PERFORMANCE SPECIFICATION 11

SPECIFICATIONS AND TEST PROCEDURES FOR PARTICULATE MATTER CONTINUOUS EMISSION MONITORING SYSTEMS AT STATIONARY SOURCES

1. 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 the PM CEMS over an extended period of time, nor to identify specific calibration techniques and auxiliary procedures to assess CEMS performance. Procedures for evaluating the ongoing performance of a PM CEMS are found 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 PM CEMS? The PS-11 applies to the PM CEMS if the owner or operator is required by any provision of *Georgia Rules or Air Quality Control* 391-3-1-.02(6)* to install and operate PM CEMS.

1.2 When must the PM CEMS comply with PS-11? The owner of operator of a PM CEMS must comply with PS-11 when directed by the applicable rule that requires installation and operation of a PM CEMS.

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

(1) A diluent monitor (i.e., O_2, CO_2, 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 the PM CEMS and the establishment of its correlation to manual reference method measurements must be determined in units of mass concentration as measured by the PM CEMS (e.g., milligrams per actual cubic meter (mg/acm) or milligrams per dry standard cubic meter (mg/dscm)).

2. What are the basic requirements of PS-11?

The PS-11 requires the owner or operator of a PM CEMS to perform initial installation and calibration procedures that confirm the acceptability of the CEMS when it is installed and placed into operation. The owner or operator must develop a site-specific correlation of the PM CEMS response against manual gravimetric reference method measurements (including those made using Methods 5 or 17 in Appendix A of this text).

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. The owner or operator should select and install a PM CEMS that is appropriate for the flue gas conditions at their 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? The owner or operator must carefully review the manual reference method data and the PM CEMS responses to include only valid, high-quality data. For the correlation, the owner or operator must convert the manual reference method data to measurement conditions (e.g., wet or dry basis) that are consistent with the PM CEMS. Then, the owner or operator must correlate the manual method and PM CEMS data in terms of the output as received from the monitor (e.g., milliamps). At the appropriate PM CEMS response specified in section 13.2 of this performance specification, the owner or operator 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, the owner or operator 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 the owner or operator will need two or more correlations. If multiple correlations are needed, the owner or operator 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 does the owner or operator design the PM CEMS correlation program? When planning the PM CEMS correlation effort, the owner or operator must address each of the items in paragraphs (1) through (7) of this section to enhance the probability of success. The owner or operator 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 be selected? The owner or operator should select a PM CEMS that is appropriate for their 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.

The owner or operator 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 the owner or operator install the PM CEMS? The 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 CEMS data be recorded? The owner or operator needs to ensure that the PM CEMS and data logger are set up to collect and record all normal emission levels and excursions. The owner or operator must ensure that the 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 be reviewed? The owner or operator must review drift data daily to document proper operation. The owner or operator must also ensure that any audit material is appropriate for the typical operating range of the PM CEMS.

(5) How long should the owner or operator operate the PM CEMS before conducting the initial correlation test? The owner or operator should allow sufficient time for the PM CEMS to operate for the owner or operator to become familiar with the PM CEMS.

(i) The owner or operator should observe PM CEMS response over time during normal and varying process conditions. This will ensure that the PM CEMS has been properly set up to operate at a range that is compatible with the concentrations and characteristics of PM emissions for their source. The owner or operator 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) The owner or operator 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. The owner or operator may find this period useful to make adjustments to the planned approach for operating the PM CEMS at their source. For instance, the owner or operator may change the measurement range or batch sampling period to something other than those initially planned to be used.

(6) How does the owner or operator of a PM CEMS conduct the initial correlation test? When conducting the initial correlation test of the PM CEMS response to PM emissions determined by the reference method, the owner or operator must pay close attention to accuracy and details. The PM CEMS must be operating properly. The owner or operator must perform the manual reference method testing accurately, with attention to eliminating site-specific systemic errors. The owner or operator must coordinate the timing of the manual reference method testing with the sampling cycle of the PM CEMS. The owner or operator must complete a

minimum of 15 manual reference method tests. The owner or operator must perform the manual reference method testing over the full range of PM CEMS responses that correspond to normal operating conditions for their source and control device and will result in the widest range of emission concentrations.

(7) How should the owner or operator of a PM CEMS perform the manual reference method testing? The owner or operator 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 the owner or operator use paired trains for the manual reference method testing. The owner or operator 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, the owner or operator may conduct the reference method test runs for less than the typical minimum test run duration of 1 hour.

(8) What does the owner or operator do with the manual reference method data and PM CEMS data? The owner or operator 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 the 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 the 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 the owner or operator of a PM CEMS perform? Before conducting the initial correlation test, the owner or operator must successfully complete a 7-day drift test (See section 8.5).

3. What special definitions apply to PS-11?

3.1 "Appropriate Measurement Range of the PM CEMS" means a measurement range that is capable of recording readings over the complete range of the 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 the source's PM emission concentrations recorded by the 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)" means the statistical term for one-half of the width of the 95 percent confidence interval around the predicated 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 the CEMS.

3.6 "Correlation" means the primary mathematical relationship for correlating the output from the 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 the PM CEMS.

3.7 "Correlation Coefficient (*r*)" means a quantitative measure of the association between the 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 the 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 the CEMS that provides the diluent gas concentration (such as O_2 or CO_2, 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 the 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 the 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 the PM CEMS output and the reference method PM concentration, as indicated by Equation 11-37.

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

3.14 "Linear Correlation" means a first-order mathematical relationship between the 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 the 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 the 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 the 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 Methods 5 and 17 (for particulate matter), found in Appendix A of this text. Only the front half and dry filter catch portions of the reference method can be correlated to the 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 the CEMS. The owner or operator must use these standards to evaluate the overall operation of the 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 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.

3.24 "Sample Volume Check" means a check of the difference between the 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 the PM CEMS.

3.27 "Upscale Drift (UD) Check" means a check of the difference between the 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 the PM CEMS to particulate-free or low-particulate concentration conditions.

3.29 "Zero Drift (ZD) Check" means a check of the difference between the 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. Are there any potential interferences for the PM CEMS?

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

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

4.2 How does the owner or operator of a PM CEMS deal with interferences? It is recommend that the owner or operator 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 the PM

CEMS measurement technology and extractive technique, the owner or operator 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 the owner or operator use? The owner or operator should use a PM CEMS measurement technology that is free of interferences from any condensible constituent in the flue gas.

5. What does the owner or operator 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 the responsibility of the owner or operator of a PM CEMS to establish appropriate safety and health practices and determine the applicable regulatory limitations before performing these procedures. The owner or operator must consult the CEMS user's manual and other reference materials recommended by the reference method for specific precautions to be taken.

6. What equipment and supplies does the owner or operator of a PM CEMS need?

Different types of PM CEMS use different operating principles. The owner or operator should select an appropriate PM CEMS based on their site-specific configurations, flue gas conditions, and PM characteristics.

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

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

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

6.1 What equipment is needed for the PM CEMS's sample interface? The PM CEMS's sample interface must be capable of delivering a representative sample of the flue gas to the 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 the PM CEMS is installed downstream of a wet air pollution control system such that the flue gases normally or occasionally contain entrained water droplets, it is recommend that the owner or operator 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 the 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) The owner or operator of a PM CEMS 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, the owner or operator must identify what, if any, additional auxiliary data from other monitoring and handling systems are necessary to convert the PM CEMS response into the units of the PM standard.

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

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

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

(2) It is recommended that a PM CEMS is selected that is capable of performing automatic diagnostic checks and sending instrument status signals (flags) to the data recorder.

(3) If the PM CEMS is an extractive type that measures the sample volume and uses the measured sample volume as part of calculating the output value, the 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 the PM CEMS.

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

6.4 What if the PM CEMS does automatic range switching? The 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 the PM CEMS does automatic range switching, the owner or operator 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? The 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. The 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 the data recorder? The CEMS data recorder must be able to accept and record electronic signals from all the monitors associated with the PM CEMS.

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

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

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

6.7 What other equipment and supplies might the owner or operator of a PM CEMS need? The owner or operator may need other supporting equipment as defined by the applicable reference method(s) (see section 7) or as specified by the CEMS manufacturer.

7. What reagents and standards does the owner or operator of a PM CEMS need?

The owner or operator 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? The owner or operator must use a zero check value that is no greater than 20 percent of the PM CEMS's response range. The owner or operator must obtain documentation on the zero check value from the PM CEMS manufacturer.

7.2 What is the reference standard value for the upscale drift check? The owner or operator 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. The owner or operator must obtain documentation on the upscale check value from the PM CEMS manufacturer.

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

8. What performance specification test procedure does the owner or operator of a PM CEMS follow?

The owner or operator of a PM CEMS must complete each of the activities in sections 8.1 through 8.8 for the performance specification test.

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

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

(i) The 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, it is recommend that the owner or operator operate the PM CEMS to maintain the sample gas temperature at the same temperature as the reference method filter.

(iii) The 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, the owner or operator must select a PM CEMS that is capable of measuring the full range of PM concentrations expected from the 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, the owner or operator should select a PM CEMS appropriate for the emission characteristics of their source.

(4) It is recommended that the owner or operator consult the PM CEMS vendor to obtain basic recommendations on the instrument capabilities and setup configuration. The owner or operator is ultimately responsible for setup and operation of the PM CEMS.

8.2 Where does the owner or operator install the PM CEMS? The owner or operator must install the PM CEMS at an accessible location downstream of all pollution control equipment. The owner or operator must perform the 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) The owner or operator of a PM CEMS must select a measurement location that minimizes problems due to flow disturbances, cyclonic flow, and varying PM stratification (refer to Method 1 in Appendix A of this text for guidance).

(2) If the owner or operator plans to achieve higher emissions for correlation test purposes by adjusting the performance of the air pollution control device (per section 8.6(4)(i)), the owner or operator must locate the 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 does the owner or operator of a PM CEMS select the reference method measurement location and traverse points? The owner or operator must follow Method 1 in Appendix A of this text for identifying manual reference method traverse points. Ideally, the owner or operator should perform the manual reference method measurements at locations that satisfy the measurement site selection criteria specified in Method 1 in Appendix A of this text of at least eight duct diameters downstream and at least two duct diameters upstream of any flow disturbance. Where necessary, the owner or operator may conduct testing at a location that is two diameters downstream and 0.5 diameters upstream of flow disturbances. If the location does not meet the minimum downstream and upstream requirements, the owner or operator must obtain approval from the Director test at the location.

8.4 What are the pretest preparation steps? The owner or operator must install the 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, it is recommended that the PM CEMS be operated according to the manufacturer's instructions to familiarize the owner or operator with its operation before the owner or operator begins correlation testing.

(i) During this initial period of operation, it is recommended that the owner or operator of a PM CEMS 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 the owner or operator is confident that the PM CEMS is operating properly, it is recommended that CEMS be operated over a correlation test planning period of sufficient duration to identify the full range of operating conditions and PM emissions to be used in the PM CEMS correlation test.

(i) During the correlation test planning period, the owner or operator should operate the process and air pollution control equipment over the normal range of operating conditions, except when the owner or operator attempt to produce higher emissions.

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

(iii) The owner or operator 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) The owner or operator must set the response range of the PM CEMS such that the instrument measures the full range of responses that correspond to the range of source operating conditions that the owner or operator will implement during correlation testing.

(4) It is recommended that the owner or operator of a PM CEMS perform preliminary reference method testing after the correlation test planning period. During this preliminary testing, the owner or operator 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, the owner or operator must perform a 7-day zero and upscale drift test (see section 8.5).

(6) The owner or operator 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 does the owner or operator perform the 7-day drift test? The owner or operator 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. The owner or operator must perform this check at least once daily over 7 consecutive days. The PM CEMS must quantify and record the zero and upscale measurements and the time of the measurements. If automatic or manual adjustments are made to the PM CEMS zero and upscale settings, the owner or operator must conduct the drift test immediately before these adjustments, or conduct it in such a way that the owner or operator can determine the amount of drift. The owner or operator 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 the 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, the owner or operator must determine the magnitude of the drift once each day, at 24-hour intervals, for 7 consecutive days while the source is operating normally.

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

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

(iii) The owner or operator must record the PM CEMS zero and upscale response and evaluate them against the zero check value and upscale check value.

(3) When must the owner or operator conduct the 7-day drift test? The owner or operator must complete a valid 7-day drift test before attempting the correlation test.

8.6 How does the owner or operator conduct the PM CEMS correlation test? The owner or operator must conduct the correlation test according to the procedure given in paragraphs (1) through (5) of this section. If multiple correlations are needed, the owner or operato must conduct sufficient testing and collect at least 15 sets of reference method and PM CEMS data for calculating each separate correlation.

(1) The owner or operator must use the reference method for PM (usually Methods 5 or 17 in Appendix A of this text) that is prescribed by the applicable regulations. The owner or operator may need to perform other reference methods or performance specifications (e.g., Method 3 for oxygen, Method 4 for moisture, each found in Appendix A of this text, etc.) depending on the units in which the PM CEMS reports PM concentration.

(i) It is recommended that paired reference method trains be used 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) The owner or operator may use test runs that are shorter than 60 minutes in duration (e.g., 20 or 30 minutes). The owner or operator may perform the 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, the reference method results obtained during the PM CEMS correlation test may be used to determine compliance so long as the source and the test conditions and procedures (e.g., reference method sample run durations) are consistent with the applicable regulations and the reference method.

(iii) The owner or operator must convert the reference method results to units consistent with the conditions of the PM CEMS measurements. For example, if the PM CEMS measures and reports PM emissions in the units of mass per actual volume of stack gas, the owner or operator must convert the reference method results to those units (e.g., mg/acm). If the PM CEMS extracts and heats the sample gas to eliminate water droplets, then measures and reports PM emissions under those actual conditions, the owner or operator must convert the reference method results to those same conditions (e.g., mg/acm at 160°C).

(2) During each test run, the owner or operator must coordinate process operations, reference method sampling, and PM CEMS operations. For example, the owner or operator 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 the PM CEMS and data logger are operating properly.

(i) The owner or operator 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, the owner or operator must start the reference method at the same time as the PM CEMS sampling.

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

(iii) The owner or operator must properly align the time periods for the PM CEMS and the reference method measurements to account for the PM CEMS response time.

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

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

(ii) The owner or operator must report all data, including the rejected data.

(iii) The owner or operator may reject the results of up to five test runs without explanation.

(iv) If the owner or operator rejects 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 of this text, or the 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 the PM CEMS is maximized. The owner or operator must first attempt to maximize the correlation range by following the procedures described in paragraphs (4)(i) through (iv) of this section. If the owner or operator cannot obtain the three levels as described in paragraphs (i) through (iv), then the owner or operator must use the procedure described in section 8.6(5).

(i) The owner or operator 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 used in the correlation tests must be distributed over the complete operating range experienced by the source.

(iii) At least 20 percent of the minimum 15 measured data points used 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, the owner or operator may only apply individual run data to one level.

(5) If the owner or operator cannot obtain three distinct levels of PM concentration as described, the owner or operator must perform correlation testing over the maximum range of PM concentrations that is practical for the PM CEMS. To ensure that the range of data used to establish the correlation for the PM CEMS is maximized, the owner or operator 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 the process is not operating, but the fans are operating or the source is combusting only natural gas).

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

8.7 What does the owner or operator do with the initial correlation test data for the PM CEMS? The owner or oeprator 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. The owner or operator 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 the PM CEMS met the requirements of this performance specification. In addition, the owner or operator must:

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

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

(3) Confirm that the reference method results are consistent with the 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 the PM CEMS correlation? Although the data the owner or operator collect during the correlation testing should be representative of the full range of normal operating conditions at their source, the owner or operator must conduct additional correlation testing if either of the conditions specified in paragraphs (1) and (2) of this section occurs.

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

(i) The 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 the 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 the PM CEMS operating hours for the previous 30-day period.

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

(i) The 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 the source are greater than 125 percent of the highest PM CEMS response used for the correlation curve for more than 5 percent of the PM CEMS operating hours for the previous 30-day period.

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

(i) The owner or operator 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 the 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, the owner or operator must report the reason for the higher PM CEMS responses.

9. What quality control measures are required?

Quality control measures for PM CEMS are specified in Appendix F, Procedure 2 of this text.

10. What calibration and standardization procedures must the owner or operator of a PM CEMS perform? [Reserved]

11. What analytical procedures apply to this procedure?

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

12. What calculations and data analyses are needed?

The owner or operator must determine the primary relationship for correlating the output from the 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. The owner or operator develops the correlation by performing an appropriate regression analysis between the PM CEMS response and the reference method data.

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

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

$$UD = \frac{\left|R_{CEM} - R_U\right|}{R_U} \times 100 \quad \text{(Eq. 11-1)}$$

Where:

UD = The upscale (high-level) drift of the PM CEMS in percent,
R_{CEM} = The measured PM CEMS response to the upscale reference standard, and
R_U = The pre-established numerical value of the upscale reference standard.

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

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

Where:

ZD = The zero (low-level) drift of the PM CEMS in percent,
R_{CEM} = The measured PM CEMS response to the zero reference standard,
R_L = The pre-established numerical value of the zero reference standard, and
R_U = The pre-established numerical value of the upscale reference standard.

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

12.2 How does the owner or operator perform the regression analysis? The owner or operator must couple each reference method PM concentration measurement, *y*, in the appropriate units, with an average PM CEMS response, *x*, over corresponding time periods. The owner or operator must complete the PM CEMS correlation calculations using data deemed acceptable by quality control procedures identified in Appendix F, Procedure 2 of this text.

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

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

(i) If the sample gas contains entrained water droplets and the PM CEMS is an extractive system that measures at actual conditions (i.e., wet basis), the owner or operator must use the measured moisture content determined from the impinger analysis when converting the 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 does the owner or operator determine the PM CEMS correlation? To predict PM concentrations from PM CEMS responses, the owner or operator 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 measurement 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 does the owner or operator evaluate a linear correlation for the 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 ($\hat{y}$) as a function of the PM CEMS response (x), as indicated by Equation 11-3:

$$\hat{y} = b_0 + b_1 x \qquad \text{(Eq. 11-3)}$$

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:

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

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:

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

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:

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

Where:

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

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

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

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

Where:

CI	=	the half range of the 95 percent confidence interval for the predicted PM concentration at the mean x value,
$t_{df,1-a/2}$	=	the value for the t statistic provided in Table 1 for df = (n-2), and
S_L	=	the scatter or deviation of y values about the correlation curve, which is determined using Equation 11-9:

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

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

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

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 (y) at the mean x value using Equation 11-11:

$$TI = k_t \cdot S_L \qquad \text{(Eq. 11-11)}$$

Where:

TI = the half range of the tolerance interval for the predicted PM concentration (y) at the mean *x* value,
k_t = as calculated using Equation 11-12, and
S_L = as calculated using Equation 11-9:

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

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 (y) at the mean *x* value as a percentage of the emission limit (TI%) using Equation 11-13:

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

Where:

TI = the half range of the tolerance interval for the predicted PM concentration (y) 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:

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

Where:

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

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

(2) How does the owner or operator evaluate a polynomial correlation for the 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:

$$\hat{y} = b_0 + b_1 x + b_2 x^2 \qquad \text{(Eq. 11-16)}$$

Where:

$\hat{y}$ = 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:

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

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

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

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 to 11-21, respectively:

$$b_0 = \frac{(S_5 \cdot S_2 \cdot S_4 + S_1 \cdot S_3 \cdot S_7 + S_2 \cdot S_6 \cdot S_3 - S_7 \cdot S_2 \cdot S_2 - S_3 \cdot S_3 \cdot S_5 - S_4 \cdot S_6 \cdot S_1)}{\det A}$$

$$b_1 = \frac{(n \cdot S_6 \cdot S_4 + S_5 \cdot S_3 \cdot S_2 + S_2 \cdot S_1 \cdot S_7 - S_2 \cdot S_6 \cdot S_2 - S_7 \cdot S_3 \cdot n - S_4 \cdot S_1 \cdot S_5)}{\det A}$$

$$b_2 = \frac{(n \cdot S_2 \cdot S_7 + S_1 \cdot S_6 \cdot S_2 + S_5 \cdot S_1 \cdot S_3 - S_2 \cdot S_2 \cdot S_5 - S_3 \cdot S_6 \cdot n - S_7 \cdot S_1 \cdot S_1)}{\det A}$$

Where:

$$\det A = n \cdot S_2 \cdot S_4 - S_2 \cdot S_2 + S_1 \cdot S_3 \cdot S_2 - S_3 \cdot S_3 \cdot n + S_2 \cdot S_1 \cdot S_3 - S_4 \cdot S_1 \cdot S_1$$

(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:

$$C_0 = \frac{(S_2 \cdot S_4 - S_3^2)}{D}, \quad C_1 = \frac{(S_3 \cdot S_2 - S_1 \cdot S_4)}{D}, \quad C_2 = \frac{(S_1 \cdot S_3 - S_2^2)}{D}, \qquad \text{(Eq. 11-23)}$$

$$C_3 = \frac{(nS_4 - S_2^2)}{D}, \quad C_4 = \frac{(S_1 \cdot S_2 - nS_3)}{D}, \quad C_5 = \frac{(nS_2 - S_1^2)}{D} \qquad \text{(Eq. 11-24)}$$

Where:

$$D = n(S_2 \cdot S_4 - S_3^2) + S_1(S_3 \cdot S_2 - S_1 \cdot S_4) + S_2(S_1 \cdot S_3 - S_2^2)$$

Calculate Δ using Equation 11-25 for each *x* value:

$$\Delta = C_0 + 2C_1 x + (2C_2 + C_3)x^2 + 2C_4 x^3 + C_5 x^4 \qquad \text{(Eq. 11-25)}$$

Determine the *x* value that corresponds to the minimum value of Δ (Δ_{min}).

Determine the scatter or deviation of ŷ values about the polynomial correlation curve (S_P) using Equation 11-26:

$$S_P = \sqrt{\frac{1}{n-3}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2} \qquad \text{(Eq. 11-26)}$$

Calculate the half range of the 95 percent confidence interval (CI) at the *x* value that corresponds to Δ_{min} using Equation 11-27:

$$CI = t_{df} \cdot S_P \sqrt{\Delta_{min}} \qquad \text{(Eq. 11-27)}$$

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 Δ_{min} as a percentage of the emission limit (CI%) using Equation 11-28:

$$CI\% = \frac{CI}{EL} \cdot 100\% \qquad \text{(Eq. 11-28)}$$

Where:

CI = the half range of the 95 percent confidence interval for the predicted PM concentration at the *x* value that corresponds to Δ_{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 Δ_{min}, as indicated in Equation 11-29 for the polynomial correlation, using Equations 11-30 and 11-31:

$$TI = k_T \cdot S_P \qquad \text{(Eq. 11-29)}$$

Where:

$$k_T = u_{n'} \cdot v_{df} \qquad \text{(Eq. 11-30)}$$

$$n' = \frac{1}{\Delta_{min}} \qquad \text{(Eq. 11-31)}$$

Where:

$u_{n'}$ = the value indicated in Table 1 for df = (n' – 3), and
v_{df} = the value indicated in Table 1 for df = (n' 3).

Calculate the tolerance interval half range for the predicted PM concentration at the *x* value that corresponds to Δ_{min} as a percentage of the emission limit (TI%) using Equation 11-32:

$$TI\% = \frac{TI}{EL} \cdot 100\% \qquad \text{(Eq. 11-32)}$$

Where:

TI = the tolerance interval half range for the predicted PM concentration at the *x* value that corresponds to Δ_{min}, and
EL = PM emission limit, as described in section 13.2.

(iv) Calculate the polynomial correlation coefficient (*r*) using Equation 11-33:

$$r = \sqrt{1 - \frac{S_P^2}{S_Y^2}} \qquad \text{(Eq. 11-33)}$$

Where:

S_P = as calculated using Equation 11-26, and

S_y = as calculated using Equation 11-15.

(3) How does the owner or operator evaluate a logarithmic correlation for the 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 $\hat{y}$, 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 percentage 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 does the owner or operator evaluate an exponential correlation for the 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:

$$\hat{y} = b_1 e^{b_0 x} \quad \text{(Eq. 11-37)}$$

(i) Perform a logarithmic transformation of each PM concentration measurement (y values) using Equation 11-38:

$$y_i' = Ln(y_i)$$

(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. Note that CI' is on the log scale. Next, calculate the upper and lower 95 percent confidence limits for the mean value 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 (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 $\bar{y}'$ using Equations 11-43 and 11-44:

$$LTL' = \bar{y}' - TI' \qquad \text{(Eq. 11-43)}$$

$$UTL' = \bar{y}' + TI' \qquad \text{(Eq. 11-44)}$$

Where:

LTL' = the lower 95 percent tolerance limit for the mean value $\bar{y}'$,
UTL' = the upper 95 percent tolerance limit for the mean value $\bar{y}'$,
$\bar{y}'$ = 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 ($\hat{y}'$), as calculated in Equation 11-11.

Calculate the half range tolerance interval (TI) on the original PM concentration scale using Equation 11-45:

$$TI = \frac{e^{UTL'} - e^{LTL'}}{2} \qquad \text{(Eq. 11-45)}$$

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.

(iv) 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 does the owner or operator evaluate a power correlation for the correlation test data? To evaluate a power correlation, which has the form indicated by Equation 11-46, follow the procedures described in paragraphs (5)(i) through (v) of this section.

$$\hat{y} = b_0 x^{b_1} \qquad \text{(Eq. 11-46)}$$

(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:

$$\hat{y}' = b'_0 + b_1 x' \qquad \text{(Eq. 11-47)}$$

Where:

$\hat{y}'$ = 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: It is not within the scope of PS-11 to address the application of correlation equations to calculate PM emission concentrations using PM CEMS response data during normal operations of a PM CEMS. However, the Environmental Protection Agency 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.

12.4.1 What correlation model should be used? Follow the procedures described in paragraphs (1) through (4) of this section to determine which correlation model the owner or operator should use.

(1) For each correlation model that the owner or operators develops 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. The owner or operator 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 the owner or operator 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 the owner or operator develops more than one correlation curve that satisfy the performance criteria specified in section 13.2 of this specification, the owner or operator should use the correlation curve with the greatest correlation coefficient. If the polynomial model has the greatest correlation coefficient, the owner or operator first must check that the polynomial correlation curve satisfies the criteria for minimum and maximum values specified in paragraph (3) of this section.

(3) The owner or operator can use the polynomial model that the owner or operator develops 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 the 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.

$$\text{maximum or minimum} = -\frac{b_1}{2b_2} \qquad \text{(Eq. 11-48)}$$

(iii) If the polynomial correlation curve has a minimum point, the owner or operator 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, the owner or operator 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, the owner or operator cannot use the polynomial correlation curve to predict PM concentrations.

(iv) If the polynomial correlation curve has a maximum, the maximum value must be greater than the allowable extrapolation limit. If the 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 the 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, the owner or operator can use the polynomial correlation curve to predict PM concentrations. If the correlation curve maximum value is less than the extrapolation limit, the owner or operator cannot use the polynomial correlation curve to predict PM concentrations.

(4) The owner or operator may petition the Director 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. What are the performance criteria for the PM CEMS?

The owner or operator must evaluate the 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? The daily PM CEMS internal drift checks must demonstrate that the average daily drift of the 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 upscale value. If the CEMS includes diluent and/or auxiliary monitors (for temperature, pressure, and/or moisture) that are employed as a necessary part of this performance specification, the owner or operator 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 the PM CEMS correlation satisfy? The 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, the owner or operator must convert the emission limit to the appropriate units of the 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 the 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 the 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)(i), (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 Δ 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 Δ 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? The owner or operator must document and maintain the response time and any changes in the response time following installation.

(1) If the owner or operator has a batch sampling PM CEMS, the owner or operator must evaluate the limits presented in paragraphs (1)(i) and (ii) of this section.

(i) The response time of the 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. The owner or operator must document any changes in the response time following installation.

(ii) The sampling time of the PM CEMS must be no less than 30 percent of the cycle time. If the owner or operator has 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 be done? The owner or operator must report the 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.). The owner or operator may need to install auxiliary data monitoring equipment to convert the units reported by the PM CEMS into units of the PM emission standard.

14. Pollution Prevention. [Reserved]

15. Waste Management. [Reserved]

16. 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_2 and NO_x, 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.

16.6.1 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. 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 the 7-day drift test data.

TABLE 1. FACTORS FOR CALCULATION OF CONFIDENCE AND TOLERANCE INTERVAL HALF RANGES

df	Student's t, t_{df}	Tolerance interval with 75% coverage and 95% confidence level		
		v_{df}(95%)	$u_{n'}$(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
53	2.006	1.192	1.161	1.384
54	2.005	1.190	1.161	1.381
55	2.004	1.188	1.160	1.379
56	2.003	1.186	1.160	1.376
57	2.002	1.184	1.160	1.374
58	2.002	1.182	1.160	1.371
59	2.001	1.180	1.160	1.369
60	2.000	1.179	1.160	1.367

References 16.8 (t values) and 16.9 (v_{df} and $u_{n'}$ values).

TABLE 2. 7-DAY DRIFT TEST DATA					
Zero Drift Day #	Date and Time	Zero Check Value (R_L)	PM CEMS Response (R_{CEMS})	Difference (R_{CEMS} - R_L)	Zero Drift ((R_{CEMS}-R_L)/R_U)H100
1					
2					
3					
4					
5					
6					
7					
Upscale Drift Day #	Date and Time	Upscale Check Value (R_U)	PM CEMS Response (R_{CEMS})	Difference (R_{CEMS} - R_U)	Upscale Drift ((R_{CEMS}-R_U)/R_U)H100%
1					
2					
3					
4					
5					
6					
7					

*Georgia Department of Natural Resources, Rules for Air Quality Control, Chapter 391-3-1.