involves using a zero and 4 upscale points of pressurized gas cylinders containing four different known concentrations of CO. There are three types of standard gases generally available:

1. National Institutes of Standards and Technology Standard Reference Material (NIST-SRM)

2. Certified Reference Material (CRM)

3. Non-CRM vendor certified

The use of Non-CRM vendor supplied gas is acceptable; however, all gases used must be certified against the Office of Air Quality’s (OAQ) primary standards no less than every eight years.

4.2.1 Determination of Concentration

The concentration supplied to the CO analyzer in a multiple cylinder calibration will be that value given (to each specific cylinder used) at certification.

4.2.2 Requirements for Calibration (include but are not limited to):

1. Certified CO cylinders, with not less than 200 psig

2. A moisture-free calibration system

3. Leak free gas connections

4. A zero air source free of CO and moisture

5. A manifold system for delivery of gas

6. A flow control device (e.g. rotameter). Gas dilution system flow meters must be certified (see Section 4.3) no less than every year.

4.3 Dilution System - Gas Blenders

This system consists of one cylinder of CO (of known concentration), a source of (zero) air free of CO and moisture, and a mixing/blending system. Dilution and gas flow may be measured with either the system's built-in certified flow meters, external certified flow devices (e.g. Bios, Gilibrator), or manually using an NIST traceable bubble meter kit.

4.3.1 Determination of Concentration

Use the following formula to determine the concentration of the CO introduced into the analyzer:

$$[CO]_{out} = \frac{[CO]_{std} \times F_{CO}}{F_D + F_{CO}}$$

Where:

$[CO]_{out}$	=	diluted CO concentration at the output manifold, in ppm
$[CO]_{std}$	=	concentration of the undiluted CO standard, in ppm
F_{CO}	=	flow rate of the CO standard corrected to 25 °C and 760 mmHg, in l/min
F_D	=	flow rate of the dilution air corrected to 25 °C and 760 mmHg, in l/min

Note: Flow must be corrected to Standard Reference Conditions (SRC). See Appendix A for formulas.

4.3.2 System Requirements (include but are not limited to):

1. Leak free gas connections

2. The dilution air must be dry and free of CO (<0.1 ppm)

3. A vented calibrator output

4. A certified measuring system

5.0 Calibration Procedure

The calibration procedure as follows is general. Always refer to the manufacturer's instruction manual for analyzer-specific alterations or explanations.

5.1 Record Keeping

Each calibration should be accompanied by a completed calibration worksheet. Appendix B represents an example. If a generic form is desired, include the following information:

1. Official site name (include AQS Number)

2. Instrumentation identification (include manufacturer's name, model and serial number)

3. Identification of person performing the calibration

4. Date of calibration

5. Calibrator identification (include manufacturer's name, model and serial number)

6. Cylinder(s) identification and concentration (include manufacturer's name and serial number)

7. Date of cylinder(s) certification

8. The site temperature in degrees Celsius (°C) and ambient pressure in millimeters of mercury (mmHg)

9. The analyzer's sample air flow, vacuum pressure, initial and final zero/span potentiometer settings

10. Span cylinder identification (include manufacturer's name and serial number)

11. Date of last calibration

12. The initial and final time (of the calibration)

13. Calibrator setting/bubble tube flow

14. Calibration result; i.e., percent difference of all points

Annotate the primary and secondary recording units and document the station logbook with the information listed below to avoid any confusion when reducing the raw data:

1. Site identification

2. Date

3. Initials of person performing the calibration

4. Parameter (CO)

5. Start/stop time

6. Results

5.2 Calibration Process

5.2.1 Manual Calibration

1. Attach the analyzer's sample line to the vented output of the calibration system. Adjust the zero air flow from the calibrator to the analyzer. The zero air flow must exceed the analyzer's total demand by at least 25% to ensure that the analyzer’s pump does not draw ambient air into the system through the vent.

2. Allow enough time for the monitor to attain a stable zero response. It is recommended that the recorder's zero control offset the chart response to +5%. This allows observation of the negative zero drift. Record the responses on the calibration worksheet.

3. Determine the concentration corresponding to 80% of the analyzer's range (i.e., for an analyzer operating in the 0-50 ppm range, 80% would be 40 ppm).

4. If using a gas blender system, determine the calibrator settings necessary to achieve the correct output by using the equation listed in Section 4.3. If using the multiple cylinder method, attach the cylinder with the correct concentration.

5. Allow the analyzer to sample until the response is stable and then adjust the span control until the required response is obtained.

6. After setting the zero and span (80%) points, introduce at least three additional upscale points, or two points for an NCore calibration, between the 0-80% ranges, making no further adjustments on the zero/span control. Record the standard concentrations (those introduced by the calibration system) and the analyzer response (observed concentration) on the calibration worksheet (see Appendix B).

7. Determine the percent difference for each set of points using the following formula:

$$\% \text{ Difference} = \frac{\text{Observed Conc} - \text{Std Conc}}{\text{Std Conc}} \times 100$$

Use the following formula to determine the observed concentration:

Observed Conc. = (Primary Recorder Response – Baseline) x Calibration Slope

And to determine the primary recorder response, use this formula:

$$\text{Primary Recorder Response (\% scale)} = \frac{[\text{CO}]_{\text{out}}}{\text{URL}} \times 100 + Z_{\text{CO}}$$

Where:

$[CO]_{out}$	=	diluted CO concentration at the output manifold, in ppm
URL	=	nominal upper range limit of the analyzer's operating range
Z_{co}	=	analyzer response to zero air, % scale

8. Repeat any points falling outside ±2% (of the line of best fit) to eliminate calibration errors. If the repeated points are still outside the 2% limits, the calibration is considered invalid. If a successful calibration cannot be completed in two attempts, the instrument must be considered suspect, and maintenance may be required. No data will be accepted without a valid calibration.

5.2.2 Remote Multi-Point Calibration

Currently all CO sites in the IDEM continuous air monitoring network are equipped with on-site Teledyne Advanced Pollution Instruments (API) mass flow calibrators. These units can be accessed remotely through the Leading Environmental Analysis and Display System (LEADS). Calibrations and certain quality assurance/quality control processes are conducted telemetrically on a routine pre-set schedule and/or on a by demand basis.

A Multi-point Calibration consists of a zero and 4 upscale points which include:

- A zero concentration (pollution free air)
- A span concentration between 80% and 90% of full range
- Three or more intermediate concentrations spaced approximately equal range

This multi-point calibration must be performed at the time of the initial installation and after a six month period has lapsed since the most recent multi-point calibration. For LEADS sites we are running a monthly multipoint calibration. All calibration points must be within ±2% of the

full range of the analyzer.

5.3 Calibration Frequency

To ensure accurate CO measurements, calibrate the analyzer at the time of installation and recalibrate at the following times:

1. No later than six months after the most recent calibration; three months for NCore

2. An interruption of more than a few days of the analyzer's operation

3. Any major repairs

4. Physical relocation of the unit

5. Any performance audit failure or excessive zero/span drift

A daily zero and span as well as one point quality control checks (see Section 8.5) may be used to determine if a calibration is necessary should conditions listed above occur.

6.0 Quality Assurance Audits

Quality assurance audits ensure the validity of the CO data submitted to the national AQS data bank. Results of these audits are also used to estimate the Precision and Accuracy (P&A) of the monitoring network's data. IDEM/OAQ/QAS submits the statewide P&A to the USEPA every quarter. See Chapter 13, "Quality Assessment and Statistical Analysis of Air Monitoring Data", of this manual for detailed information on P&A.

6.1 Data Validation and Precision Audits

Daily zero and validation (span) points as well as weekly one point quality control checks (precision) are automatically scheduled to be performed by LEADS. If done manually these checks would be run bi-weekly to assess the validity and precision of the CO data. An audit consists of challenging the analyzer with two upscale CO concentrations. The procedure is similar to a calibration, and can be done using either the direct cylinder method, or gas dilution method. The audit device must meet the same criteria as that of the system used for the calibration. It must also be certified by the IDEM-OAQ-QAS (see Section 4.0 of this chapter, and Chapter 6, "Certification Methods for Transfer Standards", in this manual).

All continuous CO analyzers are routinely audited remotely through the LEADS. The validation and precision checks are scheduled by the OAQ/AMS/LEADS Administrator and are set to run at times when ambient CO levels could be expected to be at a low. The audit consists of a daily validation (span) check (40 ppm CO), a weekly precision level check (9 ppm CO) and a daily zero concentration point.

On-site manual precision audits may be conducted by IDEM quality assurance staff on an as needed basis such as:

- LEADS communication malfunction
- Unstable or failing remote audit results

The first audit point is a CO concentration 70-90% of the upper range limit (URL). This would be 35 ppm to 45 ppm for a monitor with a range of 50 ppm. This concentration is the validation point and is used to validate data back to the most recent audit or calibration. Anything within 10% is valid data. See Chapter 11, "Valid Data Requirements," in this manual for the details of data validation. The second audit point consists of a CO concentration in the required range of 8-10 ppm, regardless of the monitor's URL. This second audit point is used to assess the precision of the data based on quarterly calculations. However, it is expected this check is within ±10%.

The following CO concentrations must be run for a validation/precision audit:

Monitor Range	**Analyzer Range**
0 - 50 ppm	35 – 45 ppm Validation point
	1 - 10 ppm Precision point
0 - 100 ppm	80 – 90 ppm Validation point
	1 - 10 ppm Precision point

6.2 On-site Analyzer Audit Procedure

Once on site, to begin the audit:

- Plug in the audit calibrator and zero air supply.
- Connect a regulator to the CO tank. Use a vacuum pump to remove air from the system between the tank and calibrator
- Log into the station laptop and access the data logger
- From the User menu, Press G to display channel identification numbers
- Press C and the ozone channel number/Q to disable the CO channel and flag the data
- Press U to return to the User Menu
- Press T
- Press R/ozone channel number to view the current voltage output
- Open the Office of Air Monitoring Database (OAMD) CO Calibrator Audit form on the field laptop
- Fill in the appropriate information including:

    a) Site Name
    b) Auditor

c) Date
d) Start time
e) Analyzer calibration slope
f) Audit and On-site Calibrator serial numbers

- Introduce zero air to the analyzer by setting the audit calibrator to zero
- Disconnect the incoming sample line at the manifold and cap the port
- Attach the incoming sample line to the output of the calibrator, venting if necessary
- Allow for stabilization
- Enter the output and the calibrator zero response on the OAMD form. The Oracle spreadsheet will automatically calculate the Zeno output to parts per million CO
- Introduce a test concentration of 40 ppm CO to the analyzer by setting the audit calibrator to 40 plus the zero response
- Allow for stabilization
- Enter the output and the calibrator response on the OAMD form. The Oracle spreadsheet will automatically calculate the Zeno output to parts per million CO and display the % difference between the standard and observed concentration
- Introduce a test concentration of 9 ppm CO to the analyzer by setting the audit calibrator to 9 plus the zero response
- Allow for stabilization
- Enter the output and the calibrator response on the OAMD form. The Oracle spread sheet will automatically calculate the Zeno output to parts per million CO and display the % difference between the standard and observed concentration
- Reconnect the incoming sample line to the manifold and disassemble the audit calibrator

6.3 Accuracy Audits

To perform accuracy audits, follow the same auditing procedures and calculations used in Section 6.1. The person who does the accuracy audit must be someone who does not do the calibration.

The following CO concentrations must be run for an accuracy audit:

Monitor Range	**Concentration (ppm)**
0-50 ppm	3.0-7.9
	16.0-30.9
	40.0-50.0

*These ranges are referenced from a 2010 EPA Office of Air Quality Planning and Standards memorandum and are not yet in the CFR. This memo can be found at: "http://www.epa.gov/ttn/amtic/files/ambient/pm25/datamang/TechMemoforPEAuditLevels.pdf"

Accuracy audits must be performed on at least 25% of the network analyzers each calendar quarter as per 40 CFR Part 58. At the end of the year, all analyzers must have had an accuracy audit. To ensure accuracy audits are not missed, it is strongly recommended that an accuracy

audit be performed on each analyzer once per quarter.

Networks having four or fewer analyzers must conduct audits so that all analyzers have had an accuracy audit by the end of the year. Accuracy would then be calculated in the 2nd and 4th quarters of the year. Because this is a statistical assessment of the accuracy of the data, it is suggested that accuracy audits be conducted more often than once per quarter (e.g., monthly). This ensures a larger and more representative database for the accuracy calculations.

40 CFR Part 58 requires that a different audit system and gas standard from that of the calibrator be used to perform the accuracy audit. The auditor should also be different from that of the person who performed the calibration. The analyzer must be collecting valid data in order to conduct an accuracy audit.

6.3.1 Accuracy Audit Procedure

The procedure outlined below is to be used for Indiana CO Monitors equipped with the LEADS. If the LEADS is not in service or another form of DAS is being utilized, flag the data with the appropriate information according to the procedure recommended by the specific DAS operations manual. Any results more than ±15% can result in data being invalid. Further research such as zero and span analysis may help pinpoint where an issue is and if any data is invalid.

Once on site, to begin the audit:

- Plug in the audit calibrator and zero air supply
- Connect a regulator to the CO tank. Use a vacuum pump to remove air from the system between the tank and calibrator
- Log into the station laptop and access the data logger
- From the User menu, Press G to display channel identification numbers
- Press C and the CO channel number/Q to disable the ozone channel and flag the data
- Press U to return to the User Menu
- Press T
- Press R/CO channel number to view the current voltage output
- Open the OAMD CO Audit form on the field laptop
- Fill in the appropriate information including:
- Site Name
- Auditor
- Date
- Start time

- Analyzer calibration slope
- Audit and On-Site Calibrator serial numbers
- Introduce zero air to the analyzer by setting the audit calibrator to zero
- Disconnect the incoming sample line at the manifold and cap the port
- Attach the incoming sample line to the output of the calibrator, venting if necessary
- Allow for stabilization
- Enter the output and the calibrator zero response on the OAMD form. The Oracle spread sheet will automatically calculate the Zeno output to parts per million CO
- Introduce a test concentration between 40.0-50.0 ppm CO to the analyzer
- Allow for stabilization
- Enter the output and the calibrator response on the OAMD field data form. The Oracle spread sheet will automatically calculate the Zeno output to parts per million CO Introduce a test concentration of between 16.0-30.9 ppm CO to the analyzer
- Allow for stabilization
- Display the % difference between the standard and observed concentration
- Enter the output and the calibrator response on the OAMD field data form. The Oracle spread sheet will automatically calculate the Zeno output to parts per million CO
- Introduce a test concentration between 3.0-7.9 ppm CO to the analyzer
- Allow for stabilization
- Enter the output and the calibrator response on the OAMD field data form. The Oracle spread sheet will automatically calculate the Zeno output to parts per million CO and display the % difference between the standard and observed concentration
- Reconnect the incoming sample line to the manifold and disassemble the audit calibrator, zero air supply, and CO tank
- Allow the CO analyzer to return to ambient conditions
- Enable the CO channel and make the appropriate electronic operator log book entries
- Enter the audit end time on the OAMD form and save the audit results

7.0 Data Reduction and Reporting

The USEPA bases National Ambient Air Quality Standards (NAAQS) for CO on measured hourly average concentrations. Table 2 of this chapter lists the NAAQS for CO. The data submitted to the State for entry into AQS must be reduced to 24 hourly average concentrations. This reduction must be done manually in networks not equipped with electronic averaging instrumentation. See Chapter 12, “Data Reduction & Audit Procedures,” in this manual for the methodology and quality assurance requirements for data reduction. Data should be submitted to

IDEM within 60 days after the quarter to allow sufficient time for review before USEPA deadlines (within 90 days after the end of each reporting period).

8.0 Routine Station Operation

Scheduled checks are essential to the quality assurance program for verifying the validity of the monitoring system. At least once each week, the network operator should visit each site to physically determine the operating conditions.

8.1 Shelter Temperature

Mean shelter temperature *should* be between 20 °C and 30 °C. A certified thermograph or other temperature recording device must be installed at the site to continuously monitor the daily temperature fluctuations (40 CFR Part 53.31(a)). Data *may* be invalidated whenever the shelter temperature falls out of the 15ºC to 33ºC range. The temperature is normally checked for accuracy every quarter and must be within 2 degrees Celsius of the transfer standard temperature device.

8.2 Shelter Sample Intake System

The following components should be inspected weekly for failures, leaks, and buildup of particulate matter or moisture:

1. Intake port
2. Particulate and moisture traps (change or empty as needed)
3. Sampling manifold and blower
4. Analyzer sampling line

8.3 Recording Device

Whether using a computer printout, a strip chart, or both, checks the following weekly:

1. Ink trace or printout for legibility

2. Ink or ribbon reservoir

3. Paper supply

4. Time synchronization

5. Agreement among recording devices

8.4 Analyzer Visual Checks

The field operator should check the operating parameters of the analyzer weekly. These will vary

from instrument to instrument but in general will include:

1. Correct settings on flow meters and regulators

2. Verification of sample mode

3. Zero and span potentiometers set and locked

4. Abnormal electronic noise or temperature

5. CO span cylinder pressure

8.5 Zero/Span Checks

Configure continuous analyzers to perform zero and span checks daily. A zero concentration and a concentration of 70-90% of the URL should be introduced into the analyzer. Most instruments have an internal or automatic capacity to cycle through a zero/span each day. If an instrument does not have this capacity, this zero/span should be done manually at least once per 2 weeks. If an analyzer drifts excessively, more frequent zeroes and spans will be required. Although not used specifically for data validation/invalidation, it does help to track a monitor's drift pattern, and may show at what particular point a monitor began to display any kind of trend. If an audit exceeds the allowed percent difference and records of zero/span checks can be supplied to identify when excessive drift began, it may not be necessary to invalidate an entire operational period. Decisions on data validation would then rest with the QAS Chief. The drift limit for the zero is 0.4 ppm in 24 hours and 0.6 ppm greater than 24 hours up to 2 weeks. The drift limit for span is 10%.

9.0 Preventive Maintenance

Analyzers must have routine preventive maintenance performed to ensure proper operation. Most manufacturers supply a preventive maintenance checklist with the instruction manual. An analyzer-specific schedule, similar to that shown below, should be located at each site. All maintenance should be recorded in the station logbook.

Sample Preventive Maintenance Schedule

Item	Action Required	Date Due	Date Performed	Next Date Due
Particulate Filter	Change	06/06/12	06/06/12	06/22/12
Pump Diaphragm	Change	06/01/12	06/06/12	12/01/12
Fan Filter	Examine	06/01/12	06/06/12	07/01/12
Span Cylinder	Check	Weekly		
Fittings/Connections	Check	Weekly		
Etc.				

10.0 LEADS

The Leading Environmental Analysis and Display System (LEADS) is a data acquisition system used by the State of Indiana's Ambient Monitoring Network. The system pairs an on-site calibrator with the analyzer in order to perform automated calibrations and span checks. It also flags invalid data automatically, which aids in the QA/QC procedure.

10.1 LEADS Automated Functions

The LEADS system automates many of the functions of the ambient monitoring network allowing fewer site visits. The table below outlines the general timeline that each site operates on.

Frequency	Activity	Description
Daily	Automated - Zero, Span (Validation)	Zero + 80% - 90% of Range
Weekly (7 Days)	Automated - Precision	SO_2, O_3, NO_2 Conc. 0.080 – 0.1 ppm CO Conc. 8 – 10 ppm
Monthly	Automated - Calibration	Zero + Four Upscale Points

10.2 LEADS Audits

LEADS Validation audits are performed daily by the system. In addition, an automated one point quality control (precision point) is run every week.

Once per quarter an accuracy audit is performed. See Section 6.3 of this chapter for more information these audits.

11.0 NCore Trace Level Monitoring

NCore consists of a network of automated multi-pollutant monitoring stations being developed to create a comprehensive near real-time report on air quality across the nation. The network will monitor CO and other precursor gases at the trace level.

11.1 NCore Monitoring Methodology

Equipment used will be similar to current models, with added modifications to allow for higher sensitivity. Analyzers will still employ non-dispersive infrared (NDIR). See Section 3.1 in this chapter for a description of this process.

The LDL should be at least 0.040 ppm, with a linear range from approximately 0.040 ppm – 5 ppm. This range can exceed 5 ppm if needed, and if the analyzer allows, multiple ranges can be monitored.

Requirements for NCore monitoring of CO (include, but are not limited to):

1. Incoming sample air must not be pressurized.

2. Air flow to the sampler from the inlet sample probe must be unrestricted.

3. Air must pass through a dryer and CO_2 scrubber before entering the sampler.

4. Zero air source lower than the instrument's lower detection limit (LDL), at least <40ppb CO.

5. NIST traceable calibration gas ±2% accuracy with nitrogen balance.

Moisture and CO_2 will both adversely affect the baseline of the analyzer. Because of the LDL, background drift will require more frequent auto zeroing/referencing.

More information on the NCore design and implementation is available online on the Technology Transfer Network (TTN) Air Monitoring Technology Information Center (AMTIC) at "http://www.epa.gov/ttn/amtic/ncore/index.html".

11.2 NCore Calibrations

NCore calibrations should consist of challenging the analyzer with a zero and at least three points along the expected range of operation. Multi-point calibrations should be performed at least once a quarter, along with the situations described earlier in Section 5.3.

The procedure for NCore calibrations is very similar to normal CO calibrations which can be found in Section 5.0 of this document. Calibration gases and calibrator mass flow meters should be NIST traceable, with the calibrator allowing for very accurate low concentrations, 0.04 ppm-0.80 ppm.

11.3 NCore Audits

A precision check should be conducted at least once every two weeks. This check consists of challenging the analyzer with a known concentration between 0.24 and 0.50 ppm. Audit procedures are similar to regular CO audits and can be found in Section 6.2 of this chapter. Please note that the allowable percent difference for valid data for trace-level is ±15%.

Table 1
Minimum Separation Distance Between
Roadways and Neighborhood Scale CO Stations

Average Vehicles (per day)	Minimum separation (meters)[1]
≤10,000	10
15,000	25
20,000	45
30,000	80
40,000	115
50,000	135
60,000 or over	Greater than 150

(1) Distances should be interpolated based on traffic flow.

Table 2
Summary of the National Ambient
Air Quality Standards

Pollutant	Time of Average	Primary Standard	Secondary Standard
Ozone (O_3)	8-Hour Average 1-Hour Average (limited areas)	0.070 ppm 0.120 ppm	Same As Primary
Sulfur Dioxide (SO_2)	1-Hour 3-Hour Average	0.075 ppm None	None 0.5 ppm
Carbon Monoxide (CO)	8-Hour Average 1-Hour Average	9 ppm 35 ppm	Same As Primary Same As Primary
Nitrogen Dioxide (NO_2)	Annual Arithmetic Mean 1-Hour Average	0.053 ppm 0.100 ppm	Same As Primary
Lead (Pb)	Rolling Quarterly Arithmetic Mean	0.15 $\mu g/m^3$	Same As Primary
Particulate Matter (PM_{10})	Annual Arithmetic Mean 24-Hour Average	150 $\mu g/m^3$	Same As Primary Same As Primary
Particulate Matter ($PM_{2.5}$)	Annual Arithmetic Mean 24-Hour Average	12 $\mu g/m^3$ 35 $\mu g/m^3$	15 $\mu g/m^3$ Same As Primary

Appendix A
Conversion Factors and Formulas

mmHg = inches of Hg x 25.4 mm/inch
Degrees Celsius (°C) = (ºF - 32) x 5/9
Kelvin (K) = (°C + 273K)

Vapor Pressure

Temperature (°C)	mmHg (H_2O)
20	17.5
21	18.6
22	19.8
23	21.1
24	22.4
25	23.8
26	25.2
27	26.7
28	28.3
29	30.0
30	31.8

Standard Reference Conditions (SRC):
Standard Barometric Pressure (P_{STD}) = 760 mmHg
Standard Temperature (T_{STD}) = 298K or (25 °C + 273K)

Formulas

1. Correction of flow rate to SRC:

$$\text{Correction Factor} = \frac{(P_{AMB} - P_{VAP}) \times T_{STD}}{T_{AMB} \times P_{STD}}$$

Where:

P_{AMB} = Ambient Barometric Pressure in mmHg
P_{VAP} = Vapor Pressure of H_2O
T_{AMB} = Ambient Air Temperature in K

2. Flow Rate (measured with a bubble meter):

$$\text{Flow Rate @ SRC} = \frac{\text{Volume Measured (cc or liters)}}{\text{Time (sec)/60 sec/min}} \times \text{SRC Correction Factor}$$

3. Calculation of a ppm concentration from a gas blended cylinder:

$$\text{ppm} = \frac{\text{Cylinder Concentration (ppm)} \times \text{Cylinder Flow Rate}}{\text{Dilution low Rate} + \text{Cylinder Flow Rate}}$$

4. Calculation of True Flow Rate from a Mass Flow Meter:

True Flow Rate = (Meter Reading × Calibration Slope) + Intercept (cc or liters)

5. Calculation of Observed Concentration:

ppm = (Monitor Response – Zero Response) × Calibration Slope

6. Calculation of Percent Difference:

$$\%\ \text{Difference} = \frac{\text{Observed Concentration (ppm)} - \text{Standard Concentration (ppm)}}{\text{Standard Concentration (ppm)}} \times 100$$

Appendix B
Carbon Monoxide (CO) Calibration
Direct Cylinder Calibration

SITE: _____ **AQS#:**_____ **INITIALS:** _____

DATE: ____/____/____ **RECAL DUE**____/____/____ **START TIME:** _____ **END TIME:** _____

Shelter Temp: _____ Ambient Pressure (mmHg): _____

ANALYZER INFORMATION

Original Monitor

Brand/Model:_____ Serial #:_____ Last Cal Date:___/___/____

Flow Rate:_____ Pressure:_____ Temp Internal:_____ Temp Chamber:_____

Calibration Factors: CO BKG PPM:_____ CO COEF:_____ Initial Zero/Span:_____/_____

Span Tank Brand/Cert Date/Serial #: _____/_____/_____

IF MONITORS CHANGED, New Monitor Brand SN:_____

VALIDATION POINT

Zero DAS:_____ DVM:_____ %Chart:_____ Monitor:_____

Validation Point DAS:_____ DVM:_____ %Chart:_____

Original Slope:_____ Original Intercept:_____

Actual Concentration:_____ STD:_____ *Corrected Actual Concentration:_____

% Difference (STD-Corrected Actual Concentration / STD × 100):_____

CALIBRATION

Cylinder Manufacturer and Serial #	Cylinder Cert. Date	Cylinder Pressure	Response	Actual Conc. in PPM	STD Cylinder Conc.	*Corrected Actual Con. In PPM	PERCENT DIFFERENCE
			DVM % DAS				
			DVM % DAS				
			DVM % DAS				
			DVM % DAS				
			DVM % DAS				

*Apply a Slope and Intercept to the Actual Concentration (in PPM) to obtain the "Corrected Actual Concentration" in PPM.

(B) SLOPE_____ Final Zero/Span:_____/_____
(A) INTERCEPT_____

Comments:

Calibration Factors: CO BKG PPM_____ CO COEF_____

Appendix C
Carbon Monoxide (CO) Calibration
Blending Calibration

Site: _____ **AQS #:** _____ **Initials:** _____
Date: _____ **Start Time:** _____ **End:** _____

Analyzer Information
Monitor Brand/Serial #: _____ Initial Zero: ____ Initial Span: _____ Range: _____ Final Zero: ____ Final Span: _____
Cylinder Information
Brand/Serial #: _____ Slope: ____ Measured Concentration Formula: _____
Calibration Information
Brand/Serial #: _____ Standard Conc. Formula:_____ Span Response: _____Zero Response: _____Certification Date: _____

Calibration Data

Primary Recording Device: _____ Units: _____
Secondary Recording Device: _____ Units: _____

Audit Point

Calibrator Setting	Flow From Standard @ SRC	Total Flow @ SRC	Monitor Response DVM / %	Measured Concentration	Standard Concentration	**Percent Difference**

Calibration Points

Appendix D
Carbon Monoxide (CO) Audit Sheet

Site Name: _____ Date: ___/___/_____

AQS#: _____ Auditor: _____

Start Time: _____

End Time: _____

ANALYZER INFORMATION

Serial Number	Brand	Model	Cal. Date	Slope	Intercept

AUDIT DEVICE INFORMATION (if blending)

Serial Number	Brand	Model	Cert. Date	Slope	Intercept

CYLINDER INFORMATION

Serial Number	Brand	Pressure	Cert. Date	Cert. (STD) Concentration

Audit

Analyzer Response Zero: _____ Audit Display Zero: _____

Audit Point or Cylinder #	Analyzer Response	Actual Conc. In PPM	STD Cylinder Conc./ Blender Display in PPM	*Corrected Actual Conc. In PPM	Percent Difference

* Apply a Slope and Intercept to the Actual Concentration to obtain Corrected Actual Concentration.