

**Pt. 60, App. B**

**APPENDIX B TO PART 60—PERFORMANCE SPECIFICATIONS**

- Performance Specification 1—Specifications and test procedures for continuous opacity monitoring systems in stationary sources
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**40 CFR Ch. I (7–1–17 Edition)**

**Opacities Monitoring Systems in Stationary Sources**

**PERFORMANCE SPECIFICATION 1—SPECIFICATIONS AND TEST PROCEDURES FOR CONTINUOUS OPACITY MONITORING SYSTEMS IN STATIONARY SOURCES**

*1.0 What Is the Purpose and Applicability of Performance Specification 1?*

Performance Specification 1 (PS-1) provides (1) requirements for the design, performance, and installation of a continuous opacity monitoring system (COMS) and (2) data computation procedures for evaluating the acceptability of a COMS. It specifies activities for two groups (1) the owner or operator and (2) the opacity monitor manufacturer.

1.1 Measurement Parameter. PS-1 covers the instrumental measurement of opacity caused by attenuation of projected light due to absorption and scatter of the light by particulate matter in the effluent gas stream.

1.2 What COMS must comply with PS-1? If you are an owner or operator of a facility with a COMS as a result of this Part, then PS-1 applies to your COMS if one of the following is true:

- (1) Your facility has a new COMS installed after February 6, 2001; or
- (2) Your COMS is replaced, relocated, or substantially refurbished (in the opinion of the regulatory authority) after February 6, 2001; or
- (3) Your COMS was installed before February 6, 2001 and is specifically required by regulatory action other than the promulgation of PS-1 to be recertified.

If you are an opacity monitor manufacturer, then paragraph 8.2 applies to you.

1.3 Does PS-1 apply to a facility with an applicable opacity limit less than 10 percent? If you are an owner or operator of a facility with a COMS as a result of this Part and the applicable opacity limit is less than 10 percent, then PS-1 applies to your COMS as described in section 1.2; taking into account (through statistical procedures or otherwise) the uncertainties associated with opacity measurements, and following the conditions for attenuators selection for low opacity applications as outlined in section 8.1(3)(ii). At your option, you, the source owner or operator, may select to establish a reduced full scale range of no less than 50 percent opacity instead of the 80 percent as prescribed in section 3.5, if the applicable opacity limit for your facility is less than 10 percent. The EPA recognizes that reducing the range of the analyzer to 50 percent does not necessarily result in any measurable improvement in measurement accuracy at opacity levels less than 10 percent; however, it may allow improved chart recorder interpretation.

1.4 What data uncertainty issues apply to COMS data? The measurement uncertainties associated with COMS data result from several design and performance factors including limitations on the availability of calibration attenuators for opacities less than about 6 percent (3 percent for single-pass instruments), calibration error tolerances, zero and upscale drift tolerances, and allowance for dust compensation that are significant relative to low opacity levels. The full scale requirements of this PS may also contribute to measurement uncertainty for opacity measurements where the applicable limits are below 10 percent opacity.

#### 2.0 What Are the Basic Requirements of PS-1?

PS-1 requires (1) opacity monitor manufacturers comply with a comprehensive series of design and performance specifications and test procedures to certify opacity monitoring equipment before shipment to the end user, (2) the owner or operator to follow installation guidelines, and (3) the owner or operator to conduct a set of field performance tests that confirm the acceptability of the COMS after it is installed.

2.1 ASTM D 6216-98 is the reference for design specifications, manufacturer's performance specifications, and test procedures. The opacity monitor manufacturer must periodically select and test an opacity monitor, that is representative of a group of monitors produced during a specified period or lot, for conformance with the design specifications in ASTM D 6216-98. The opacity monitor manufacturer must test each opacity monitor for conformance with the manufacturer's performance specifications in ASTM D 6216-98.

2.2 section 8.1(2) provides guidance for locating an opacity monitor in vertical and horizontal ducts. You are encouraged to seek approval for the opacity monitor location from the appropriate regulatory authority prior to installation.

2.3 After the COMS is installed and calibrated, the owner or operator must test the COMS for conformance with the field performance specifications in PS-1.

#### 3.0 What Special Definitions Apply to PS-1?

3.1 All definitions and discussions from section 3 of ASTM D 6216-98 are applicable to PS-1.

3.2 *Centroid Area.* A concentric area that is geometrically similar to the stack or duct cross-section and is no greater than 1 percent of the stack or duct cross-sectional area.

3.3 *Data Recorder.* That portion of the installed COMS that provides a permanent record of the opacity monitor output in terms of opacity. The data recorder may include automatic data reduction capabilities.

3.4 *External Audit Device.* The inherent design, equipment, or accommodation of the opacity monitor allowing the independent assessment of the COMS's calibration and operation.

3.5 *Full Scale.* The maximum data display output of the COMS. For purposes of record-keeping and reporting, full scale will be greater than 80 percent opacity.

3.6 *Operational Test Period.* A period of time (168 hours) during which the COMS is expected to operate within the established performance specifications without any unscheduled maintenance, repair, or adjustment.

3.7 *Primary Attenuators.* Those devices (glass or grid filter that reduce the transmission of light) calibrated according to procedures in section 7.1.

3.8 *Secondary Attenuators.* Those devices (glass or grid filter that reduce the transmission of light) calibrated against primary attenuators according to procedures in section 7.2.

3.9 *System Response Time.* The amount of time the COMS takes to display 95 percent of a step change in opacity on the COMS data recorder.

#### 4.0 Interferences. Water Droplets

##### 5.0 What Do I Need To Know To Ensure the Safety of Persons Using PS-1?

The procedures required under PS-1 may involve hazardous materials, operations, and equipment. PS-1 does not purport to address all of the safety problems associated with these procedures. Before performing these procedures, you must establish appropriate safety and health practices, and you must determine the applicable regulatory limitations. You should consult the COMS user's manual for specific precautions to take.

##### 6.0 What Equipment and Supplies Do I Need?

6.1 *Continuous Opacity Monitoring System.* You, as owner or operator, are responsible for purchasing an opacity monitor that meets the specifications of ASTM D 6216-98, including a suitable data recorder or automated data acquisition handling system. Example data recorders include an analog strip chart recorder or more appropriately an electronic data acquisition and reporting system with an input signal range compatible with the analyzer output.

6.2 *Calibration Attenuators.* You, as owner or operator, are responsible for purchasing a minimum of three calibration attenuators that meet the requirements of PS-1. Calibration attenuators are optical filters with neutral spectral characteristics. Calibration attenuators must meet the requirements in section 7 and must be of sufficient size to attenuate the entire light beam received by the detector of the COMS. For transmissometers operating over a narrow



bandwidth (e.g., laser), a calibration attenuator's value is determined for the actual operating wavelengths of the transmissometer. Some filters may not be uniform across the face. If errors result in the daily calibration drift or calibration error test, you may want to examine the across-face uniformity of the filter.

6.3 *Calibration Spectrophotometer.* Whoever calibrates the attenuators must have a spectrophotometer that meets the following minimum design specifications:

Parameter	Specification
Wavelength range .....	300-800 nm.
Detector angle of view .....	<10°
Accuracy .....	<0.5% transmittance, NIST traceable calibration.

7.0 *What Reagents and Standards Do I Need?*

You will need to use attenuators (i.e., neutral density filters) to check the daily calibration drift and calibration error of a COMS. Attenuators are designated as either primary or secondary based on how they are calibrated.

7.1 Attenuators are designated primary in one of two ways:

- (1) They are calibrated by NIST; or
- (2) They are calibrated on a 6-month frequency through the assignment of a luminous transmittance value in the following manner:

(i) Use a spectrophotometer meeting the specifications of section 6.3 to calibrate the required filters. Verify the spectrophotometer calibration through use of a NIST 930D Standard Reference Material (SRM). A SRM 930D consists of three neutral density glass filters and a blank, each mounted in a cuvette. The wavelengths and temperature to be used in the calibration are listed on the NIST certificate that accompanies the reported values. Determine and record a transmittance of the SRM values at the NIST wavelengths (three filters at five wavelengths each for a total of 15 determinations). Calculate a percent difference between the NIST certified values and the spectrophotometer response. At least 12 of the 15 differences (in percent) must be within ±0.5 percent of the NIST SRM values. No difference can be greater than ±1.0 percent. Recalibrate the SRM or service the spectrophotometer if the calibration results fail the criteria.

(ii) Scan the filter to be tested and the NIST blank from wavelength 380 to 780 nm, and record the spectrophotometer percent transmittance responses at 10 nm intervals. Test in this sequence: blank filter, tested filter, tested filter rotated 90 degrees in the plane of the filter, blank filter. Calculate the average transmittance at each 10 nm interval. If any pair of the tested filter transmittance values (for the same filter and wave-

length) differ by more than ±0.25 percent, rescan the tested filter. If the filter fails to achieve this tolerance, do not use the filter in the calibration tests of the COMS.

(iii) Correct the tested filter transmittance values by dividing the average tested filter transmittance by the average blank filter transmittance at each 10 nm interval.

(iv) Calculate the weighted (to the response of the human eye), tested filter transmittance by multiplying the transmittance value by the corresponding response factor shown in table 1-1, to obtain the Source C Human Eye Response.

(v) Recalibrate the primary attenuators semi-annually if they are used for the required calibration error test. Recalibrate the primary attenuators annually if they are used only for calibration of secondary attenuators.

7.2 Attenuators are designated secondary if the filter calibration is done using a laboratory-based transmissometer. Conduct the secondary attenuator calibration using a laboratory-based transmissometer calibrated as follows:

(i) Use at least three primary filters of nominal luminous transmittance 50, 70 and 90 percent, calibrated as specified in section 7.1(2)(i), to calibrate the laboratory-based transmissometer. Determine and record the slope of the calibration line using linear regression through zero opacity. The slope of the calibration line must be between 0.99 and 1.01, and the laboratory-based transmissometer reading for each primary filter must not deviate by more than ±2 percent from the linear regression line. If the calibration of the laboratory-based transmissometer yields a slope or individual readings outside the specified ranges, secondary filter calibrations cannot be performed. Determine the source of the variations (either transmissometer performance or changes in the primary filters) and repeat the transmissometer calibration before proceeding with the attenuator calibration.

(ii) Immediately following the laboratory-based transmissometer calibration, insert the secondary attenuators and determine and record the percent effective opacity value per secondary attenuator from the calibration curve (linear regression line).

(iii) Recalibrate the secondary attenuators semi-annually if they are used for the required calibration error test.

8.0 *What Performance Procedures Are Required To Comply With PS-1?*

Procedures to verify the performance of the COMS are divided into those completed by the owner or operator and those completed by the opacity monitor manufacturer.

8.1 What procedures must I follow as the Owner or Operator?

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(1) You must purchase an opacity monitor that complies with ASTM D 6216-98 and obtain a certificate of conformance from the opacity monitor manufacturer.

(2) You must install the opacity monitor at a location where the opacity measurements are representative of the total emissions from the affected facility. You must meet this requirement by choosing a measurement location and a light beam path as follows:

(i) Measurement Location. Select a measurement location that is (1) at least 4 duct diameters downstream from all particulate

control equipment or flow disturbance, (2) at least 2 duct diameters upstream of a flow disturbance, (3) where condensed water vapor is not present, and (4) accessible in order to permit maintenance. Alternatively, you may select a measurement location specified in paragraph 8.1(2)(ii) or 8.1(2)(iii).

(ii) Light Beam Path. Select a light beam path that passes through the centroidal area of the stack or duct. Also, you must follow these additional requirements or modifications for these measurement locations:

If your measurement location is in a:	And is:	Then use a light beam path that is:
1. Straight vertical section of stack or duct.	Less than 4 equivalent diameters downstream from a bend.	In the plane defined by the upstream bend (see figure 1-1).
2. Straight vertical section of stack or duct.	Less than 4 equivalent diameters upstream from a bend.	In the plane defined by the downstream bend (see figure 1-2).
3. Straight vertical section of stack or duct.	Less than 4 equivalent diameters downstream and is also less than 1 diameter upstream from a bend.	In the plane defined by the upstream bend (see figure 1-3).
4. Horizontal section of stack or duct.	At least 4 equivalent diameters downstream from a vertical bend.	In the horizontal plane that is between $\frac{1}{8}$ and $\frac{1}{2}$ the distance up the vertical axis from the bottom of the duct (see figure 1-4).
5. Horizontal section of duct.	Less than 4 equivalent diameters downstream from a vertical bend.	In the horizontal plane that is between $\frac{1}{8}$ and $\frac{3}{8}$ the distance up the vertical axis from the bottom of the duct for upward flow in the vertical section, and is between $\frac{1}{8}$ and $\frac{1}{2}$ the distance up the vertical axis from the bottom of the duct for downward flow (figure 1-5).

(iii) Alternative Locations and Light Beam Paths. You may select locations and light beam paths, other than those cited above, if you demonstrate, to the satisfaction of the Administrator or delegated agent, that the average opacity measured at the alternative location or path is equivalent to the opacity as measured at a location meeting the criteria of sections 8.1(2)(i) and 8.1(2)(ii). The opacity at the alternative location is considered equivalent if (1) the average opacity value measured at the alternative location is within  $\pm 10$  percent of the average opacity value measured at the location meeting the installation criteria, and (2) the difference between any two average opacity values is less than 2 percent opacity (absolute). You use the following procedure to conduct this demonstration: simultaneously measure the opacities at the two locations or paths for a minimum period of time (e.g., 180-minutes) covering the range of normal operating conditions and compare the results. The opacities of the two locations or paths may be measured at different times, but must represent the same process operating conditions. You may use alternative procedures for determining acceptable locations if those procedures are approved by the Administrator.

(3) Field Audit Performance Tests. After you install the COMS, you must perform the following procedures and tests on the COMS.

(i) Optical Alignment Assessment. Verify and record that all alignment indicator devices show proper alignment. A clear indication of alignment is one that is objectively apparent relative to reference marks or conditions.

(ii) Calibration Error Check. Conduct a three-point calibration error test using three calibration attenuators that produce outlet pathlength corrected, single-pass opacity values shown in ASTM D 6216-98, section 7.5. If your applicable limit is less than 10 percent opacity, use attenuators as described in ASTM D 6216-98, section 7.5 for applicable standards of 10 to 19 percent opacity. Confirm the external audit device produces the proper zero value on the COMS data recorder. Separately, insert each calibration attenuators (low, mid, and high-level) into the external audit device. While inserting each attenuator, (1) ensure that the entire light beam passes through the attenuator, (2) minimize interference from reflected light, and (3) leave the attenuator in place for at least two times the shortest recording interval on the COMS data recorder. Make a total of five nonconsecutive readings for each attenuator. At the end of the test, correlate each attenuator insertion to the corresponding value from the data recorder. Subtract the single-pass calibration attenuator values corrected to the stack exit conditions from the COMS responses. Calculate



the arithmetic mean difference, standard deviation, and confidence coefficient of the five measurements value using equations 1-3, 1-4, and 1-5. Calculate the calibration error as the sum of the absolute value of the mean difference and the 95 percent confidence coefficient for each of the three test attenuators using equation 1-6. Report the calibration error test results for each of the three attenuators.

(iii) System Response Time Check. Using a high-level calibration attenuator, alternately insert the filter five times and remove it from the external audit device. For each filter insertion and removal, measure the amount of time required for the COMS to display 95 percent of the step change in opacity on the COMS data recorder. For the upscale response time, measure the time from insertion to display of 95 percent of the final, steady upscale reading. For the downscale response time, measure the time from removal to display 5 percent of the initial upscale reading. Calculate the mean of the five upscale response time measurements and the mean of the five downscale response time measurements. Report both the upscale and downscale response times.

(iv) Averaging Period Calculation and Recording Check. After the calibration error check, conduct a check of the averaging period calculation (e.g., 6-minute integrated average). Consecutively insert each of the calibration error check attenuators (low, mid, and high-level) into the external audit device for a period of two times the averaging period plus 1 minute (e.g., 13 minutes for a 6-minute averaging period). Compare the path length corrected opacity value of each attenuator to the valid average value calculated by the COMS data recording device for that attenuator.

(4) Operational Test Period. Before conducting the operational testing, you must have successfully completed the field audit tests described in sections 8.1(3)(i) through 8.1(3)(iv). Then, you operate the COMS for an initial 168-hour test period while the source is operating under normal operating conditions. If normal operations contain routine source shutdowns, include the source's down periods in the 168-hour operational test period. However, you must ensure that the following minimum source operating time is included in the operational test period: (1) For a batch operation, the operational test period must include at least one full cycle of batch operation during the 168-hour period unless the batch operation is longer than 168 hours or (2) for continuous operating processes, the unit must be operating for at least 50 percent of the 168-hour period. Except during times of instrument zero and upscale calibration drift checks, you must analyze the effluent gas for opacity and produce a permanent record of the COMS output. During this period, you may not perform un-

scheduled maintenance, repair, or adjustment to the COMS. Automatic zero and calibration adjustments (*i.e.*, intrinsic adjustments), made by the COMS without operator intervention or initiation, are allowable at any time. At the end of the operational test period, verify and record that the COMS optical alignment is still correct. If the test period is interrupted because of COMS failure, record the time when the failure occurred. After the failure is corrected, you restart the 168-hour period and tests from the beginning (0-hour). During the operational test period, perform the following test procedures:

(i) Zero Calibration Drift Test. At the outset of the 168-hour operational test period and at each 24-hour interval, the automatic calibration check system must initiate the simulated zero device to allow the zero drift to be determined. Record the COMS response to the simulated zero device. After each 24-hour period, subtract the COMS zero reading from the nominal value of the simulated zero device to calculate the 24-hour zero drift (ZD). At the end of the 168-hour period, calculate the arithmetic mean, standard deviation, and confidence coefficient of the 24-hour ZDs using equations 1-3, 1-4, and 1-5. Calculate the sum of the absolute value of the mean and the absolute value of the confidence coefficient using equation 1-6, and report this value as the 24-hour ZD error.

(ii) Upscale Calibration Drift Test. At each 24-hour interval after the simulated zero device value has been checked, check and record the COMS response to the upscale calibration device. After each 24-hour period, subtract the COMS upscale reading from the nominal value of the upscale calibration device to calculate the 24-hour calibration drift (CD). At the end of the 168-hour period, calculate the arithmetic mean, standard deviation, and confidence coefficient of the 24-hour CD using equations 1-3, 1-4, and 1-5. Calculate the sum of the absolute value of the mean and the absolute value of the confidence coefficient using equation 1-6, and report this value as the 24-hour CD error.

(5) Retesting. If the COMS fails to meet the specifications for the tests conducted under the operational test period, make the necessary corrections and restart the operational test period. Depending on the opinion of the enforcing agency, you may have to repeat some or all of the field audit tests.

8.2 What are the responsibilities of the Opacity Monitor Manufacturer?

You, the manufacturer, must carry out the following activities:

(1) Conduct the verification procedures for design specifications in section 6 of ASTM D 6216-98.

(2) Conduct the verification procedures for performance specifications in section 7 of ASTM D 6216-98.

(3) Provide to the owner or operator, a report of the opacity monitor's conformance to

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the design and performance specifications required in sections 6 and 7 of ASTM D 6216-98 in accordance with the reporting requirements of section 9 in ASTM D 6216-98.

*9.0 What quality control measures are required by PS-1?*

Opacity monitor manufacturers must initiate a quality program following the requirements of ASTM D 6216-98, section 8. The quality program must include (1) a quality system and (2) a corrective action program.

*10.0 Calibration and Standardization*  
[Reserved]

*11.0 Analytical Procedure* [Reserved]

*12.0 What Calculations Are Needed for PS-1?*

12.1 Desired Attenuator Values. Calculate the desired attenuator value corrected to the emission outlet pathlength as follows:

$$OP_2 = 1 - (1 - OP_1)^{\frac{L_2}{L_1}} \quad \text{Eq. 1-1}$$

Where:

$\bar{x}$  = Arithmetic mean

n = Number of data points

$$\sum_{i=1}^n x_i = \text{Algebraic sum of the individual measurements, } x_i.$$

12.4 Standard Deviation. Calculate the standard deviation as follows:

$$S_d = \sqrt{\frac{\sum_{i=1}^n x_i^2 - \frac{\left(\sum_{i=1}^n x_i\right)^2}{n}}{n-1}} \quad \text{Eq. 1-4}$$

Where:

$S_d$  = Standard deviation of a data set.

12.5 Confidence Coefficient. Calculate the 2.5 percent error confidence coefficient (one-tailed) as follows:

$$CC = \frac{t_{0.975} S_d}{\sqrt{n}} \quad \text{Eq. 1-5}$$

Where:

$OP_1$  = Nominal opacity value of required low-, mid-, or high-range calibration attenuators.

$OP_2$  = Desired attenuator opacity value from ASTM D 6216-98, section 7.5 at the opacity limit required by the applicable subpart.

$L_1$  = Monitoring pathlength.

$L_2$  = Emission outlet pathlength.

12.2 Luminous Transmittance Value of a Filter. Calculate the luminous transmittance of a filter as follows:

$$LT = \frac{\sum_{i=300nm}^{i=800nm} T_i}{100,000} \quad \text{Eq. 1-2}$$

Where:

LT = Luminous transmittance

$T_i$  = Weighted tested filter transmittance.

12.3 Arithmetic Mean. Calculate the arithmetic mean of a data set as follows:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad \text{Eq. 1-3}$$

Where:

CC = Confidence coefficient

$t_{0.975}$  = t - value (see table 1-2).

12.6 Calibration Error. Calculate the error (calibration error, zero drift error, and calibration drift error) as follows:

$$Er = |\bar{x}| + |CC| \quad \text{Eq. 1-6}$$

Where:

Er = Error.

12.7 Conversion of Opacity Values for Monitor Pathlength to Emission Outlet Pathlength. When the monitor pathlength is different from the emission outlet pathlength, use either of the following equations to convert from one basis to the other (this conversion may be automatically calculated by the monitoring system):



$$\log (1-Op_2) = \frac{L_2}{L_1} \log (1-Op_1) \quad \text{Eq. 1-7}$$

$$OD_2 = \frac{L_2}{L_1} \times OD_1 \quad \text{Eq. 1-8}$$

Where:

$Op_1$  = Opacity of the effluent based upon  $L_1$ .

$Op_2$  = Opacity of the effluent based upon  $L_2$ .

$L_1$  = Monitor pathlength.

$L_2$  = Emission outlet pathlength.

$OD_1$  = Optical density of the effluent based upon  $L_1$ .

$OD_2$  = Optical density of the effluent based upon  $L_2$ .

12.8 Mean Response Wavelength. Calculate the mean of the effective spectral response curve from the individual responses at the specified wavelength values as follows:

$$L = \frac{\sum_{i=1}^n L_i g_i}{\sum_{i=1}^n g_i} \quad \text{Eq. 1-9}$$

Where:

$L$  = mean of the effective spectral response curve

$L_i$  = The specified wavelength at which the response  $g_i$  is calculated at 20 nm intervals.

$g_i$  = The individual response value at  $L_i$ .

#### 13.0 What Specifications Does a COMS Have To Meet for Certification?

A COMS must meet the following design, manufacturer's performance, and field audit performance specifications:

13.1 Design Specifications. The opacity monitoring equipment must comply with the design specifications of ASTM D 6216-98.

13.2 Manufacturer's Performance Specifications. The opacity monitor must comply with the manufacturer's performance specifications of ASTM D 6216-98.

13.3 Field Audit Performance Specifications. The installed COMS must comply with the following performance specifications:

(1) Optical Alignment. Objectively indicate proper alignment relative to reference marks (e.g., bull's-eye) or conditions.

(2) Calibration Error. The calibration error must be  $\leq 3$  percent opacity for each of the three calibration attenuators.

(3) System Response Time. The COMS upscale and downscale response times must be  $\leq 10$  seconds as measured at the COMS data recorder.

(4) Averaging Period Calculation and Recording. The COMS data recorder must average and record each calibration attenuator value to within  $\pm 2$  percent opacity of the certified value of the attenuator.

(5) Operational Test Period. The COMS must be able to measure and record opacity and to perform daily calibration drift assessments for 168 hours without unscheduled maintenance, repair, or adjustment.

(6) Zero and Upscale Calibration Drift Error. The COMS zero and upscale calibration drift error must not exceed 2 percent opacity over a 24 hour period.

#### 14.0 Pollution Prevention [Reserved]

#### 15.0 Waste Management [Reserved]

#### 16.0 Which references are relevant to this method?

1. Experimental Statistics. Department of Commerce. National Bureau of Standards Handbook 91. Paragraph 3-3.1.4. 1963. 3-31 p.

2. Performance Specifications for Stationary Source Monitoring Systems for Gases and Visible Emissions. EPA-650/2-74-013, January 1974. U. S. Environmental Protection Agency, Research Triangle Park, NC.

3. Koontz, E.C., Walton, J. Quality Assurance Programs for Visible Emission Evaluations. Tennessee Division of Air Pollution Control. Nashville, TN. 78th Meeting of the Air Pollution Control Association. Detroit, MI. June 16-21, 1985.

4. Evaluation of Opacity CEMS Reliability and Quality Assurance Procedures. Volume 1. U. S. Environmental Protection Agency. Research Triangle Park, NC. EPA-340/1-86-009a.

5. Nimeroff, I. "Colorimetry Precision Measurement and Calibration." NBS Special Publication 300. Volume 9. June 1972.

6. Technical Assistance Document: Performance Audit Procedures for Opacity Monitors. U. S. Environmental Protection Agency. Research Triangle Park, NC. EPA-600/8-87-025. April 1987.

7. Technical Assistance Document: Performance Audit Procedures for Opacity Monitors. U. S. Environmental Protection Agency. Research Triangle Park, NC. EPA-450/4-92-010. April 1992.

8. ASTM D 6216-98: Standard Practice for Opacity Monitor Manufacturers to Certify Conformance with Design and Performance Specifications. American Society for Testing and Materials (ASTM). April 1998.

#### 17.0 What tables and diagrams are relevant to this method?

#### 17.1 Reference Tables.

TABLE 1-1—SOURCE C, HUMAN EYE RESPONSE FACTOR

Wavelength nanometers	Weighting factor <sup>a</sup>	Wavelength nanometers	Weighting factor <sup>a</sup>
380	0	590	6627
390	0	600	5316
400	2	610	4176
410	9	620	3153
420	37	630	2190
430	122	640	1443
440	262	650	886
450	443	660	504
460	694	670	259
470	1058	680	134
480	1618	690	62
490	2358	700	29
500	3401	720	14
510	4833	720	6
520	6462	730	3
530	7934	740	2
540	9194	750	1
550	9832	760	1
560	9641	770	0
570	9147	780	0
580	7992		

<sup>1</sup> Total of weighting factors = 100,000.

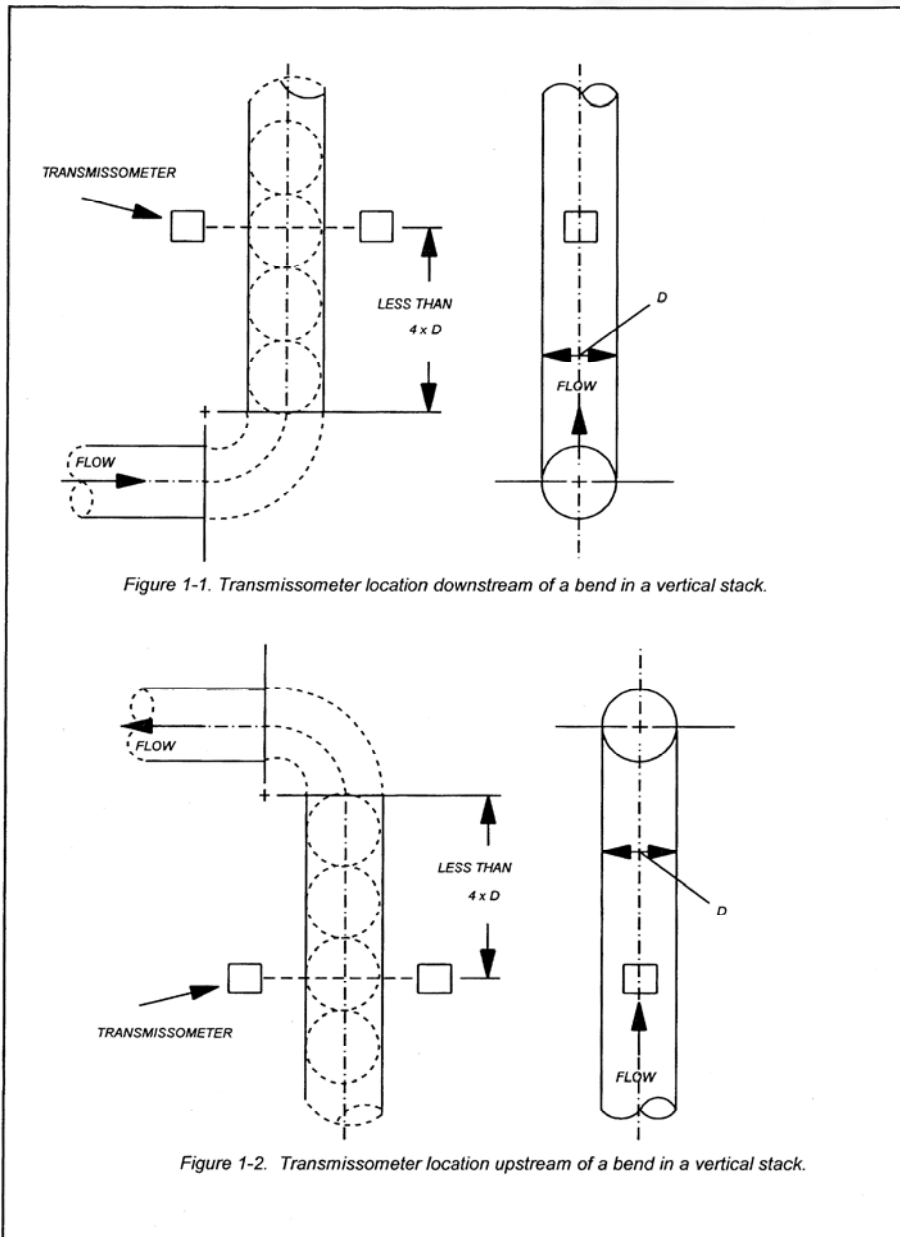
TABLE 1-2<sup>T</sup> VALUES

n <sup>a</sup>	t <sub>0.975</sub>	n <sup>a</sup>	t <sub>0.975</sub>	n <sup>a</sup>	t <sub>0.975</sub>
2	12.706	7	2.447	12	2.201
3	4.303	8	2.365	13	2.179
4	3.182	9	2.306	14	2.160
5	2.776	10	2.262	15	2.145
6	2.571	11	2.228	16	2.131

<sup>a</sup> The values in this table are already corrected for n-1 degrees of freedom. Use n equal to the number of individual values.

17.2 Diagrams.





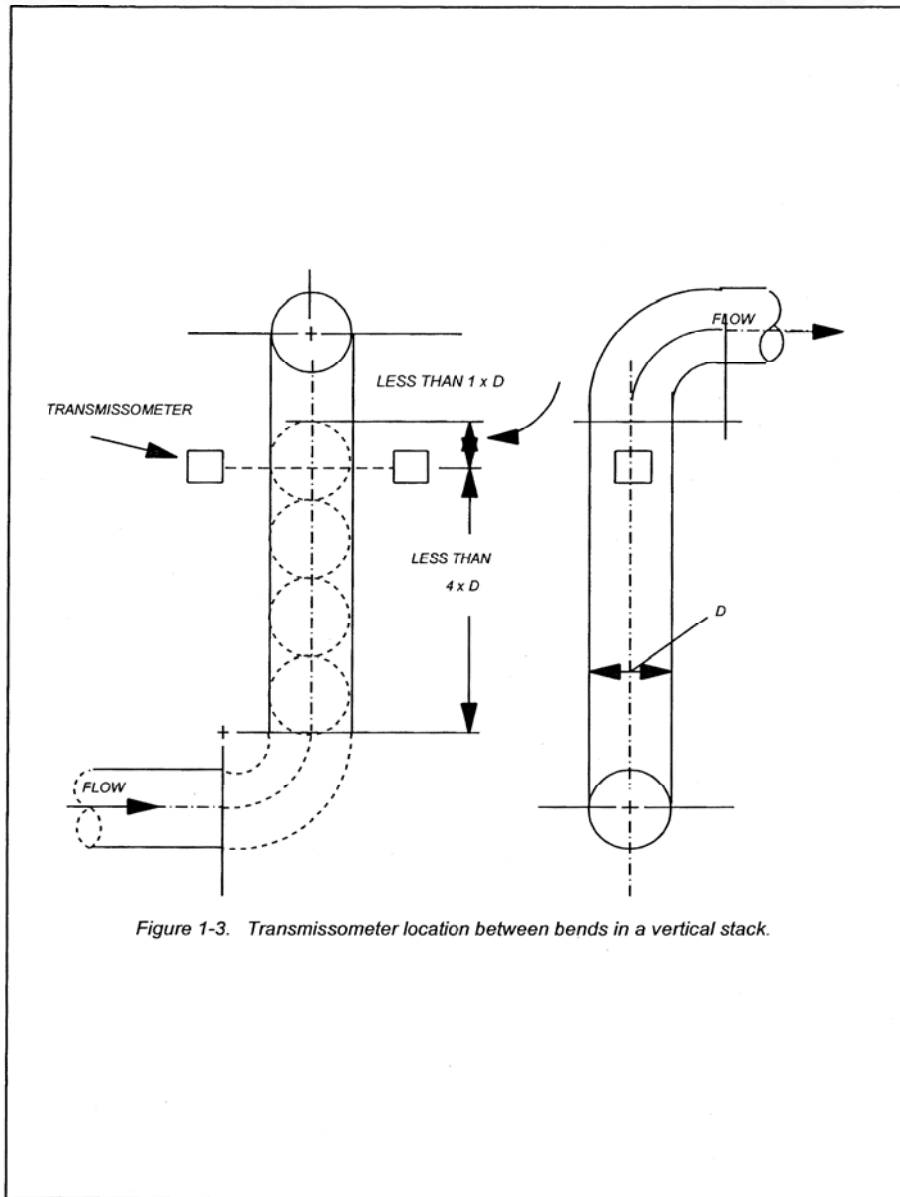


Figure 1-3. Transmissometer location between bends in a vertical stack.



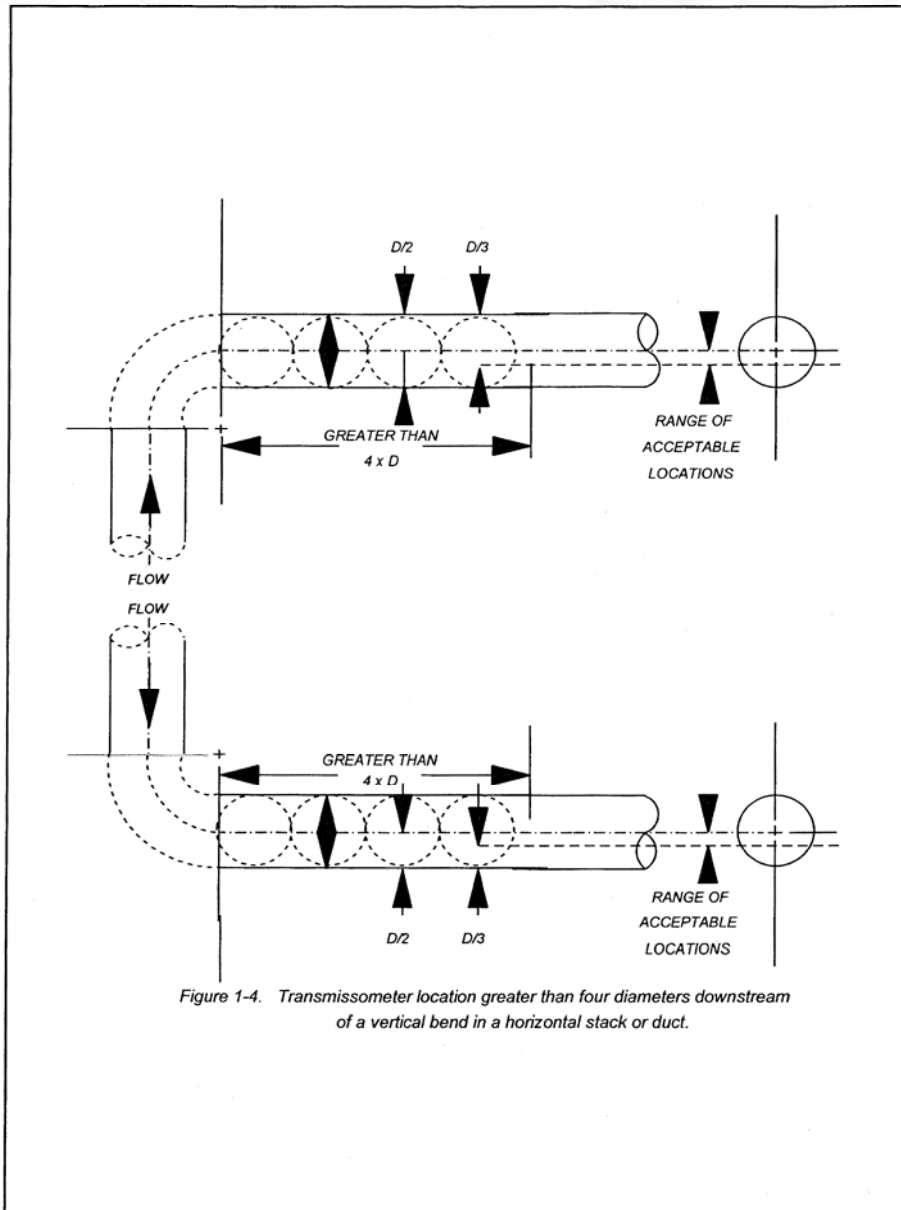


Figure 1-4. Transmissometer location greater than four diameters downstream of a vertical bend in a horizontal stack or duct.

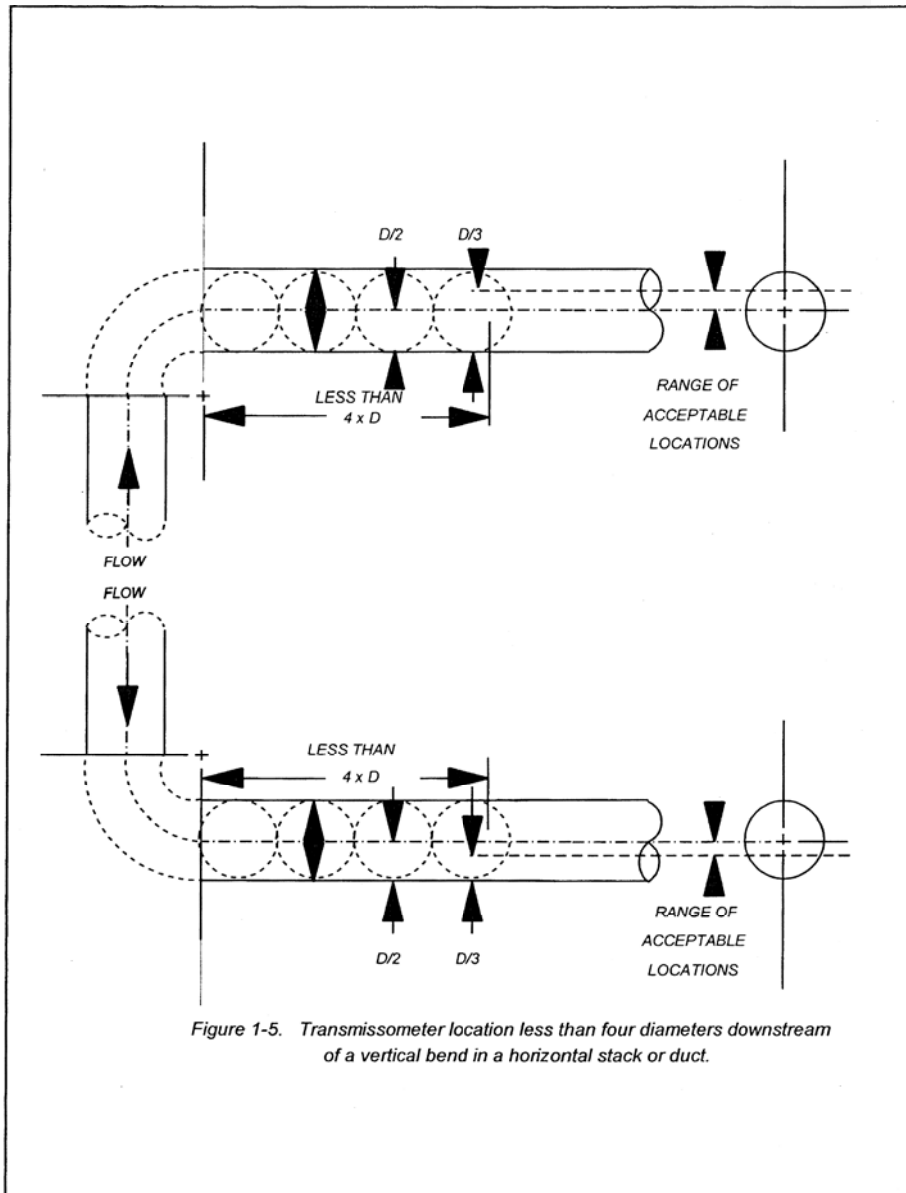


Figure 1-5. Transmissometer location less than four diameters downstream of a vertical bend in a horizontal stack or duct.

PERFORMANCE SPECIFICATION 2—SPECIFICATIONS AND TEST PROCEDURES FOR SO<sub>2</sub> AND NO<sub>x</sub> CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1.0 Scope and Application

1.1 Analytes

Analyte	CAS Nos.
Sulfur Dioxide (SO <sub>2</sub> ) .....	7449-09-5
Nitrogen Oxides (NO <sub>x</sub> ) .....	10102-44-0 (NO <sub>2</sub> ), 10024-97-2 (NO)

1.2 Applicability.

1.2.1 This specification is for evaluating the acceptability of SO<sub>2</sub> and NO<sub>x</sub> continuous emission monitoring systems (CEMS) at the time of installation or soon after and whenever specified in the regulations. The CEMS may include, for certain stationary sources, a diluent (O<sub>2</sub> or CO<sub>2</sub>) monitor.

1.2.2 This specification is not designed to evaluate the installed CEMS performance over an extended period of time nor does it identify specific calibration techniques and other auxiliary procedures to assess the CEMS performance. The source owner or operator is responsible to calibrate, maintain, and operate the CEMS properly. The Administrator may require, under section 114 of the Act, the operator to conduct CEMS performance evaluations at other times besides the initial test to evaluate the CEMS performance. See 40 CFR Part 60, § 60.13(c).

2.0 Summary of Performance Specification

Procedures for measuring CEMS relative accuracy and calibration drift are outlined. CEMS installation and measurement location specifications, equipment specifications, performance specifications, and data reduction procedures are included. Conformance of the CEMS with the Performance Specification is determined.

3.0 Definitions

3.1 *Calibration Drift (CD)* means the difference in the CEMS output readings from the established reference value after a stated period of operation during which no unscheduled maintenance, repair, or adjustment took place.

3.2 *Centroidal Area* means a concentric area that is geometrically similar to the stack or duct cross section and is no greater than 1 percent of the stack or duct cross-sectional area.

3.3 *Continuous Emission Monitoring System* means the total equipment required for the determination of a gas concentration or emission rate. The sample interface, pollutant analyzer, diluent analyzer, and data recorder are the major subsystems of the CEMS.

3.4 *Data Recorder* means that portion of the CEMS that provides a permanent record of the analyzer output. The data recorder may include automatic data reduction capabilities.

3.5 *Diluent Analyzer* means that portion of the CEMS that senses the diluent gas (i.e., CO<sub>2</sub> or O<sub>2</sub>) and generates an output proportional to the gas concentration.

3.6 *Path CEMS* means a CEMS that measures the gas concentration along a path greater than 10 percent of the equivalent diameter of the stack or duct cross section.

3.7 *Point CEMS* means a CEMS that measures the gas concentration either at a single point or along a path equal to or less than 10 percent of the equivalent diameter of the stack or duct cross section.

3.8 *Pollutant Analyzer* means that portion of the CEMS that senses the pollutant gas and generates an output proportional to the gas concentration.

3.9 *Relative Accuracy (RA)* means the absolute mean difference between the gas concentration or emission rate determined by the CEMS and the value determined by the reference method (RM), plus the 2.5 percent error confidence coefficient of a series of tests, divided by the mean of the RM tests or the applicable emission limit.

3.10 *Sample Interface* means that portion of the CEMS used for one or more of the following: sample acquisition, sample delivery, sample conditioning, or protection of the monitor from the effects of the stack effluent.

3.11 *Span Value* means the calibration portion of the measurement range as specified in the applicable regulation or other requirement. If the span is not specified in the applicable regulation or other requirement, then it must be a value approximately equivalent to two times the emission standard. For spans less than 500 ppm, the span value may either be rounded upward to the next highest multiple of 10 ppm, or to the next highest multiple of 100 ppm such that the equivalent emission concentration is not less than 30 percent of the selected span value.

4.0 Interferences [Reserved]

5.0 Safety

The procedures required under this performance specification may involve hazardous materials, operations, and equipment. This performance specification may not address all of the safety problems associated with these procedures. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicable regulatory limitations prior to performing these procedures. The CEMS user's manual and materials recommended by the reference method should be consulted for specific precautions to be taken.



## 6.0 Equipment and Supplies

## 6.1 CEMS Equipment Specifications.

6.1.1 Data Recorder. The portion of the CEMS that provides a record of analyzer output. The data recorder may record other pertinent data such as effluent flow rates, various instrument temperatures or abnormal CEMS operation. The data recorder output range must include the full range of expected concentration values in the gas stream to be sampled including zero and span values.

6.1.1.1 For a CEMS intended to measure an uncontrolled emission (*e.g.*, SO<sub>2</sub> measurements at the inlet of a flue gas desulfurization unit), the high-level value should be between 1.25 and 2 times the maximum potential emission level over the appropriate averaging time, unless otherwise specified in an applicable subpart of the regulations.

6.1.1.2 For a CEMS installed to measure controlled emissions or emissions that are in compliance with an applicable regulation, the high-level value between 1.5 times the pollutant concentration corresponding to the emission standard level and the span value given in the applicable regulations is adequate.

6.1.1.3 Alternative high-level values may be used, provided the source can measure emissions which exceed the full-scale limit in accordance with the requirements of applicable regulations.

6.1.1.4 If an analog data recorder is used, the data recorder output must be established so that the high-level value would read between 90 and 100 percent of the data recorder full scale. (This scale requirement may not be applicable to digital data recorders.) The zero and high level calibration gas, optical filter, or cell values should be used to establish the data recorder scale.

6.1.2 The CEMS design should also allow the determination of calibration drift at the zero and span values. If this is not possible or practical, the design must allow these determinations to be conducted at a low-level value (zero to 20 percent of the span value) and at a value between 50 and 100 percent of the span value. In special cases, the Administrator may approve a single-point calibration drift determination.

6.2 Other equipment and supplies, as needed by the applicable reference method(s) (see section 8.4.2 of this Performance Specification), may be required.

## 7.0 Reagents and Standards

7.1 Reference Gases, Gas Cells, or Optical Filters. As specified by the CEMS manufacturer for calibration of the CEMS (these need not be certified).

7.2 Reagents and Standards. May be required as needed by the applicable reference method(s) (see section 8.4.2 of this Performance Specification).

## 8.0 Performance Specification Test Procedure

## 8.1 Installation and Measurement Location Specifications.

8.1.1 CEMS Installation. Install the CEMS at an accessible location where the pollutant concentration or emission rate measurements are directly representative or can be corrected so as to be representative of the total emissions from the affected facility or at the measurement location cross section. Then select representative measurement points or paths for monitoring in locations that the CEMS will pass the RA test (see section 8.4). If the cause of failure to meet the RA test is determined to be the measurement location and a satisfactory correction technique cannot be established, the Administrator may require the CEMS to be relocated. Suggested measurement locations and points or paths that are most likely to provide data that will meet the RA requirements are listed below.

8.1.2 CEMS Measurement Location. It is suggested that the measurement location be (1) at least two equivalent diameters downstream from the nearest control device, the point of pollutant generation, or other point at which a change in the pollutant concentration or emission rate may occur and (2) at least a half equivalent diameter upstream from the effluent exhaust or control device.

8.1.2.1 Point CEMS. It is suggested that the measurement point be (1) no less than 1.0 meter (3.3 ft) from the stack or duct wall or (2) within or centrally located over the centroidal area of the stack or duct cross section.

8.1.2.2 Path CEMS. It is suggested that the effective measurement path (1) be totally within the inner area bounded by a line 1.0 meter (3.3 ft) from the stack or duct wall, or (2) have at least 70 percent of the path within the inner 50 percent of the stack or duct cross-sectional area, or (3) be centrally located over any part of the centroidal area.

## 8.1.3 Reference Method Measurement Location and Traverse Points.

8.1.3.1 Select, as appropriate, an accessible RM measurement point at least two equivalent diameters downstream from the nearest control device, the point of pollutant generation, or other point at which a change in the pollutant concentration or emission rate may occur, and at least a half equivalent diameter upstream from the effluent exhaust or control device. When pollutant concentration changes are due solely to diluent leakage (*e.g.*, air heater leakages) and pollutants and diluents are simultaneously measured at the same location, a half diameter may be used in lieu of two equivalent diameters. The CEMS and RM locations need not be the same.

8.1.3.2 Select traverse points that assure acquisition of representative samples over

the stack or duct cross section. The minimum requirements are as follows: Establish a "measurement line" that passes through the centroidal area and in the direction of any expected stratification. If this line interferes with the CEMS measurements, displace the line up to 30 cm (12 in.) (or 5 percent of the equivalent diameter of the cross section, whichever is less) from the centroidal area. Locate three traverse points at 16.7, 50.0, and 83.3 percent of the measurement line. If the measurement line is longer than 2.4 meters (7.9 ft) and pollutant stratification is not expected, the three traverse points may be located on the line at 0.4, 1.2, and 2.0 meters from the stack or duct wall. This option must not be used after wet scrubbers or at points where two streams with different pollutant concentrations are combined. If stratification is suspected, the following procedure is suggested. For rectangular ducts, locate at least nine sample points in the cross section such that sample points are the centroids of similarly-shaped, equal area divisions of the cross section. Measure the pollutant concentration, and, if applicable, the diluent concentration at each point using appropriate reference methods or other appropriate instrument methods that give responses relative to pollutant concentrations. Then calculate the mean value for all sample points. For circular ducts, conduct a 12-point traverse (*i.e.*, six points on each of the two perpendicular diameters) locating the sample points as described in 40 CFR 60, Appendix A, Method 1. Perform the measurements and calculations as described above. Determine if the mean pollutant concentration is more than 10% different from any single point. If so, the cross section is considered to be stratified, and the tester may not use the alternative traverse point locations (...0.4, 1.2, and 2.0 meters from the stack or duct wall.) but must use the three traverse points at 16.7, 50.0, and 83.3 percent of the entire measurement line. Other traverse points may be selected, provided that they can be shown to the satisfaction of the Administrator to provide a representative sample over the stack or duct cross section. Conduct all necessary RM tests within 3 cm (1.2 in.) of the traverse points, but no closer than 3 cm (1.2 in.) to the stack or duct wall.

8.2 Pretest Preparation. Install the CEMS, prepare the RM test site according to the specifications in section 8.1, and prepare the CEMS for operation according to the manufacturer's written instructions.

8.3 Calibration Drift Test Procedure.

8.3.1 *CD Test Period.* While the affected facility is operating, determine the magnitude of the CD once each day (at 24-hour intervals) for 7 consecutive calendar days according to the procedure given in sections 8.3.2 through 8.3.4. Alternatively, the CD test may be conducted over 7 consecutive unit operating days.

8.3.2 The purpose of the CD measurement is to verify the ability of the CEMS to conform to the established CEMS calibration used for determining the emission concentration or emission rate. Therefore, if periodic automatic or manual adjustments are made to the CEMS zero and calibration settings, conduct the CD test immediately before these adjustments, or conduct it in such a way that the CD can be determined.

8.3.3 Conduct the CD test at the two points specified in section 6.1.2. Introduce to the CEMS the reference gases, gas cells, or optical filters (these need not be certified). Record the CEMS response and subtract this value from the reference value (see example data sheet in Figure 2-1).

8.4 Relative Accuracy Test Procedure.

8.4.1 *RA Test Period.* Conduct the RA test according to the procedure given in sections 8.4.2 through 8.4.6 while the affected facility is operating at more than 50 percent of normal load, or as specified in an applicable subpart. The RA test may be conducted during the CD test period.

8.4.2 *Reference Methods.* Unless otherwise specified in an applicable subpart of the regulations, Methods 3B, 4, 6, and 7, or their approved alternatives, are the reference methods for diluent (O<sub>2</sub> and CO<sub>2</sub>), moisture, SO<sub>2</sub>, and NO<sub>x</sub>, respectively.

8.4.3 *Sampling Strategy for RM Tests.* Conduct the RM tests in such a way that they will yield results representative of the emissions from the source and can be correlated to the CEMS data. It is preferable to conduct the diluent (if applicable), moisture (if needed), and pollutant measurements simultaneously. However, diluent and moisture measurements that are taken within an hour of the pollutant measurements may be used to calculate dry pollutant concentration and emission rates. In order to correlate the CEMS and RM data properly, note the beginning and end of each RM test period of each run (including the exact time of day) on the CEMS chart recordings or other permanent record of output. Use the following strategies for the RM tests:

8.4.3.1 For integrated samples (*e.g.*, Methods 6 and Method 4), make a sample traverse of at least 21 minutes, sampling for an equal time at each traverse point (see section 8.1.3.2 for discussion of traverse points).

8.4.3.2 For grab samples (*e.g.*, Method 7), take one sample at each traverse point, scheduling the grab samples so that they are taken simultaneously (within a 3-minute period) or at an equal interval of time apart over the span of time the CEM pollutant is measured. A test run for grab samples must be made up of at least three separate measurements.

NOTE: At times, CEMS RA tests are conducted during new source performance standards performance tests. In these cases, RM results obtained during CEMS RA tests may



be used to determine compliance as long as the source and test conditions are consistent with the applicable regulations.

8.4.4 Number of RM Tests. Conduct a minimum of nine sets of all necessary RM test runs.

NOTE: More than nine sets of RM tests may be performed. If this option is chosen, a maximum of three sets of the test results may be rejected so long as the total number of test results used to determine the RA is greater than or equal to nine. However, all data must be reported, including the rejected data.

8.4.5 Correlation of RM and CEMS Data. Correlate the CEMS and the RM test data as to the time and duration by first determining from the CEMS final output (the one used for reporting) the integrated average pollutant concentration or emission rate for each pollutant RM test period. Consider system response time, if important, and confirm that the pair of results are on a consistent moisture, temperature, and diluent concentration basis. Then, compare each integrated CEMS value against the corresponding average RM value. Use the following guidelines to make these comparisons.

8.4.5.1 If the RM has an integrated sampling technique, make a direct comparison of the RM results and CEMS integrated average value.

8.4.5.2 If the RM has a grab sampling technique, first average the results from all grab samples taken during the test run, and then compare this average value against the integrated value obtained from the CEMS chart recording or output during the run. If the pollutant concentration is varying with time over the run, the arithmetic average of the CEMS value recorded at the time of each grab sample may be used.

8.4.6 Calculate the mean difference between the RM and CEMS values in the units of the

emission standard, the standard deviation, the confidence coefficient, and the relative accuracy according to the procedures in section 12.0.

8.5 Reporting. At a minimum (check with the appropriate regional office, State, or Local agency for additional requirements, if any), summarize in tabular form the results of the CD tests and the RA tests or alternative RA procedure, as appropriate. Include all data sheets, calculations, charts (records of CEMS responses), cylinder gas concentration certifications, and calibration cell response certifications (if applicable) necessary to confirm that the performance of the CEMS met the performance specifications.

#### 9.0 Quality Control [Reserved]

#### 10.0 Calibration and Standardization [Reserved]

#### 11.0 Analytical Procedure

Sample collection and analysis are concurrent for this Performance Specification (see section 8.0). Refer to the RM for specific analytical procedures.

#### 12.0 Calculations and Data Analysis

Summarize the results on a data sheet similar to that shown in Figure 2-2 (in section 18.0).

12.1 All data from the RM and CEMS must be on a consistent dry basis and, as applicable, on a consistent diluent basis and in the units of the emission standard. Correct the RM and CEMS data for moisture and diluent as follows:

12.1.1 Moisture Correction (as applicable). Correct each wet RM run for moisture with the corresponding Method 4 data; correct each wet CEMS run using the corresponding CEMS moisture monitor data using Equation 2-1.

$$\text{Concentration}_{(\text{dry})} = \frac{\text{Concentration}_{\text{wet}}}{(1 - B_{\text{ws}})} \quad \text{Eq. 2-1}$$

12.1.2 Correction to Units of Standard (as applicable). Correct each dry RM run to the units of the emission standard with the corresponding Method 3B data; correct each dry

CEMS run using the corresponding CEMS diluent monitor data as follows:

12.1.2.1 Correct to Diluent Basis. The following is an example of concentration (ppm) correction to 7% oxygen.

$$\text{ppm}_{(\text{corr})} = \text{ppm}_{(\text{uncorr})} \left[ \frac{20.9 - 7.0}{20.9 - \%O_{2(\text{dry})}} \right] \quad \text{Eq. 2-2}$$



The following is an example of mass/gross calorific value (lbs/million Btu) correction.

$$\text{lbs/MMBtu} = \text{Conc}_{(\text{dry})} (\text{F-factor}) (20.9/20.9 - \%O_2)$$

12.2 Arithmetic Mean. Calculate the arithmetic mean of the difference,  $d$ , of a data set as follows:

$$\bar{d} = \frac{1}{n} \sum_{i=1}^n d_i \quad \text{Eq. 2-3}$$

Where:

$n$  = Number of data points.

$$\sum_{i=1}^n d_i = \text{Algebraic summation of the individual differences } d_i.$$

12.3 Standard Deviation. Calculate the standard deviation,  $S_d$ , as follows:

$$S_d = \left[ \frac{\sum_{i=1}^n d_i^2 - \frac{\left[ \sum_{i=1}^n d_i \right]^2}{n}}{n-1} \right]^{1/2} \quad \text{Eq. 2-4}$$

12.4 Confidence Coefficient. Calculate the 2.5 percent error confidence coefficient (one-tailed),  $CC$ , as follows:

$$CC = t_{0.975} \frac{S_d}{\sqrt{n}} \quad \text{Eq. 2-5}$$

Where:

$t_{0.975}$  =  $t$ -value (see Table 2-1).

12.5 Relative Accuracy. Calculate the RA of a set of data as follows:

$$RA = \frac{\left[ |\bar{d}| + |CC| \right]}{\overline{RM}} \times 100 \quad \text{Eq. 2-6}$$

Where:

$|\bar{d}|$  = Absolute value of the mean differences (from Equation 2-3).

$|CC|$  = Absolute value of the confidence coefficient (from Equation 2-3).

$\overline{RM}$  = Average RM value. In cases where the average emissions for the test are less than 50 percent of the applicable standard, substitute the emission standard value in the denominator of Eq. 2-6 in place of  $\overline{RM}$ . In all other cases, use  $\overline{RM}$ .

13.0 Method Performance

13.1 Calibration Drift Performance Specification. The CEMS calibration must not drift or deviate from the reference value of the gas cylinder, gas cell, or optical filter by more than 2.5 percent of the span value. If

the CEMS includes pollutant and diluent monitors, the CD must be determined separately for each in terms of concentrations (See Performance Specification 3 for the diluent specifications), and none of the CDs may exceed the specification.

13.2 Relative Accuracy Performance Specification. The RA of the CEMS must be no greater than 20 percent when RM is used in the denominator of Eq. 2-6 (average emissions during test are greater than 50 percent of the emission standard) or 10 percent when the applicable emission standard is used in the denominator of Eq. 2-6 (average emissions during test are less than 50 percent of the emission standard). For SO<sub>2</sub> emission standards of 130 to and including 86 ng/J (0.30 and 0.20 lb/million Btu), inclusive, use 15 percent of the applicable standard; below 86 ng/J (0.20 lb/million Btu), use 20 percent of the emission standard.

13.3 For instruments that use common components to measure more than one effluent gas constituent, all channels must simultaneously pass the RA requirement, unless it can be demonstrated that any adjustments made to one channel did not affect the others.

14.0 Pollution Prevention [Reserved]

15.0 Waste Management [Reserved]

16.0 Alternative Procedures

Paragraphs 60.13(j)(1) and (2) of 40 CFR part 60 contain criteria for which the reference method procedure for determining relative accuracy (see section 8.4 of this Performance Specification) may be waived and the following procedure substituted.

16.1 Conduct a complete CEMS status check following the manufacturer's written instructions. The check should include operation of the light source, signal receiver, timing mechanism functions, data acquisition and data reduction functions, data recorders, mechanically operated functions (mirror movements, zero pipe operation, calibration gas valve operations, etc.), sample filters, sample line heaters, moisture traps, and other related functions of the

CEMS, as applicable. All parts of the CEMS shall be functioning properly before proceeding to the alternative RA procedure.

16.2 Alternative RA Procedure.

16.2.1 Challenge each monitor (both pollutant and diluent, if applicable) with cylinder gases of known concentrations or calibration cells that produce known responses at two measurement points within the ranges shown in Table 2-2 (Section 18).

16.2.2 Use a separate cylinder gas (for point CEMS only) or calibration cell (for path CEMS or where compressed gas cylinders can not be used) for measurement points 1 and 2. Challenge the CEMS and record the responses three times at each measurement point. The Administrator may allow dilution of cylinder gas using the performance criteria in Test Method 205, 40 CFR Part 51, Appendix M. Use the average of the three responses in determining relative accuracy.

16.2.3 Operate each monitor in its normal sampling mode as nearly as possible. When using cylinder gases, pass the cylinder gas through all filters, scrubbers, conditioners, and other monitor components used during normal sampling and as much of the sampling probe as practical. When using calibration cells, the CEMS components used in the normal sampling mode should not be bypassed during the RA determination. These include light sources, lenses, detectors, and reference cells. The CEMS should be challenged at each measurement point for a sufficient period of time to assure adsorption-desorption reactions on the CEMS surfaces have stabilized.

16.2.4 Use cylinder gases that have been certified by comparison to National Institute of Standards and Technology (NIST) gaseous standard reference material (SRM) or NIST/EPA approved gas manufacturer's certified reference material (CRM) (See Reference 2 in section 17.0) following EPA Traceability Protocol Number 1 (See Reference 3 in section 17.0). As an alternative to Protocol Number 1 gases, CRM's may be used directly as alternative RA cylinder gases. A list of gas manufacturers that have prepared approved CRM's is available from EPA at the address shown in Reference 2. Procedures for preparation of CRM's are described in Reference 2.

16.2.5 Use calibration cells certified by the manufacturer to produce a known response in the CEMS. The cell certification procedure shall include determination of CEMS response produced by the calibration cell in direct comparison with measurement of gases of known concentration. This can be accomplished using SRM or CRM gases in a laboratory source simulator or through extended tests using reference methods at the CEMS location in the exhaust stack. These procedures are discussed in Reference 4 in section 17.0. The calibration cell certification procedure is subject to approval of the Administrator.

16.3 The differences between the known concentrations of the cylinder gases and the concentrations indicated by the CEMS are used to assess the accuracy of the CEMS. The calculations and limits of acceptable relative accuracy are as follows:

16.3.1 For pollutant CEMS:

$$RA = \left| \left( \frac{\bar{d}}{AC} \right) 100 \right| \leq 15 \text{ percent} \quad \text{Eq. 2-7}$$

Where:

$\bar{d}$  = Average difference between responses and the concentration/responses (see section 16.2.2).

AC = The known concentration/response of the cylinder gas or calibration cell.

16.3.2 For diluent CEMS:

$RA \leq d; \leq 0.7$  percent O<sub>2</sub> or CO<sub>2</sub>, as applicable.

NOTE: Waiver of the relative accuracy test in favor of the alternative RA procedure does not preclude the requirements to complete the CD tests nor any other requirements specified in an applicable subpart for reporting CEMS data and performing CEMS drift checks or audits.

17.0 References

1. Department of Commerce. Experimental Statistics. Handbook 91. Washington, D.C. p. 3-31, paragraphs 3-3.1.4.

2. "A Procedure for Establishing Traceability of Gas Mixtures to Certain National Bureau of Standards Standard Reference Materials." Joint publication by NBS and EPA. EPA 600/7-81-010. Available from U.S. Environmental Protection Agency, Quality Assurance Division (MD-77), Research Triangle Park, North Carolina 27711.

3. "Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors. (Protocol Number 1)." June 1978. Protocol Number 1 is included in the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III,

**Pt. 60, App. B, Spec. 2**

**40 CFR Ch. I (7-1-17 Edition)**

Stationary Source Specific Methods. EPA-600/4-77-027b. August 1977.

4. "Gaseous Continuous Emission Monitoring Systems—Performance Specification Guidelines for SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub>, O<sub>2</sub>, and TRS." EPA-450/3-82-026. Available from the U.S.

EPA, Emission Measurement Center, Emission Monitoring and Data Analysis Division (MD-19), Research Triangle Park, North Carolina 27711.

*18.0 Tables, Diagrams, Flowcharts, and Validation Data*

**TABLE 2-1—t-VALUES**

n <sup>a</sup>	t <sub>0.975</sub>	n <sup>a</sup>	t <sub>0.975</sub>	n <sup>a</sup>	t <sub>0.975</sub>
2	12.706	7	2.447	12	2.201
3	4.303	8	2.365	13	2.179
4	3.182	9	2.306	14	2.160
5	2.776	10	2.262	15	2.145
6	2.571	11	2.228	16	2.131

<sup>a</sup> The values in this table are already corrected for n - 1 degrees of freedom. Use n equal to the number of individual values.

**TABLE 2-2—MEASUREMENT RANGE**

Measurement point	Pollutant monitor	Diluent monitor for	
		CO <sub>2</sub>	O <sub>2</sub>
1	20-30% of span value	5-8% by volume	4-6% by volume.
2	50-60% of span value	10-14% by volume	8-12% by volume.



Figure 2-1. Calibration Drift Determination

	Day	Date and time	Calibration value (C)	Monitor value (M)	Difference (C-M)	Percent of span value (C-M) / span value x 100
Low-level						
High-level						

FIGURE 2-2. RELATIVE ACCURACY DETERMINATION.

Run No.	Date and time	SO <sub>2</sub>			NO <sub>x</sub> <sup>b</sup>			CO <sub>2</sub> or O <sub>2</sub> <sup>a</sup>		SO <sub>2</sub> <sup>a</sup>			NO <sub>x</sub> <sup>a</sup>		
		RM	CEMS	Diff	RM	CEMS	Diff	RM	CEMS	RM	CEMS	Diff	RM	CEMS	Diff
		ppm <sup>c</sup>			ppm <sup>c</sup>			% <sup>c</sup>	% <sup>c</sup>	mass/GCV			mass/GCV		
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
Average															
Confidence Interval															
Accuracy															

<sup>a</sup>For Steam generators.  
<sup>b</sup>Average of three samples.  
<sup>c</sup>Make sure that RM and CEMS data are on a consistent basis, either wet or dry.

PERFORMANCE SPECIFICATION 3—SPECIFICATIONS AND TEST PROCEDURES FOR O<sub>2</sub> AND CO<sub>2</sub> CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1.0 Scope and Application

1.1 Analytes.

Analytes	CAS No.
Carbon Dioxide (CO <sub>2</sub> ) .....	124-38-9
Oxygen (O <sub>2</sub> ) .....	7782-44-7

1.2 Applicability.

1.2.1 This specification is for evaluating acceptability of O<sub>2</sub> and CO<sub>2</sub> continuous emission monitoring systems (CEMS) at the time of installation or soon after and whenever specified in an applicable subpart of the regulations. This specification applies to O<sub>2</sub> or CO<sub>2</sub> monitors that are not included under Performance Specification 2 (PS 2).

1.2.2 This specification is not designed to evaluate the installed CEMS performance over an extended period of time, nor does it identify specific calibration techniques and other auxiliary procedures to assess the

CEMS performance. The source owner or operator, is responsible to calibrate, maintain, and operate the CEMS properly. The Administrator may require, under section 114 of the Act, the operator to conduct CEMS performance evaluations at other times besides the initial test to evaluate the CEMS performance. See 40 CFR part 60, section 60.13(c).

1.2.3 The definitions, installation and measurement location specifications, calculations and data analysis, and references are the same as in PS 2, sections 3, 8.1, 12, and 17, respectively, and also apply to O<sub>2</sub> and CO<sub>2</sub> CEMS under this specification. The performance and equipment specifications and the relative accuracy (RA) test procedures for O<sub>2</sub> and CO<sub>2</sub> CEMS do not differ from those for SO<sub>2</sub> and NO<sub>x</sub> CEMS (see PS 2), except as noted below.

2.0 Summary of Performance Specification

The RA and calibration drift (CD) tests are conducted to determine conformance of the CEMS to the specification.

## Environmental Protection Agency

## Pt. 60, App. B, Spec. 3

### 3.0 Definitions

Same as in section 3.0 of PS 2.

### 4.0 Interferences [Reserved]

### 5.0 Safety

This performance specification may involve hazardous materials, operations, and equipment. This performance specification may not address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicable regulatory limitations prior to performing this performance specification. The CEMS users manual should be consulted for specific precautions to be taken with regard to the analytical procedures.

### 6.0 Equipment and Supplies

Same as section 6.0 of PS2.

### 7.0 Reagents and Standards

Same as section 7.0 of PS2.

### 8.0 Sample Collection, Preservation, Storage, and Transport

8.1 Relative Accuracy Test Procedure. Sampling Strategy for reference method (RM) Tests, Correlation of RM and CEMS Data, and Number of RM Tests. Same as PS 2, sections 8.4.3, 8.4.5, and 8.4.4, respectively.

8.2 Reference Method. Unless otherwise specified in an applicable subpart of the reg-

ulations, Method 3B or other approved alternative is the RM for O<sub>2</sub> or CO<sub>2</sub>.

### 9.0 Quality Control [Reserved]

### 10.0 Calibration and Standardization [Reserved]

### 11.0 Analytical Procedure

Sample collection and analyses are concurrent for this performance specification (see section 8). Refer to the RM for specific analytical procedures.

### 12.0 Calculations and Data Analysis

Summarize the results on a data sheet similar to that shown in Figure 2.2 of PS2. Calculate the arithmetic difference between the RM and the CEMS output for each run. The average difference of the nine (or more) data sets constitute the RA.

### 13.0 Method Performance

13.1 Calibration Drift Performance Specification. The CEMS calibration must not drift by more than 0.5 percent O<sub>2</sub> or CO<sub>2</sub> from the reference value of the gas, gas cell, or optical filter.

13.2 CEMS Relative Accuracy Performance Specification. The RA of the CEMS must be no greater than 20.0 percent of the mean value of the reference method (RM) data when calculated using equation 3-1. The results are also acceptable if the result of Equation 3-2 is less than or equal to 1.0 percent O<sub>2</sub> (or CO<sub>2</sub>).



$$RA = \frac{[|\bar{d}| + |CC|]}{\overline{RM}} \times 100$$

Eq. 3-1

Where:

$|\bar{d}|$  = Absolute value of the mean of the differences (from Equation 2-3 of Performance Specification 2).

$|CC|$  = Absolute value of the confidence coefficient (from Equation 2-5 of Performance Specification 2).

$\overline{RM}$  = Average Reference Method value.

$$RA = \overline{RM} - \overline{CEMS} \quad \text{Eq. 3-2}$$

$\overline{RM}$  = Average Reference Method value.

$\overline{CEMS}$  = Average CEMS value.

14.0 Pollution Prevention [Reserved]

15.0 Waste Management [Reserved]

16.0 References

Same as in section 17.0 of PS 2.

17.0 Tables, Diagrams, Flowcharts, and Validation Data [Reserved]

PERFORMANCE SPECIFICATION 4—SPECIFICATIONS AND TEST PROCEDURES FOR CARBON MONOXIDE CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1.0 Scope and Application

1.1 Analytes.

Analyte	CAS No.
Carbon Monoxide (CO) .....	630-08-0

1.2 Applicability.

1.2.1 This specification is for evaluating the acceptability of carbon monoxide (CO) continuous emission monitoring systems (CEMS) at the time of installation or soon after and whenever specified in an applicable subpart of the regulations. This specification was developed primarily for CEMS having span values of 1,000 ppmv CO.

1.2.2 This specification is not designed to evaluate the installed CEMS performance over an extended period of time nor does it identify specific calibration techniques and other auxiliary procedures to assess CEMS performance. The source owner or operator is responsible to calibrate, maintain, and operate the CEMS. The Administrator may require, under section 114 of the Act, the source owner or operator to conduct CEMS performance evaluations at other times besides the initial test to evaluate the CEMS performance. See 40 CFR part 60, section 60.13(c).

1.2.3 The definitions, performance specification test procedures, calculations, and data analysis procedures for determining calibration drift (CD) and relative accuracy (RA) of Performance Specification 2 (PS 2), sections 3, 8.0, and 12, respectively, apply to this specification.

2.0 Summary of Performance Specification

The CD and RA tests are conducted to determine conformance of the CEMS to the specification.

3.0 Definitions

Same as in section 3.0 of PS 2

## Environmental Protection Agency

## Pt. 60, App. B, Spec. 4A

### 4.0 Interferences [Reserved]

### 5.0 Safety

This performance specification may involve hazardous materials, operations, and equipment. This performance specification may not address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicable regulatory limitations prior to performing this performance specification. The CEMS users manual should be consulted for specific precautions to be taken with regard to the analytical procedures.

### 6.0 Equipment and Supplies

Same as section 6.0 of PS 2.

### 7.0 Reagents and Standards

Same as section 7.0 of PS 2.

### 8.0 Sample Collection, Preservation, Storage, and Transport

8.1 Relative Accuracy Test Procedure. Sampling Strategy for reference method (RM) Tests, Number of RM Tests, and Correlation of RM and CEMS Data are the same as PS 2, sections 8.4.3, 8.4.4, and 8.4.5, respectively.

8.2 Reference Methods. Unless otherwise specified in an applicable subpart of the regulation, Method 10, 10A, 10B or other approved alternative are the RM for this PS.

### 9.0 Quality Control [Reserved]

### 10.0 Calibration and Standardization [Reserved]

### 11.0 Analytical Procedure

Sample collection and analysis are concurrent for this performance specification (see section 8.0). Refer to the RM for specific analytical procedures.

### 12.0 Calculations and Data Analysis

Same as section 12.0 of PS 2.

### 13.0 Method Performance

13.1 Calibration Drift. The CEMS calibration must not drift or deviate from the reference value of the calibration gas, gas cell, or optical filter by more than 5 percent of the established span value for 6 out of 7 test days (e.g., the established span value is 1000 ppm for Subpart J affected facilities).

13.2 Relative Accuracy. The RA of the CEMS must be no greater than 10 percent when the average RM value is used to calculate RA or 5 percent when the applicable emission standard is used to calculate RA.

### 14.0 Pollution Prevention [Reserved]

### 15.0 Waste Management [Reserved]

### 16.0 Alternative Procedures [Reserved]

### 17.0 References

1. Ferguson, B.B., R.E. Lester, and W.J. Mitchell. Field Evaluation of Carbon Monoxide and Hydrogen Sulfide Continuous Emission Monitors at an Oil Refinery. U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication No. EPA-600/4-82-054. August 1982. 100 p.

2. "Gaseous Continuous Emission Monitoring Systems—Performance Specification Guidelines for SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub>, O<sub>2</sub>, and TRS." EPA-450/3-82-026. U.S. Environmental Protection Agency, Technical Support Division (MD-19), Research Triangle Park, NC 27711.

3. Repp, M. Evaluation of Continuous Monitors for Carbon Monoxide in Stationary Sources. U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication No. EPA-600/2-77-063. March 1977. 155 p.

4. Smith, F., D.E. Wagoner, and R.P. Donovan. Guidelines for Development of a Quality Assurance Program: Volume VIII—Determination of CO Emissions from Stationary Sources by NDIR Spectrometry. U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication No. EPA-650/4-74-005-h. February 1975. 96 p.

### 18.0 Tables, Diagrams, Flowcharts, and Validation Data

Same as section 18.0 of PS 2.

## PERFORMANCE SPECIFICATION 4A—SPECIFICATIONS AND TEST PROCEDURES FOR CARBON MONOXIDE CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

### 1.0 Scope and Application

#### 1.1 Analytes.

Analyte	CAS No.
Carbon Monoxide (CO) .....	630-80-0

#### 1.2 Applicability.

1.2.1 This specification is for evaluating the acceptability of carbon monoxide (CO) continuous emission monitoring systems (CEMS) at the time of installation or soon after and whenever specified in an applicable subpart of the regulations. This specification was developed primarily for CEMS that comply with low emission standards (less than 200 ppmv).

1.2.2 This specification is not designed to evaluate the installed CEMS performance over an extended period of time nor does it identify specific calibration techniques and other auxiliary procedures to assess CEMS performance. The source owner or operator



is responsible to calibrate, maintain, and operate the CEMS. The Administrator may require, under section 114 of the Act, the source owner or operator to conduct CEMS performance evaluations at other times besides the initial test to evaluate CEMS performance. See 40 CFR Part 60, section 60.13(c).

1.2.3 The definitions, performance specification, test procedures, calculations and data analysis procedures for determining calibration drifts (CD) and relative accuracy (RA), of Performance Specification 2 (PS 2), sections 3, 8.0, and 12, respectively, apply to this specification.

*2.0 Summary of Performance Specification*

The CD and RA tests are conducted to determine conformance of the CEMS to the specification.

*3.0 Definitions*

Same as in section 3.0 of PS 2.

*4.0 Interferences [Reserved]*

*5.0 Safety*

This performance specification may involve hazardous materials, operations, and equipment. This performance specification may not address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicable regulatory limitations prior to performing this performance specification. The CEMS users manual should be consulted for specific precautions to be taken with regard to the analytical procedures.

*6.0 Equipment and Supplies*

Same as section 6.0 of PS 2 with the following additions.

*6.1 Data Recorder Scale.*

6.1.1 This specification is the same as section 6.1 of PS 2. The CEMS shall be capable of measuring emission levels under normal conditions and under periods of short-duration peaks of high concentrations. This dual-range capability may be met using two separate analyzers (one for each range) or by using dual-range units which have the capability of measuring both levels with a single unit. In the latter case, when the reading goes above the full-scale measurement value of the lower range, the higher-range operation shall be started automatically. The CEMS recorder range must include zero and a high-level value. Under applications of consistent low emissions, a single-range analyzer is allowed provided normal and spike emissions can be quantified. In this case, set an appropriate high-level value to include all emissions.

6.1.2 For the low-range scale of dual-range units, the high-level value shall be between

1.5 times the pollutant concentration corresponding to the emission standard level and the span value. For the high-range scale, the high-level value shall be set at 2000 ppm, as a minimum, and the range shall include the level of the span value. There shall be no concentration gap between the low-and high-range scales.

*7.0 Reagents and Standards*

Same as section 7.0 of PS 2.

*8.0 Sample Collection, Preservation, Storage, and Transport*

8.1 Relative Accuracy Test Procedure. Sampling Strategy for reference method (RM) Tests, Number of RM Tests, and Correlation of RM and CEMS Data are the same as PS 2, sections 8.4.3, 8.4.4, and 8.4.5, respectively.

8.2 Reference Methods. Unless otherwise specified in an applicable subpart of the regulation, Methods 10, 10A, 10B, or other approved alternative is the RM for this PS. When evaluating nondispersive infrared CEMS using Method 10 as the RM, the alternative interference trap specified in section 16.0 of Method 10 shall be used.

8.3 Response Time Test Procedure. The response time test applies to all types of CEMS, but will generally have significance only for extractive systems. The entire system is checked with this procedure including applicable sample extraction and transport, sample conditioning, gas analyses, and data recording.

8.3.1 Introduce zero gas into the system. When the system output has stabilized (no change greater than 1 percent of full scale for 30 sec), introduce an upscale calibration gas and wait for a stable value. Record the time (upscale response time) required to reach 95 percent of the final stable value. Next, reintroduce the zero gas and wait for a stable reading before recording the response time (downscale response time). Repeat the entire procedure until you have three sets of data to determine the mean upscale and downscale response times. The slower or longer of the two means is the system response time.

8.4 Interference Check. The CEMS must be shown to be free from the effects of any interferences.

*9.0 Quality Control [Reserved]*

*10.0 Calibration and Standardization [Reserved]*

*11.0 Analytical Procedure*

Sample collection and analysis are concurrent for this performance specification (see section 8.0). Refer to the RM for specific analytical procedures.



12.0 *Calculations and Data Analysis. Same as section 12.0 of PS 2*

13.0 *Method Performance*

13.1 *Calibration Drift.* The CEMS calibration must not drift or deviate from the reference value of the calibration gas, gas cell, or optical filter by more than 5 percent of the established span value for 6 out of 7 test days.

13.2 *Relative Accuracy.* The RA of the CEMS must be no greater than 10 percent when the average RM value is used to calculate RA, 5 percent when the applicable emission standard is used to calculate RA, or within 5 ppmv when the RA is calculated as the absolute average difference between the RM and CEMS plus the 2.5 percent confidence coefficient.

13.3 *Response Time.* The CEMS response time shall not exceed 240 seconds to achieve 95 percent of the final stable value.

14.0 *Pollution Prevention [Reserved]*

15.0 *Waste Management [Reserved]*

16.0 *Alternative Procedures*

16.1 Under conditions where the average CO emissions are less than 10 percent of the standard and this is verified by Method 10, a cylinder gas audit may be performed in place of the RA test to determine compliance with these limits. In this case, the cylinder gas shall contain CO in 12 percent carbon dioxide as an interference check. If this option is exercised, Method 10 must be used to verify that emission levels are less than 10 percent of the standard.

17.0 *References*

Same as section 17 of PS 4.

18.0 *Tables, Diagrams, Flowcharts, and Validation Data*

Same as section 18.0 of PS 2.

PERFORMANCE SPECIFICATION 4B—SPECIFICATIONS AND TEST PROCEDURES FOR CARBON MONOXIDE AND OXYGEN CONTINUOUS MONITORING SYSTEMS IN STATIONARY SOURCES

a. *Applicability and Principle*

1.1 *Applicability.* a. This specification is to be used for evaluating the acceptability of carbon monoxide (CO) and oxygen (O<sub>2</sub>) continuous emission monitoring systems (CEMS) at the time of or soon after installation and whenever specified in the regulations. The CEMS may include, for certain stationary sources, (a) flow monitoring equipment to allow measurement of the dry volume of stack effluent sampled, and (b) an automatic sampling system.

b. This specification is not designed to evaluate the installed CEMS' performance

over an extended period of time nor does it identify specific calibration techniques and auxiliary procedures to assess the CEMS' performance. The source owner or operator, however, is responsible to properly calibrate, maintain, and operate the CEMS. To evaluate the CEMS' performance, the Administrator may require, under section 114 of the Act, the operator to conduct CEMS performance evaluations at times other than the initial test.

c. The definitions, installation and measurement location specifications, test procedures, data reduction procedures, reporting requirements, and bibliography are the same as in PS 3 (for O<sub>2</sub>) and PS 4A (for CO) except as otherwise noted below.

1.2 *Principle.* Installation and measurement location specifications, performance specifications, test procedures, and data reduction procedures are included in this specification. Reference method tests, calibration error tests, calibration drift tests, and interferant tests are conducted to determine conformance of the CEMS with the specification.

b. *Definitions*

2.1 *Continuous Emission Monitoring System (CEMS).* This definition is the same as PS 2 section 2.1 with the following addition. A continuous monitor is one in which the sample to be analyzed passes the measurement section of the analyzer without interruption.

2.2 *Response Time.* The time interval between the start of a step change in the system input and when the pollutant analyzer output reaches 95 percent of the final value.

2.3 *Calibration Error (CE).* The difference between the concentration indicated by the CEMS and the known concentration generated by a calibration source when the entire CEMS, including the sampling interface is challenged. A CE test procedure is performed to document the accuracy and linearity of the CEMS over the entire measurement range.

3. *Installation and Measurement Location Specifications*

3.1 *The CEMS Installation and Measurement Location.* This specification is the same as PS 2 section 3.1 with the following additions. Both the CO and O<sub>2</sub> monitors should be installed at the same general location. If this is not possible, they may be installed at different locations if the effluent gases at both sample locations are not stratified and there is no in-leakage of air between sampling locations.

3.1.1 *Measurement Location.* Same as PS 2 section 3.1.1.

3.1.2 *Point CEMS.* The measurement point should be within or centrally located over the centroidal area of the stack or duct cross section.

3.1.3 *Path CEMS.* The effective measurement path should: (1) Have at least 70 percent of the path within the inner 50 percent of the stack or duct cross sectional area, or (2) be centrally located over any part of the centroidal area.

3.2 *Reference Method (RM) Measurement Location and Traverse Points.* This specification is the same as PS 2 section 3.2 with the following additions. When pollutant concentration changes are due solely to diluent leakage and CO and O<sub>2</sub> are simultaneously measured at the same location, one half diameter may be used in place of two equivalent diameters.

3.3 *Stratification Test Procedure.* Stratification is defined as the difference in excess of 10 percent between the average concentration in the duct or stack and the concentration at any point more than 1.0 meter from the duct or stack wall. To determine whether effluent stratification exists, a dual probe system should be used to determine the average effluent concentration while measurements at each traverse point are being made. One probe, located at the stack or duct centroid, is used as a stationary reference point to indicate change in the effluent concentration over time. The second probe is used for sampling at the traverse points specified in Method 1 (40 CFR part 60 appendix A). The monitoring system samples sequentially at the reference and traverse points throughout the testing period for five minutes at each point.

*d. Performance and Equipment Specifications*

4.1 *Data Recorder Scale.* For O<sub>2</sub>, same as specified in PS 3, except that the span must be 25 percent. The span of the O<sub>2</sub> may be higher if the O<sub>2</sub> concentration at the sampling point can be greater than 25 percent. For CO, same as specified in PS 4A, except that the low-range span must be 200 ppm and the high range span must be 3000 ppm. In addition, the scale for both CEMS must record all readings within a measurement range with a resolution of 0.5 percent.

4.2 *Calibration Drift.* For O<sub>2</sub>, same as specified in PS 3. For CO, the same as specified in PS 4A except that the CEMS calibration must not drift from the reference value of the calibration standard by more than 3 percent of the span value on either the high or low range.

4.3 *Relative Accuracy (RA).* For O<sub>2</sub>, same as specified in PS 3. For CO, the same as specified in PS 4A.

4.4 *Calibration Error (CE).* The mean difference between the CEMS and reference values at all three test points (see Table I) must be no greater than 5 percent of span value for CO monitors and 0.5 percent for O<sub>2</sub> monitors.

4.5 *Response Time.* The response time for the CO or O<sub>2</sub> monitor must not exceed 2 minutes.

*e. Performance Specification Test Procedure*

5.1 *Calibration Error Test and Response Time Test Periods.* Conduct the CE and response time tests during the CD test period.

*F. The CEMS Calibration Drift and Response Time Test Procedures*

The response time test procedure is given in PS 4A, and must be carried out for both the CO and O<sub>2</sub> monitors.

7. *Relative Accuracy and Calibration Error Test Procedures*

7.1 *Calibration Error Test Procedure.* Challenge each monitor (both low and high range CO and O<sub>2</sub>) with zero gas and EPA Protocol 1 cylinder gases at three measurement points within the ranges specified in Table I.

TABLE I. CALIBRATION ERROR CONCENTRATION RANGES

Measurement point	CO Low range (ppm)	CO High range (ppm)	O <sub>2</sub> (%)
1 .....	0-40	0-600	0-2
2 .....	60-80	900-1200	8-10
3 .....	140-160	2100-2400	14-16

Operate each monitor in its normal sampling mode as nearly as possible. The calibration gas must be injected into the sample system as close to the sampling probe outlet as practical and should pass through all CEMS components used during normal sampling. Challenge the CEMS three non-consecutive times at each measurement point and record the responses. The duration of each gas injection should be sufficient to ensure that the CEMS surfaces are conditioned.

7.1.1 *Calculations.* Summarize the results on a data sheet. Average the differences between the instrument response and the certified cylinder gas value for each gas. Calculate the CE results for the CO monitor according to:

$$CE = |d/FS| \times 100 \text{ (1)}$$

Where d is the mean difference between the CEMS response and the known reference concentration, and FS is the span value. The CE for the O<sub>2</sub> monitor is the average percent O<sub>2</sub> difference between the O<sub>2</sub> monitor and the certified cylinder gas value for each gas.

7.2 *Relative Accuracy Test Procedure.* Follow the RA test procedures in PS 3 (for O<sub>2</sub>) section 3 and PS 4A (for CO) section 4.

7.3 *Alternative RA Procedure.* Under some operating conditions, it may not be possible to obtain meaningful results using the RA test procedure. This includes conditions where consistent, very low CO emission or low CO emissions interrupted periodically by short duration, high level spikes are observed. It may be appropriate in these circumstances to waive the RA test and substitute the following procedure.



Conduct a complete CEMS status check following the manufacturer's written instructions. The check should include operation of the light source, signal receiver, timing mechanism functions, data acquisition and data reduction functions, data recorders, mechanically operated functions, sample filters, sample line heaters, moisture traps, and other related functions of the CEMS, as applicable. All parts of the CEMS must be functioning properly before the RA requirement can be waived. The instrument must also successfully pass the CE and CD specifications. Substitution of the alternate procedure requires approval of the Regional Administrator.

8. Bibliography

1. 40 CFR Part 266, Appendix IX, section 2, "Performance Specifications for Continuous Emission Monitoring Systems."

PERFORMANCE SPECIFICATION 5—SPECIFICATIONS AND TEST PROCEDURES FOR TRS CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

1.0 Scope and Application

1.1 Analytes.

Analyte	CAS No.
Total Reduced Sulfur (TRS) .....	NA

1.2 Applicability. This specification is for evaluating the applicability of TRS continuous emission monitoring systems (CEMS) at the time of installation or soon after and whenever specified in an applicable subpart of the regulations. The CEMS may include oxygen monitors which are subject to Performance Specification 3 (PS 3).

1.3 The definitions, performance specification, test procedures, calculations and data analysis procedures for determining calibration drifts (CD) and relative accuracy (RA) of PS 2, sections 3.0, 8.0, and 12.0, respectively, apply to this specification.

2.0 Summary of Performance Specification

The CD and RA tests are conducted to determine conformance of the CEMS to the specification.

3.0 Definitions

Same as in section 3.0 of PS 2.

4.0 Interferences [Reserved]

5.0 Safety

This performance specification may involve hazardous materials, operations, and equipment. This performance specification may not address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicable regulatory limitations prior

to performing this performance specification. The CEMS users manual should be consulted for specific precautions to be taken with regard to the analytical procedures.

6.0 Equipment and Supplies

Same as section 6.0 of PS 2.

7.0 Reagents and Standards

Same as section 7.0 of PS 2.

8.0 Sample Collection, Preservation, Storage, and Transport

8.1 Relative Accuracy Test Procedure. Sampling Strategy for reference method (RM) Tests, Number of RM Tests, and Correlation of RM and CEMS Data are the same as PS 2, sections 8.4.3, 8.4.4, and 8.4.5, respectively.

NOTE: For Method 16, a sample is made up of at least three separate injects equally space over time. For Method 16A, a sample is collected for at least 1 hour.

8.2 Reference Methods. Unless otherwise specified in the applicable subpart of the regulations, Method 16, Method 16A, 16B or other approved alternative is the RM for TRS.

9.0 Quality Control [Reserved]

10.0 Calibration and Standardization [Reserved]

11.0 Analytical Procedure

Sample collection and analysis are concurrent for this performance specification (see section 8.0). Refer to the reference method for specific analytical procedures.

12.0 Calculations and Data Analysis

Same as section 12.0 of PS 2.

13.0 Method Performance

13.1 Calibration Drift. The CEMS detector calibration must not drift or deviate from the reference value of the calibration gas by more than 5 percent of the established span value for 6 out of 7 test days. This corresponds to 1.5 ppm drift for Subpart BB sources where the span value is 30 ppm. If the CEMS includes pollutant and diluent monitors, the CD must be determined separately for each in terms of concentrations (see PS 3 for the diluent specifications).

13.2 Relative Accuracy. The RA of the CEMS must be no greater than 20 percent when the average RM value is used to calculate RA or 10 percent when the applicable emission standard is used to calculate RA.



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14.0 *Pollution Prevention* [Reserved]

15.0 *Waste Management* [Reserved]

16.0 *Alternative Procedures* [Reserved]

17.0 *References*

1. Department of Commerce. Experimental Statistics, National Bureau of Standards, Handbook 91, 1963. Paragraphs 3-3.1.4, p. 3-31.

2. A Guide to the Design, Maintenance and Operation of TRS Monitoring Systems. National Council for Air and Stream Improvement Technical Bulletin No. 89, September 1977.

3. Observation of Field Performance of TRS Monitors on a Kraft Recovery Furnace. National Council for Air and Stream Improvement Technical Bulletin No. 91, January 1978.

18.0 *Tables, Diagrams, Flowcharts, and Validation Data*

Same as section 18.0 of PS 2.

PERFORMANCE SPECIFICATION 6—SPECIFICATIONS AND TEST PROCEDURES FOR CONTINUOUS EMISSION RATE MONITORING SYSTEMS IN STATIONARY SOURCES

1.0 *Scope and Application*

1.1 *Applicability.* This specification is used for evaluating the acceptability of continuous emission rate monitoring systems (CERMSs).

1.2 The installation and measurement location specifications, performance specification test procedure, calculations, and data analysis procedures, of Performance Specifications (PS 2), sections 8.0 and 12, respectively, apply to this specification.

2.0 *Summary of Performance Specification*

The calibration drift (CD) and relative accuracy (RA) tests are conducted to determine conformance of the CERMS to the specification.

3.0 *Definitions*

The definitions are the same as in section 3 of PS 2, except this specification refers to the continuous emission rate monitoring system rather than the continuous emission monitoring system. The following definitions are added:

3.1 *Continuous Emission Rate Monitoring System (CERMS).* The total equipment required for the determining and recording the pollutant mass emission rate (in terms of mass per unit of time).

3.2 *Flow Rate Sensor.* That portion of the CERMS that senses the volumetric flow rate and generates an output proportional to that flow rate. The flow rate sensor shall have provisions to check the CD for each flow rate

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parameter that it measures individually (e.g., velocity, pressure).

4.0 *Interferences* [Reserved]

5.0 *Safety*

This performance specification may involve hazardous materials, operations, and equipment. This performance specification may not address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicable regulatory limitations prior to performing this performance specification. The CERMS users manual should be consulted for specific precautions to be taken with regard to the analytical procedures.

6.0 *Equipment and Supplies*

Same as section 6.0 of PS 2.

7.0 *Reagents and Standards*

Same as section 7.0 of PS 2.

8.0 *Sample Collection, Preservation, Storage, and Transport*

8.1 *Calibration Drift Test Procedure.*

8.1.1 The CD measurements are to verify the ability of the CERMS to conform to the established CERMS calibrations used for determining the emission rate. Therefore, if periodic automatic or manual adjustments are made to the CERMS zero and calibration settings, conduct the CD tests immediately before these adjustments, or conduct them in such a way that CD can be determined.

8.1.2 Conduct the CD tests for pollutant concentration at the two values specified in section 6.1.2 of PS 2. For other parameters that are selectively measured by the CERMS (e.g., velocity, pressure, flow rate), use two analogous values (e.g., Low: 0-20% of full scale, High: 50-100% of full scale). Introduce to the CERMS the reference signals (these need not be certified). Record the CERMS response to each and subtract this value from the respective reference value (see example data sheet in Figure 6-1).

8.2 *Relative Accuracy Test Procedure.*

8.2.1 *Sampling Strategy for reference method (RM) Tests, Correlation of RM and CERMS Data, and Number of RM Tests* are the same as PS 2, sections 8.4.3, 8.4.5, and 8.4.4, respectively. Summarize the results on a data sheet. An example is shown in Figure 6-1. The RA test may be conducted during the CD test period.

8.2.2 *Reference Methods.* Unless otherwise specified in the applicable subpart of the regulations, the RM for the pollutant gas is the

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Appendix A method that is cited for compliance test purposes, or its approved alternatives, Methods 2, 2A, 2B, 2C, or 2D, as applicable, are the RMs for the determination of volumetric flow rate.

*9.0 Quality Control* [Reserved]

*10.0 Calibration and Standardization* [Reserved]

*11.0 Analytical Procedure*

Same as section 11.0 of PS 2.

*12.0 Calculations and Data Analysis*

Same as section 12.0 of PS 2.

*13.0 Method Performance*

13.1 Calibration Drift. Since the CERMS includes analyzers for several measurements, the CD shall be determined separately for each analyzer in terms of its specific measurement. The calibration for each analyzer associated with the measurement of flow rate shall not drift or deviate from each reference value of flow rate by more than 3 percent of the respective high-level value. The CD specification for each analyzer for which

other PSs have been established (e.g., PS 2 for SO<sub>2</sub> and NO<sub>x</sub>), shall be the same as in the applicable PS.

13.2 CERMS Relative Accuracy. The RA of the CERMS shall be no greater than 20 percent of the mean value of the RM's test data in terms of the units of the emission standard, or 10 percent of the applicable standard, whichever is greater.

*14.0 Pollution Prevention* [Reserved]

*15.0 Waste Management* [Reserved]

*16.0 Alternative Procedures*

Same as in section 16.0 of PS 2.

*17.0 References*

1. Brooks, E.F., E.C. Beder, C.A. Flegal, D.J. Luciani, and R. Williams. Continuous Measurement of Total Gas Flow Rate from Stationary Sources. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. EPA-650/2-75-020. February 1975. 248 p.

*18.0 Tables, Diagrams, Flowcharts, and Validation Data*

Run No.	Date and time	Emission rate (kg/hr) <sup>a</sup>		
		CERMS	RMs	Difference (RMs-CERMS)
1				
2				
3				
4				
5				
6				
7				
8				
9				

<sup>a</sup> The RMs and CERMS data as corrected to a consistent basis (i.e., moisture, temperature, and pressure conditions).

Figure 6-1—Emission Rate Determinations

PERFORMANCE SPECIFICATION 7—SPECIFICATIONS AND TEST PROCEDURES FOR HYDROGEN SULFIDE CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

*1.0 Scope and Application*

1.1 Analytes.

Analyte	CAS No.
Hydrogen Sulfide .....	7783-06-4

1.2 Applicability.

1.2.1 This specification is to be used for evaluating the acceptability of hydrogen sulfide (H<sub>2</sub>S) continuous emission monitoring systems (CEMS) at the time of or soon after installation and whenever specified in an applicable subpart of the regulations.

1.2.2 This specification is not designed to evaluate the installed CEMS performance over an extended period of time nor does it identify specific calibration techniques and other auxiliary procedures to assess CEMS performance. The source owner or operator, however, is responsible to calibrate, maintain, and operate the CEMS. To evaluate CEMS performance, the Administrator may



require, under section 114 of the Act, the source owner or operator to conduct CEMS performance evaluations at other times besides the initial test. See section 60.13(c).

#### 2.0 Summary

Calibration drift (CD) and relative accuracy (RA) tests are conducted to determine that the CEMS conforms to the specification.

#### 3.0 Definitions

Same as section 3.0 of PS 2.

#### 4.0 Interferences [Reserved]

#### 5.0 Safety

The procedures required under this performance specification may involve hazardous materials, operations, and equipment. This performance specification may not address all of the safety problems associated with these procedures. It is the responsibility of the user to establish appropriate safety problems associated with these procedures. It is the responsibility of the user to establish appropriate safety and health practices and determine the application regulatory limitations prior to performing these procedures. The CEMS user's manual and materials recommended by the reference method should be consulted for specific precautions to be taken.

#### 6.0 Equipment and Supplies

6.1 Instrument Zero and Span. This specification is the same as section 6.1 of PS 2.

6.2 Calibration Drift. The CEMS calibration must not drift or deviate from the reference value of the calibration gas or reference source by more than 5 percent of the established span value for 6 out of 7 test days (e.g., the established span value is 300 ppm for Subpart J fuel gas combustion devices).

6.3 Relative Accuracy. The RA of the CEMS must be no greater than 20 percent when the average reference method (RM) value is used to calculate RA or 10 percent when the applicable emission standard is used to calculate RA.

#### 7.0 Reagents and Standards

Same as section 7.0 of PS 2.

#### 8.0 Sample Collection, Preservation, Storage, and Transport.

8.1 Installation and Measurement Location Specification. Same as section 8.1 of PS 2.

8.2 Pretest Preparation. Same as section 8.2 of PS 2.

8.3 Calibration Drift Test Procedure. Same as section 8.3 of PS 2.

8.4 Relative Accuracy Test Procedure.

8.4.1 Sampling Strategy for RM Tests, Number of RM Tests, Correlation of RM and CEMS Data, and Calculations. These are the

same as that in PS-2, Sections 8.4.3 (except as specified below), 8.4.4, 8.4.5, and 8.4.6, respectively.

8.4.2 Reference Methods. Unless otherwise specified in an applicable subpart of the regulation, Methods 11, 15, and 16 may be used for the RM for this PS.

8.4.2.1 Sampling Time Per Run—Method 11. A sampling run, when Method 11 (integrated sampling) is used, shall consist of a single measurement for at least 10 minutes and 0.010 dscm (0.35 dscf). Each sample shall be taken at approximately 30-minute intervals.

8.4.2.2 Sampling Time Per Run—Methods 15 and 16. The sampling run shall consist of two injections equally spaced over a 30-minute period following the procedures described in the particular method. NOTE: Caution! Heater or non-approved electrical probes should not be used around explosive or flammable sources.

8.5 Reporting. Same as section 8.5 of PS 2.

#### 9.0 Quality Control [Reserved]

#### 10.0 Calibration and Standardizations [Reserved]

#### 11.0 Analytical Procedures

Sample Collection and analysis are concurrent for this PS (see section 8.0). Refer to the RM for specific analytical procedures.

#### 12.0 Data Analysis and Calculations

Same as section 12.0 of PS 2.

#### 13.0 Method Performance [Reserved]

#### 14.0 Pollution Prevention [Reserved]

#### 15.0 Waste Management [Reserved]

#### 16.0 References

1. U.S. Environmental Protection Agency. Standards of Performance for New Stationary Sources; Appendix B; Performance Specifications 2 and 3 for SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub>, and O<sub>2</sub> Continuous Emission Monitoring Systems; Final Rule. 48 CFR 23608. Washington, D.C. U.S. Government Printing Office. May 25, 1983.

2. U.S. Government Printing Office. Gaseous Continuous Emission Monitoring Systems—Performance Specification Guidelines for SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub>, O<sub>2</sub>, and TRS. U.S. Environmental Protection Agency. Washington, D.C. EPA-450/3-82-026. October 1982. 26 p.

3. Maines, G.D., W.C. Kelly (Scott Environmental Technology, Inc.), and J.B. Homolya. Evaluation of Monitors for Measuring H<sub>2</sub>S in Refinery Gas. Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, N.C. Contract No. 68-02-2707. 1978. 60 p.

4. Ferguson, B.B., R.E. Lester (Harmon Engineering and Testing), and W.J. Mitchell. Field Evaluation of Carbon Monoxide and



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Hydrogen Sulfide Continuous Emission Monitors at an Oil Refinery. Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA-600/4-82-054. August 1982. 100 p.

5. Letter to RAMCON Environmental Corp. from Robert Kellam, December 27, 1992.

### *17.0 Tables, Diagrams, Flowcharts, and Validation Data*

Same as section 18.0 of PS 2.

## PERFORMANCE SPECIFICATION 8—PERFORMANCE SPECIFICATIONS FOR VOLATILE ORGANIC COMPOUND CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

### *1.0 Scope and Application*

1.1 Analytes. Volatile Organic Compounds (VOCs).

1.2 Applicability.

1.2.1 This specification is to be used for evaluating a continuous emission monitoring system (CEMS) that measures a mixture of VOC's and generates a single combined response value. The VOC detection principle may be flame ionization (FI), photoionization (PI), non-dispersive infrared absorption (NDIR), or any other detection principle that is appropriate for the VOC species present in the emission gases and that meets this performance specification. The performance specification includes procedures to evaluate the acceptability of the CEMS at the time of or soon after its installation and whenever specified in emission regulations or permits. This specification is not designed to evaluate the installed CEMS performance over an extended period of time, nor does it identify specific calibration techniques and other auxiliary procedures to assess the CEMS performance. The source owner or operator, however, is responsible to calibrate, maintain, and operate the CEMS properly. To evaluate the CEMS performance, the Administrator may require, under section 114 of the Act, the operator to conduct CEMS performance evaluations in addition to the initial test. See section 60.13(c).

1.2.2 In most emission circumstances, most VOC monitors can provide only a relative measure of the total mass or volume concentration of a mixture of organic gases, rather than an accurate quantification. This problem is removed when an emission standard is based on a total VOC measurement as obtained with a particular detection principle. In those situations where a true mass or volume VOC concentration is needed, the problem can be mitigated by using the VOC CEMS as a relative indicator of total VOC concentration if statistical analysis indicates that a sufficient margin of compliance exists for this approach to be acceptable. Otherwise, consideration can be given to calibrating the CEMS with a mixture of the

same VOC's in the same proportions as they actually occur in the measured source. In those circumstances where only one organic species is present in the source, or where equal incremental amounts of each of the organic species present generate equal CEMS responses, the latter choice can be more easily achieved.

### *2.0 Summary of Performance Specification*

2.1 Calibration drift and relative accuracy tests are conducted to determine adherence of the CEMS with specifications given for those items. The performance specifications include criteria for installation and measurement location, equipment and performance, and procedures for testing and data reduction.

### *3.0 Definitions.*

Same as section 3.0 of PS 2.

### *4.0 Interferences [Reserved]*

### *5.0 Safety*

The procedures required under this performance specification may involve hazardous materials, operations, and equipment. This performance specification may not address all of the safety problems associated with these procedures. It is the responsibility of the user to establish appropriate safety problems associated with these procedures. It is the responsibility of the user to establish appropriate safety and health practices and determine the application regulatory limitations prior to performing these procedures. The CEMS user's manual and materials recommended by the reference method should be consulted for specific precautions to be taken.

### *6.0 Equipment and Supplies*

6.1 VOC CEMS Selection. When possible, select a VOC CEMS with the detection principle of the reference method specified in the regulation or permit (usually either FI, NDIR, or PI). Otherwise, use knowledge of the source process chemistry, previous emission studies, or gas chromatographic analysis of the source gas to select an appropriate VOC CEMS. Exercise extreme caution in choosing and installing any CEMS in an area with explosive hazard potential.

6.2 Data Recorder Scale. Same as section 6.1 of PS 2.

### *7.0 Reagents and Standards [Reserved]*

### *8.0 Sample Collection, Preservation, Storage, and Transport*

8.1 Installation and Measurement Location Specifications. Same as section 8.1 of PS 2.

8.2 Pretest Preparation. Same as section 8.2 of PS 2.

8.3 Reference Method (RM). Use the method specified in the applicable regulation or permit, or any approved alternative, as the RM.

8.4 Sampling Strategy for RM Tests, Correlation of RM and CEMS Data, and Number of RM Tests. Follow PS 2, sections 8.4.3, 8.4.5, and 8.4.4, respectively.

8.5 Reporting. Same as section 8.5 of PS 2.

#### 9.0 Quality Control [Reserved]

#### 10.0 Calibration and Standardization [Reserved]

##### 11.0 Analytical Procedure

Sample collection and analysis are concurrent for this PS (see section 8.0). Refer to the RM for specific analytical procedures.

##### 12.0 Calculations and Data Analysis

Same as section 12.0 of PS 2.

##### 13.0 Method Performance

13.1 Calibration Drift. The CEMS calibration must not drift by more than 2.5 percent of the span value.

13.2 CEMS Relative Accuracy. Unless stated otherwise in the regulation or permit, the RA of the CEMS must not be greater than 20 percent of the mean value of the RM test data in terms of the units of the emission standard, or 10 percent of the applicable standard, whichever is greater.

#### 14.0 Pollution Prevention [Reserved]

#### 15.0 Waste Management [Reserved]

#### 16.0 References

Same as section 17.0 of PS 2.

#### 17.0 Tables, Diagrams, Flowcharts, and Validation Data [Reserved]

### PERFORMANCE SPECIFICATION 8A—SPECIFICATIONS AND TEST PROCEDURES FOR TOTAL HYDROCARBON CONTINUOUS MONITORING SYSTEMS IN STATIONARY SOURCES

#### 1. Applicability and Principle

1.1 *Applicability*. These performance specifications apply to hydrocarbon (HC) continuous emission monitoring systems (CEMS) installed on stationary sources. The specifications include procedures which are intended to be used to evaluate the acceptability of the CEMS at the time of its installation or whenever specified in regulations or permits. The procedures are not designed to evaluate CEMS performance over an extended period of time. The source owner or operator is responsible for the proper calibration, maintenance, and operation of the CEMS at all times.

1.2 *Principle*. A gas sample is extracted from the source through a heated sample

line and heated filter to a flame ionization detector (FID). Results are reported as volume concentration equivalents of propane. Installation and measurement location specifications, performance and equipment specifications, test and data reduction procedures, and brief quality assurance guidelines are included in the specifications. Calibration drift, calibration error, and response time tests are conducted to determine conformance of the CEMS with the specifications.

#### 2. Definitions

2.1 *Continuous Emission Monitoring System (CEMS)*. The total equipment used to acquire data, which includes sample extraction and transport hardware, analyzer, data recording and processing hardware, and software. The system consists of the following major subsystems:

2.1.1 *Sample Interface*. That portion of the system that is used for one or more of the following: Sample acquisition, sample transportation, sample conditioning, or protection of the analyzer from the effects of the stack effluent.

2.1.2 *Organic Analyzer*. That portion of the system that senses organic concentration and generates an output proportional to the gas concentration.

2.1.3 *Data Recorder*. That portion of the system that records a permanent record of the measurement values. The data recorder may include automatic data reduction capabilities.

2.2 *Instrument Measurement Range*. The difference between the minimum and maximum concentration that can be measured by a specific instrument. The minimum is often stated or assumed to be zero and the range expressed only as the maximum.

2.3 *Span or Span Value*. Full scale instrument measurement range. The span value must be documented by the CEMS manufacturer with laboratory data.

2.4 *Calibration Gas*. A known concentration of a gas in an appropriate diluent gas.

2.5 *Calibration Drift (CD)*. The difference in the CEMS output readings from the established reference value after a stated period of operation during which no unscheduled maintenance, repair, or adjustment takes place. A CD test is performed to demonstrate the stability of the CEMS calibration over time.

2.6 *Response Time*. The time interval between the start of a step change in the system input (e.g., change of calibration gas) and the time when the data recorder displays 95 percent of the final value.

2.7 *Accuracy*. A measurement of agreement between a measured value and an accepted or



true value, expressed as the percentage difference between the true and measured values relative to the true value. For these performance specifications, accuracy is checked by conducting a calibration error (CE) test.

**2.8 Calibration Error (CE).** The difference between the concentration indicated by the CEMS and the known concentration of the cylinder gas. A CE test procedure is performed to document the accuracy and linearity of the monitoring equipment over the entire measurement range.

**2.9 Performance Specification Test (PST) Period.** The period during which CD, CE, and response time tests are conducted.

**2.10 Centroidal Area.** A concentric area that is geometrically similar to the stack or duct cross section and is no greater than 1 percent of the stack or duct cross-sectional area.

### 3. Installation and Measurement Location Specifications

**3.1 CEMS Installation and Measurement Locations.** The CEMS must be installed in a location in which measurements representative of the source's emissions can be obtained. The optimum location of the sample interface for the CEMS is determined by a number of factors, including ease of access for calibration and maintenance, the degree to which sample conditioning will be required, the degree to which it represents total emissions, and the degree to which it represents the combustion situation in the firebox (where applicable). The location should be as free from in-leakage influences as possible and reasonably free from severe flow disturbances. The sample location should be at least two equivalent duct diameters downstream from the nearest control device, point of pollutant generation, or other point at which a change in the pollutant concentration or emission rate occurs and at least 0.5 diameter upstream from the exhaust or control device. The equivalent duct diameter is calculated as per 40 CFR part 60, appendix A, method 1, section 2.1. If these criteria are not achievable or if the location is otherwise less than optimum, the possibility of stratification should be investigated as described in section 3.2. The measurement point must be within the centroidal area of the stack or duct cross section.

**3.2 Stratification Test Procedure.** Stratification is defined as a difference in excess of 10 percent between the average concentration in the duct or stack and the concentration at any point more than 1.0 meter from the duct or stack wall. To determine whether effluent stratification exists, a dual probe system should be used to determine the average effluent concentration while measurements at each traverse point are being made. One probe, located at the stack or duct centroid, is used as a stationary reference point to indicate the change in effluent concentration over time. The second probe is used for sam-

pling at the traverse points specified in 40 CFR part 60 appendix A, method 1. The monitoring system samples sequentially at the reference and traverse points throughout the testing period for five minutes at each point.

### 4. CEMS Performance and Equipment Specifications

If this method is applied in highly explosive areas, caution and care must be exercised in choice of equipment and installation.

**4.1 Flame Ionization Detector (FID) Analyzer.** A heated FID analyzer capable of meeting or exceeding the requirements of these specifications. Heated systems must maintain the temperature of the sample gas between 150 °C (300 °F) and 175 °C (350 °F) throughout the system. This requires all system components such as the probe, calibration valve, filter, sample lines, pump, and the FID to be kept heated at all times such that no moisture is condensed out of the system. The essential components of the measurement system are described below:

**4.1.1 Sample Probe.** Stainless steel, or equivalent, to collect a gas sample from the centroidal area of the stack cross-section.

**4.1.2 Sample Line.** Stainless steel or Teflon tubing to transport the sample to the analyzer.

**NOTE:** Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

**4.1.3 Calibration Valve Assembly.** A heated three-way valve assembly to direct the zero and calibration gases to the analyzer is recommended. Other methods, such as quick-connect lines, to route calibration gas to the analyzers are applicable.

**4.1.4 Particulate Filter.** An in-stack or out-of-stack sintered stainless steel filter is recommended if exhaust gas particulate loading is significant. An out-of-stack filter must be heated.

**4.1.5 Fuel.** The fuel specified by the manufacturer (e.g., 40 percent hydrogen/60 percent helium, 40 percent hydrogen/60 percent nitrogen gas mixtures, or pure hydrogen) should be used.

**4.1.6 Zero Gas.** High purity air with less than 0.1 parts per million by volume (ppm) HC as methane or carbon equivalent or less than 0.1 percent of the span value, whichever is greater.

**4.1.7 Calibration Gases.** Appropriate concentrations of propane gas (in air or nitrogen). Preparation of the calibration gases should be done according to the procedures in EPA Protocol 1. In addition, the manufacturer of the cylinder gas should provide a recommended shelf life for each calibration gas cylinder over which the concentration does not change by more than  $\pm 2$  percent from the certified value.



4.2 *CEMS Span Value.* 100 ppm propane. The span value must be documented by the CEMS manufacturer with laboratory data.

4.3 *Daily Calibration Gas Values.* The owner or operator must choose calibration gas concentrations that include zero and high-level calibration values.

4.3.1 The zero level may be between zero and 0.1 ppm (zero and 0.1 percent of the span value).

4.3.2 The high-level concentration must be between 50 and 90 ppm (50 and 90 percent of the span value).

4.4 *Data Recorder Scale.* The strip chart recorder, computer, or digital recorder must be capable of recording all readings within the CEMS' measurement range and must have a resolution of 0.5 ppm (0.5 percent of span value).

4.5 *Response Time.* The response time for the CEMS must not exceed 2 minutes to achieve 95 percent of the final stable value.

4.6 *Calibration Drift.* The CEMS must allow the determination of CD at the zero and high-level values. The CEMS calibration response must not differ by more than  $\pm 3$  ppm ( $\pm 3$  percent of the span value) after each 24-hour period of the 7-day test at both zero and high levels.

4.7 *Calibration Error.* The mean difference between the CEMS and reference values at all three test points listed below must be no greater than 5 ppm ( $\pm 5$  percent of the span value).

4.7.1 *Zero Level.* Zero to 0.1 ppm (0 to 0.1 percent of span value).

4.7.2 *Mid-Level.* 30 to 40 ppm (30 to 40 percent of span value).

4.7.3 *High-Level.* 70 to 80 ppm (70 to 80 percent of span value).

4.8 *Measurement and Recording Frequency.* The sample to be analyzed must pass through the measurement section of the analyzer without interruption. The detector must measure the sample concentration at least once every 15 seconds. An average emission rate must be computed and recorded at least once every 60 seconds.

4.9 *Hourly Rolling Average Calculation.* The CEMS must calculate every minute an hourly rolling average, which is the arithmetic mean of the 60 most recent 1-minute average values.

4.10 *Retest.* If the CEMS produces results within the specified criteria, the test is successful. If the CEMS does not meet one or more of the criteria, necessary corrections must be made and the performance tests repeated.

#### 5. Performance Specification Test (PST) Periods

5.1 *Pretest Preparation Period.* Install the CEMS, prepare the PTM test site according to the specifications in section 3, and prepare the CEMS for operation and calibration according to the manufacturer's written instructions. A pretest conditioning period

similar to that of the 7-day CD test is recommended to verify the operational status of the CEMS.

5.2 *Calibration Drift Test Period.* While the facility is operating under normal conditions, determine the magnitude of the CD at 24-hour intervals for seven consecutive days according to the procedure given in section 6.1. All CD determinations must be made following a 24-hour period during which no unscheduled maintenance, repair, or adjustment takes place. If the combustion unit is taken out of service during the test period, record the onset and duration of the downtime and continue the CD test when the unit resumes operation.

5.3 *Calibration Error Test and Response Time Test Periods.* Conduct the CE and response time tests during the CD test period.

#### 6. Performance Specification Test Procedures

6.1 *Relative Accuracy Test Audit (RATA) and Absolute Calibration Audits (ACA).* The test procedures described in this section are in lieu of a RATA and ACA.

##### 6.2 Calibration Drift Test.

6.2.1 *Sampling Strategy.* Conduct the CD test at 24-hour intervals for seven consecutive days using calibration gases at the two daily concentration levels specified in section 4.3. Introduce the two calibration gases into the sampling system as close to the sampling probe outlet as practical. The gas must pass through all CEM components used during normal sampling. If periodic automatic or manual adjustments are made to the CEMS zero and calibration settings, conduct the CD test immediately before these adjustments, or conduct it in such a way that the CD can be determined. Record the CEMS response and subtract this value from the reference (calibration gas) value. To meet the specification, none of the differences may exceed 3 percent of the span of the CEM.

6.2.2 *Calculations.* Summarize the results on a data sheet. An example is shown in Figure 1. Calculate the differences between the CEMS responses and the reference values.

6.3 *Response Time.* The entire system including sample extraction and transport, sample conditioning, gas analyses, and the data recording is checked with this procedure.

6.3.1 Introduce the calibration gases at the probe as near to the sample location as possible. Introduce the zero gas into the system. When the system output has stabilized (no change greater than 1 percent of full scale for 30 sec), switch to monitor stack effluent and wait for a stable value. Record the time (upscale response time) required to reach 95 percent of the final stable value.

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6.3.2 Next, introduce a high-level calibration gas and repeat the above procedure. Repeat the entire procedure three times and determine the mean upscale and downscale response times. The longer of the two means is the system response time.

**6.4 Calibration Error Test Procedure.**

6.4.1 *Sampling Strategy.* Challenge the CEMS with zero gas and EPA Protocol 1 cylinder gases at measurement points within the ranges specified in section 4.7.

6.4.1.1 The daily calibration gases, if Protocol 1, may be used for this test.

SOURCE:	DATE:
MONITOR:	LOCATION:
SERIAL NUMBER:	SPAN:

	DAY	DATE	TIME	CALIBRATION VALUE	MONITOR RESPONSE	DIFFERENCE	PERCENT OF SPAN <sup>1/</sup>
ZERO/LOW LEVEL	1						
	2						
	3						
	4						
	5						
	6						
	7						
HIGH LEVEL	1						
	2						
	3						
	4						
	5						
	6						
	7						

<sup>1/</sup> = Acceptance Criteria: ≤ 3% of span each day for seven days.

FIGURE 1: Calibration Drift Determination

6.4.1.2 Operate the CEMS as nearly as possible in its normal sampling mode. The calibration gas should be injected into the sampling system as close to the sampling probe outlet as practical and must pass through all filters, scrubbers, conditioners, and other monitor components used during normal sampling. Challenge the CEMS three non-

consecutive times at each measurement point and record the responses. The duration of each gas injection should be for a sufficient period of time to ensure that the CEMS surfaces are conditioned.

6.4.2 *Calculations.* Summarize the results on a data sheet. An example data sheet is shown in Figure 2. Average the differences between

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the instrument response and the certified cylinder gas value for each gas. Calculate three CE results according to Equation 1. No confidence coefficient is used in CE calculations.

*7. Equations*

Calibration Error. Calculate CE using Equation 1.

$$CE = |d/FS| \times 100 \quad (\text{Eq. 1})$$

Where:

$d$  = Mean difference between CEMS response and the known reference concentration, determined using Equation 2.

$$\bar{d} = \frac{1}{n} \sum_{i=1}^n d_i \quad (\text{Eq. 2})$$

Where:

$d_i$  = Individual difference between CEMS response and the known reference concentration.

*8. Reporting*

At a minimum, summarize in tabular form the results of the CD, response time, and CE test, as appropriate. Include all data sheets, calculations, CEMS data records, and cylinder gas or reference material certifications.

SOURCE:	DATE:
MONITOR:	LOCATION:
SERIAL NUMBER:	SPAN:

RUN NUMBER	CALIBRATION VALUE	MONITOR RESPONSE	DIFFERENCE		
			Zero/Low	Mid	High
1 - Zero					
2 - Mid					
3 - High					
4 - Mid					
5 - Zero					
6 - High					
7 - Zero					
8 - Mid					
9 - High					
Mean Difference =					
Calibration Error =			%	%	%

FIGURE 2: Calibration Error Determination

*9. References*

1. Measurement of Volatile Organic Compounds-Guideline Series. U.S. Environmental Protection Agency, Research Triangle Park,

North Carolina, 27711, EPA-450/2-78-041, June 1978.

2. Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source



Emission Monitors (Protocol No. 1). U.S. Environmental Protection Agency ORD/EMSL, Research Triangle Park, North Carolina, 27711, June 1978.

3. Gasoline Vapor Emission Laboratory Evaluation-Part 2. U.S. Environmental Protection Agency, OAQPS, Research Triangle Park, North Carolina, 27711, EMB Report No. 76-GAS-6, August 1975.

#### PERFORMANCE SPECIFICATION 9—SPECIFICATIONS AND TEST PROCEDURES FOR GAS CHROMATOGRAPHIC CONTINUOUS EMISSION MONITORING SYSTEMS IN STATIONARY SOURCES

##### 1.0 Scope and Application

1.1 Applicability. These requirements apply to continuous emission monitoring systems (CEMSs) that use gas chromatography (GC) to measure gaseous organic compound emissions. The requirements include procedures intended to evaluate the acceptability of the CEMS at the time of its installation and whenever specified in regulations or permits. Quality assurance procedures for calibrating, maintaining, and operating the CEMS properly at all times are also given in this procedure.

##### 2.0 Summary of Performance Specification

2.1 Calibration precision, calibration error, and performance audit tests are conducted to determine conformance of the CEMS with these specifications. Daily calibration and maintenance requirements are also specified.

##### 3.0 Definitions

3.1 Gas Chromatograph (GC). That portion of the system that separates and detects organic analytes and generates an output proportional to the gas concentration. The GC must be temperature controlled.

NOTE: The term temperature controlled refers to the ability to maintain a certain temperature around the column. Temperature-programmable GC is not required for this performance specification, as long as all other requirements for precision, linearity and accuracy listed in this performance specification are met. It should be noted that temperature programming a GC will speed up peak elution, thus allowing increased sampling frequency.

3.1.1 Column. Analytical column capable of separating the analytes of interest.

3.1.2 Detector. A detection system capable of detecting and quantifying all analytes of interest.

3.1.3 Integrator. That portion of the system that quantifies the area under a particular sample peak generated by the GC.

3.1.4 Data Recorder. A strip chart recorder, computer, or digital recorder capable of recording all readings within the instrument's calibration range.

3.2 Calibration Precision. The error between triplicate injections of each calibration standard.

##### 4.0 Interferences [Reserved]

##### 5.0 Safety

The procedures required under this performance specification may involve hazardous materials, operations, and equipment. This performance specification does not purport to address all of the safety problems associated with these procedures. It is the responsibility of the user to establish appropriate safety problems associated with these procedures. It is the responsibility of the user to establish appropriate safety and health practices and determine the application regulatory limitations prior to performing these procedures. The CEMS user's manual and materials recommended by the reference method should be consulted for specific precautions to be taken.

##### 6.0 Equipment and Supplies

6.1 Presurvey Sample Analysis and GC Selection. Determine the pollutants to be monitored from the applicable regulation or permit and determine the approximate concentration of each pollutant (this information can be based on past compliance test results). Select an appropriate GC configuration to measure the organic compounds. The GC components should include a heated sample injection loop (or other sample introduction systems), separatory column, temperature-controlled oven, and detector. If the source chooses dual column and/or dual detector configurations, each column/detector is considered a separate instrument for the purpose of this performance specification and thus the procedures in this performance specification shall be carried out on each system. If this method is applied in highly explosive areas, caution should be exercised in selecting the equipment and method of installation.

6.2 Sampling System. The sampling system shall be heat traced and maintained at a minimum of 120 °C with no cold spots. All system components shall be heated, including the probe, calibration valve, sample lines, sampling loop (or sample introduction system), GC oven, and the detector block (when appropriate for the type of detector being utilized, *e.g.*, flame ionization detector).

##### 7.0 Reagents and Standards

7.1 Calibration Gases. Obtain three concentrations of calibration gases certified by the manufacturer to be accurate to within 2 percent of the value on the label. A gas dilution system may be used to prepare the calibration gases from a high concentration certified standard if the gas dilution system

meets the requirements specified in Test Method 205, 40 CFR Part 51, Appendix M. The performance test specified in Test Method 205 shall be repeated quarterly, and the results of the Method 205 test shall be included in the report. The calibration gas concentration of each target analyte shall be as follows (measured concentration is based on the presurvey concentration determined in section 6.1).

**NOTE:** If the low level calibration gas concentration falls at or below the limit of detection for the instrument for any target pollutant, a calibration gas with a concentration at 4 to 5 times the limit of detection for the instrument may be substituted for the low-level calibration gas listed in section 7.1.1.

7.1.1 Low-level. 40-60 percent of measured concentration.

7.1.2 Mid-level. 90-110 percent of measured concentration.

7.1.3 High-level. 140-160 percent of measured concentration, or select highest expected concentration.

7.2 Performance Audit Gas. A certified EPA audit gas shall be used, when possible. A gas mixture containing all the target compounds within the calibration range and certified by EPA's Traceability Protocol for Assay and Certification of Gaseous Calibration Standards may be used when EPA performance audit materials are not available. The instrument relative error shall be  $\leq 10$  percent of the certified value of the audit gas.

#### 8.0 Sample Collection, Preservation, Storage, and Transport

8.1 Installation and Measurement Location Specifications. Install the CEMs in a location where the measurements are representative of the source emissions. Consider other factors, such as ease of access for calibration and maintenance purposes. The location should not be close to air in-leakages. The sampling location should be at least two equivalent duct diameters downstream from the nearest control device, point of pollutant generation, or other point at which a change in the pollutant concentration or emission rate occurs. The location should be at least 0.5 diameter upstream from the exhaust or control device. To calculate equivalent duct diameter, see section 12.2 of Method 1 (40 CFR Part 60, Appendix A). Sampling locations not conforming to the requirements in this section may be used if necessary upon approval of the Administrator.

8.2 Pretest Preparation Period. Using the procedures described in Method 18 (40 CFR Part 60, Appendix A), perform initial tests to determine GC conditions that provide good resolution and minimum analysis time for compounds of interest. Resolution interferences that may occur can be elimi-

nated by appropriate GC column and detector choice or by shifting the retention times through changes in the column flow rate and the use of temperature programming.

8.3 7-Day Calibration Error (CE) Test Period. At the beginning of each 24-hour period, set the initial instrument setpoints by conducting a multi-point calibration for each compound. The multi-point calibration shall meet the requirements in section 13.3. Throughout the 24-hour period, sample and analyze the stack gas at the sampling intervals prescribed in the regulation or permit. At the end of the 24 hour period, inject the three calibration gases for each compound in triplicate and determine the average instrument response. Determine the CE for each pollutant at each level using the equation in section 9-2.

Each CE shall be  $\leq 10$  percent. Repeat this procedure six more times for a total of 7 consecutive days.

8.4 Performance Audit Test Periods. Conduct the performance audit once during the initial 7-day CE test and quarterly thereafter. Sample and analyze the EPA audit gas(es) (or the gas mixture prepared by EPA's traceability protocol if an EPA audit gas is not available) three times. Calculate the average instrument response. Report the audit results as part of the reporting requirements in the appropriate regulation or permit (if using a gas mixture, report the certified cylinder concentration of each pollutant).

8.5 Reporting. Follow the reporting requirements of the applicable regulation or permit. If the reporting requirements include the results of this performance specification, summarize in tabular form the results of the CE tests. Include all data sheets, calculations, CEMS data records, performance audit results, and calibration gas concentrations and certifications.

#### 9.0 Quality Control [Reserved]

##### 10.0 Calibration and Standardization

10.1 Initial Multi-Point Calibration. After initial startup of the GC, after routine maintenance or repair, or at least once per month, conduct a multi-point calibration of the GC for each target analyte. The multi-point calibration for each analyte shall meet the requirements in section 13.3.

10.2 Daily Calibration. Once every 24 hours, analyze the mid-level calibration standard for each analyte in triplicate. Calculate the average instrument response for each analyte. The average instrument response shall not vary more than 10 percent from the certified concentration value of the cylinder for each analyte. If the difference between the analyzer response and the cylinder concentration for any target compound is greater than 10 percent, immediately inspect the



instrument making any necessary adjustments, and conduct an initial multi-point calibration as described in section 10.1.

11.0 Analytical Procedure. Sample Collection and Analysis Are Concurrent for This Performance Specification (See section 8.0)

12.0 Calculations and Data Analysis

12.1 Nomenclature.

C<sub>m</sub> = average instrument response, ppm.  
 C<sub>a</sub> = cylinder gas value, ppm.  
 F = Flow rate of stack gas through sampling system, in Liters/min.

n = Number of measurement points.  
 r<sup>2</sup> = Coefficient of determination.  
 V = Sample system volume, in Liters, which is the volume inside the sample probe and tubing leading from the stack to the sampling loop.  
 x = CEMS response.  
 y = Actual value of calibration standard.

12.2 Coefficient of Determination. Calculate r<sup>2</sup> using linear regression analysis and the average concentrations obtained at three calibration points as shown in Equation 9-1.

$$r^2 = \left( \frac{n \sum x_i y_i - (\sum x_i)(\sum y_i)}{\sqrt{(n \sum y_i^2 - \sum y_i \sum y_i)(n \sum x_i^2 - \sum x_i \sum x_i)}} \right)^2 \quad \text{Eq. 9-1}$$

12.3 Calibration Error Determination. Determine the percent calibration error (CE) at each concentration for each pollutant using the following equation.

$$CE = \frac{C_m - C_a}{C_a} \times 100 \quad \text{Eq. 9-2}$$

12.4 Sampling System Time Constant (T).

$$T = \frac{F}{V} \quad \text{Eq. 9-3}$$

13.0 Method Performance

13.1 Calibration Error (CE). The CEMS must allow the determination of CE at all three calibration levels. The average CEMS calibration response must not differ by more than 10 percent of calibration gas value at each level after each 24-hour period of the initial test.

13.2 Calibration Precision and Linearity. For each triplicate injection at each concentration level for each target analyte, any one injection shall not deviate more than 5 percent from the average concentration measured at that level. The linear regression curve for each organic compound at all three levels shall have an r<sup>2</sup> ≥ 0.995 (using Equation 9-1).

13.3 Measurement Frequency. The sample to be analyzed shall flow continuously through the sampling system. The sampling system time constant shall be ≤ 5 minutes or the sampling frequency specified in the applicable regulation, whichever is less. Use Equation 9-3 to determine T. The analytical system shall be capable of measuring the effluent stream at the frequency specified in the appropriate regulation or permit.

14.0 Pollution Prevention [Reserved]

15.0 Waste Management [Reserved]

16.0 References [Reserved]

17.0 Tables, Diagrams, Flowcharts, and Validation Data [Reserved]

PERFORMANCE SPECIFICATION 11—SPECIFICATIONS AND TEST PROCEDURES FOR PARTICULATE MATTER CONTINUOUS EMISSION MONITORING SYSTEMS AT STATIONARY SOURCES

1.0 What Are the Purpose and Applicability of Performance Specification 11?

The purpose of Performance Specification 11 (PS-11) is to establish the initial installation and performance procedures that are required for evaluating the acceptability of a particulate matter (PM) continuous emission monitoring system (CEMS); it is not to evaluate the ongoing performance of your PM CEMS over an extended period of time, nor to identify specific calibration techniques and auxiliary procedures to assess CEMS performance. You will find procedures for evaluating the ongoing performance of a PM CEMS in Procedure 2 of Appendix F—Quality Assurance Requirements for Particulate Matter Continuous Emission Monitoring Systems Used at Stationary Sources.

1.1 Under what conditions does PS-11 apply to my PM CEMS? The PS-11 applies to your PM CEMS if you are required by any provision of Title 40 of the Code of Federal Regulations (CFR) to install and operate PM CEMS.

1.2 When must I comply with PS-11? You must comply with PS-11 when directed by



the applicable rule that requires you to install and operate a PM CEMS.

1.3 What other monitoring must I perform? To report your PM emissions in units of the emission standard, you may need to monitor additional parameters to correct the PM concentration reported by your PM CEMS. Your CEMS may include the components listed in paragraphs (1) through (3) of this section:

(1) A diluent monitor (*i.e.*, O<sub>2</sub>, CO<sub>2</sub>, or other CEMS specified in the applicable regulation), which must meet its own performance specifications (also found in this appendix).

(2) Auxiliary monitoring equipment to allow measurement, determination, or input of the flue gas temperature, pressure, moisture content, and/or dry volume of stack effluent sampled, and

(3) An automatic sampling system. The performance of your PM CEMS and the establishment of its correlation to manual reference method measurements must be determined in units of mass concentration as measured by your PM CEMS (*e.g.*, milligrams per actual cubic meter (mg/acm) or milligrams per dry standard cubic meter (mg/dscm)).

#### 2.0 What Are the Basic Requirements of PS-11?

The PS-11 requires you to perform initial installation and calibration procedures that confirm the acceptability of your CEMS when it is installed and placed into operation. You must develop a site-specific correlation of your PM CEMS response against manual gravimetric reference method measurements (including those made using EPA Methods 5, 5L, or 17).

2.1 What types of PM CEMS technologies are covered? Several different types of PM CEMS technologies (*e.g.*, light scattering, Beta attenuation, etc.) can be designed with in-situ or extractive sample gas handling systems. Each PM CEMS technology and sample gas handling technology has certain site-specific advantages. You should select and install a PM CEMS that is appropriate for the flue gas conditions at your source.

2.2 How is PS-11 different from other performance specifications? The PS-11 is based on a technique of correlating PM CEMS responses relative to emission concentrations determined by the reference method. This technique is called "the correlation." This differs from CEMS used to measure gaseous pollutants that have available calibration gases of known concentration. Because the type and characteristics of PM vary from source to source, a single PM correlation, applicable to all sources, is not possible.

2.3 How are the correlation data handled? You must carefully review your manual reference method data and your PM CEMS responses to include only valid, high-quality data. For the correlation, you must convert the manual reference method data to meas-

urement conditions (*e.g.*, wet or dry basis) that are consistent with your PM CEMS. Then, you must correlate the manual method and PM CEMS data in terms of the output as received from the monitor (*e.g.*, milliamperes). At the appropriate PM CEMS response specified in section 13.2 of this performance specification, you must calculate the confidence interval half range and tolerance interval half range as a percentage of the applicable PM concentration emission limit and compare the confidence interval and tolerance interval percentages with the performance criteria. Also, you must calculate the correlation coefficient and compare the correlation coefficient with the applicable performance criterion specified in section 13.2 of this performance specification.

Situations may arise where you will need two or more correlations. If you need multiple correlations, you must collect sufficient data for each correlation, and each correlation must satisfy the performance criteria specified in section 13.2 of this performance specification.

2.4 How do I design my PM CEMS correlation program? When planning your PM CEMS correlation effort, you must address each of the items in paragraphs (1) through (7) of this section to enhance the probability of success. You will find each of these elements further described in this performance specification or in the applicable reference method procedure.

(1) What type of PM CEMS should I select? You should select a PM CEMS that is appropriate for your source with technical consideration for potential factors such as interferences, site-specific configurations, installation location, flue gas conditions, PM concentration range, and other PM characteristics. You can find guidance on which technology is best suited for specific situations in our report "Current Knowledge of Particulate Matter (PM) Continuous Emission Monitoring" (PM CEMS Knowledge Document, see section 16.5).

(2) Where should I install my PM CEMS? Your PM CEMS must be installed in a location that is most representative of PM emissions, as determined by the reference method, such that the correlation between PM CEMS response and emissions determined by the reference method will meet these performance specifications. Care must be taken in selecting a location and measurement point to minimize problems due to flow disturbances, cyclonic flow, and varying PM stratification.

(3) How should I record my CEMS data? You need to ensure that your PM CEMS and data logger are set up to collect and record all normal emission levels and excursions. You must ensure that your data logger and PM CEMS have been properly programmed to accept and transfer status signals of valid

monitor operation (*e.g.*, flags for internal calibration, suspect data, or maintenance periods).

(4) What CEMS data should I review? You must review drift data daily to document proper operation. You must also ensure that any audit material is appropriate for the typical operating range of your PM CEMS.

(5) How long should I operate my PM CEMS before conducting the initial correlation test? You should allow sufficient time for your PM CEMS to operate for you to become familiar with your PM CEMS.

(i) You should observe PM CEMS response over time during normal and varying process conditions. This will ensure that your PM CEMS has been properly set up to operate at a range that is compatible with the concentrations and characteristics of PM emissions for your source. You should use this information to establish the range of operating conditions necessary to determine the correlations of PM CEMS data to manual reference method measurements over a wide operating range.

(ii) You must determine the types of process changes that will influence, on a definable and repeatable basis, flue gas PM concentrations and the resulting PM CEMS responses. You may find this period useful to make adjustments to your planned approach for operating your PM CEMS at your source. For instance, you may change the measurement range or batch sampling period to something other than those you initially planned to use.

(6) How do I conduct the initial correlation test? When conducting the initial correlation test of your PM CEMS response to PM emissions determined by the reference method, you must pay close attention to accuracy and details. Your PM CEMS must be operating properly. You must perform the manual reference method testing accurately, with attention to eliminating site-specific systemic errors. You must coordinate the timing of the manual reference method testing with the sampling cycle of your PM CEMS. You must complete a minimum of 15 manual reference method tests. You must perform the manual reference method testing over the full range of PM CEMS responses that correspond to normal operating conditions for your source and control device and will result in the widest range of emission concentrations.

(7) How should I perform the manual reference method testing? You must perform the manual reference method testing in accordance with specific rule requirements, coordinated closely with PM CEMS and process operations. It is highly recommended that you use paired trains for the manual reference method testing. You must perform the manual reference method testing over a suitable PM concentration range that corresponds to the full range of normal process

and control device operating conditions. Because the manual reference method testing for this correlation test is not for compliance reporting purposes, you may conduct the reference method test runs for less than the typical minimum test run duration of 1 hour.

(8) What do I do with the manual reference method data and PM CEMS data? You must complete each of the activities in paragraphs (8)(i) through (v) of this section.

(i) Screen the manual reference method data for validity (*e.g.*, isokinetics, leak checks), quality assurance, and quality control (*e.g.*, outlier identification).

(ii) Screen your PM CEMS data for validity (*e.g.*, daily drift check requirements) and quality assurance (*e.g.*, flagged data).

(iii) Convert the manual reference method test data into measurement units (*e.g.*, mg/acm) consistent with the measurement conditions of your PM CEMS.

(iv) Calculate the correlation equation(s) as specified in section 12.3.

(v) Calculate the correlation coefficient, confidence interval half range, and tolerance interval half range for the complete set of PM CEMS and reference method correlation data for comparison with the correlation performance criteria specified in section 13.2.

2.5 What other procedures must I perform? Before conducting the initial correlation test, you must successfully complete a 7-day drift test (See section 8.5).

### 3.0 What Special Definitions Apply to PS-11?

3.1 "Appropriate Measurement Range of your PM CEMS" means a measurement range that is capable of recording readings over the complete range of your source's PM emission concentrations during routine operations. The appropriate range is determined during the pretest preparations as specified in section 8.4.

3.2 "Appropriate Data Range for PM CEMS Correlation" means the data range that reflects the full range of your source's PM emission concentrations recorded by your PM CEMS during the correlation test planning period or other normal operations as defined in the applicable regulations.

3.3 "Batch Sampling" means that gas is sampled on an intermittent basis and concentrated on a collection medium before intermittent analysis and follow-up reporting. Beta gauge PM CEMS are an example of batch sampling devices.

3.4 "Confidence Interval Half Range (CI)" is a statistical term and means one-half of the width of the 95 percent confidence interval around the predicted mean PM concentration (*y* value) calculated at the PM CEMS response value (*x* value) where the confidence interval is narrowest. Procedures for calculating CI are specified in section 12.3. The CI as a percent of the emission



limit value (CI%) is calculated at the appropriate PM CEMS response value and must satisfy the criteria specified in section 13.2 (2).

3.5 "Continuous Emission Monitoring System (CEMS)" means all of the equipment required for determination of PM mass concentration in units of the emission standard. The sample interface, pollutant monitor, diluent monitor, other auxiliary data monitor(s), and data recorder are the major subsystems of your CEMS.

3.6 "Correlation" means the primary mathematical relationship for correlating the output from your PM CEMS to a PM concentration, as determined by the PM reference method. The correlation is expressed in the measurement units that are consistent with the measurement conditions (e.g., mg/dscm, mg/acm) of your PM CEMS.

3.7 "Correlation Coefficient (r)" means a quantitative measure of the association between your PM CEMS outputs and the reference method measurements. Equations for calculating the r value are provided in section 12.3(1)(iv) for linear correlations and in section 12.3(2)(iv) for polynomial correlations.

3.8 "Cycle Time" means the time required to complete one sampling, measurement, and reporting cycle. For a batch sampling PM CEMS, the cycle time would start when sample gas is first extracted from the stack/duct and end when the measurement of that batch sample is complete and a new result for that batch sample is produced on the data recorder.

3.9 "Data Recorder" means the portion of your CEMS that provides a permanent record of the monitor output in terms of response and status (flags). The data recorder may also provide automatic data reduction and CEMS control capabilities (see section 6.6).

3.10 "Diluent Monitor and Other Auxiliary Data Monitor(s) (if applicable)" means the portion of your CEMS that provides the diluent gas concentration (such as O<sub>2</sub> or CO<sub>2</sub>, as specified by the applicable regulations), temperature, pressure, and/or moisture content, and generates an output proportional to the diluent gas concentration or gas property.

3.11 "Drift Check" means a check of the difference between your PM CEMS output readings and the established reference value of a reference standard or procedure after a stated period of operation during which no unscheduled maintenance, repair, or adjustment took place. The procedures used to determine drift are specific to the operating principles of your specific PM CEMS. A drift check includes both a zero drift check and an upscale drift check.

3.12 "Exponential Correlation" means an exponential equation used to define the relationship between your PM CEMS output and

the reference method PM concentration, as indicated by Equation 11-37.

3.13 "Flagged Data" means data marked by your CEMS indicating that the response value(s) from one or more CEMS subsystems is suspect or invalid or that your PM CEMS is not in source-measurement operating mode.

3.14 "Linear Correlation" means a first-order mathematical relationship between your PM CEMS output and the reference method PM concentration that is linear in form, as indicated by Equation 11-3.

3.15 "Logarithmic Correlation" means a first-order mathematical relationship between the natural logarithm of your PM CEMS output and the reference method PM concentration that is linear in form, as indicated by Equation 11-34.

3.16 "Low-Emitting Source" means a source that operated at no more than 50 percent of the emission limit during the most recent performance test, and, based on the PM CEMS correlation, the daily average emissions for the source, measured in the units of the applicable emission limit, have not exceeded 50 percent of the emission limit for any day since the most recent performance test.

3.17 "Paired Trains" means two reference method trains that are used to conduct simultaneous measurements of PM concentrations. Guidance on the use of paired sampling trains can be found in the PM CEMS Knowledge Document (see section 16.5).

3.18 "Polynomial Correlation" means a second-order equation used to define the relationship between your PM CEMS output and reference method PM concentration, as indicated by Equation 11-16.

3.19 "Power Correlation" means an equation used to define a power function relationship between your PM CEMS output and the reference method concentration, as indicated by Equation 11-42.

3.20 "Reference Method" means the method defined in the applicable regulations, but commonly refers to those methods collectively known as EPA Methods 5, 5L, and 17 (for particulate matter), found in Appendix A of 40 CFR 60. Only the front half and dry filter catch portions of the reference method can be correlated to your PM CEMS output.

3.21 "Reference Standard" means a reference material or procedure that produces a known and unchanging response when presented to the pollutant monitor portion of your CEMS. You must use these standards to evaluate the overall operation of your PM CEMS, but not to develop a PM CEMS correlation.

3.22 "Response Time" means the time interval between the start of a step change in the system input and the time when the pollutant monitor output reaches 95 percent of the final value (see sections 6.5 and 13.3 for procedures and acceptance criteria).



3.23 "Sample Interface" means the portion of your CEMS used for one or more of the following: sample acquisition, sample delivery, sample conditioning, or protection of the monitor from the effects of the stack effluent.

3.24 "Sample Volume Check" means a check of the difference between your PM CEMS sample volume reading and the sample volume reference value.

3.25 "Tolerance Interval half range (TI)" means one-half of the width of the tolerance interval with upper and lower limits, within which a specified percentage of the future data population is contained with a given level of confidence, as defined by the respective tolerance interval half range equations in section 12.3(1)(iii) for linear correlations and in section 12.3(2)(iii) for polynomial correlations. The TI as a percent of the emission limit value (TI%) is calculated at the appropriate PM CEMS response value specified in section 13.2(3).

3.26 "Upscale Check Value" means the expected response to a reference standard or procedure used to check the upscale response of your PM CEMS.

3.27 "Upscale Drift (UD) Check" means a check of the difference between your PM CEMS output reading and the upscale check value.

3.28 "Zero Check Value" means the expected response to a reference standard or procedure used to check the response of your PM CEMS to particulate-free or low-particulate concentration conditions.

3.29 "Zero Drift (ZD) Check" means a check of the difference between your PM CEMS output reading and the zero check value.

3.30 "Zero Point Correlation Value" means a value added to PM CEMS correlation data to represent low or near zero PM concentration data (see section 8.6 for rationale and procedures).

#### 4.0 Are There Any Potential Interferences for My PM CEMS?

Yes, condensable water droplets or condensable acid gas aerosols (*i.e.*, those with condensation temperatures above those specified by the reference method) at the measurement location can be interferences for your PM CEMS if the necessary precautions are not met.

4.1 Where are interferences likely to occur? Interferences may develop if your CEMS is installed downstream of a wet air pollution control system or any other conditions that produce flue gases, which, at your PM CEMS measurement point, normally or occasionally contain entrained water droplets or condensable salts before release to the atmosphere.

4.2 How do I deal with interferences? We recommend that you use a PM CEMS that extracts and heats representative samples of

the flue gas for measurement to simulate results produced by the reference method for conditions such as those described in section 4.1. Independent of your PM CEMS measurement technology and extractive technique, you should have a configuration simulating the reference method to ensure that:

(1) No formation of new PM or deposition of PM occurs in sample delivery from the stack or duct; and

(2) No condensate accumulates in the sample flow measurement apparatus.

4.3 What PM CEMS measurement technologies should I use? You should use a PM CEMS measurement technology that is free of interferences from any condensable constituent in the flue gas.

#### 5.0 What Do I Need To Know To Ensure the Safety of Persons Using PS-11?

People using the procedures required under PS-11 may be exposed to hazardous materials, operations, site conditions, and equipment. This performance specification does not purport to address all of the safety issues associated with its use. It is your responsibility to establish appropriate safety and health practices and determine the applicable regulatory limitations before performing these procedures. You must consult your CEMS user's manual and other reference materials recommended by the reference method for specific precautions to be taken.

#### 6.0 What Equipment and Supplies Do I Need?

Different types of PM CEMS use different operating principles. You should select an appropriate PM CEMS based on your site-specific configurations, flue gas conditions, and PM characteristics.

(1) Your PM CEMS must sample the stack effluent continuously or, for batch sampling PM CEMS, intermittently.

(2) You must ensure that the averaging time, the number of measurements in an average, the minimum data availability, and the averaging procedure for your CEMS conform with those specified in the applicable emission regulation.

(3) Your PM CEMS must include, as a minimum, the equipment described in sections 6.1 through 6.7.

6.1 What equipment is needed for my PM CEMS's sample interface? Your PM CEMS's sample interface must be capable of delivering a representative sample of the flue gas to your PM CEMS. This subsystem may be required to heat the sample gas to avoid PM deposition or moisture condensation, provide dilution air, perform other gas conditioning to prepare the sample for analysis, or measure the sample volume or flow rate.

(1) If your PM CEMS is installed downstream of a wet air pollution control system such that the flue gases normally or occasionally contain entrained water droplets,

we recommend that you select a sampling system that includes equipment to extract and heat a representative sample of the flue gas for measurement so that the pollutant monitor portion of your CEMS measures only dry PM. Heating should be sufficient to raise the temperature of the extracted flue gas above the water condensation temperature and should be maintained at all times and at all points in the sample line from where the flue gas is extracted, including the pollutant monitor and any sample flow measurement devices.

(2) You must consider the measured conditions of the sample gas stream to ensure that manual reference method test data are converted to units of PM concentration that are appropriate for the correlation calculations. Additionally, you must identify what, if any, additional auxiliary data from other monitoring and handling systems are necessary to convert your PM CEMS response into the units of the PM standard.

(3) If your PM CEMS is an extractive type and your source's flue gas volumetric flow rate varies by more than 10 percent from nominal, your PM CEMS should maintain an isokinetic sampling rate (within 10 percent of true isokinetic). If your extractive-type PM CEMS does not maintain an isokinetic sampling rate, you must use actual site-specific data or data from a similar installation to prove to us, the State, and/or local enforcement agency that isokinetic sampling is not necessary.

6.2 What type of equipment is needed for my PM CEMS? Your PM CEMS must be capable of providing an electronic output that can be correlated to the PM concentration.

(1) Your PM CEMS must be able to perform zero and upscale drift checks. You may perform these checks manually, but performing these checks automatically is preferred.

(2) We recommend that you select a PM CEMS that is capable of performing automatic diagnostic checks and sending instrument status signals (flags) to the data recorder.

(3) If your PM CEMS is an extractive type that measures the sample volume and uses the measured sample volume as part of calculating the output value, your PM CEMS must be able to perform a check of the sample volume to verify the accuracy of the sample volume measuring equipment. The sample volume check must be conducted daily and at the normal sampling rate of your PM CEMS.

6.3 What is the appropriate measurement range for my PM CEMS? Initially, your PM CEMS must be set up to measure over the expected range of your source's PM emission concentrations during routine operations. You may change the measurement range to a more appropriate range prior to correlation testing.

6.4 What if my PM CEMS does automatic range switching? Your PM CEMS may be equipped to perform automatic range switching so that it is operating in a range most sensitive to the detected concentrations. If your PM CEMS does automatic range switching, you must configure the data recorder to handle the recording of data values in multiple ranges during range-switching intervals.

6.5 What averaging time and sample intervals should be used? Your CEMS must sample the stack effluent such that the averaging time, the number of measurements in an average, the minimum sampling time, and the averaging procedure for reporting and determining compliance conform with those specified in the applicable regulation. Your PM CEMS must be designed to meet the specified response time and cycle time established in this performance specification (see section 13.3).

6.6 What type of equipment is needed for my data recorder? Your CEMS data recorder must be able to accept and record electronic signals from all the monitors associated with your PM CEMS.

(1) Your data recorder must record the signals from your PM CEMS that can be correlated to PM mass concentrations. If your PM CEMS uses multiple ranges, your data recorder must identify what range the measurement was made in and provide range-adjusted results.

(2) Your data recorder must accept and record monitor status signals (flagged data).

(3) Your data recorder must accept signals from auxiliary data monitors, as appropriate.

6.7 What other equipment and supplies might I need? You may need other supporting equipment as defined by the applicable reference method(s) (see section 7) or as specified by your CEMS manufacturer.

#### 7.0 What Reagents and Standards Do I Need?

You will need reference standards or procedures to perform the zero drift check, the upscale drift check, and the sample volume check.

7.1 What is the reference standard value for the zero drift check? You must use a zero check value that is no greater than 20 percent of the PM CEMS's response range. You must obtain documentation on the zero check value from your PM CEMS manufacturer.

7.2 What is the reference standard value for the upscale drift check? You must use an upscale check value that produces a response between 50 and 100 percent of the PM CEMS's response range. For a PM CEMS that produces output over a range of 4 mA to 20 mA, the upscale check value must produce a response in the range of 12 mA to 20 mA. You must obtain documentation on the upscale



check value from your PM CEMS manufacturer.

7.3 What is the reference standard value for the sample volume check? You must use a reference standard value or procedure that produces a sample volume value equivalent to the normal sampling rate. You must obtain documentation on the sample volume value from your PM CEMS manufacturer.

*8.0 What Performance Specification Test Procedure Do I Follow?*

You must complete each of the activities in sections 8.1 through 8.8 for your performance specification test.

8.1 How should I select and set up my equipment? You should select a PM CEMS that is appropriate for your source, giving consideration to potential factors such as flue gas conditions, interferences, site-specific configuration, installation location, PM concentration range, and other PM characteristics. Your PM CEMS must meet the equipment specifications in sections 6.1 and 6.2.

(1) You should select a PM CEMS that is appropriate for the flue gas conditions at your source. If your source's flue gas contains entrained water droplets, we recommend that your PM CEMS include a sample delivery and conditioning system that is capable of extracting and heating a representative sample.

(i) Your PM CEMS must maintain the sample at a temperature sufficient to prevent moisture condensation in the sample line before analysis of PM.

(ii) If condensible PM is an issue, we recommend that you operate your PM CEMS to maintain the sample gas temperature at the same temperature as the reference method filter.

(iii) Your PM CEMS must avoid condensation in the sample flow rate measurement lines.

(2) Some PM CEMS do not have a wide measurement range capability. Therefore, you must select a PM CEMS that is capable of measuring the full range of PM concentrations expected from your source from normal levels through the emission limit concentration.

(3) Some PM CEMS are sensitive to particle size changes, water droplets in the gas stream, particle charge, stack gas velocity changes, or other factors. Therefore, you should select a PM CEMS appropriate for the emission characteristics of your source.

(4) We recommend that you consult your PM CEMS vendor to obtain basic recommendations on the instrument capabilities and setup configuration. You are ultimately responsible for setup and operation of your PM CEMS.

8.2 Where do I install my PM CEMS? You must install your PM CEMS at an accessible location downstream of all pollution control

equipment. You must perform your PM CEMS concentration measurements from a location considered representative or be able to provide data that can be corrected to be representative of the total PM emissions as determined by the manual reference method.

(1) You must select a measurement location that minimizes problems due to flow disturbances, cyclonic flow, and varying PM stratification (refer to Method 1 for guidance).

(2) If you plan to achieve higher emissions for correlation test purposes by adjusting the performance of the air pollution control device (per section 8.6(4)(i)), you must locate your PM CEMS and reference method sampling points well downstream of the control device (*e.g.*, downstream of the induced draft fan), in order to minimize PM stratification that may be created in these cases.

8.3 How do I select the reference method measurement location and traverse points? You must follow EPA Method 1 for identifying manual reference method traverse points. Ideally, you should perform your manual reference method measurements at locations that satisfy the measurement site selection criteria specified in EPA Method 1 of at least eight duct diameters downstream and at least two duct diameters upstream of any flow disturbance. Where necessary, you may conduct testing at a location that is two diameters downstream and 0.5 diameters upstream of flow disturbances. If your location does not meet the minimum downstream and upstream requirements, you must obtain approval from us to test at your location.

8.4 What are my pretest preparation steps? You must install your CEMS and prepare the reference method test site according to the specifications in sections 8.2 and 8.3.

(1) After completing the initial field installation, we recommend that you operate your PM CEMS according to the manufacturer's instructions to familiarize yourself with its operation before you begin correlation testing.

(i) During this initial period of operation, we recommend that you conduct daily checks (zero and upscale drift and sample volume, as appropriate), and, when any check exceeds the daily specification (see section 13.1), make adjustments and perform any necessary maintenance to ensure reliable operation.

(2) When you are confident that your PM CEMS is operating properly, we recommend that you operate your CEMS over a correlation test planning period of sufficient duration to identify the full range of operating conditions and PM emissions to be used in your PM CEMS correlation test.

(i) During the correlation test planning period, you should operate the process and air pollution control equipment over the normal



range of operating conditions, except when you attempt to produce higher emissions.

(ii) Your data recorder should record PM CEMS response during the full range of routine process operating conditions.

(iii) You should try to establish the relationships between operating conditions and PM CEMS response, especially those conditions that produce the highest PM CEMS response over 15-minute averaging periods, and the lowest PM CEMS response as well. The objective is to be able to reproduce the conditions for purposes of the actual correlation testing discussed in section 8.6.

(3) You must set the response range of your PM CEMS such that the instrument measures the full range of responses that correspond to the range of source operating conditions that you will implement during correlation testing.

(4) We recommend that you perform preliminary reference method testing after the correlation test planning period. During this preliminary testing, you should measure the PM emission concentration corresponding to the highest PM CEMS response observed during the full range of normal operation, when perturbing the control equipment, or as the result of PM spiking.

(5) Before performing correlation testing, you must perform a 7-day zero and upscale drift test (see section 8.5).

(6) You must not change the response range of the monitor once the response range has been set and the drift test successfully completed.

8.5 How do I perform the 7-day drift test? You must check the zero (or low-level value between 0 and 20 percent of the response range of the instrument) and upscale (between 50 and 100 percent of the instrument's response range) drift. You must perform this check at least once daily over 7 consecutive days. Your PM CEMS must quantify and record the zero and upscale measurements and the time of the measurements. If you make automatic or manual adjustments to your PM CEMS zero and upscale settings, you must conduct the drift test immediately before these adjustments, or conduct it in such a way that you can determine the amount of drift. You will find the calculation procedures for drift in section 12.1 and the acceptance criteria for allowable drift in section 13.1.

(1) What is the purpose of 7-day drift tests? The purpose of the 7-day drift test is to demonstrate that your system is capable of operating in a stable manner and maintaining its calibration for at least a 7-day period.

(2) How do I conduct the 7-day drift test? To conduct the 7-day drift test, you must determine the magnitude of the drift once each day, at 24-hour intervals, for 7 consecutive days while your source is operating normally.

(i) You must conduct the 7-day drift test at the two points specified in section 8.5. You may perform the 7-day drift tests automatically or manually by introducing to your PM CEMS suitable reference standards (these need not be certified) or by using other appropriate procedures.

(ii) You must record your PM CEMS zero and upscale response and evaluate them against the zero check value and upscale check value.

(3) When must I conduct the 7-day drift test? You must complete a valid 7-day drift test before attempting the correlation test.

8.6 How do I conduct my PM CEMS correlation test? You must conduct the correlation test according to the procedure given in paragraphs (1) through (5) of this section. If you need multiple correlations, you must conduct testing and collect at least 15 sets of reference method and PM CEMS data for calculating each separate correlation.

(1) You must use the reference method for PM (usually EPA Methods 5, 5I, or 17) that is prescribed by the applicable regulations. You may need to perform other reference methods or performance specifications (*e.g.*, Method 3 for oxygen, Method 4 for moisture, etc.) depending on the units in which your PM CEMS reports PM concentration.

(i) We recommend that you use paired reference method trains when collecting manual PM data to identify and screen the reference method data for imprecision and bias. Procedures for checking reference method data for bias and precision can be found in the PM CEMS Knowledge Document (see section 16.5).

(ii) You may use test runs that are shorter than 60 minutes in duration (*e.g.*, 20 or 30 minutes). You may perform your PM CEMS correlation tests during new source performance standards performance tests or other compliance tests subject to the Clean Air Act or other statutes, such as the Resource Conservation and Recovery Act. In these cases, your reference method results obtained during the PM CEMS correlation test may be used to determine compliance so long as your source and the test conditions and procedures (*e.g.*, reference method sample run durations) are consistent with the applicable regulations and the reference method.

(ii) You must convert the reference method results to units consistent with the conditions of your PM CEMS measurements. For example, if your PM CEMS measures and reports PM emissions in the units of mass per actual volume of stack gas, you must convert your reference method results to those units (*e.g.*, mg/acm). If your PM CEMS extracts and heats the sample gas to eliminate water droplets, then measures and reports PM emissions under those actual conditions,

you must convert your reference method results to those same conditions (e.g., mg/acm at 160 °C).

(2) During each test run, you must coordinate process operations, reference method sampling, and PM CEMS operations. For example, you must ensure that the process is operating at the targeted conditions, both reference method trains are sampling simultaneously (if paired sampling trains are being used), and your PM CEMS and data logger are operating properly.

(i) You must coordinate the start and stop times of each run between the reference method sampling and PM CEMS operation. For a batch sampling PM CEMS, you must start the reference method at the same time as your PM CEMS sampling.

(ii) You must note the times for port changes (and other periods when the reference method sampling may be suspended) on the data sheets so that you can adjust your PM CEMS data accordingly, if necessary.

(iii) You must properly align the time periods for your PM CEMS and your reference method measurements to account for your PM CEMS response time.

(3) You must conduct a minimum of 15 valid runs each consisting of simultaneous PM CEMS and reference method measurement sets.

(i) You may conduct more than 15 sets of CEMS and reference method measurements. If you choose this option, you may reject certain test results so long as the total number of valid test results you use to determine the correlation is greater than or equal to 15.

(ii) You must report all data, including the rejected data.

(iii) You may reject the results of up to five test runs without explanation.

(iv) If you reject the results of more than five test runs, the basis for rejecting the results of the additional test runs must be explicitly stated in the reference method, this performance specification, Procedure 2 of appendix F, or your quality assurance plan.

(4) Simultaneous PM CEMS and reference method measurements must be performed in a manner to ensure that the range of data that will be used to establish the correlation for your PM CEMS is maximized. You must first attempt to maximize your correlation range by following the procedures described in paragraphs (4)(i) through (iv) of this section. If you cannot obtain the three levels as described in paragraphs (1) through (iv), then you must use the procedure described in section 8.6(5).

(i) You must attempt to obtain the three different levels of PM mass concentration by varying process operating conditions, varying PM control device conditions, or by means of PM spiking.

(ii) The three PM concentration levels you use in the correlation tests must be distrib-

uted over the complete operating range experienced by your source.

(iii) At least 20 percent of the minimum 15 measured data points you use should be contained in each of the following levels:

- Level 1: From no PM (zero concentration) emissions to 50 percent of the maximum PM concentration;

- Level 2: 25 to 75 percent of the maximum PM concentration; and

- Level 3: 50 to 100 percent of the maximum PM concentration.

(iv) Although the above levels overlap, you may only apply individual run data to one level.

(5) If you cannot obtain three distinct levels of PM concentration as described, you must perform correlation testing over the maximum range of PM concentrations that is practical for your PM CEMS. To ensure that the range of data used to establish the correlation for your PM CEMS is maximized, you must follow one or more of the steps in paragraphs (5)(i) through (iv) of this section.

(i) Zero point data for *in-situ* instruments should be obtained, to the extent possible, by removing the instrument from the stack and monitoring ambient air on a test bench.

(ii) Zero point data for extractive instruments should be obtained by removing the extractive probe from the stack and drawing in clean ambient air.

(iii) Zero point data also can be obtained by performing manual reference method measurements when the flue gas is free of PM emissions or contains very low PM concentrations (e.g., when your process is not operating, but the fans are operating or your source is combusting only natural gas).

(iv) If none of the steps in paragraphs (5)(i) through (iii) of this section are possible, you must estimate the monitor response when no PM is in the flue gas (e.g., 4 mA = 0 mg/acm).

8.7 What do I do with the initial correlation test data for my PM CEMS? You must calculate and report the results of the correlation testing, including the correlation coefficient, confidence interval, and tolerance interval for the PM CEMS response and reference method correlation data that are used to establish the correlation, as specified in section 12. You must include all data sheets, calculations, charts (records of PM CEMS responses), process data records including PM control equipment operating parameters, and reference media certifications necessary to confirm that your PM CEMS met the requirements of this performance specification. In addition, you must:

(1) Determine the integrated (arithmetic average) PM CEMS output over each reference method test period;

(2) Adjust your PM CEMS outputs and reference method test data to the same clock time (considering response time of your PM CEMS);



(3) Confirm that the reference method results are consistent with your PM CEMS response in terms of, where applicable, moisture, temperature, pressure, and diluent concentrations; and

(4) Determine whether any of the reference method test results do not meet the test method criteria.

8.8 What is the limitation on the range of my PM CEMS correlation? Although the data you collect during the correlation testing should be representative of the full range of normal operating conditions at your source, you must conduct additional correlation testing if either of the conditions specified in paragraphs (1) and (2) of this section occurs.

(1) If your source is a low-emitting source, as defined in section 3.16 of this specification, you must conduct additional correlation testing if either of the events specified in paragraphs (1)(i) or (ii) of this section occurs while your source is operating under normal conditions.

(i) Your source generates 24 consecutive hourly average PM CEMS responses that are greater than 125 percent of the highest PM CEMS response (*e.g.*, mA reading) used for the correlation curve or are greater than the PM CEMS response that corresponds to 50 percent of the emission limit, whichever is greater, or

(ii) The cumulative hourly average PM CEMS responses generated by your source are greater than 125 percent of the highest PM CEMS response used for the correlation curve or are greater than the PM CEMS response that corresponds to 50 percent of the emission limit, whichever is greater, for more than 5 percent of your PM CEMS operating hours for the previous 30-day period.

(2) If your source is not a low-emitting source, as defined in section 3.16 of this specification, you must conduct additional correlation testing if either of the events specified in paragraph (i) or (ii) of this section occurs while your source is operating under normal conditions.

(i) Your source generates 24 consecutive hourly average PM CEMS responses that are greater than 125 percent of the highest PM CEMS response (*e.g.*, mA reading) used for the correlation curve, or

(ii) The cumulative hourly average PM CEMS responses generated by your source are greater than 125 percent of the highest PM CEMS response used for the correlation curve for more than 5 percent of your PM

CEMS operating hours for the previous 30-day period.

(3) If additional correlation testing is required, you must conduct at least three additional test runs under the conditions that caused the higher PM CEMS response.

(i) You must complete the additional testing and use the resulting new data along with the previous data to calculate a revised correlation equation within 60 days after the occurrence of the event that requires additional testing, as specified in paragraphs 8.8(1) and (2).

(4) If your source generates consecutive PM CEMS hourly responses that are greater than 125 percent of the highest PM CEMS response used to develop the correlation curve for 24 hours or for a cumulative period that amounts to more than 5 percent of the PM CEMS operating hours for the previous 30-day period, you must report the reason for the higher PM CEMS responses.

9.0 What Quality Control Measures Are Required?

Quality control measures for PM CEMS are specified in 40 CFR 60, Appendix F, Procedure 2.

10.0 What Calibration and Standardization Procedures Must I Perform? [Reserved]

11.0 What Analytical Procedures Apply to This Procedure?

Specific analytical procedures are outlined in the applicable reference method(s).

12.0 What Calculations and Data Analyses Are Needed?

You must determine the primary relationship for correlating the output from your PM CEMS to a PM concentration, typically in units of mg/acm or mg/dscm of flue gas, using the calculations and data analysis process in sections 12.2 and 12.3. You develop the correlation by performing an appropriate regression analysis between your PM CEMS response and your reference method data.

12.1 How do I calculate upscale drift and zero drift? You must determine the difference in your PM CEMS output readings from the established reference values (zero and upscale check values) after a stated period of operation during which you performed no unscheduled maintenance, repair or adjustment.

(1) Calculate the upscale drift (UD) using Equation 11-1:

$$UD = \frac{|R_{CEM} - R_U|}{R_T} \times 100 \qquad \text{Eq. 11-1}$$



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Where:

- UD = The upscale (high-level) drift of your PM CEMS in percent,
- R<sub>CEM</sub> = The measured PM CEMS response to the upscale reference standard,

- R<sub>U</sub> = The pre-established numerical value of the upscale reference standard, and
- R<sub>r</sub> = The response range of the analyzer.

(2) Calculate the zero drift (ZD) using Equation 11-2:

$$ZD = \frac{|R_{CEM} - R_U|}{R_r} \times 100 \quad \text{Eq. 11-2}$$

Where:

- ZD = The zero (low-level) drift of your PM CEMS in percent,
- R<sub>CEM</sub> = The measured PM CEMS response to the zero reference standard,
- R<sub>U</sub> = The pre-established numerical value of the zero reference standard, and
- R<sub>r</sub> = The response range of the analyzer.

(3) Summarize the results on a data sheet similar to that shown in Table 2 (see section 17).

12.2 How do I perform the regression analysis? You must couple each reference method PM concentration measurement, y, in the appropriate units, with an average PM CEMS response, x, over corresponding time periods. You must complete your PM CEMS correlation calculations using data deemed acceptable by quality control procedures identified in 40 CFR 60, Appendix F, Procedure 2.

(1) You must evaluate all flagged or suspect data produced during measurement periods and determine whether they should be excluded from your PM CEMS's average.

(2) You must assure that the reference method and PM CEMS results are on a consistent moisture, temperature, and diluent basis. You must convert the reference method PM concentration measurements (dry standard conditions) to the units of your PM CEMS measurement conditions. The conditions of your PM CEMS measurement are monitor-specific. You must obtain from your PM CEMS vendor or instrument manufacturer the conditions and units of measurement for your PM CEMS.

(i) If your sample gas contains entrained water droplets and your PM CEMS is an extractive system that measures at actual conditions (i.e., wet basis), you must use the measured moisture content determined from the impinger analysis when converting your reference method PM data to PM CEMS conditions; do not use the moisture content calculated from a psychrometric chart based on saturated conditions.

12.3 How do I determine my PM CEMS correlation? To predict PM concentrations from PM CEMS responses, you must use the calculation method of least squares presented in paragraphs (1) through (5) of this section. When performing the calculations, each reference method PM concentration measure-

ment must be treated as a discrete data point; if using paired sampling trains, do not average reference method data pairs for any test run.

This performance specification describes procedures for evaluating five types of correlation models: linear, polynomial, logarithmic, exponential, and power. Procedures for selecting the most appropriate correlation model are presented in section 12.4 of this specification.

(1) How do I evaluate a linear correlation for my correlation test data? To evaluate a linear correlation, follow the procedures described in paragraphs (1)(i) through (iv) of this section.

(i) Calculate the linear correlation equation, which gives the predicted PM concentration (y) as a function of the PM CEMS response (x), as indicated by Equation 11-3:

$$\hat{y} = b_0 + b_1x \quad \text{(Eq. 11-3)}$$

Where:

- $\hat{y}$  = the predicted PM concentration,
- $b_0$  = the intercept for the correlation curve, as calculated using Equation 11-4,
- $b_1$  = the slope of the correlation curve, as calculated using Equation 11-6, and
- x = the PM CEMS response value.

Calculate the y intercept ( $b_0$ ) of the correlation curve using Equation 11-4:

$$b_0 = \bar{y} - b_1 \cdot \bar{x} \quad \text{(Eq. 11-4)}$$

Where:

- $\bar{x}$  = the mean value of the PM CEMS response data, as calculated using Equation 11-5, and
- $\bar{y}$  = the mean value of the PM concentration data, as calculated using Equation 11-5:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i, \quad \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i \quad \text{(Eq. 11-5)}$$

Where:

- $x_i$  = the PM CEMS response value for run i,
- $y_i$  = the PM concentration value for run i, and
- n = the number of data points.

Calculate the slope ( $b_1$ ) of the correlation curve using Equation 11-6:

$$b_1 = \frac{S_{xy}}{S_{xx}} \quad (\text{Eq. 11-6})$$

$$S_{xx} = \sum_{i=1}^n (x_i - \bar{x})^2, \quad S_{xy} = \sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y}) \quad (\text{Eq. 11-7})$$

(ii) Calculate the half range of the 95 percent confidence interval (CI) for the predicted PM concentration ( ) at the mean value of x, using Equation 11-8:

$$CI = t_{df, 1-\alpha/2} \cdot S_L \sqrt{\frac{1}{n}} \quad (\text{Eq. 11-8})$$

Where:

CI = the half range of the 95 percent confidence interval for the predicted PM concentration at the mean x value,

$t_{df, 1-\alpha/2}$  = the value for the t statistic provided in Table 1 for  $df = (n - 2)$ , and

$S_L$  = the scatter or deviation of values about the correlation curve, which is determined using Equation 11-9:

$$S_L = \sqrt{\frac{1}{n-2} \sum_{i=1}^n (\hat{y}_i - y_i)^2} \quad (\text{Eq. 11-9})$$

Calculate the confidence interval half range for the predicted PM concentration ( ) at the mean x value as a percentage of the emission limit (CI%) using Equation 11-10:

$$CI\% = \frac{CI}{EL} \cdot 100\% \quad (\text{Eq. 11-10})$$

Where:

CI = the half range of the 95 percent confidence interval for the predicted PM concentration at the mean x value, and  
 EL = PM emission limit, as described in section 13.2.

(iii) Calculate the half range of the tolerance interval (TI) for the predicted PM concentration ( ) at the mean x value using Equation 11-11:

$$TI = k_T \cdot S_L \quad (\text{Eq. 11-11})$$

Where:

TI = the half range of the tolerance interval for the predicted PM concentration ( ) at the mean x value,

$k_T$  = as calculated using Equation 11-12, and  
 $S_L$  = as calculated using Equation 11-9:

Where:

$S_{xx}$ ,  $S_{xy}$  = as calculated using Equation 11-7:

$$k_T = u_{n'} \cdot v_{df} \quad (\text{Eq. 11-12})$$

Where:

$n'$  = the number of test runs (n).

$u_{n'}$  = the tolerance factor for 75 percent coverage at 95 percent confidence provided in Table 1 for  $df = (n - 2)$ , and

$v_{df}$  = the value from Table 1 for  $df = (n - 2)$ .

Calculate the half range of the tolerance interval for the predicted PM concentration ( ) at the mean x value as a percentage of the emission limit (TI%) using Equation 11-13:

$$TI\% = \frac{TI}{EL} \cdot 100\% \quad (\text{Eq. 11-13})$$

Where:

TI = the half range of the tolerance interval for the predicted PM concentration ( ) at the mean x value, and

EL = PM emission limit, as described in section 13.2.

(iv) Calculate the linear correlation coefficient (r) using Equation 11-14:

$$r = \sqrt{1 - \frac{S_L^2}{S_y^2}} \quad (\text{Eq. 11-14})$$

Where:

$S_L$  = as calculated using Equation 11-9, and  
 $S_y$  = as calculated using Equation 11-15:

$$S_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n - 1}} \quad (\text{Eq. 11-15})$$

(2) How do I evaluate a polynomial correlation for my correlation test data? To evaluate a polynomial correlation, follow the procedures described in paragraphs (2)(i) through (iv) of this section.

(i) Calculate the polynomial correlation equation, which is indicated by Equation 11-16, using Equations 11-17 through 11-22:

$$\hat{y} = b_0 + b_1x + b_2x^2 \quad (\text{Eq. 11-16})$$

Where:



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= the PM CEMS concentration predicted by the polynomial correlation equation, and  $b_0, b_1, b_2$  = the coefficients determined from the solution to the matrix equation  $Ab = B$

Where:

$$A = \begin{bmatrix} n & S_1 & S_2 \\ S_1 & S_2 & S_3 \\ S_2 & S_3 & S_4 \end{bmatrix}, \quad b = \begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix}, \quad B = \begin{bmatrix} S_5 \\ S_6 \\ S_7 \end{bmatrix}.$$

$$S_1 = \sum_{i=1}^n (x_i), S_2 = \sum_{i=1}^n (x_i^2), S_3 = \sum_{i=1}^n (x_i^3), S_4 = \sum_{i=1}^n (x_i^4) \quad (\text{Eq. 11-17})$$

$$S_5 = \sum_{i=1}^n (y_i), S_6 = \sum_{i=1}^n (x_i y_i), S_7 = \sum_{i=1}^n (x_i^2 y_i). \quad (\text{Eq. 11-18})$$

Where:

$X_i$  = the PM CEMS response for run  $i$ ,  
 $Y_i$  = the reference method PM concentration for run  $i$ , and

$n$  = the number of test runs.

Calculate the polynomial correlation curve coefficients ( $b_0, b_1$ , and  $b_2$ ) using Equations 11-19 through 11-21, respectively:

$$b_0 = \frac{(S_5 \cdot S_2 \cdot S_4 + S_1 \cdot S_3 \cdot S_2 + S_2 \cdot S_6 \cdot S_3 - S_2 \cdot S_2 \cdot S_2 - S_3 \cdot S_3 \cdot S_3 - S_4 \cdot S_6 \cdot S_1)}{\det A} \quad (\text{Eq. 11-19})$$

$$b_1 = \frac{(n \cdot S_6 \cdot S_4 + S_5 \cdot S_3 \cdot S_2 + S_2 \cdot S_1 \cdot S_7 - S_2 \cdot S_6 \cdot S_2 - S_7 \cdot S_3 \cdot n - S_4 \cdot S_1 \cdot S_5)}{\det A} \quad (\text{Eq. 11-20})$$

$$b_2 = \frac{(n \cdot S_2 \cdot S_7 + S_1 \cdot S_6 \cdot S_2 + S_2 \cdot S_1 \cdot S_3 - S_2 \cdot S_2 \cdot S_5 - S_3 \cdot S_6 \cdot n - S_7 \cdot S_1 \cdot S_1)}{\det A} \quad (\text{Eq. 11-21})$$

Where:

$$\det A = n \cdot S_2 \cdot S_4 - S_2 \cdot S_2 \cdot S_2 + S_1 \cdot S_3 \cdot S_2 - S_3 \cdot S_3 \cdot n + S_2 \cdot S_1 \cdot S_3 - S_4 \cdot S_1 \cdot S_1 \quad (\text{Eq. 11-22})$$

(ii) Calculate the 95 percent confidence interval half range (CI) by first calculating the C coefficients ( $C_0$  to  $C_5$ ) using Equations 11-23 and 11-24:

$$C_0 = \frac{(S_2 \cdot S_4 - S_3^2)}{D}, \quad C_1 = \frac{(S_3 \cdot S_2 - S_1 \cdot S_4)}{D}, \quad C_2 = \frac{(S_1 \cdot S_3 - S_2^2)}{D},$$

$$C_3 = \frac{(nS_4 - S_2^2)}{D}, \quad C_4 = \frac{(S_1 \cdot S_2 - nS_3)}{D}, \quad C_5 = \frac{(nS_2 - S_1^2)}{D} \quad (\text{Eq. 11-23})$$

Where:

$$D = n(S_2 \cdot S_4 - S_3^2) + S_1(S_3 \cdot S_2 - S_1 \cdot S_4) + S_2(S_1 \cdot S_3 - S_2^2) \quad (\text{Eq. 11-24})$$

Calculate  $\Delta$  using Equation 11-25 for each  $x$  value:

$$\Delta = C_0 + 2C_1x + (2C_2 + C_3)x^2 + 2C_4x^3 + C_5x^4 \quad (\text{Eq. 11-25})$$

Determine the  $x$  value that corresponds to the minimum value of  $\Delta$  ( $\Delta_{\min}$ ). Determine the scatter or deviation of values about the polynomial correlation curve ( $S_p$ ) using Equation 11-26:

$$S_p = \sqrt{\frac{1}{n-3} \sum_{i=1}^n (\hat{y}_i - y_i)^2} \quad (\text{Eq. 11-26})$$

Calculate the half range of the 95 percent confidence interval (CI) for the predicted PM concentration ( $\hat{y}$ ) at the  $x$  value that corresponds to  $\Delta_{\min}$  using Equation 11-27:

$$CI = t_{df} \cdot S_p \sqrt{\Delta_{\min}} \quad (\text{Eq. 11-27})$$

Where:

$df = (n-3)$ , and

$t_{df}$  = as listed in Table 1 (see section 17).

Calculate the half range of the 95 percent confidence interval for the predicted PM concentration at the  $x$  value that corresponds to  $\Delta_{\min}$  as a percentage of the emission limit (CI%) using Equation 11-28:

$$CI\% = \frac{CI}{EL} \cdot 100\% \quad (\text{Eq. 11-28})$$

Where:

CI = the half range of the 95 percent confidence interval for the predicted PM

concentration at the  $x$  value that corresponds to  $\Delta_{\min}$ , and

EL = PM emission limit, as described in section 13.2.

(iii) Calculate the tolerance interval half range (TI) for the predicted PM concentration at the  $x$  value that corresponds to  $\Delta_{\min}$ , as indicated in Equation 11-29 for the polynomial correlation, using Equations 11-30 and 11-31:

$$TI = k_T \cdot S_p \quad (\text{Eq. 11-29})$$

Where:

$$k_T = u_{n'} \cdot v_{df} \quad (\text{Eq. 11-30})$$

$$n' = \frac{1}{\Delta} \quad (\text{Eq. 11-31})$$

$u_{n'}$  = the value indicated in Table 1 for  $df = (n'-3)$ , and



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$v_{df}$  = the value indicated in Table 1 for  $df = (n^c - 3)$ .

Calculate the tolerance interval half range for the predicted PM concentration at the  $x$  value that corresponds to  $\Delta_{min}$  as a percentage of the emission limit (TI%) using Equation 11-32:

$$TI\% = \frac{TI}{EL} \cdot 100 \quad (\text{Eq. 11-32})$$

Where:

TI = the tolerance interval half range for the predicted PM concentration at the  $x$  value that corresponds to  $\Delta_{min}$ , and

EL = PM emission limit, as described in section 13.2.

(iv) Calculate the polynomial correlation coefficient ( $r$ ) using Equation 11-33:

$$r = \sqrt{1 - \frac{S_p^2}{S_y^2}} \quad (\text{Eq. 11-33})$$

Where:

$S_p$  = as calculated using Equation 11-26, and  
 $S_y$  = as calculated using Equation 11-15.

(3) How do I evaluate a logarithmic correlation for my correlation test data? To evaluate a logarithmic correlation, which has the form indicated by Equation 11-34, follow the procedures described in paragraphs (3)(i) through (iii) of this section.

$$\hat{y} = b_0 + b_1 \ln(x) \quad (\text{Eq. 11-34})$$

(i) Perform a logarithmic transformation of each PM CEMS response value ( $x$  values) using Equation 11-35:

$$x_i' = \ln(x_i) \quad (\text{Eq. 11-35})$$

Where:

$x_i'$  = is the transformed value of  $x_i$ , and  
 $\ln(x_i)$  = the natural logarithm of the PM CEMS response for run  $i$ .

(ii) Using the values for  $x_i'$  in place of the values for  $x_i$ , perform the same procedures used to develop the linear correlation equation described in paragraph (1)(i) of this section. The resulting equation has the form indicated by Equation 11-36:

$$\hat{y} = b_0 + b_1 x' \quad (\text{Eq. 11-36})$$

Where:

$x'$  = the natural logarithm of the PM CEMS response, and the variables  $b_0$ , and  $b_1$  are as defined in paragraph (1)(i) of this section.

(iii) Using the values for  $x_i'$  in place of the values for  $x_i$ , calculate the confidence interval half range at the mean  $x'$  value as a per-

centage of the emission limit (CI%), the tolerance interval half range at the mean  $x'$  value as a percentage of the emission limit (TI%), and the correlation coefficient ( $r$ ) using the procedures described in paragraphs (1)(ii) through (iv) of this section.

(4) How do I evaluate an exponential correlation for my correlation test data? To evaluate an exponential correlation, which has the form indicated by Equation 11-37, follow the procedures described in paragraphs (4)(i) through (v) of this section:

$$\hat{y} = b_0 e^{b_1 x} \quad (\text{Eq. 11-37})$$

(i) Perform a logarithmic transformation of each PM concentration measurement ( $y$  values) using Equation 11-38:

$$y_i' = \ln(y_i) \quad (\text{Eq. 11-38})$$

Where:

$y_i'$  = is the transformed value of  $y_i$ , and  
 $\ln(y_i)$  = the natural logarithm of the PM concentration measurement for run  $i$ .

(ii) Using the values for  $y_i'$  in place of the values for  $y_i$ , perform the same procedures used to develop the linear correlation equation described in paragraph (1)(i) of this section. The resulting equation will have the form indicated by Equation 11-39.

$$\hat{y}' = b_0' + b_1 x \quad (\text{Eq. 11-39})$$

Where:

$\hat{y}'$  = the predicted log PM concentration value,  
 $b_0'$  = the natural logarithm of  $b_0$ , and the variables  $b_0$ ,  $b_1$ , and  $x$  are as defined in paragraph (1)(i) of this section.

(iii) Using the values for  $y_i'$  in place of the values for  $y_i$ , calculate the half range of the 95 percent confidence interval (CI'), as described in paragraph (1)(ii) of this section for CI. Note that CI' is on the log scale. Next, calculate the upper and lower 95 percent confidence limits for the mean value  $\bar{y}'$  using Equations 11-40 and 11-41:

$$LCL' = \bar{y}' - CI' \quad (\text{Eq. 11-40})$$

$$UCL' = \bar{y}' + CI' \quad (\text{Eq. 11-41})$$

Where:

LCL' = the lower 95 percent confidence limit for the mean value  $\bar{y}'$ .

UCL' = the upper 95 percent confidence limit for the mean value  $\bar{y}'$ .

$\bar{y}'$  = the mean value of the log-transformed PM concentrations, and

CI' = the half range of the 95 percent confidence interval for the predicted PM concentration ( $\hat{y}$ ), as calculated in Equation 11-8.

Calculate the half range of the 95 percent confidence interval (CI) on the original PM concentration scale using Equation 11-42:

$$CI = \frac{e^{UCL'} - e^{LCL'}}{2} \quad (\text{Eq. 11-42})$$

Where:

CI = the half range of the 95 percent confidence interval on the original PM concentration scale, and UCL' and LCL' are as defined previously.

Calculate the half range of the 95 percent confidence interval for the predicted PM concentration corresponding to the mean value of x as a percentage of the emission limit (CI%) using Equation 11-10.

(iv) Using the values for  $y'_i$  in place of the values for  $y_i$ , calculate the half range tolerance interval (TI'), as described in paragraph (1)(iii) of this section for TI. Note that TI' is on the log scale. Next, calculate the half range tolerance limits for the mean value  $\underline{y}'$  using Equations 11-43 and 11-44:

$$LTL' = \underline{y}' - TI' \quad (\text{Eq. 11-43})$$

$$UTL' = \underline{y}' + TI' \quad (\text{Eq. 11-44})$$

Where:

LTL' = the lower 95 percent tolerance limit for the mean value  $\underline{y}'$ ,

UTL' = the upper 95 percent tolerance limit for the mean value  $\underline{y}'$ ,

$\underline{y}'$  = the mean value of the log-transformed PM concentrations, and

TI' = the half range of the 95 percent tolerance interval for the predicted PM concentration ('), as calculated in Equation 11-11.

Calculate the half range tolerance interval (TI) on the original PM concentration scale using Equation 11-45:

$$TI = \frac{e^{UTL'} - e^{LTL'}}{2} \quad (\text{Eq. 11-45})$$

TI = the half range of the 95 percent tolerance interval on the original PM scale, and UTL' and LTL' are as defined previously.

Calculate the tolerance interval half range for the predicted PM concentration corresponding to the mean value of x as a percentage of the emission limit (TI%) using Equation 11-13.

(v) Using the values for  $y''_i$  in place of the values for  $y_i$ , calculate the correlation coefficient (r) using the procedure described in paragraph (1)(iv) of this section.

(5) How do I evaluate a power correlation for my correlation test data? To evaluate a power correlation, which has the form indi-

cated by Equation 11-46, follow the procedures described in paragraphs (5)(i) through (v) of this section.

$$\hat{y} = b_0 x^{b_1} \quad (\text{Eq. 11-46})$$

(i) Perform logarithmic transformations of each PM CEMS response (x values) and each PM concentration measurement (y values) using Equations 11-35 and 11-38, respectively.

(ii) Using the values for  $x''_i$  in place of the values for  $x_i$ , and the values for  $y''_i$  in place of the values for  $y_i$ , perform the same procedures used to develop the linear correlation equation described in paragraph (1)(i) of this section. The resulting equation will have the form indicated by Equation 11-47:

$$\hat{y}' = b'_0 + b_1 x' \quad (\text{Eq. 11-47})$$

Where:

' = the predicted log PM concentration value, and

$x'$  = the natural logarithm of the PM CEMS response values,

$b'_0$  = the natural logarithm of  $b_0$ , and the variables  $b_0$ ,  $b_1$ , and  $x$  are as defined in paragraph (1)(i) of this section.

(iii) Using the same procedure described for exponential models in paragraph (4)(iii) of this section, calculate the half range of the 95 percent confidence interval for the predicted PM concentration corresponding to the mean value of  $x'$  as a percentage of the emission limit.

(iv) Using the same procedure described for exponential models in paragraph (4)(iv) of this section, calculate the tolerance interval half range for the predicted PM concentration corresponding to the mean value of  $x'$  as a percentage of the emission limit.

(v) Using the values for  $y'_i$  in place of the values for  $y_i$ , calculate the correlation coefficient (r) using the procedure described in paragraph (1)(iv) of this section.

*Note:* PS-11 does not address the application of correlation equations to calculate PM emission concentrations using PM CEMS response data during normal operations of a PM CEMS. However, we will provide guidance on the use of specific correlation models (i.e., logarithmic, exponential, and power models) to calculate PM concentrations in an operating PM CEMS in situations when the PM CEMS response values are equal to or less than zero, and the correlation model is undefined.

12.4 Which correlation model should I use? Follow the procedures described in paragraphs (1) through (4) of this section to determine which correlation model you should use.

(1) For each correlation model that you develop using the procedures described in section 12.3 of this specification, compare the confidence interval half range percentage, tolerance interval half range percentage, and



correlation coefficient to the performance criteria specified in section 13.2 of this specification. You can use the linear, logarithmic, exponential, or power correlation model if the model satisfies all of the performance criteria specified in section 13.2 of this specification. However, to use the polynomial model you first must check that the polynomial correlation curve satisfies the criteria for minimum and maximum values specified in paragraph (3) of this section.

(2) If you develop more than one correlation curve that satisfy the performance criteria specified in section 13.2 of this specification, you should use the correlation curve with the greatest correlation coefficient. If the polynomial model has the greatest correlation coefficient, you first must check that the polynomial correlation curve satisfies the criteria for minimum and maximum values specified in paragraph (3) of this section.

(3) You can use the polynomial model that you develop using the procedures described in section 12.3(2) if the model satisfies the performance criteria specified in section 13.2 of this specification, and the minimum or maximum value of the polynomial correlation curve does not occur within the expanded data range. The minimum or maximum value of the polynomial correlation curve is the point where the slope of the curve equals zero. To determine if the minimum or maximum value occurs within the expanded data range, follow the procedure described in paragraphs (3)(i) through (iv) of this section.

(i) Determine if your polynomial correlation curve has a minimum or maximum point by comparing the polynomial coefficient  $b_2$  to zero. If  $b_2$  is less than zero, the curve has a maximum value. If  $b_2$  is greater than zero, the curve has a minimum value. (Note: If  $b_2$  equals zero, the correlation curve is linear.)

(ii) Calculate the minimum value using Equation 11-48.

$$\text{min or max} = -\frac{b_1}{2b_2} \quad (\text{Eq. 11-48})$$

(iii) If your polynomial correlation curve has a minimum point, you must compare the minimum value to the minimum PM CEMS response used to develop the correlation curve. If the correlation curve minimum value is less than or equal to the minimum PM CEMS response value, you can use the polynomial correlation curve, provided the correlation curve also satisfies all of the performance criteria specified in section 13.2 of this specification. If the correlation curve minimum value is greater than the minimum PM CEMS response value, you cannot use the polynomial correlation curve to predict PM concentrations.

(iv) If your polynomial correlation curve has a maximum, the maximum value must be greater than the allowable extrapolation limit. If your source is not a low-emitting source, as defined in section 3.16 of this specification, the allowable extrapolation limit is 125 percent of the highest PM CEMS response used to develop the correlation curve. If your source is a low-emitting source, the allowable extrapolation limit is 125 percent of the highest PM CEMS response used to develop the correlation curve or the PM CEMS response that corresponds to 50 percent of the emission limit, whichever is greater. If the polynomial correlation curve maximum value is greater than the extrapolation limit, and the correlation curve satisfies all of the performance criteria specified in section 13.2 of this specification, you can use the polynomial correlation curve to predict PM concentrations. If the correlation curve maximum value is less than the extrapolation limit, you cannot use the polynomial correlation curve to predict PM concentrations.

(4) You may petition the Administrator for alternative solutions or sampling recommendations if the correlation models described in section 12.3 of this specification do not satisfy the performance criteria specified in section 13.2 of this specification.

### 13.0 What Are the Performance Criteria for My PM CEMS?

You must evaluate your PM CEMS based on the 7-day drift check, the accuracy of the correlation, and the sampling periods and cycle/response time.

13.1 What is the 7-day drift check performance specification? Your daily PM CEMS internal drift checks must demonstrate that the average daily drift of your PM CEMS does not deviate from the value of the reference light, optical filter, Beta attenuation signal, or other technology-suitable reference standard by more than 2 percent of the response range. If your CEMS includes diluent and/or auxiliary monitors (for temperature, pressure, and/or moisture) that are employed as a necessary part of this performance specification, you must determine the calibration drift separately for each ancillary monitor in terms of its respective output (see the appropriate performance specification for the diluent CEMS specification). None of the calibration drifts may exceed their individual specification.

13.2 What performance criteria must my PM CEMS correlation satisfy? Your PM CEMS correlation must meet each of the minimum specifications in paragraphs (1), (2), and (3) of this section. Before confidence and tolerance interval half range percentage calculations are made, you must convert the emission limit to the appropriate units of your PM CEMS measurement conditions using the average of emissions gas property

values (e.g., diluent concentration, temperature, pressure, and moisture) measured during the correlation test.

(1) The correlation coefficient must satisfy the criterion specified in paragraph (1)(i) or (ii), whichever applies.

(i) If your source is not a low-emitting source, as defined in section 3.16 of this specification, the correlation coefficient ( $r$ ) must be greater than or equal to 0.85.

(ii) If your source is a low-emitting source, as defined in section 3.16 of this specification, the correlation coefficient ( $r$ ) must be greater than or equal to 0.75.

(2) The confidence interval half range must satisfy the applicable criterion specified in paragraph (2)(1), (ii), or (iii) of this section, based on the type of correlation model.

(i) For linear or logarithmic correlations, the 95 percent confidence interval half range at the mean PM CEMS response value from the correlation test must be within 10 percent of the PM emission limit value specified in the applicable regulation. Therefore, the CI% calculated using Equation 11-10 must be less than or equal to 10 percent.

(ii) For polynomial correlations, the 95 percent confidence interval half range at the PM CEMS response value from the correlation test that corresponds to the minimum value for  $\Delta$  must be within 10 percent of the PM emission limit value specified in the applicable regulation. Therefore, the CI% calculated using Equation 11-28 must be less than or equal to 10 percent.

(iii) For exponential or power correlations, the 95 percent confidence interval half range at the mean of the logarithm of the PM CEMS response values from the correlation test must be within 10 percent of the PM emission limit value specified in the applicable regulation. Therefore, the CI% calculated using Equation 11-10 must be less than or equal to 10 percent.

(3) The tolerance interval half range must satisfy the applicable criterion specified in paragraph (3)(i), (ii), or (iii) of this section, based on the type of correlation model.

(i) For linear or logarithmic correlations, the half range tolerance interval with 95 percent confidence and 75 percent coverage at the mean PM CEMS response value from the correlation test must be within 25 percent of the PM emission limit value specified in the applicable regulation. Therefore, the TI% calculated using Equation 11-13 must be less than or equal to 25 percent.

(ii) For polynomial correlations, the half range tolerance interval with 95 percent confidence and 75 percent coverage at the PM CEMS response value from the correlation test that corresponds to the minimum value for  $\Delta$  must be within 25 percent of the PM emission limit value specified in the applicable regulation. Therefore, the TI% calculated using Equation 11-32 must be less than or equal to 25 percent.

(iii) For exponential or power correlations, the half range tolerance interval with 95 percent confidence and 75 percent coverage at the mean of the logarithm of the PM CEMS response values from the correlation test must be within 25 percent of the PM emission limit value specified in the applicable regulation. Therefore, the TI% calculated using Equation 11-13 must be less than or equal to 25 percent.

13.3 What are the sampling periods and cycle/response time? You must document and maintain the response time and any changes in the response time following installation.

(1) If you have a batch sampling PM CEMS, you must evaluate the limits presented in paragraphs (1)(i) and (ii) of this section.

(i) The response time of your PM CEMS, which is equivalent to the cycle time, must be no longer than 15 minutes. In addition, the delay between the end of the sampling time and reporting of the sample analysis must be no greater than 3 minutes. You must document any changes in the response time following installation.

(ii) The sampling time of your PM CEMS must be no less than 30 percent of the cycle time. If you have a batch sampling PM CEMS, sampling must be continuous except during pauses when the collected pollutant on the capture media is being analyzed and the next capture medium starts collecting a new sample.

13.4 What PM compliance monitoring must I do? You must report your CEMS measurements in the units of the standard expressed in the regulations (e.g., mg/dscm @ 7 percent oxygen, pounds per million Btu (lb/mmBtu), etc.). You may need to install auxiliary data monitoring equipment to convert the units reported by your PM CEMS into units of the PM emission standard.

#### 14.0 Pollution Prevention [Reserved]

#### 15.0 Waste Management [Reserved]

#### 16.0 Which References Are Relevant to This Performance Specification?

16.1 Technical Guidance Document: Compliance Assurance Monitoring. U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Emission Measurement Center, August 1998.

16.2 40 CFR 60, Appendix B, "Performance Specification 2—Specifications and Test Procedures for SO<sub>2</sub> and NO<sub>x</sub>, Continuous Emission Monitoring Systems in Stationary Sources."

16.3 40 CFR 60, Appendix B, "Performance Specification 1—Specification and Test Procedures for Opacity Continuous Emission Monitoring Systems in Stationary Sources."

16.4 40 CFR 60, Appendix A, "Method 1—Sample and Velocity Traverses for Stationary Sources."



16.5 "Current Knowledge of Particulate Matter (PM) Continuous Emission Monitoring." EPA-454/R-00-039. U.S. Environmental Protection Agency, Research Triangle Park, NC, September 2000.

16.6 40 CFR 266, Appendix IX, section 2, "Performance Specifications for Continuous Emission Monitoring Systems."

16.7 ISO 10155, "Stationary Source Emissions—Automated Monitoring of Mass Concentrations of Particles: Performance Characteristics, Test Procedures, and Specifications." American National Standards Institute, New York City, 1995.

16.8 Snedecor, George W. and Cochran, William G. (1989), Statistical Methods, Eighth Edition, Iowa State University Press.

16.9 Wallis, W. A. (1951) "Tolerance Intervals for Linear Regression," in Second Berkeley Symposium on Mathematical Statistics and Probability, ed. J. Neyman, Berkeley: University of California Press, pp. 43-51.

17.0 What Reference Tables and Validation Data Are Relevant to PS-11?

Use the information in Table 1 for determining the confidence and tolerance interval half ranges. Use Table 2 to record your 7-day drift test data.

TABLE 1—FACTORS FOR CALCULATION OF CONFIDENCE AND TOLERANCE INTERVAL HALF RANGES

df	Student's $t_{\alpha}$	Tolerance interval with 75% coverage and 95% confidence level		
		$v_{df}$ (95%)	$u_{df}$ (75%)	$k_T$
3	3.182	2.920	1.266	3.697
4	2.776	2.372	1.247	2.958
5	2.571	2.089	1.233	2.576
6	2.447	1.915	1.223	2.342
7	2.365	1.797	1.214	2.183
8	2.306	1.711	1.208	2.067
9	2.262	1.645	1.203	1.979
10	2.228	1.593	1.198	1.909
11	2.201	1.551	1.195	1.853
12	2.179	1.515	1.192	1.806
13	2.160	1.485	1.189	1.766
14	2.145	1.460	1.186	1.732
15	2.131	1.437	1.184	1.702
16	2.120	1.418	1.182	1.676
17	2.110	1.400	1.181	1.653
18	2.101	1.384	1.179	1.633
19	2.093	1.370	1.178	1.614
20	2.086	1.358	1.177	1.597
21	2.080	1.346	1.175	1.582
22	2.074	1.335	1.174	1.568
23	2.069	1.326	1.173	1.555
24	2.064	1.316	1.172	1.544
25	2.060	1.308	1.172	1.533
26	2.056	1.300	1.171	1.522
27	2.052	1.293	1.170	1.513
28	2.048	1.286	1.170	1.504
29	2.045	1.280	1.169	1.496
30	2.042	1.274	1.168	1.488
31	2.040	1.268	1.168	1.481
32	2.037	1.263	1.167	1.474
33	2.035	1.258	1.167	1.467
34	2.032	1.253	1.166	1.461
35	2.030	1.248	1.166	1.455
36	2.028	1.244	1.165	1.450
37	2.026	1.240	1.165	1.444
38	2.024	1.236	1.165	1.439
39	2.023	1.232	1.164	1.435
40	2.021	1.228	1.164	1.430
41	2.020	1.225	1.164	1.425
42	2.018	1.222	1.163	1.421
43	2.017	1.218	1.163	1.417
44	2.015	1.215	1.163	1.413
45	2.014	1.212	1.163	1.410
46	2.013	1.210	1.162	1.406
47	2.012	1.207	1.162	1.403
48	2.011	1.204	1.162	1.399
49	2.010	1.202	1.162	1.396
50	2.009	1.199	1.161	1.393
51	2.008	1.197	1.161	1.390
52	2.007	1.195	1.161	1.387