

Performance Specification 11—Specifications and Test Procedures for Particulate Matter Continuous Emission Monitoring Systems at Stationary Sources

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

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

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

1.2 When must I comply with PS-11? You must comply with PS-11 when directed by the applicable rule that requires you to install and operate a PM CEMS.

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

(1) A diluent monitor (*i.e.*, O₂, CO₂, or other CEMS specified in the applicable regulation), which must meet its own performance specifications (also found in this appendix),

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

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

2.0 What Are the Basic Requirements of PS-11?

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

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

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

2.3 How are the correlation data handled? You must carefully review your manual reference method data and your PM CEMS responses to include only valid, high-quality data. For the correlation, you must convert the manual reference method data to measurement conditions (*e.g.*, wet or dry basis) that are consistent with your PM CEMS. Then, you must correlate the manual method and PM CEMS data in terms of the output as received from the monitor (*e.g.*, milliamps). At the appropriate PM CEMS response specified in section 13.2 of this performance specification, you must calculate the confidence interval half range and tolerance interval half range as a percentage of the applicable PM concentration emission limit and compare the confidence interval and tolerance interval percentages

with the performance criteria. Also, you must calculate the correlation coefficient and compare the correlation coefficient with the applicable performance criterion specified in section 13.2 of this performance specification.

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

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

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

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

(3) How should I record my CEMS data? You need to ensure that your PM CEMS and data logger are set up to collect and record all normal emission levels and excursions. You must ensure that your data logger and PM CEMS have been properly programmed to accept and transfer status signals of valid monitor operation (e.g., flags for internal calibration, suspect data, or maintenance periods).

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

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

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

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

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

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

manual reference method testing over a suitable PM concentration range that corresponds to the full range of normal process and control device operating conditions. Because the manual reference method testing for this correlation test is not for compliance reporting purposes, you may conduct the reference method test runs for less than the typical minimum test run duration of 1 hour.

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

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

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

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

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

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

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

3.0 What Special Definitions Apply to PS-11?

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

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

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

3.4 "Confidence Interval Half Range (CI)" is a statistical term and means one-half of the width of the 95 percent confidence interval around the predicted mean PM concentration (y value) calculated at the PM CEMS response value (x value) where the confidence interval is narrowest. Procedures for calculating CI are specified in section 12.3. The CI as a percent of the emission limit value (CI%) is calculated at the appropriate PM CEMS response value and must satisfy the criteria specified in Section 13.2 (2).

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

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

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

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

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

3.10 “Diluent Monitor and Other Auxiliary Data Monitor(s) (if applicable)” means the portion of your CEMS that provides the diluent gas concentration (such as O₂ or CO₂, as specified by the applicable regulations), temperature, pressure, and/or moisture content, and generates an output proportional to the diluent gas concentration or gas property.

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

3.12 “Exponential Correlation” means an exponential equation used to define the relationship between your PM CEMS output and the reference method PM concentration, as indicated by Equation 11–37.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.0 Are There Any Potential Interferences for My PM CEMS?

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

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

4.2 How do I deal with interferences? We recommend that you use a PM CEMS that extracts and heats representative samples of the flue gas for measurement to simulate results produced by the reference method for conditions such as those described in section 4.1. Independent of your PM CEMS measurement technology and extractive technique, you should have a configuration simulating the reference method to ensure that:

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

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

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

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

People using the procedures required under PS-11 may be exposed to hazardous materials, operations, site conditions, and equipment. This performance specification does not purport to address all of the safety issues associated with its use. It is your responsibility to establish appropriate safety and health practices and determine the

applicable regulatory limitations before performing these procedures. You must consult your CEMS user's manual and other reference materials recommended by the reference method for specific precautions to be taken.

6.0 What Equipment and Supplies Do I Need?

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

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

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

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

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

(1) If your PM CEMS is installed downstream of a wet air pollution control system such that the flue gases normally or occasionally contain entrained water droplets, we recommend that you select a sampling system that includes equipment to extract and heat a representative sample of the flue gas for measurement so that the pollutant monitor portion of your CEMS measures only dry PM. Heating should be sufficient to raise the temperature of the extracted flue gas above the water condensation temperature and should be maintained at all times and at all points in the sample line from where the flue gas is extracted, including the pollutant monitor and any sample flow measurement devices.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

7.0 What Reagents and Standards Do I Need?

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

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

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

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

8.0 What Performance Specification Test Procedure Do I Follow?

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

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

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

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

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

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

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

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

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

8.2 Where do I install my PM CEMS? You must install your PM CEMS at an accessible location downstream of all pollution control equipment. You must perform your PM CEMS concentration measurements from a location considered representative or be able to provide data that can be corrected to be representative of the total PM emissions as determined by the manual reference method.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(ii) The three PM concentration levels you use in the correlation tests must be distributed over the complete operating range experienced by your source.

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

- Level 1: From no PM (zero concentration) emissions to 50 percent of the maximum PM concentration;
- Level 2: 25 to 75 percent of the maximum PM concentration; and
- Level 3: 50 to 100 percent of the maximum PM concentration.

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

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

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

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

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

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

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

- (1) Determine the integrated (arithmetic average) PM CEMS output over each reference method test period;
- (2) Adjust your PM CEMS outputs and reference method test data to the same clock time (considering response time of your PM CEMS);
- (3) Confirm that the reference method results are consistent with your PM CEMS response in terms of, where applicable, moisture, temperature, pressure, and diluent concentrations; and
- (4) Determine whether any of the reference method test results do not meet the test method criteria.

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

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

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

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

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

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

(ii) The cumulative hourly average PM CEMS responses generated by your source are greater than 125 percent of the highest PM CEMS response used for the correlation curve for more than 5 percent of your PM CEMS operating hours for the previous 30-day period.

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

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

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

9.0 What Quality Control Measures Are Required?

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

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

11.0 What Analytical Procedures Apply to This Procedure?

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

12.0 What Calculations and Data Analyses Are Needed?

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

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

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

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

Where:

UD = The upscale (high-level) drift of your PM CEMS in percent,

R_{CEM} = The measured PM CEMS response to the upscale reference standard, and

R_U = The preestablished 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 your PM CEMS in percent,

R_{CEM} = The measured PM CEMS response to the zero reference standard,

R_L = The preestablished numerical value of the zero reference standard, and

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

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

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

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

12.3 How do I determine my PM CEMS correlation? To predict PM concentrations from PM CEMS responses, you must use the calculation method of least squares presented in paragraphs (1) through (5) of this section. When performing the calculations, each reference method PM concentration 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 do I evaluate a linear correlation for my correlation test data? To evaluate a linear correlation, follow the procedures described in paragraphs (1)(i) through (iv) of this section.

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

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

Where:

y = the predicted PM concentration,

b_0 = the intercept for the correlation curve, as calculated using Equation 11-4,

b_1 = the slope of the correlation curve, as calculated using Equation 11-6, and

x = the PM CEMS response value.

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

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

Where:

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

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

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

Where:

x_i = the PM CEMS response value for run i ,

y_i = the PM concentration value for run i , and

n = the number of data points.

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

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

Where:

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

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

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

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

Where:

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

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

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

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

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

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

Where:

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

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

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

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

Where:

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

k_T = as calculated using Equation 11-12, and

S_L = as calculated using Equation 11-9:

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

Where:

n' = the number of test runs (n),

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

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

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

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

Where:

TI = the half range of the tolerance interval for the predicted PM concentration (\hat{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:

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

Where:

S_L = as calculated using Equation 11-9, and

S_y = as calculated using Equation 11-15:

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

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

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

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

Where:

\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:

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

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

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

Where:

X_i = the PM CEMS response for run i ,

Y_i = the reference method PM concentration for run i , and

n = the number of test runs.

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

$$b_0 = \frac{(S_5 \cdot S_2 \cdot S_4 + S_1 \cdot S_3 \cdot S_7 + S_2 \cdot S_6 \cdot S_3 - S_7 \cdot S_2 \cdot S_2 - S_3 \cdot S_3 \cdot S_3 - S_4 \cdot S_6 \cdot S_1)}{\det A} \quad (\text{Eq. 11-19})$$

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

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

Where:

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

(ii) Calculate the 95 percent confidence interval half range (CI) by first calculating the C coefficients (Coto C5) using Equations 11–23 and 11–24:

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

$$C_3 = \frac{(nS_4 - S_2^2)}{D}, \quad C_4 = \frac{(S_1 \cdot S_2 - nS_3)}{D}, \quad C_5 = \frac{(nS_2 - S_1^2)}{D} \quad (\text{Eq. 11-23})$$

Where:

$$D = n(S_2 \cdot S_4 - S_3^2) + S_1(S_3 \cdot S_2 - S_1 \cdot S_4) + S_2(S_1 \cdot S_3 - S_2^2) \quad (\text{Eq. 11-24})$$

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

$$\Delta = C_0 + 2C_1x + (2C_2 + C_3)x^2 + 2C_4x^3 + C_5x^4 \quad (\text{Eq. 11-25})$$

Determine the x value that corresponds to the minimum value of Δ (Δ_{\min}). Determine the scatter or deviation of values about the polynomial correlation curve (S_p) using Equation 11-26:

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

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

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

Where:

$df = (n-3)$, and

t_{df} = as listed in Table 1 (see section 17).

Calculate the half range of the 95 percent confidence interval for the predicted PM concentration at the x value that corresponds to Δ_{\min} as a percentage of the emission limit (CI%) using Equation 11-28:

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

Where:

CI = the half range of the 95 percent confidence interval for the predicted PM concentration at the x value that corresponds to 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:

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

Where:

$$k_T = u_{\alpha} \cdot v_{df} \quad (\text{Eq. 11-30})$$

$$n' = \frac{1}{\Delta} \quad (\text{Eq. 11-31})$$

u_{α} = 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:

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

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:

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

Where:

S_P = as calculated using Equation 11–26, and

S_y = as calculated using Equation 11–15.

(3) How do I evaluate a logarithmic correlation for my correlation test data? To evaluate a logarithmic correlation, which has the form indicated by Equation 11–34, follow the procedures described in paragraphs (3)(i) through (iii) of this section.

$$\hat{y} = b_0 + b_1 \text{Ln}(x) \quad (\text{Eq. 11-34})$$

(i) Perform a logarithmic transformation of each PM CEMS response value (x values) using Equation 11–35:

$$x_i' = \text{Ln}(x_i) \quad (\text{Eq. 11-35})$$

Where:

x_i' = is the transformed value of x_i , and

$\text{Ln}(x_i)$ = the natural logarithm of the PM CEMS response for run i.

(ii) Using the values for x_i' in place of the values for x_i , perform the same procedures used to develop the linear correlation equation described in paragraph (1)(i) of this section. The resulting equation has the form indicated by Equation 11–36:

$$\hat{y} = b_0 + b_1 x' \quad (\text{Eq. 11-36})$$

Where:

x' = the natural logarithm of the PM CEMS response, and the variables b_0 , and b_1 are as defined in paragraph (1)(i) of this section.

(iii) Using the values for x'_i in place of the values for x_i , calculate the confidence interval half range at the mean x' value as a 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 do I evaluate an exponential correlation for my correlation test data? To evaluate an exponential correlation, which has the form indicated by Equation 11–37, follow the procedures described in paragraphs (4)(i) through (v) of this section:

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

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

$$y'_i = \text{Ln}(y_i) \quad (\text{Eq. 11-38})$$

Where:

y'_i = the transformed value of y_i , and

$\text{Ln}(y_i)$ = 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' in place of the values for y_i , calculate the half range of the 95 percent confidence interval (CI'), as described in paragraph (1)(ii) of this section for CI. Note that CI' is on the log scale. Next, calculate the upper and lower 95 percent confidence limits for the mean value y' using Equations 11–40 and 11–41:

$$\text{LCL}' = \bar{y}' - \text{CI}' \quad (\text{Eq. 11-40}) \quad \text{UCL}' = \bar{y}' + \text{CI}' \quad (\text{Eq. 11-41})$$

Where:

LCL' = the lower 95 percent confidence limit for the mean value y' ,

UCL' = the upper 95 percent confidence limit for the mean value y' ,

\bar{y}' = the mean value of the log-transformed PM concentrations, and

CI' = the half range of the 95 percent confidence interval for the predicted PM concentration (\hat{Y}'), as calculated in Equation 11–8.

Calculate the half range of the 95 percent confidence interval (CI) on the original PM concentration scale using Equation 11–42:

$$CI = \frac{e^{UCL} - e^{LCL}}{2} \quad (\text{Eq. 11-42})$$

Where:

CI = the half range of the 95 percent confidence interval on the original PM concentration scale, and UCL' and LCL' are as defined previously.

Calculate the half range of the 95 percent confidence interval for the predicted PM concentration corresponding to the mean value of x as a percentage of the emission limit (CI%) using Equation 11-10.

(iv) Using the values for y' 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 y' using Equations 11-43 and 11-44:

$$LTL' = \underline{y}' - TI' \quad (\text{Eq. 11-43}) \quad UTL' = \underline{y}' + TI' \quad (\text{Eq. 11-44})$$

Where:

LTL' = the lower 95 percent tolerance limit for the mean value y' ,

UTL' = the upper 95 percent tolerance limit for the mean value y' ,

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:

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

TI = the half range of the 95 percent tolerance interval on the original PM scale, and UTL' and LTL' are as defined previously.

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

(v) Using the values for y' in place of the values for y_i , calculate the correlation coefficient (r) using the procedure described in paragraph (1)(iv) of this section.

(5) How do I evaluate a power correlation for my correlation test data? To evaluate a power correlation, which has the form indicated by Equation 11-46, follow the procedures described in paragraphs (5)(i) through (v) of this section.

$$\hat{y} = b_p x^h \quad (\text{Eq. 11-46})$$

(i) Perform logarithmic transformations of each PM CEMS response (x values) and each PM concentration measurement (y values) using Equations 11-35 and 11-38, respectively.

(ii) Using the values for x' in place of the values for x_i , and the values for y' in place of the values for y_i , perform the same procedures used to develop the linear correlation equation described in paragraph (1)(i) of this section. The resulting equation will have the form indicated by Equation 11-47:

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

Where:

\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' in place of the values for y , calculate the correlation coefficient (r) using the procedure described in paragraph (1)(iv) of this section.

Note: PS-11 does not address the application of correlation equations to calculate PM emission concentrations using PM CEMS response data during normal operations of a PM CEMS. However, we will provide guidance on the use of specific correlation models (i.e., logarithmic, exponential, and power models) to calculate PM concentrations in an operating PM CEMS in situations when the PM CEMS response values are equal to or less than zero, and the correlation model is undefined.

12.4 Which correlation model should I use? Follow the procedures described in paragraphs (1) through (4) of this section to determine which correlation model you should use.

(1) For each correlation model that you develop using the procedures described in section 12.3 of this specification, compare the confidence interval half range percentage, tolerance interval half range percentage, and correlation coefficient to the performance criteria specified in section 13.2 of this specification. You can use the linear, logarithmic, exponential, or power correlation model if the model satisfies all of the performance criteria specified in section 13.2 of this specification. However, to use the polynomial model you first must check that the polynomial correlation curve satisfies the criteria for minimum and maximum values specified in paragraph (3) of this section.

(2) If you develop more than one correlation curve that satisfy the performance criteria specified in section 13.2 of this specification, you should use the correlation curve with the greatest correlation coefficient. If the polynomial model has the greatest correlation coefficient, you first must check that the polynomial correlation curve satisfies the criteria for minimum and maximum values specified in paragraph (3) of this section.

(3) You can use the polynomial model that you develop using the procedures described in section 12.3(2) if the model satisfies the performance criteria specified in section 13.2 of this specification, and the minimum or maximum value of the polynomial correlation curve does not occur within the expanded data range. The minimum or maximum value of the polynomial correlation curve is the point where the slope of the curve equals zero. To determine if the minimum or maximum value occurs within the expanded data range, follow the procedure described in paragraphs (3)(i) through (iv) of this section.

(i) Determine if your polynomial correlation curve has a minimum or maximum point by comparing the polynomial coefficient b_2 to zero. If b_2 is less than zero, the curve has a maximum value. If b_2 is greater than zero, the curve has a minimum value. (Note: If b_2 equals zero, the correlation curve is linear.)

(ii) Calculate the minimum value using Equation 11-48.

$$\text{min or max} = -\frac{b_1}{2b_2} \quad (\text{Eq. 11-48})$$

(iii) If your polynomial correlation curve has a minimum point, you must compare the minimum value to the minimum PM CEMS response used to develop the correlation curve. If the correlation curve minimum value is less than or equal to the minimum PM CEMS response value, you can use the polynomial correlation curve, provided the correlation curve also satisfies all of the performance criteria specified in section 13.2 of this specification. If the correlation curve minimum value is greater than the minimum PM CEMS response value, you cannot use the polynomial correlation curve to predict PM concentrations.

(iv) If your polynomial correlation curve has a maximum, the maximum value must be greater than the allowable extrapolation limit. If your source is not a low-emitting source, as defined in section 3.16 of this specification, the allowable extrapolation limit is 125 percent of the highest PM CEMS response used to develop the correlation curve. If your source is a low-emitting source, the allowable extrapolation limit is 125 percent of the highest PM CEMS response used to develop the correlation curve or the PM CEMS response that corresponds to 50 percent of the emission limit, whichever is greater. If the polynomial correlation curve maximum value is greater than the extrapolation limit, and the correlation curve satisfies all of the performance criteria specified in section 13.2 of this specification, you can use the polynomial correlation curve to predict PM concentrations. If the correlation curve maximum value is less than the extrapolation limit, you cannot use the polynomial correlation curve to predict PM concentrations.

(4) You may petition the Administrator for alternative solutions or sampling recommendations if the correlation models described in section 12.3 of this specification do not satisfy the performance criteria specified in section 13.2 of this specification.

13.0 What Are the Performance Criteria for My PM CEMS?

You must evaluate your PM CEMS based on the 7-day drift check, the accuracy of the correlation, and the sampling periods and cycle/response time.

13.1 What is the 7-day drift check performance specification? Your daily PM CEMS internal drift checks must demonstrate that the average daily drift of your PM CEMS does not deviate from the value of the reference light, optical filter, Beta attenuation signal, or other technology-suitable reference standard by more than 2 percent of the upscale value. If your CEMS includes diluent and/or auxiliary monitors (for temperature, pressure, and/or moisture) that are employed as a necessary part of this performance specification, you must determine the calibration drift separately for each ancillary monitor in terms of its respective output (see the appropriate performance specification for the diluent CEMS specification). None of the calibration drifts may exceed their individual specification.

13.2 What performance criteria must my PM CEMS correlation satisfy? Your PM CEMS correlation must meet each of the minimum specifications in paragraphs (1), (2), and (3) of this section. Before confidence and tolerance interval half range percentage calculations are made, you must convert the emission limit to the appropriate units of your PM CEMS measurement conditions using the average of emissions gas property values (e.g., diluent concentration, temperature, pressure, and moisture) measured during the correlation test.

(1) The correlation coefficient must satisfy the criterion specified in paragraph (1)(i) or (ii), whichever applies.

(i) If your source is not a low-emitting source, as defined in section 3.16 of this specification, the correlation coefficient (r) must be greater than or equal to 0.85.

(ii) If your source is a low-emitting source, as defined in section 3.16 of this specification, the correlation coefficient (r) must be greater than or equal to 0.75.

(2) The confidence interval half range must satisfy the applicable criterion specified in paragraph (2)(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? You must document and maintain the response time and any changes in the response time following installation.

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

(i) The response time of your PM CEMS, which is equivalent to the cycle time, must be no longer than 15 minutes. In addition, the delay between the end of the sampling time and reporting of the sample analysis must be no greater than 3 minutes. You must document any changes in the response time following installation.

(ii) The sampling time of your PM CEMS must be no less than 30 percent of the cycle time. If you have a batch sampling PM CEMS, sampling must be continuous except during pauses when the collected pollutant on the capture media is being analyzed and the next capture medium starts collecting a new sample.

13.4 What PM compliance monitoring must I do? You must report your CEMS measurements in the units of the standard expressed in the regulations (e.g., mg/dscm @ 7 percent oxygen, pounds per million Btu (lb/mmBtu), etc.). You may need to install auxiliary data monitoring equipment to convert the units reported by your PM CEMS into units of the PM emission standard.

14.0 *Pollution Prevention*[Reserved]

15.0 *Waste Management*[Reserved]

16.0 *Which References Are Relevant to This Performance Specification?*

16.1 Technical Guidance Document: Compliance Assurance Monitoring. U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Emission Measurement Center. August 1998.

16.2 40 CFR 60, Appendix B, "Performance Specification 2—Specifications and Test Procedures for SO₂, 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 40 CFR 266, Appendix IX, Section 2, "Performance Specifications for Continuous Emission Monitoring Systems."

16.7 ISO 10155, "Stationary Source Emissions—Automated Monitoring of Mass Concentrations of Particles: Performance Characteristics, Test Procedures, and Specifications." American National Standards Institute, New York City. 1995.

16.8 Snedecor, George W. and Cochran, William G. (1989), Statistical Methods, Eighth Edition, Iowa State University Press.

16.9 Wallis, W. A. (1951) "Tolerance Intervals for Linear Regression," in Second Berkeley Symposium on Mathematical Statistics and Probability, ed. J. Neyman, Berkeley: University of California Press, pp. 43–51.

17.0 *What Reference Tables and Validation Data Are Relevant to PS-11?*

Use the information in Table 1 for determining the confidence and tolerance interval half ranges. Use Table 2 to record your 7-day drift test data.

Table 1—Factors for Calculation of Confidence and Tolerance Interval Half Ranges

| df | Student's t_{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_{dr} 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 $((R_{CEMS}-R_L) / R_U) \times 100$ |
|-------------------------|----------------------|--|---|---|--|
| 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) × 100% |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |