



# Standard Test Method for Determination of Nitrogen Oxides, Carbon Monoxide, and Oxygen Concentrations in Emissions from Natural Gas-Fired Reciprocating Engines, Combustion Turbines, Boilers, and Process Heaters Using Portable Analyzers<sup>1</sup>

This standard is issued under the fixed designation D 6522; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

## 1. Scope

1.1 This test method covers the determination of nitrogen oxides (NO and NO<sub>2</sub>), carbon monoxide (CO), and oxygen (O<sub>2</sub>) concentrations in controlled and uncontrolled emissions from natural gas-fired reciprocating engines, combustion turbines, boilers, and process heaters. Due to the inherent cross sensitivities of the electrochemical cells, this test method should not be applied to other pollutants or emission sources without a complete investigation of possible analytical interferences and a comparative evaluation with EPA test methods.

1.1.1 The procedures and specifications of this method were developed during laboratory and field tests funded by the Gas Research Institute (GRI).<sup>2</sup> Comparative emission tests were conducted only on natural gas-fired combustion sources.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 1356 Terminology Relating to Sampling and Analysis of Atmospheres<sup>3</sup>

2.2 *EPA Methods from 40 CFR Part 60, Appendix A*<sup>4</sup>  
Method 3A - Determination of Oxygen and Carbon Dioxide

Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)

Method 7E - Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)

Method 10 - Determination of Carbon Monoxide Emissions from Stationary Source

Method 20 - Determination of Nitrogen Oxides, Sulfur Dioxide, and Diluent Emissions from Stationary Gas Turbines

2.3 *EPA Methods from 40 CFR Part 63, Appendix A*<sup>4</sup>

Method 301 - Field Validation of Pollutant Measurement Methods from Various Waste Media

2.4 *EPA Methods from 40 CFR Part 75, Appendix H*<sup>4</sup>  
Revised Traceability Protocol No. 1: Protocol G1 and G2 Procedures

## 3. Terminology

3.1 For terminology relevant to this test method, see Terminology D 1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *measurement system, n*—total equipment required for the determination of gas concentration. The measurement system consists of the following major subsystems:

3.2.1.1 *data recorder, n*—a strip chart recorder, computer, or digital recorder for recording measurement data.

3.2.1.2 *electrochemical cell, n*—that portion of the system that senses the gas to be measured and generates an output proportional to its concentration, or any cell that uses diffusion-limited oxidation and reduction reactions to produce an electrical potential between a sensing electrode and a counter electrode.

3.2.1.3 *external interference gas scrubber, n*—tube filled with scrubbing agent used to remove interfering compounds upstream of some electrochemical cells.

3.2.1.4 *sample interface, n*—that portion of a system used for one or more of the following: sample acquisition, sample transport, sample conditioning, or protection of the electrochemical cells from particulate matter and condensed moisture.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.03 on Ambient Atmospheres and Source Emissions.

Current edition approved Feb. 10, 2000/April 2000.

<sup>2</sup> Gas Research Institute Topical Report, "Development of an Electrochemical Cell Emission Analyzer Test Method," GRI-96/0008, July 1997.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 11.03.

<sup>4</sup> Available from Superintendent of Documents, U. G. Government Printing Office, Washington, DC 20402.

3.2.2 *interference check, n*—method of quantifying analytical interferences from components in the stack gas other than the analyte.

3.2.3 *initial NO cell temperature, n*—temperature of the NO cell that is recorded during the most recent pretest calibration error check.

3.2.3.1 *Discussion*—Since the NO cell can experience significant zero drift with temperature changes in some situations, the temperature must be monitored if the analyzer does not display negative concentration results.

3.2.4 *linearity check, n*—method of demonstrating the ability of a gas analyzer to respond consistently over a range of gas concentrations.

3.2.5 *nominal range, n*—range of concentrations over which each cell is operated (25 % to 125 % of span gas value).

3.2.5.1 *Discussion*—Several nominal ranges may be used for any given cell as long as the linearity and stability check results remain within specification.

3.2.6 *response time, n*—amount of time required for the measurement system to display 95 % of a step change in gas concentration on the data recorder.

3.2.7 *span gas, n*—known concentration of a gas in an appropriate diluent gas.

3.2.8 *span calibration error, n*—difference between the gas concentration exhibited by the gas analyzer and the known concentration of the span gas.

3.2.9 *stability check, n*—method of demonstrating that an electrochemical cell operated over a given nominal range provides a stable response and is not significantly affected by prolonged exposure to the analyte.

3.2.10 *stability time, n*—elapsed time from the start of the gas injection to the start of the 30-min stability check period, as determined during the stability check.

3.2.11 *zero calibration error, n*—gas concentration exhibited by the gas analyzer in response to zero-level calibration gas.

**4. Summary of Test Method**

4.1 A gas sample is continuously extracted from a stack and conveyed to a portable analyzer for determination of NO, NO<sub>2</sub>, CO, and O<sub>2</sub> gas concentrations using electrochemical cells. Analyzer design specifications, performance specifications, and test procedures are provided to ensure reliable data. Additions to or modifications of vendor-supplied analyzers (for example, heated sample line, flow meters, and so forth) may be required to meet the design specifications of this test method.

**5. Significance and Use**

5.1 The results of this test method may be used to determine nitrogen oxides and carbon monoxide emissions from natural gas combustion.

5.2 This test method may also be used to monitor emissions to optimize process operation for nitrogen oxides and carbon monoxide control.

**6. Interferences**

6.1 NO and NO<sub>2</sub> can interfere with CO concentration measurements, and NO<sub>2</sub> can interfere with NO concentration

measurements. The interference effects for the CO and NO emission measurements are quantified in 9.2 and shall not exceed 5 % of the measurement.

**7. Apparatus**

7.1 The minimum detectable limit depends on the nominal range of the electrochemical cell, calibration drift, and signal-to-noise ratio of the measurement system. For a well designed system, the minimum detectable limit should be less than 2 % of the nominal range.

7.2 Any measurement system that meets the performance and design specifications in Sections 9 and 10.4.11 of this test method may be used. The sampling system shall maintain the gas sample at a temperature above the dew point up to the moisture removal system. The sample conditioning system shall be designed so that there are no entrained water droplets in the gas sample when it contacts the electrochemical cells. A schematic of an acceptable measurement system is shown in Fig. 1. The essential components of the measurement system are described below:

7.3 *Sample Probe*, glass, stainless steel, or other nonreactive material, of sufficient length to traverse the sample points, and, if necessary, heated to prevent condensation.

7.4 *Heated Sample Line*, heated (sufficient to prevent condensation), nonreactive tubing, to transport the sample gas to the moisture removal system.

7.5 *Sample Transport Lines*, nonreactive tubing to transport the sample from the moisture removal system to the sample pump, sample flow rate control, and electrochemical cells.

7.6 *Calibration Assembly*, a tee-fitting to attach to the probe tip for introducing calibration gases at ambient pressure during the calibration error checks. The vented end of the tee should have a flow indicator to ensure sufficient calibration gas flow. Any other method that introduces calibration gases at the probe at atmospheric pressure may be used.

7.7 *Moisture Removal System*, a chilled condenser or similar device (for example, permeation dryer), to remove condensate

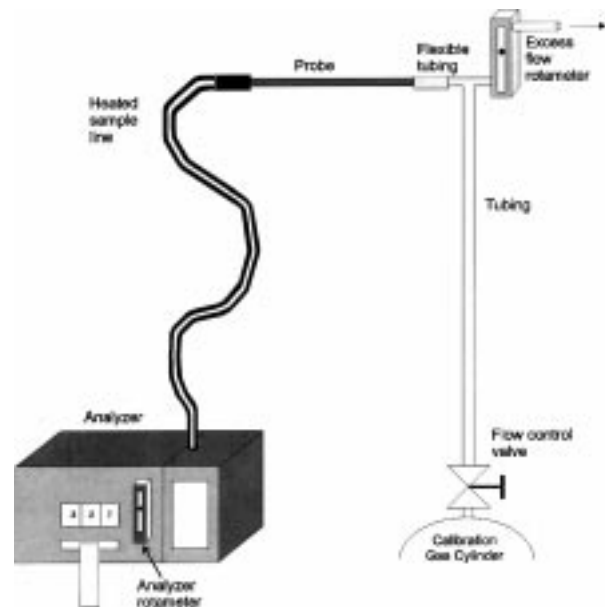


FIG. 1 Calibration System Schematic

continuously from the sample gas while maintaining minimal contact between the condensate and the sample gas.

7.8 *Particulate Filters*—Filters at the probe or the inlet or outlet of the moisture removal system and inlet of the analyzer may be used to prevent accumulation of particulate material in the measurement system and extend the useful life of the components. All filters shall be fabricated of materials that are nonreactive to the gas being sampled.

7.9 *Sample Pump*, a leak-free pump, to pull the sample gas through the system at a flow rate sufficient to minimize the response time of the measurement system. The pump must be constructed of any material that is nonreactive to the gas being sampled.

7.10 *Sample Flow Rate Control*, a sample flow rate control valve and rotameter, or equivalent, to maintain a constant sampling rate within 10 % during sampling and calibration error checks. The components shall be fabricated of materials that are nonreactive to the gas being sampled.

7.11 *Gas Analyzer*, a device containing electrochemical cells to determine the NO, NO<sub>2</sub>, CO, and O<sub>2</sub> concentrations in the sample gas stream and, if necessary, to correct for interference effects. The analyzer shall meet the applicable performance specifications of Section 9. A means of controlling the analyzer flow rate and a device for determining proper sample flow rate (for example, precision rotameter, pressure gage downstream of all flow controls, and so forth) shall be provided at the analyzer.

NOTE 1—Housing the analyzer in a clean, thermally-stable, vibration-free environment will minimize drift in the analyzer calibration, but this is not a requirement of the test method.

7.12 *Data Recorder*, a strip chart recorder, computer, or digital recorder, for recording measurement data. The data recorder resolution (that is, readability) shall be at least 1 ppm for CO, NO, and NO<sub>2</sub>; 0.1 % O<sub>2</sub> for O<sub>2</sub>; and 1° (C or F) for temperature. Alternatively, a digital or analog meter having the same resolution may be used to obtain the analyzer responses and the readings may be recorded manually.

7.13 *External Interference Gas Scrubber*, used by some analyzers to remove interfering compounds upstream of a CO electrochemical cell. The scrubbing agent should be visible and should have a means of determining when the agent is exhausted (that is, color indication).

7.14 *NO Cell Temperature Indicator*, a thermocouple, thermistor, or other device must be used to monitor the temperature of the NO electrochemical cell. The temperature may be monitored at the surface or within the cell.

## 8. Reagents and Materials

8.1 The analytical range for each gas component is determined by the electrochemical cell design. A portion of the analytical range is selected by choosing a span gas concentration near the flue gas concentrations.

8.2 *Calibration Gases*—The calibration gases for the gas analyzer shall be CO in nitrogen or CO in nitrogen and O<sub>2</sub>, NO in nitrogen, NO<sub>2</sub> in air or nitrogen, and O<sub>2</sub> in nitrogen.

8.2.1 For the mid-level and span cylinder gases, use calibration gases certified according to EPA Protocol G1 or G2 procedures.

8.2.2 Alternative certification techniques may be used, if approved in writing by the applicable regulatory agency.

8.3 *Span Gases*—Use these gases for calibration error, linearity, and interference checks of each nominal range of each cell. Select concentrations as follows:

8.3.1 *CO and NO Span Gases*—Choose a span gas concentration such that the average stack gas reading for each test run is greater than 25 % of the span gas concentration. Alternatively, choose the span gas such that it is not greater than twice the concentration equivalent to the emission standard. If concentration results exceed 125 % of the span gas at any time during the sampling run, then the test run for that channel is invalid.

8.3.2 *NO<sub>2</sub> Span Gas*—Choose a span gas concentration such that the average stack gas reading for each test run is greater than 25 % of the span gas concentration. Alternatively, choose the span gas concentration such that it is not greater than the ppm concentration value of the NO span gas. The tester should be aware that NO<sub>2</sub> cells are generally designed to measure much lower concentrations than NO cells and the span gas should be chosen accordingly. If concentration results exceed 125 % of the span gas at any time during the sampling run then the test run for that channel is invalid.

8.3.3 *O<sub>2</sub> Span Gas*—Choose a span gas concentration such that the difference between the span gas concentration and the average stack gas reading for each run is less than 10 % O<sub>2</sub>. Where the stack oxygen is high, dry ambient air (20.9 % O<sub>2</sub>) may be used.

8.4 *Mid-Level Gases*—Select mid-level gas concentrations that are 40 to 60 % of the span gas concentrations.

8.5 *Zero Gas*—Zero gas must have concentrations of less than 0.25 % of the span gas for each component. Ambient air may be used in a well-ventilated area.

## 9. Preparation of Apparatus

### 9.1 Linearity Check:

9.1.1 Conduct the linearity check once for each nominal range that is to be used on each electrochemical cell (NO, NO<sub>2</sub>, CO, and O<sub>2</sub>) before each field test program.

9.1.1.1 Repeat the linearity check immediately after 5 days of analyzer operation, if a field test program lasts longer than 5 days.

9.1.1.2 Repeat the linearity check whenever a cell is replaced.

9.1.2 If the analyzer uses an external interference gas scrubber with a color indicator, verify that the scrubbing agent is not depleted, following the analyzer manufacturer's recommended procedure.

9.1.3 Calibrate the analyzer with zero and span gases.

9.1.4 Inject the zero, mid-level, and span gases that are appropriate for each nominal range to be used on each cell. Gases need not be injected through the entire sample handling system.

9.1.5 Purge the analyzer, briefly with ambient air between gas injections.

9.1.6 For each gas injection, verify that the flow rate is constant and that the analyzer responses have stabilized.

9.1.7 Record all of the responses (stabilized) on a form similar to Fig. 2.



9.3.1 Conduct the stability check once for each nominal range that is to be used on each pollutant electrochemical cell (NO, NO<sub>2</sub>, and CO) before each field test program.

9.3.1.1 Repeat the stability check immediately after 5 days of analyzer operation, if a field test program lasts longer than 5 days.

9.3.1.2 Repeat the stability check if a cell is replaced or if a cell is exposed to gas concentrations greater than 125 % of the highest span gas concentration.

9.3.2 Inject the span gas into the analyzer and record the analyzer response at least once per minute until the conclusion of the test. One-minute average values may be used instead of instantaneous readings.

9.3.3 After the analyzer response has stabilized, continue to flow the span gas for at least 30 min.

9.3.3.1 If the concentration reaches a peak value within 5 min, the data may be recorded for at least 15 min (rather than 30 min) following the peak.

9.3.3.2 If the 15-min test period is used, a more stringent specification shall be met (see 9.3.8).

9.3.4 Make no adjustments to the analyzer during the test except to maintain constant flow.

9.3.5 Record the stability time as the number of minutes elapsed between the start of the gas injection and the start of the 30-min (or 15-min) stability check period.

9.3.6 Determine the highest and lowest concentrations recorded during the 30-min period and record the results on a form similar to Fig. 3.

9.3.7 Calculate the absolute value of the difference between the maximum and minimum values recorded during the 30-min period (or the 15-min period) for the CO, NO, and NO<sub>2</sub> span gases.

#### 9.3.8 *Stability Specifications:*

9.3.8.1 Thirty-minute period— $\leq 2.0$  % of the span gas concentration.

9.3.8.2 Fifteen-minute period— $\leq 1.0$  % of the span gas concentration.

## 10. Procedure

### 10.1 *Reciprocating Engines—Selection of Sampling Site and Sampling Points:*

10.1.1 Select a sampling site located at least five stack, duct, or pipe diameters downstream of any turbocharger exhaust, crossover junction, or recirculation take-offs and upstream of any dilution air inlet.

10.1.2 Locate the sampling site no closer than 1 m or three stack, duct, or pipe diameters (whichever is less) upstream of the gas discharge to the atmosphere.

10.1.3 Use a minimum of three sampling points located at positions of 16.7, 50, and 83.3 % of the stack, duct, or pipe diameter.

10.1.4 Alternatively, the tester may choose an alternative sampling location or sample from a single point in the center of the stack, duct, or pipe, if previous test data demonstrate that the stack, duct, or pipe gas concentration does not vary significantly across the duct diameter, or both.

### 10.2 *Combustion Turbines—Selection of Sampling Site and Sampling Points:*

10.2.1 Select a sampling site and sample points according to the procedures in 40 CFR, Part 60, Appendix A, Method 20.

10.2.2 Alternatively, the tester may choose an alternative sampling location or sample from a single point in the center of the stack, duct, or pipe if previous test data demonstrate that the stack, duct, or pipe gas concentrations of CO, NO<sub>x</sub>, and O<sub>2</sub> do not vary significantly across the duct diameter, or both.

#### 10.3 *Warm Up Period:*

10.3.1 Assemble the sampling system and allow the analyzer and sample interface to warm up and adjust to ambient temperature at the location where the stack measurements will take place.

10.3.2 The warm-up period ensures that excessive calibration drift does not occur due to temperature changes. If the pretest and post test calibration error check results are within the specifications of the method and the NO cell temperature meets the requirements of 10.5.3, then the duration of the warm-up period is considered sufficient.

#### 10.4 *Pretest Calibration Error Check:*

10.4.1 Conduct the calibration error check at the sampling location (near the sampling port) just prior to the start of an emissions test or test run. Keep the analyzer in the same location until the post test calibration error check is conducted.

10.4.2 For analyzers that have an external interference gas scrubber tube, inspect the condition of the scrubbing agent and ensure that it will not be exhausted during sampling.

10.4.3 Inject the zero and span calibration gases at the probe tip using the calibration assembly.

10.4.4 Ensure that the calibration gases flow through all parts of the sample interface (including any exhaust lines).

10.4.5 During this check, make no adjustments to the system except those necessary to achieve the correct calibration gas flow rate at the analyzer.

10.4.6 Set the analyzer flow rate to the value recommended by the analyzer manufacturer.

10.4.7 Allow each reading to stabilize (no less than the stability time noted during the stability check) before recording the result on a form similar to Fig. 4.

10.4.8 After achieving a stable response, disconnect the gas and briefly purge with ambient air.

10.4.9 Determine the NO and CO response times by observing the time required to respond to 95 % of a step change in the analyzer response for both the zero and span gases. Note the longer of the two times as the response time. For NO<sub>2</sub> span gas record the time required to respond to 90 % of a step change.

10.4.10 Calibrate all electrochemical cells in the analyzer if the analyzer uses an internal calculation method to compensate for interferences.

10.4.11 If the zero and span calibration error test results are not within the specifications stated below, take corrective action and repeat the calibration error check until acceptable performance is achieved.

10.4.11.1 *Zero Calibration Error Specifications*— $\leq 3$  % of the span gas value for NO, NO<sub>2</sub>, and CO channels;  $\leq 0.3$  % O<sub>2</sub> for the O<sub>2</sub> channel.

10.4.11.2 *Span Calibration Error Specifications*— $\leq 5$  % of the span gas value for NO, NO<sub>2</sub>, and CO channels;  $\leq 0.5$  % O<sub>2</sub> for the O<sub>2</sub> channel.

Date \_\_\_\_\_ Analyst \_\_\_\_\_

Analyzer Manufacturer/Model No. \_\_\_\_\_

Analyzer Serial Number \_\_\_\_\_

Pollutant Channel \_\_\_\_\_ Span Gas Concentration \_\_\_\_\_

Elapsed Time (Minutes)	Analyzer Response	Elapsed Time (Cont.)	Analyzer Response	Elapsed Time (Cont.)	Analyzer Response
1		17		33	
2		18		34	
3		19		35	
4		20		36	
5		21		37	
6		22		38	
7		23		39	
8		24		40	
9		25		41	
10		26		42	
11		27		43	
12		28		44	
13		29		45	
14		30		46	
15		31		47	
16		32		48	

For 30-minute stability period: \_\_\_\_\_ maximum \_\_\_\_\_ minimum

For 15-minute stability period: \_\_\_\_\_ maximum \_\_\_\_\_ minimum

 Maximum Deviation =  $100 \times (\text{max.} - \text{min.}) / \text{span gas conc.} =$  \_\_\_\_\_

Stability Time \_\_\_\_\_

**FIG. 3 Stability Check Data Sheet**
**10.5 NO Cell Temperature Monitoring:**

10.5.1 Record the initial NO cell temperature during the pretest calibration error check.

10.5.2 Monitor and record the temperature regularly (at least once each 5 min) during the sample collection period.

 10.5.3 If at any time during sampling the NO cell temperature is  $\geq 29.4^{\circ}\text{C}$  ( $85^{\circ}\text{F}$ ) and has increased or decreased by more than  $2.8^{\circ}\text{C}$  ( $5^{\circ}\text{F}$ ) since the pretest calibration, do the following:

10.5.3.1 Stop sampling immediately.

10.5.3.2 Conduct a post test calibration error check according to 10.7.

10.5.3.3 Re-zero the analyzer.

10.5.3.4 Then conduct another pretest calibration error check before continuing.

**10.6 Sample Collection:**

10.6.1 Position the sampling probe at the first measurement point and begin sampling at the same rate used during the calibration error check.

Emission Source \_\_\_\_\_

Emission Test Run Number(s) \_\_\_\_\_ Start Test Period \_\_\_\_\_

Stop Test Period \_\_\_\_\_

Date \_\_\_\_\_

Analyst \_\_\_\_\_

Analyzer Manufacturer/Model No. \_\_\_\_\_

Analyzer Serial Number \_\_\_\_\_

**Pretest Calibration Error Check Results:**

Initial NO cell temperature \_\_\_\_\_

Gas Injection	Gas Conc.	NO Response	NO <sub>2</sub> Response	CO Response	O <sub>2</sub> Response	Calib. Error (%)
NO Zero						
NO Span						
NO <sub>2</sub> Zero						
NO <sub>2</sub> Span						
CO Zero						
CO Span						
O <sub>2</sub> Zero						
O <sub>2</sub> Span						

**Post Test Calibration Error Check Results:**

Final NO cell temperature \_\_\_\_\_

Gas Injection	Gas Conc.	NO Response	NO <sub>2</sub> Response	CO Response	O <sub>2</sub> Response	Calib. Error (%)
NO Zero						
NO Span						
NO <sub>2</sub> Zero						
NO <sub>2</sub> Span						
CO Zero						
CO Span						
O <sub>2</sub> Zero						
O <sub>2</sub> Span						

**FIG. 4 Calibration Error Check Data Sheet**

10.6.2 Maintain constant rate sampling (that is,  $\pm 10\%$  of the analyzer flow rate value used in 10.4.6) during the entire test run.

10.6.3 Sample for an equal period of time at each test point.

10.6.4 Sample the stack, duct, or pipe gas for at least twice the response time or the period of the stability time, whichever is greater, before collecting test data at each point.

10.6.5 If recording emission data manually, record concentration values at least once each minute. If a computer or the analyzer record data automatically, record the concentration data either (a) at least once each minute, or (b) as a block average for the test run using values sampled at least once each minute.

10.6.6 Do not break any seals in the sample handling system until after the post test calibration error check (this includes opening the moisture removal system to drain condensate).

#### 10.7 Post Test Calibration Error Check:

10.7.1 Immediately after the test run or set of test runs, conduct span and zero calibration error checks using the procedure in 10.4 at the sampling location.

10.7.1.1 The frequency of post test calibration checks depends on the individual analyzer performance and the temperature conditions at the sampling location. The operator is responsible for conducting calibration checks with sufficient frequency to ensure that the post test calibration check results are acceptable.

10.7.2 Make no changes to the sampling system or analyzer calibration until all of the calibration error test results have been recorded.

10.7.3 If the zero or span calibration error exceeds the specifications in 10.4.11, invalidate all test data collected since the previous calibration error check.

10.7.4 If the sampling system is disassembled or the analyzer calibration is adjusted, repeat the calibration error check before conducting the next test or test run.

#### 10.8 Interference Verification:

10.8.1 Review the results of the post test calibrations and compare them to the results of the most recent interference test.

10.8.2 Calculate interference responses ( $I_{NO}$  and  $I_{CO}$ ) using the procedure in 10.2 and the post test calibration results and average emission concentrations for the test.

10.8.3 If an interference response exceeds 5 %, invalidate all emission test results since the last successful interference test for that compound.

#### 10.9 Re-Zero:

10.9.1 At least once every 3 h or each time the analyzer sampling location changes, recalibrate the analyzer at the zero level according to the manufacturer's instructions and conduct a pretest calibration error test before resuming sampling.

10.9.2 If the analyzer is capable of reporting negative concentration data (at least 5 % of the span gas below zero), then the tester is not required to re-zero the analyzer.

## 11. Calculation

11.1 *Calibration Corrections*—The tester may choose to correct the emissions data for a test run using the pretest and post test calibration error results according to the following formula:

$$C_{GAS} = (C_R - C_O) \frac{C_{MA}}{C_M - C_O} \quad (1)$$

where:

$C_{GAS}$  = corrected flue gas concentration,  
 $C_R$  = flue gas concentration indicated by gas analyzer,  
 $C_O$  = average of initial and final zero checks,  
 $C_M$  = average of initial and final span checks, and  
 $C_{MA}$  = actual concentration of span gas.

#### 11.2 CO Interference Response:

$$I_{CO} = [(R_{CO-NO}/C_{NOG} \times C_{NOS}/C_{COS}) + (R_{CO-NO_2}/C_{NO_2G} \times C_{NO_2S}/C_{COS})] \times 100 \quad (2)$$

where:

$I_{CO}$  = CO interference response, %,  
 $R_{CO-NO}$  = CO response to NO span gas, ppm CO,  
 $C_{NOG}$  = concentration of NO span gas, ppm NO,  
 $C_{NOS}$  = concentration of NO in stack gas, ppm NO,  
 $C_{COS}$  = concentration of CO in stack gas, ppm CO,  
 $R_{CO-NO_2}$  = CO response to NO<sub>2</sub> span gas, ppm CO,  
 $C_{NO_2G}$  = concentration of NO<sub>2</sub> span gas, ppm NO<sub>2</sub>, and  
 $C_{NO_2S}$  = concentration of NO<sub>2</sub> in stack gas, ppm NO<sub>2</sub>.

#### 11.3 NO Interference Response:

$$I_{NO} = [(R_{NO-NO_2}/C_{NO_2G}) \times (C_{NO_2S}/C_{NOxS})] \times 100 \quad (3)$$

where:

$I_{NO}$  = NO interference response, %,  
 $R_{NO-NO_2}$  = NO response to NO<sub>2</sub> span gas, ppm NO,  
 $C_{NO_2G}$  = concentration of NO<sub>2</sub> span gas, ppm NO<sub>2</sub>,  
 $C_{NO_2S}$  = concentration of NO<sub>2</sub> in stack gas, ppm NO<sub>2</sub>,  
 and  
 $C_{NOxS}$  = concentration of NO<sub>x</sub> in stack gas, ppm NO<sub>x</sub>.

## 12. Report

12.1 Report the following information:

12.1.1 Summary of emission test results.

12.1.2 Include the following information:

12.1.2.1 Results from linearity, interference, and stability checks.

12.1.2.2 Results of pretest and post-test calibration error checks.

12.1.2.3 Calibration gas certifications.

## 13. Precision and Bias

13.1 *Precision*—The precision of the test method was determined using the statistical procedures in EPA Method 301 as described in the GRI Topical Report<sup>2</sup> to calculate the variance of the test method results. During each of five field tests, two electrochemical cell analyzers were operated according to the method and the results were compared simultaneous results from EPA Methods 3A, 7E, and 10 (40CFR, Part 60, Appendix B).

13.1.1 *Repeatability (Single Analyst)*—Statistical analysis of each of the ten comparative tests, using an F-test, indicated that the test method was not less precise than the EPA methods. For NO<sub>x</sub> concentration measurements, the relative standard deviation (RSD) results were between 0.3 and 4.7 %. For CO concentration measurements, the RSD results were between 0.1 and 0.7 %. For O<sub>2</sub> measurements, the RSD results were between 0.1 and 0.5 %.

13.1.2 *Reproducibility (Multilaboratories)*—Multilaboratory testing was not conducted as part of the validation testing, but two electrochemical cell analyzers were operated simultaneously. The two analyzers were supplied by different



manufacturers and included different sample conditioning system designs. For each field test comparison, the difference between the RSD values for the two analyzers was not greater than 0.5 %.

### 13.2 Bias:

13.2.1 *Bias Due to Interference*—Paragraph 9.2 of the test method contains a procedure for quantifying the interference bias associated with each emission measurement. The test method requires that the interference bias is not greater than 5 % of the measured concentration.

13.2.2 *Bias Due to Calibration Standards*—Paragraph 8.2.1 of the test method ensures that bias due to calibration standards should be less than 1 or 2 %, depending on the analyte and concentration.

13.2.3 *Validation Testing for Bias*—During the field tests cited in 13.1, bias was determined by comparison with EPA test method results. For NO<sub>x</sub> concentration measurements, a posi-

tive bias of between 0.0 and 7.9 % was observed when compared to EPA method results. However, EPA test method results are subject to a negative bias due to loss of NO<sub>2</sub> in the sample conditioning system and the NO<sub>2</sub>-to-NO converter. For CO concentration measurements, the measured bias was between -1.0 and 8.5 % relative to the EPA methods. For O<sub>2</sub> measurements, the measured bias was between 0.0 and 3.1 % relative to the EPA methods. Bias observed during the validation testing includes bias from calibration standards because separate calibration standards were used for this test method and the EPA methods.

## 14. Keywords

14.1 electrochemical cells; carbon monoxide emissions; emissions; natural gas combustion; oxygen emissions; portable analyzers; test method for nitrogen oxides

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