Current as of 03/09/09

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 recordkeeping 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 wavelength) 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?

(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.

(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 1/3 and 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 1/2 and 2/3 the distance up the vertical axis from the bottom of the duct for upward flow in the vertical section, and is between 1/3 and 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 ±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 unscheduled 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 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:

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

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:

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

Where:

LT=Luminous transmittance

T_i=Weighted tested filter transmittance.

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

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

Where:

$\overline{x}$ = Arithmetic mean

n=Number of data points

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

12.4 Standard Deviation. Calculate the standard deviation as follows:

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

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:

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

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:

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

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):

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

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

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:

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

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 ≤3 percent opacity for each of the three calibration attenuators.

(3) System Response Time. The COMS upscale and downscale response times must be ≤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 ±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[a]	Wavelength nanometers	Weighting factor[a]
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	9841	770	0
570	9147	780	0
580	7992		

[1]Total of weighting factors=100,000.

[a]The values in this table are already corrected for n-1 degrees of freedom. Use n equal to the number of individual values.

Table 1–2[T] Values

n[a]	$t_{0.975}$	n[a]	$t_{0.975}$	n[a]	$t_{0.975}$
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

[a]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 1-1. Transmissometer location downstream of a bend in a vertical stack.

Figure 1-2. Transmissometer location upstream of a bend in a vertical stack.

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.