EXAMPLE PERFORMANCE SPECIFICATIONS

Example Specifications and Test Procedures for Predictive Emission Monitoring Systems

1. APPLICABILITY AND PRINCIPLE

1.1 Applicability.

1.1.1 This specification is to be used for evaluating the acceptability of predictive emission monitoring systems (PEMS's) at the time of or soon after installation and whenever specified in the regulations. The PEMS may include, for certain stationary sources, a diluent (O_2 or CO_2) PEMS.

1.1.2 This specification is not designed to evaluate the installed PEMS performance over an extended period of time nor does it identify specific validation techniques and other auxiliary procedures to assess the PEMS performance. The source owner or operator, however, is responsible to validate, maintain, and operate the PEMS properly. To evaluate the PEMS performance, the Administrator may require, under Section 114 of the Act, the operator to conduct PEMS performance evaluations at other times besides the initial test.

1.1.3 The owner or operator may conduct this performance specification test in a restricted range of operation in accordance. For example, if the permitted range of operation of the emissions unit were between 50% and 100% of the possible range, and the owner or operator wishes to restrict the emissions unit to operation between 80% and 100% of the possible range for some reason (e.g. production schedules), the initial performance specification test may be performed for that restricted range. If, at a later date, the owner or operator elects to operate outside of the restricted range, then the owner or operator must conduct a relative accuracy (RA) test within 60 days of operation in that range to demonstrate that the PEMS can provide acceptable data when operating in the new range. The RA test at the new range is to be done by performing a single 9 point RA test within the new range using the appropriate test methods.

1.2 Principle. Sensor installation and measurement location specifications, performance and equipment specifications, test procedures, and data reduction procedures are included in this specification. Reference method tests and PEMS drift tests are conducted to determine conformance of the PEMS with the specification.

2. DEFINITIONS

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

2.2 PEMS. The total equipment required for the determination of a gas concentration or emission rate. The system consists of the following major subsystems:

2.2.1 Sensors and Sensor Interface. That portion of the PEMS used for the following: Process data acquisition; process data transportation between the sensors and the emission model(s); and sensor validation.

2.2.2 Emission Model(s). That portion of the PEMS that utilizes process data or reconciled process data and generates an output proportional to the gas concentration or emission rate. The emission model may generate emissions data in terms of the applicable emission limitation without the use of a diluent emission model.

2.2.3 Diluent Emission Model (if applicable). That portion of the PEMS that utilizes process data or reconciled process data and generates an output proportional to the diluent gas concentration (e.g., CO_2 or O_2).

2.2.4 Data Recorder. That portion of the PEMS that provides a permanent record of the analyzer output. The data recorder may
include automatic data reduction capabilities. The data recorder may include electronic data records, paper records, or a combination of electronic data and paper records

2.2.5 Sensor Validation System. That portion of the PEMS that analyzes the process data to ensure the accuracy of the gas concentration determined by the emission model(s) including any diluent emissions model(s), and to provide reconciled process data in the event of a failed sensor.

2.3 PEMS Drift (PD). The difference in the PEMS output readings from the reference value(s) due to the effect of sensor drift and the effect of utilizing reconciled process data for when a sensor or any combination of sensors has failed.

2,4 Reference value. Based on reference method testing, a baseline PEMS measurement during which time each sensor has been determined to be functioning properly.

2.5 Relative Accuracy (RA). The absolute mean difference between the gas concentration or emission rate determined by the PEMS and the value determined by the reference methods (RM's) plus the 2.5 percent error confidence coefficient of a series of tests divided by the mean of the RM tests or the applicable emission limit.

2.6 Representative Results. As defined by the RM test procedure outlined in this specification.

2.7 Failed Sensor or Sensor Failure. A sensor which, by comparison to the other sensors, has been determined to have failed or drifted such that the difference between PEMS output readings and reference values are beyond the allowable PEMS drift criteria.

3. INSTALLATION AND MEASUREMENT LOCATION SPECIFICATIONS

3.1 Sensor Installation. All sensors shall be installed at an accessible location in order to be able to perform, as necessary, repairs and replacements. Accessible locations does not require the installation of permanently installed platforms or ladders. Sensors may be at locations which require emission unit shutdown in order to repair or replace a failed sensor. After repair or replacement of a sensor, the process data from the sensor shall be, if necessary, corrected to provide process data which is representative of the process data obtained from the previously installed sensor.

3.2 Reference Method Measurement Location and Traverse Points.

3.2.1 Select, as appropriate, an accessible Reference Method (RM) measurement point at least two equivalent diameter downstream from the nearest control device, the point of pollutant generation, or other point at which a change in the pollutant concentration or emission rate may occur, and at least a half equivalent diameter upstream from the effluent exhaust or control device. When pollutant concentration changes are due solely to diluent leakage (e.g., air heater leakages) and pollutants and diluents are simultaneously measured at the same location, a half diameter may be used in lieu of two equivalent diameters.

Then select a traverse point or points that assure acquisition of representative samples over the stack or duct cross section. The following procedure is used to establish a traverse point which yields representative results: Establish the number and location of each traverse point for the sampling location in conformance with Test Method 1; Measure emissions in accordance with the applicable RM test method(s) at each traverse point for a period of two minutes plus the twice the test method’s system response time; Determine the average of the emissions; and Locate the traverse point with emissions nearest the average of the emissions as the sampling location for the RM tests. Results from previous studies may be used.

In lieu of determining a single traverse point to provide representative emissions, the following procedure may be used to locate the traverse points for conducting the RM tests: Establish a "measurement line" that passes through the centroidal area and in the direction of any expected stratification; Locate a minimum of three traverse points at 16.7, 50.0, and 83.3 percent of the measurement line or, if the measurement line is longer than 2.4 meters, the tester may choose to locate the three traverse points on the line at 0.4, 1.2, and 2.0 meters from the stack or duct.

The tester may select other traverse points, provided that they can be shown to the satisfaction of the Administrator to provide a representative sample over the stack or duct cross section. Conduct all necessary RM tests within 3 cm (but no less than 3 cm from the stack or duct wall) of the traverse point or points.

4. PERFORMANCE AND EQUIPMENT SPECIFICATIONS

4.1 Data Recorder Scale. The PEMS data recorder response range must include a low-level (zero to 20% of the applicable emission standard) and a high-level value. The high-level value is chosen by the source owner or operator and is defined as follows:

4.1.1 For a PEMS intended to measure an uncontrolled emission (e.g., NO_x measurements at the stack of a natural gas fired boiler), the high-level value must be between 1.25 and 2 times the average potential emission level, unless otherwise specified in an applicable regulations. For a PEMS installed to measure controlled emissions, the high-level value must be between 1.5 and 2.0 times the pollutant concentration corresponding to the emission standard level. For a PEMS installed to measures emissions that are in compliance with an applicable regulation, the high-level value must be between 1.1 and 1.5 times the pollutant concentration corresponding to the emission standard level. If approved by the Permitting Authority. a lower high-level value may be used.

4.1.2 The data recorder output must be established so that the high-level value is read between 90 and 100 percent of the data recorder full scale. This scale requirement is not applicable to digital data recorders.

4.1.3 The PEMS design must allow the automatic or manual determination of failed sensors. At a minimum, an hourly determination must be performed.

4.1.4 In the event of a failed sensor(s), the PEMS design may include the automatic or manual reconciliation of the process data provided that the PEMS emissions have been demonstrated to not have drifted by more than 20 percent of the applicable emission standard.

4.2 PEMS Drift. The PEMS must not drift or deviate from the reference value by more than 20 percent of the applicable emission standard based upon a perturbation analysis of the effect of sensor drift and the effect of utilizing reconciled process data for when a sensor or any combination of sensors has failed. If the PEMS includes emission and diluent models, the PEMS drift (PD) must be determined separately for each.

4.3 PEMS Relative Accuracy. The RA of the PEMS must be no greater than 20 percent of the mean value of the RM test data in terms of the units of the emission standard or 10 percent of the applicable emission standard, whichever is greater. For emissions below 1/4 of the applicable emission standard, use 20 percent of the standard.

5. PERFORMANCE SPECIFICATION TEST PROCEDURES

5.1 Pretest Preparation. Install the PEMS, prepare the RM test site according to the specifications in Section 3, and prepare the PEMS for operation according to the manufacturer's written instructions.

5.2 PEMS DRIFT TEST PROCEDURE.

5.2.1 Prior to the initial RATA, a demonstration of the ability of the PEMS to identify failed sensors and, if applicable, to reconcile failed sensors while maintaining the PEMS drift to less than 20% of the applicable standard shall be performed. This demonstration shall be conducted at a high-level reference value or a range of high-level reference values. The high-level reference value(s) must be between 75% to 100% of the pollutant concentration which corresponds to the applicable emission standard. The perturbation analysis shall be conducted as follows:

5.2.2 General Records. Record: the high-level reference value(s); the expected range of sensor values; the baseline sensor values at the reference values; the percent change in sensor value from the baseline sensor value established as the point at which the sensor is considered to have failed; and the sensor value which results in the sensor to be considered a failed sensor.

5.2.3 Analysis of Failed Sensor Values. Artificially perturb each sensor to the sensor value immediately prior to the sensor value which results in the sensor to be considered a failed sensor, and then record the sensor value and PEMS value. Calculate and record the PEMS drift for each sensor. The PEMS drift for each perturbed sensor value must be less than 20% of the applicable emission standard.

5.2.4 Analysis of Sensor Reconciliation. Artificially perturb each sensor to the sensor value which results in the sensor to be considered a failed sensor, and then record the calculated sensor value and PEMS value. Calculate and record the PEMS drift for each sensor. The PEMS drift for each reconciled sensor value must be less than 20% of the applicable emission standard. Repeat the procedure for the high-level reference value.

5.2.5 Analysis of Combinations of Failed Sensors. Artificially perturb combinations of sensors to the sensor values which result in the sensors to be considered failed sensors, and then record the reconciled sensor values and PEMS value. Calculate the PEMS drift for each combination of failed sensors analyzed. Determine each combination of failed sensors which result in a PEMS drift of less than 20% of the applicable emission standard. The PEMS drift for each combination of reconciled sensor values must be less than 20% of the applicable emission standard in order to be acceptable.

5.3 RELATIVE ACCURACY TEST PROCEDURE

5.3.1 Sampling Strategy for RM Tests. Conduct the RM tests in such a way that they will yield results representative of the emissions from the source and can be correlated to the PEMS data. In order to correlate the PEMS and RM data properly, mark the beginning and end of each RM test period of each run (including the exact time of the day) on the PEMS permanent record of output. Use the following strategies for the RM tests:

5.3.2 Instrumental Test Methods. For all types of emission units, instrumental test methods, e.g., Method 3A, Method 6C, and Method 7E, are recommended.

5.3.3 Non-instrumental Test Methods. For emission units with consistent emissions, integrated or grab non-instrumental test methods, e.g., Method 6 or Method 7, respectively, may be used. A test run for grab samples must be made up of at least three separate measurements. Note that for emission units with varying emissions, if non-instrumental test methods are to be used, then integrated non-instrumental test methods must be used since grab sampling techniques may not provide representative emissions data.

5.3.4 Note. At times, PEMS RA tests are conducted during new source performance standards performance tests. In these cases, RM results obtained during PEMS RA tests may be used to determine compliance as long as the source and test conditions are consistent with the applicable regulations.

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

5.3.6 If the RM has an instrumental or an integrated non-instrumental sampling technique, make a direct comparison of the RM results and PEMS integrated average value.

5.3.7 If the RM has a grab sampling technique, first average the results from all grab samples taken during the test run, and then compare this average value against the integrated value obtained from the PEMS during the run.

5.3.8 Number of RM Tests. Conduct a minimum of nine sets of all necessary RM tests. Three sets must be conducted at low-level gas concentrations or emission rates, three at normal-level, and three at high-level. Note: The tester may choose to perform more than nine sets of RM tests. If this option is chosen, the tester may, at his discretion, reject a maximum of three sets of the test results so long as the total number of test results used to determine the RA is greater than or equal to nine, but all data including the rejected data must be reported.

5.3.9 Reference Methods. Unless otherwise specified in an applicable regulations, the test methods contained in 40 CFR Part 60, Appendix A are required. The instrumental test methods, e.g., Methods 3A, 6C, and 7E, are recommended. The tester should ensure that the test method chosen will be able to provide accurate and precise emissions data.

5.3.10 Calculations. Summarize the results on a data sheet.
Calculate the mean of the RM values. Calculate the arithmetic differences between the RM and the PEMS output sets. Then calculate the mean of the difference, standard deviation, confidence coefficient, and PEMS RA, using Equations P-1, P-2, P-3, and P-4, respectively.

6. EQUATIONS

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

$$\overline{d} = \frac{1}{n}\sum_{i=1}^{n} d_i$$

(Eq. P-1)

Where: n = Number of data points.

d_i = Difference between RM test result and PEMS output

When the mean of the differences of pairs of data is calculated, be sure to correct the data for moisture, if applicable.

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

$$S_d = \left[\frac{\sum_{i=1}^{n} d_i^2 - \frac{\left(\sum_{i=1}^{n} d_i\right)^2}{n}}{n-1} \right]^{1/2}$$

(Eq. P-2)

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

$$CC = t_{0.975}\frac{S_d}{\sqrt{n}}$$

(Eq. P-3)

Where: $t_{0.975}$ = t-value (see Table P-1).

TABLE P-1. t-VALUES

n^a	$t_{0.975}$	n^a	$t_{0.975}$	n^a	$t_{0.975}$
2	20.706	7	2.447	20	2.201
3	4.303	8	2.365	13	2.179
4	3.182	9	2.306	14	2.160
5	2.776	10	2.262	15	2.145
6	2.571	11	2.228	16	2.131

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

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

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

(Eq. P-4)

Where: $|\bar{d}|$ = Absolute value of the mean differences (from Eq. P-1).

|CC| = Absolute value of the confidence coefficien (from Eq. P-3).

$\overline{RM}$ = Average RM value or applicable standard.

7. REPORTING

At a minimum (check with the appropriate regional office, or State, or local agency for additional requirements, if any) summarize in tabular form the results of the PD tests and the RA tests or alternative RA procedure as appropriate. Include all data sheets, calculations, and charts (records of PEMS responses), necessary to substantiate that the performance of the PEMS met the performance specifications.