

# ICAC Test Method For Periodic Monitoring

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## Test Method - Determination of Oxygen, Carbon Monoxide and Oxides of Nitrogen from Stationary Sources For Periodic Monitoring (Portable Electrochemical Analyzer Procedure)

### 1. APPLICABILITY AND PRINCIPLE

**1.1 Applicability.** This method is applicable to 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 combustion sources using fuels such as natural gas, propane, butane, and fuel oils. This method is designed to provide a reasonable assurance of compliance using periodic monitoring or testing. This method is not intended for use where an EPA reference test method is required. Due to inherent cross sensitivities of electrochemical (EC) cells, this method should not be applied to other pollutants or emission sources without a complete investigation of possible analytical interferences and a comparative evaluation with other EPA test methods.

**1.2 Principle.** A gas sample is extracted from a stack and is conveyed to a portable EC analyzer for determination of NO, NO<sub>2</sub>, CO and O<sub>2</sub> gas concentrations. Analyzer performance specifications and test procedures are provided to ensure reliable data. Additions to, or modifications of, vendor supplied analyzers (e. g. heated sample lines, thermocouples, flow meters, etc.) may be required to meet the design specifications of this test method. Changes that diminish the analyzer from the as-verified (see Definitions, Section 3.15) configuration are not permitted.

### 2. RANGE AND SENSITIVITY

**2.1 Analytical Range.** The instrument and EC cell design will determine the analytical range for each gas component. The nominal range is defined by choosing a span gas concentration near the maximum anticipated flue gas concentration for that constituent or near the permitted level as determined by the appropriate regulatory agency.

**2.1.1 NO, NO<sub>2</sub> and CO Span Gases.** Choose a span gas concentration such that the average stack gas reading for each test run is between 25 and 150 percent of the span gas concentration. Alternatively, choose the span gas such that it does not exceed twice the concentration equivalent to the permitted level. If the actual emissions exceed 150 percent of the span gas value at any time during the sampling run, the test run for that channel shall be invalid. The NO<sub>2</sub> span gas concentration should be selected at a level within the NO<sub>2</sub> sensor's measuring range, but for span gas stability and availability considerations, above 75 ppm (in a base of air) is acceptable.

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**2.1.2 O<sub>2</sub> Span Gas.** The difference between the span gas concentration and the average stack gas reading for each sample run shall be less than 15% O<sub>2</sub>. Where the stack oxygen readings are above 6%, dry ambient air (20.9% O<sub>2</sub>) may be used for the span gas. Oxygen readings below 6% should be verified with low concentration calibration gas.

**2.2 Sensitivity Range.** The minimum detectable limit depends on the nominal range and resolution of the electrochemical cell and signal to noise ratio of the measurement system. The minimum detectable limit should be 2 percent of the nominal range or 1 ppm, whichever is less restrictive.

## 3. DEFINITIONS

**3.1 Measurement System.** The total equipment required for the determination of gas species concentrations. The measurement system consists of the following major subsystems:

**3.1.1 Sample Interface.** The portion of a system used for one or more of the following: sample acquisition, sample transport, sample conditioning or protection of the analyzer from the effects of the stack effluent, particulate matter and condensed moisture.

**3.1.2 Interference Gas Scrubber.** A device used to remove or neutralize compounds likely to interfere with the selective operation of the cell.

**3.1.3 Electrochemical Cell.** A device, similar to a fuel cell, that senses a specific gas and generates a current output proportional to the gas concentration.

**3.1.4 Moisture Removal System.** Any device used to reduce the concentration of moisture in the sample stream for protecting the EC cells from the damaging effects of condensation and for minimizing errors in readings caused by the scrubbing of soluble gases.

**3.1.5 Data Recorder.** A strip chart recorder, computer or digital recorder for logging measurement data from the analyzer output. The digital data display may be used when taking manual measurements.

**3.2 Nominal Range.** The range of concentrations over which each cell is operated (25% to 150% of span gas value). Several nominal ranges may be used for any given cell as long as the calibration and repeatability check for that range remains within specification.

**3.3 Span Gas.** A known concentration of a gas in an appropriate diluent gas.

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- 3.4 Zero Calibration Error.** The gas concentration output exhibited by the gas analyzer in response to zero-level calibration gas.
- 3.5 Span Calibration Error.** The difference between the gas concentration exhibited by the gas analyzer and the known concentration of the span gas.
- 3.6 Interference Check.** A method of quantifying analytical interference from components in the stack gases other than the targeted analyte.
- 3.7 Repeatability Check.** A method of demonstrating that an EC operated over a given nominal range provides a stable and consistent response and is not significantly affected by repeated exposure to the targeted analyte.
- 3.8 Response Time.** The amount of time required for the measurement system to display 95 percent of a step change in gas concentration.
- 3.9 Initial EC Cell Temperature.** The temperature of the EC cells recorded during the most recent pretest calibration check.
- 3.10 Sample Flow Rate.** The flow rate of the gas sample through the analyzer. In some situations, EC cells can experience drift with the changes in flow rate. The flow rate must be monitored during calibration and testing.
- 3.11 Measurement Cycle.** A timed three-phase cycle whereby an analyzer's response rises through a ramp-up phase followed by a stable test data collection phase then purged of the gas sample during a refresh phase. The "Ramp-up Phase" exposes the analyzer to the gas sample for 5 minutes ( $t_0 - t_5$ ). The "Test Data Phase" is the time of the stabilized gas sample measurements ( $t_5 - t_7$ ) with recordings starting at  $t_{5.15}$ . The "Refresh Phase" is the timed process where the EC cells are purged or flushed with fresh air ( $t_7 - t_{15}$ ). The refresh phase replenishes requisite  $O_2$  and moisture in the electrolyte reserve and provides a mechanism to de-gas (desorption) the interference gas scrubbers and filters to ensure a stable and accurate EC cell response. A diagram of this measurement cycle is shown in Figure 1A. Measurement cycles can be coupled together for evaluations lasting hours providing all other test method specifications are met. Measurement cycles may deviate from those recommended in this protocol if they are approved by the applicable regulatory agency.
- 3.12 Test Day.** A time not to exceed twelve hours from the time of the pre-test verification to the post-test verification. During this time, testing may occur without further need of calibration providing all other testing specifications have been met.

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**3.13 Pre-Test/Post-Test Verification.** The procedure executed at the beginning and end of each test day to bracket test readings with a controlled performance assurance test.

**3.14 NO<sub>x</sub> Measurement.** If the NO<sub>2</sub> percentage of NO<sub>x</sub> is less than 10 percent, you may either measure NO<sub>2</sub> or estimate total NO<sub>x</sub> by adding to the NO measurement that amount representing the estimated percentage of NO<sub>2</sub>. Historical values may be used to establish the percent of NO<sub>2</sub> provided the determination of NO<sub>2</sub> was based on a stack test. Direct measurement of NO<sub>2</sub> shall be required if the NO<sub>2</sub> percentage is greater than 10 percent of the total NO<sub>x</sub>.

**3.15 "As-verified".** Refers to the analyzer and sampling system configuration as was tested by independent third party organizations (i.e. EPA ETV, SCAQMD, TUV or equivalent).

## 4. MEASUREMENT SYSTEM PERFORMANCE SPECIFICATIONS

**4.1 Zero Calibration Error.** The zero level output shall be less than or equal to  $\pm 3$  percent of the span gas value or  $\pm 1$  ppm, whichever is less restrictive, for the NO, NO<sub>2</sub> and CO channels and less than or equal to  $\pm 0.3$  percent O<sub>2</sub> for the O<sub>2</sub> channel (see Section 6.2.1 for zero calibration procedure).

**4.2 Span Calibration Error.** The average calculated "test data phase" error shall be less than or equal to  $\pm 5$  percent of the span gas value or  $\pm 1$  ppm, whichever is less restrictive, for the NO, NO<sub>2</sub>, CO and O<sub>2</sub> channels. The maximum allowable deviation of any single "test data phase" reading shall be less than or equal to  $\pm 2$  percent or 1ppm, whichever is less restrictive, of the average (see Section 6.2.2 for span calibration procedure).

**4.3 Interference Response.** The CO, NO, and NO<sub>2</sub> interference response must be less than or equal to  $\pm 5$  percent of the span gas concentration. Analyzers that have been verified for interference response by a recognized agency (Section 5.1.10) shall be considered in compliance with this interference check specification. The potential for interference from other flue gas constituents should be reviewed with the analyzer manufacturer based on site-specific data (see Section 6.3 for interference response procedure).

**4.4 Repeatability Check Response.** The calculated average of the "test data phase" for the NO, NO<sub>2</sub> and CO span gases shall not vary more than  $\pm 3$  percent or  $\pm 1$  ppm, whichever is less restrictive, of the span gas value over four measurement cycles (see Section 6.4 for repeatability check procedure).

## 5. APPARATUS AND REAGENTS

**5.1 Measurement System.** Use any measurement system that meets the performance and design

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specifications in Sections 4 and 5 of this method. The sampling system shall maintain the gas sample at conditions that will prevent condensation in the lines or when it contacts the EC cells. A diagram of an acceptable measurement system is shown in Figure 2. The essential components of the measurement system are described below.

**5.1.1 Sample Probe.** Glass, stainless steel or other non-reactive material of sufficient length to traverse the sample points. The sample probe shall be designed to prevent condensation.

**5.1.2 Sample Line.** Non-reactive tubing designed to transport the effluent from the sample probe to the moisture removal system. The sample line shall be designed to prevent condensation.

**5.1.3 Sample Transport Lines.** Non-reactive tubing to transport the sample from the moisture removal system to the electrochemical cell.

**5.1.4 Calibration Assembly.** A three-way valve assembly, tee or equivalent for introducing calibration gases at ambient pressure to the sample probe during calibration checks. The assembly shall be designed such that only calibration gas is processed and that calibration gases flow through all gas path filters.

**5.1.5 Moisture Removal System.** A chilled condenser or similar device to remove condensate continuously from the sample gas while maintaining minimal contact between the condensate and the sample gas shall be required if the  $\text{NO}_2$  portion of  $\text{NO}_x$  is greater than 10 percent. Alternatively, for gas streams with less than 10 percent  $\text{NO}_2$ , a device that uses ambient means to condense moisture from the gas stream before the EC cells is acceptable for this method.

**5.1.6 Particulate Filter.** Filters before the 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 non-reactive to the gas being sampled.

**5.1.7 Sample Pump.** A leak-free pump that will provide the sample gas to the system at a flow rate sufficient to minimize the response time of the measurement system. If upstream of the EC cells, the pump shall be constructed of any material that is non-reactive to the gas being sampled.

**5.1.8 Sample Flow Rate Monitoring.** A rotameter or equivalent device must be used to measure the sample flow rate through the analyzer such that either:

1. The analyzer sample flow rate must not vary by more than  $\pm 10\%$  throughout the pre-test & post-test verification calibrations and source measurement cycles, or
2. The analyzer sample flow rate must be maintained within a tolerance range that does not affect the gas concentration readings by more than  $\pm 3\%$ . This flow rate tolerance range must be as-verified or

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certified by the analyzer manufacturer. (Appendix B)

**5.1.9 Sample Gas Manifold.** A manifold used to divert a portion of the sample gas stream to the analyzer and the remainder to the by-pass discharge vent. This is to be used on high pressure exhaust streams to prevent damage to the measurement system and to avoid false readings. The sample gas manifold should also include provisions for introducing calibration gases directly to the analyzer. The manifold may be constructed of any material that is non-reactive to the gas being sampled.

**5.1.10 Gas Analyzer.** A device containing EC 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 4 and 5 of this method. It is recommended that the analyzer shall be verified for NO<sub>x</sub> measurements by a recognized testing agency (e.g. ETV, SCAQMD or TUV) or as approved by EPA Method 301 verification.

**5.1.11 Data Recorder.** A strip chart recorder, computer or digital recorder for logging analyzer output data. The data recorder resolution (i. e. readability) shall be at least 1 ppm for CO, NO and NO<sub>2</sub>; 0.1% for O<sub>2</sub>; and one degree (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.

**5.1.12 Interference Gas Scrubber.** A device used by some analyzers to remove interfering compounds upstream of a CO electrochemical cell. If external interference gas scrubbers are required in the original as-verified configuration, they must be used with this protocol. The gas scrubber should have a means to determine when the agent is exhausted. The scrubbing agent shall be changed in accordance with the manufacturer's recommendations.

**5.1.13 EC Cell Temperature Indicator.** The analyzer shall be equipped with a temperature measurement device (e.g. thermocouple, thermistor or equivalent) to monitor the EC cell temperature. The temperature may be monitored at the surface, within the cell, or in close proximity to the cells such that it indicates the operating temperature of the cells. At no time shall the analyzer be used outside the manufacturer's recommended operating range.

**5.2 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 and O<sub>2</sub> in nitrogen. Clean, dry air (20.9 percent O<sub>2</sub>) may be used for calibration of the O<sub>2</sub> cell.

**5.2.1 Span Gases.** Used for calibration and error checking. Select concentrations according to procedures specified in Section 2.

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**5.2.2 Zero Gas.** Concentration of less than 0.25 percent of the span gas for each component. Fresh air, free from ambient CO and NO<sub>x</sub> or other combustion gases, may be used.

## 6. MEASUREMENT SYSTEM PERFORMANCE CHECK PROCEDURES

The following procedures define the process to follow in order to verify analyzer performance and accuracy during the test day measurement cycles.

**6.1 Calibration Gas Concentration Verification.** For the span gases, use certified calibration gases. For O<sub>2</sub> calibration and CO and NO<sub>x</sub> zero gas, fresh air, free from ambient CO and NO<sub>x</sub> shall be permitted. Alternative certification techniques may be used if they are approved in writing by the applicable regulatory agency.

**6.2 Pre-Test Verification (Calibration).** Conduct the following procedure once for each nominal range that is to be used on each EC cell before taking test data during the field test day. Repeat the calibration check if a cell is replaced. There is no prescribed order that the EC cells must be calibrated in. However, each cell must complete the measurement cycle during the calibration check. Assemble the measurement system by following the manufacturer's recommended procedures for preparing and preconditioning the gas analyzer. Assure the system has no leaks and verify the gas scrubbing agent is not depleted.

**6.2.1 Zero Calibration Check Procedure.** Calibrate the O<sub>2</sub> EC cell at 20.9 percent using fresh air. For the O<sub>2</sub>, CO, NO and NO<sub>2</sub> EC cells introduce the zero gas and record the reading. Include the time, EC cell temperature, and sample flow rate on a form similar to Figure 3 (see Section 4.1 for specifications).

**6.2.2 Span Calibration Check Procedure.** Individually inject each span gas into the analyzer and record the zero start time ( $t_0$ ). Record all analyzer output responses, the EC cell temperature, and the flow rate during this "ramp-up phase" once per minute for the first 5 minutes. At 5 minutes ( $t_5$ ) begin the "test data phase" and record readings every 15 seconds for a total of two minutes ( $t_{5:15} - t_7$ ) or as required by permit conditions. The "refresh phase" will be performed for the next eight minutes ( $t_7 - t_{15}$ ) with fresh air, free from CO, NO<sub>x</sub> and other pollutants. Record data every minute. Repeat the steps in Section 6.2.2 to verify the calibration for each component gas. Gases shall be injected through the entire sample handling system.

**6.2.3 Calibration Check Calculation.** Calculate mean average of the readings from the "test data phase" ( $t_5 - t_7$ ). The acceptable mean average is within  $\pm 5$  percent of the span gas concentration and the maximum deviation from the average for each of the individual readings ( $t_{5:15} - t_7$ ) is less than or equal to  $\pm$

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2 percent. Record the average value and maximum deviation for each species monitored. Data shall conform to Section 4.2. If an invalid calibration is exhibited, take corrective action and repeat the analyzer calibration check until acceptable performance is achieved (see Figure 1B). The flow rate and EC cell temperature shall conform to the specifications in Section 5.1.8 and 5.1.13, respectively.

*Example: If the span gas value is 100 ppm, the average of the readings for that parameter may be within  $\pm 5$  ppm of 100 ppm, i.e. 95 to 105 ppm. The test cycle is invalid if the maximum deviation of any single reading comprising that average is greater than  $\pm 2\%$  or 2 ppm (i.e. average = 102 ppm; single readings of below 100 ppm and above 104 ppm are disallowed).*

**6.3 Interference Check.** During the calibration check of a single gas species (e.g. CO), record the response displayed by the other EC cells (i.e. NO & NO<sub>2</sub>). Record the interference response for each EC cell to each calibration gas. The interference will conform to the specifications in Section 4.3.

**6.4 Repeatability Check.** Conduct the following procedure once for each nominal range that is to be used on each electrochemical cell (NO, NO<sub>2</sub> and CO) within five days prior to each field test program. If a field-test program lasts longer than five days, this procedure shall be performed before each five days of analyzer operation. Perform the repeatability check if a cell is replaced or if a cell is exposed to gas concentrations greater than 150 percent of the highest span gas concentration.

**6.4.1 Repeatability Check Procedures.** Perform a measurement cycle by injecting the span gas into the analyzer and record the readings. Follow Section 6.2.2 procedures. Record the readings on a form similar to the one found in Figure 3. Repeat the measurements for a total of four cycles. During the repeatability checks, do not adjust the system except where necessary to achieve the correct calibration gas flow rate at the analyzer.

**6.4.2 Repeatability Check Calculations.** Determine the highest and lowest average "test data phase" concentration recorded from the repeatability check and record the results on a form similar to Figure 3. The absolute value of the difference between the maximum and minimum average values recorded during the test must not vary more than  $\pm 3$  percent or 1 ppm whichever is less restrictive of the span gas concentration results (see Figure 1C).

**6.5 Post-Test Verification (Calibration).** Perform the post-test verification calibration check in the same manner as shown in Section 6.2 of this method at the end of each test day. If the post-test verification calibration checks do not meet the specifications, all test data for that component, based upon that test day calibration are null and void and re-calibration and re-testing is required. Make no changes to the sampling system or analyzer calibration until all of the post-test verification checks have been recorded.

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## 7. EMISSION TEST PROCEDURE

### 7.1 Selection of Sampling Site and Sampling Points.

**7.1.1 Reciprocating Engines.** Select a sampling site located at least two stack diameters downstream of any disturbance (e.g. turbocharger exhaust, crossover junction or recirculation take-off) and one-half stack diameter upstream of the gas discharge to the atmosphere. Use a sampling location at a single point near the center of the duct or use the point required by the local regulator.

**7.1.2 Combustion Turbines.** Select a sampling site and sample points according to the procedures in 40 CFR, Part 60, Appendix A, Method 20. An alternative sampling location and/or sample from a single point in the center of the duct may be used if previous test data demonstrate that the stack gas concentrations of CO, NO<sub>x</sub> and O<sub>2</sub> do not vary significantly across the duct diameter. Use of the point required by the local regulator is also acceptable.

**7.1.3 Process Boilers.** Select a sampling site located at least two stack diameters downstream of any disturbance and one-half stack diameter upstream of the gas discharge to atmosphere. Use a sampling location at a single point near the center of the duct or use the point required by the local regulator.

**7.2 Sample Collection.** Prior to sample collection, ensure that the pre-test verification has been performed in accordance with Section 6.2. Zero the analyzer with fresh air. Position the probe at the first sampling point and begin the measurement cycle at the same flow rate used during the calibration check. Begin the 5-minute "ramp-up phase" (  $t_0 - t_5$  ). Record the gas sample readings, sample flow rate and EC cell temperature on a form similar to Figure 3. The "test data phase" runs for two minutes (  $t_5 - t_7$  ). Record the readings at 15-second intervals beginning at  $t_{5.15}$  . The "refresh phase" begins at  $t_7$  and runs for 8 minutes (  $t_7$  to  $t_{15}$  ) or until the analyzer has "refreshed" in accordance with the manufacturer's specification. Record the readings. For each run use the "test data phase" measurements to calculate the average effluent concentration.

**7.3 EC Cell Temperature and Flow Monitoring.** For each measurement cycle, the temperature measurement of the EC cells shall not vary more than  $\pm 10^{\circ}\text{F}$ . The overall EC cell temperature variation shall be less than  $\pm 20^{\circ}\text{F}$  from the pre-test verification check to the final post-test verification check. The sample flow rate shall be in accordance with Section 5.1.8.

**7.4 Post-Test Verification Check.** Conduct the post-test verification check after the test run or set of

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test runs and within 12 hours of the initial calibration check. Conduct span and zero calibration checks using the procedure in Section 6.2. Make no changes to the sampling system or analyzer calibration until all post-test verification checks have been recorded. If the zero or span calibration error exceeds the specification in Sections 4.1 and 4.2 then all test data collected since the previous successful calibration checks are invalid and re-calibration and re-testing is required. If the sampling system is disassembled or the analyzer calibration is adjusted, repeat the calibration check before conducting the next source test.

## 8. EMISSION CALCULATION

The average gas effluent concentration is determined from the mean average gas concentration calculated using the emissions data collected during the "test data phase". Emissions may be calculated and reported in units of the allowable emission limit as specified in the permit or as required by the local agency for purposes of facility compliance. The emissions may be stated in units of pounds per hour (lbs/hr), grams per horsepower-hour (gm/hp-hr), pounds per million Btu (lbs/MMBtu) or as required for the facility. Appendix A provides example test result forms with emission rate calculations, f-factors, and the flow rate certification procedure for analyzer manufactures. Alternately, EPA Reference Method 19 may also be used as the basis for calculating the emissions and EPA Reference Methods 1-4 may be used to obtain a stack volumetric flow rate.

## BIBLIOGRAPHY

1. "Development of an Electrochemical Cell Emission Analyzer Test Method", Topical Report, Phil Juneau, Emission Monitoring, Inc., July 1997.
2. "Determination of Nitrogen Oxides, Carbon Monoxide, and Oxygen Emissions from Natural Gas-Fired Engines, Boilers, and Process Heaters Using Portable Analyzers", EMC Conditional Test Method (CTM-30), Gas Research Institute Method GRI-96/0008, Revision 7, October 13, 1997.
3. "State of Wyoming Air Quality Division Portable Analyzer Monitoring Protocol", Wyoming Department of Environmental Quality, Air Quality Division, January 1999.
4. "Product Data Handbook" Issue 3.0, Volume II: Emissions, City Technology Ltd., December 1996.
5. "Code of Federal Regulations", Protection of Environment, 40 CFR, Part 60, Appendix A, Methods, 1-4, 19, 20.

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## FIGURES

**Figures 1A - Measurement Cycle**

**1B - Span Calibration**

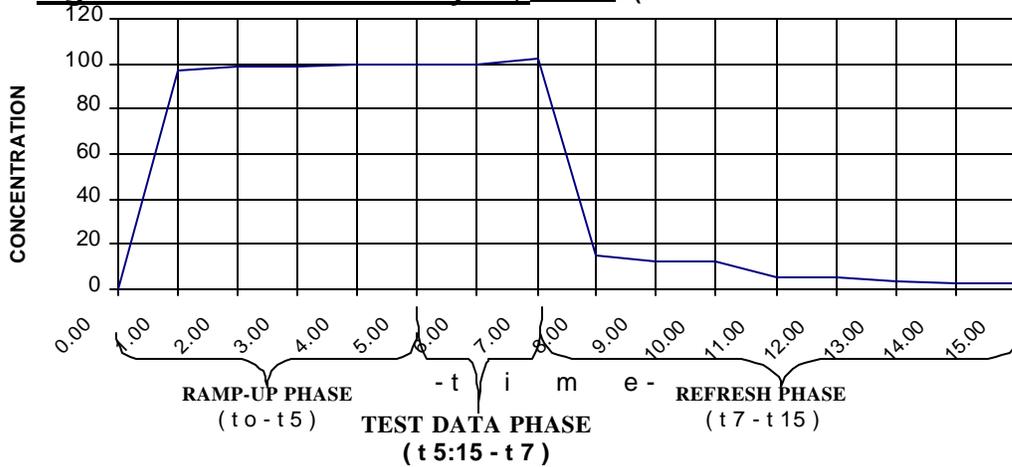
**1C - Repeatability**

**Figure 2 - Calibration & Testing Schematic**

**Figure 3 - Periodic Monitoring Report**

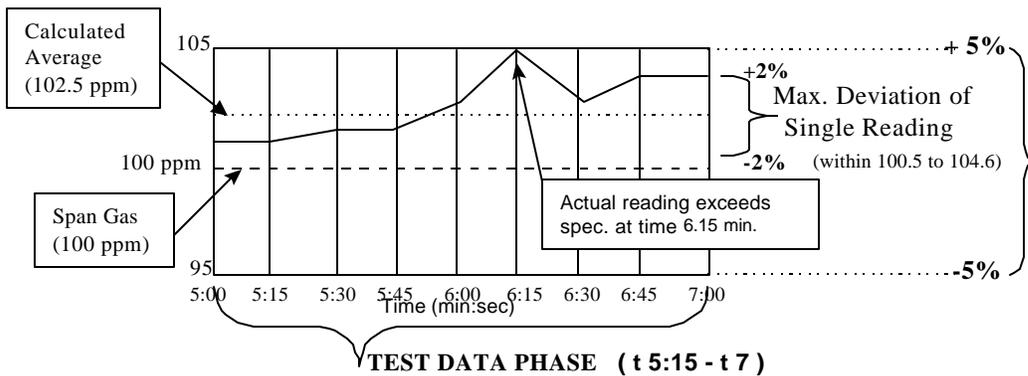
# FIGURES - 1A, 1B, 1C

**Figure 1A - Measurement Cycle, 15 Min.** (For calibration and source measurements)



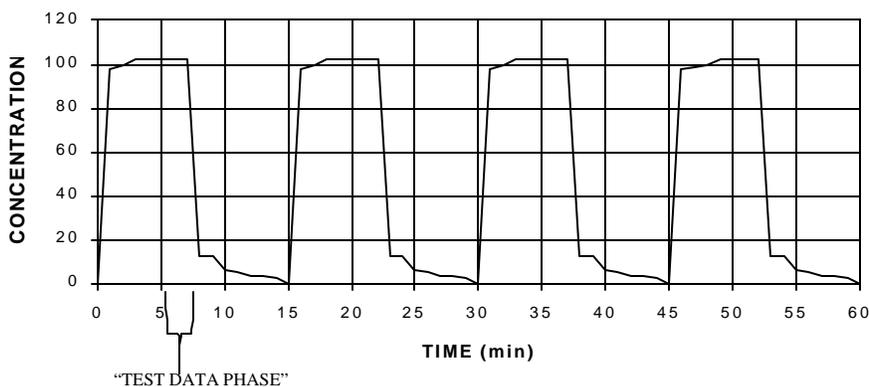
**Figure 1B - Span Calibration** (For span calibration only)

**Span Calibration Error** - The calculated "TEST DATA PHASE" average shall be less than  $\pm 5\%$  of the span or  $\pm 1$  ppm whichever is less restrictive for NO, NO<sub>2</sub>, CO and O<sub>2</sub>. The **Maximum Allowable Deviation** of any single "test data phase" reading shall be  $\pm 2\%$  or 1 ppm, whichever is less restrictive, of the average. (The example below does not meet this specification)

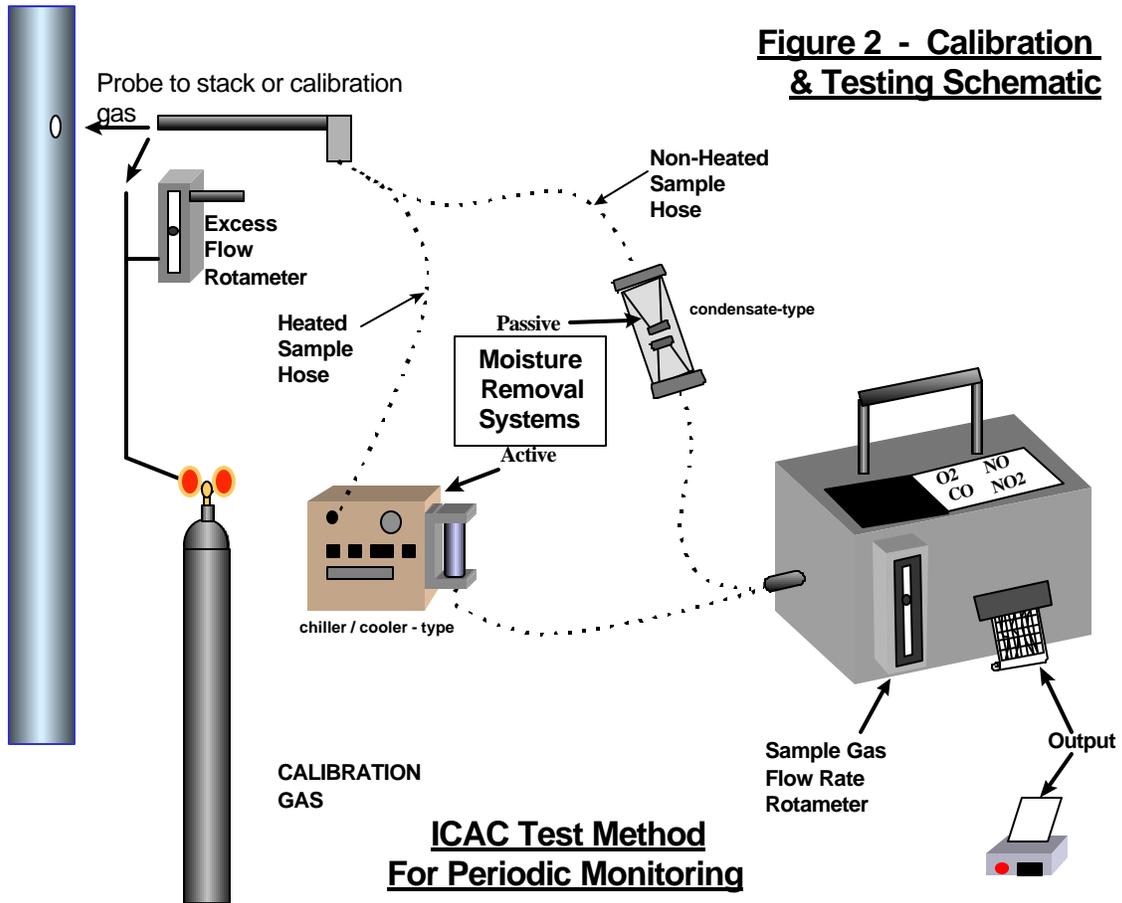


**Figure 1C - Repeatability** 4 Measurement cycles = 1 hour (for repeatability calibration only)

**Repeatability** - The calculated average for the "TEST DATA PHASE" for NO, NO<sub>2</sub> & CO shall not vary more than  $\pm 3\%$  or  $\pm 1$  ppm, whichever is less restrictive, of the span gas value for 4 measurement cycles



**Figure 2 - Calibration & Testing Schematic**



**Figure 3 - Periodic Monitoring Report**

Facility Name & Address Phone					Emission Point			
Analyzer make & model:					Serial #			
<b>Calibration Gas Verification Information</b>								
Calibration Gas Info. (manufacturer, expiration, etc.)		Gas type	O <sub>2</sub> %	CO ppm	NO ppm	NO <sub>2</sub> ppm		
		Concent.						
<b>MEASUREMENT CYCLE (circle measurement task below)</b>								
<i>Pre-Test Verification</i> (zero, span, interference)		<i>Repeatability</i> (once per five days)		<i>Source Test</i> (_____)		<i>Post-Test Verification</i> (zero, span Interference)		
Three Phases	Date:		Analyzer Response				Cell Temp	Flow Rate
	Start time:	AM/	O <sub>2</sub> %	CO ppm	NO ppm	NO <sub>2</sub> ppm		
RAMP- UP Phase	t <sub>1</sub>							
	t <sub>2</sub>							
	t <sub>3</sub>							
	t <sub>4</sub>							
	t <sub>5</sub>							
TEST DATA Phase	t <sub>5:15</sub>							
	t <sub>5:30</sub>							
	t <sub>5:45</sub>							
	t <sub>6:00</sub>							
	t <sub>6:15</sub>							
	t <sub>6:30</sub>							
	t <sub>6:45</sub>							
	t <sub>7:00</sub>							
<i>Mean Average Concentration</i> (sum of t <sub>5:15</sub> through t <sub>7:00</sub> ÷ 8)								
<i>Maximum Deviation (no single reading exceeds ± 2% of mean average)</i>								
<b>Acceptable "Test Data Phase"</b>		<b>Yes or No</b>	<b>Yes or No</b>	<b>Yes or No</b>	<b>Yes or No</b>			
RE- FRESH Phase	t <sub>7</sub>							
	t <sub>8</sub>							
	t <sub>9</sub>							
	t <sub>10</sub>							
	t <sub>11</sub>							
	t <sub>12</sub>							
	t <sub>13</sub>							
	t <sub>14</sub>							
t <sub>15</sub>								
Stop Time AM / PM								
<b>Cell Temperature (± 10°F for each run, Not to exceed 20° F for test day) and Sample Flow Rate are within specifications (± 10% or as verified)</b>						<b>Yes or No</b>	<b>Yes or No</b>	

## APPENDIX A

**Test Results - Boilers & Heaters**  
(Operated at 90% of permitted load or greater during test? Yes or NO)

<b>Facility name, address</b>		<b>Emission Point:</b>
		<b>Test date:</b>

<b>NAME:</b>	<b>DATE:</b>
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Fuel Consumption ( cf/hr, or gal/hr, etc...)	Fuel Heat Content ( Btu/cf, or Btu/gal, etc...)	Boiler / Heater tested firing rate ( MMBtu/hr, or hp/hr, etc...)

The tester may chose to correct the emissions data for a test run using the pre-test verification calibration and post-test verifications results. Use equation below for this correction.

$$C_{GAS} = (C_A - C_{PO}) \times \frac{C_S}{C_{PS} - C_{PO}}$$

- $C_{GAS}$  = corrected flue gas concentration
- $C_A$  = "Test Data Phase" average concentration indicated by portable analyzer
- $C_{PO}$  = average of Pre-test and Post-test Zero check
- $C_{PS}$  = average of Pre-test and Post-test Span checks
- $C_S$  = actual concentration of span gas

**Emission Calculations:**

$$\text{lb/MMBtu NOx} = (\text{ppm NOx}_{\text{corrected}}) (1.19 \times 10^{-7}) (\text{F Factor}_{\text{Note 1}}) \left( \frac{20.9}{20.9 - O_2\%_{\text{corrected}}} \right)$$

$$\text{lb/MMBtu CO} = (\text{ppm CO}_{\text{corrected}}) (7.27 \times 10^{-8}) (\text{F Factor}_{\text{Note 1}}) \left( \frac{20.9}{20.9 - O_2\%_{\text{corrected}}} \right)$$

$$\text{lb/hr NOx} = (\text{lb/MMBtu NOx}) (\text{Heat Input}_{\text{Note 2}})$$

$$\text{lb/hr CO} = (\text{lb/MMBtu CO}) (\text{Heat Input}_{\text{Note 2}})$$

Note 1: Use "F Factor" unless calculated based on the actual fuel gas composition and the higher heating value of the fuel.

Note 2: Heat input shall be based on the average hourly fuel usage rate during the test and the higher heating value of the fuel consumed if the boiler / heater is equipped with a fuel meter or the permitted maximum heat input if a fuel meter is

**NOx ( NO + NO<sub>2</sub> ) Results**

Ave. Tested NO ppm	NO ppm (corrected)	Ave. Tested NO <sub>2</sub> ppm	NO <sub>2</sub> ppm (corrected)	NOx ppm (corrected)	As Tested	Allowable
					lb/MMBtu =	lb/MMBtu =
					lb/hr =	lb/hr =

**O<sub>2</sub> Results**

**CO Results**

Ave. Tested O <sub>2</sub> %	O <sub>2</sub> % (corrected)	Ave. Tested CO ppm	CO ppm (corrected)	As Tested	Allowable
				lb/MMBtu =	lb/MMBtu =
				lb/hr =	lb/hr =

**Test Results - Reciprocating Engines - Below 500 HP**  
 (Operated at 90% of permitted load or greater during test? YES or NO )

Facility name, address		Emission Point: Test date:

**NAME:** \_\_\_\_\_ **DATE:** \_\_\_\_\_

Suction/ Discharge Pressure	RPM	Fuel Throughput "compressed"	Fuel consumed "burned"	Fuel Heat Content	Unit Fuel Useage Spec.	Engine Tested Horsepower

The tester may chose to correct the emissions data for a test run using the pre-test verification calibration and post-test verifications results. Use equation below for this correction.

$C_{GAS} = (C_A - C_{PO}) \times \frac{C_S}{C_{PS} - C_{PO}}$	<p><math>C_{GAS}</math> = corrected flue gas concentration  <math>C_A</math> = "Test Data Phase" average concentration indicated by portable analyzer  <math>C_{PO}</math> = average of Pre-test and Post-test Zero check  <math>C_{PS}</math> = average of Pre-test and Post-test Span checks  <math>C_S</math> = actual concentration of span gas</p>
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**Emission Calculations:**

$$\text{gm/hp-hr NOx} = (\text{ppm NOx}_{\text{corrected}}) (1.19 \times 10^{-7}) (\text{F Factor}_{\text{Note 1}}) (\underline{20.9}) (\text{Specific Fuel Consumption}_{\text{Note 2}}) (10^{-6}) (454) / 20.9 - O_2\%_{\text{corrected}}$$

$$\text{gm/hp-hr CO} = (\text{ppm CO}_{\text{corrected}}) (7.27 \times 10^{-8}) (\text{F Factor}_{\text{Note 1}}) (\underline{20.9}) (\text{Specific Fuel Consumption}_{\text{Note 2}}) (10^{-6}) (454) / 20.9 - O_2\%_{\text{corrected}}$$

$$\text{lb/hr NOx} = (\text{gm/hp-hr NOx}) (\text{Engine Horsepower}_{\text{Note 3}}) / 454$$

$$\text{lb/hr CO} = (\text{gm/hp-hr CO}) (\text{Engine Horsepower}_{\text{Note 3}}) / 454$$

Note 1: Use "F Factor" unless calculated based on the actual fuel gas composition and the higher heating value of the fuel.

Note 2: Use Manufacture's specific fuel composition based on the higher heating value of the fuel. If the manufacturer does not provide a lower heating value, then multiply by 1.11 to obtain the specific fuel consumption based upon the higher heating value of the fuel

Note 3: Use derived operating horsepower (include calculation method). If derived horsepower is not available or cannot be obtained, use site rated horsepower.

**NOx ( NO + NO<sub>2</sub> ) Results**

Ave. Tested NO ppm	NO ppm (corrected)	Ave. Tested NO <sub>2</sub> ppm	NO <sub>2</sub> ppm (corrected)	NOx ppm (corrected)	As Tested	Allowable
					gm/hp-hrs =	gm/hp-hrs =
					lb/hr =	lb/hr =

**O<sub>2</sub> Results**

**CO Results**

Ave. Tested O <sub>2</sub> %	O <sub>2</sub> % (corrected)	Ave. Tested CO ppm	CO ppm (corrected)	As Tested	Allowable
				gm/hp-hrs =	gm/hp-hrs =
				lb/hr =	lb/hr =



				lb/hr =	lb/hr =
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**Test Results - Reciprocating Engines & Combustion Turbines - Above 500 HP w/ Fuel Meter**  
(Operated at 90% of permitted load or greater during test? YES or NO )

<b>Facility name, address</b>		<b>Emission Point:</b> <b>Test date:</b>

**NAME:** \_\_\_\_\_ **DATE:** \_\_\_\_\_

Suction/ Discharge Pressure	RPM	Fuel Throughput "compressed"	Fuel consumed "burned"	Fuel Heat Content	Unit Fuel Usage Spec.	Engine Tested Horsepower

The tester may chose to correct the emissions data for a test run using the pre-test verification calibration and post-test verifications results. Use equation below for this correction.

$$C_{GAS} = (C_A - C_{PO}) \times \frac{C_S}{C_{PS} - C_{PO}}$$

$C_{GAS}$  = corrected flue gas concentration  
 $C_A$  = "Test Data Phase" average concentration indicated by portable analyzer  
 $C_{PO}$  = average of Pre-test and Post-test Zero check  
 $C_{PS}$  = average of Pre-test and Post-test Span checks  
 $C_S$  = actual concentration of span gas

**Emission Calculations:**

**lb/hr NOx = (ppm NOx<sub>corrected</sub>) (1.19x10<sup>-7</sup>) (F Factor<sub>Note 1</sub>) ( 20.9 ) (Heat Input / hr<sub>Note 2</sub>)**  

$$\frac{20.9 - O_2 \% \text{ corrected}}{20.9 - O_2 \% \text{ corrected}}$$

**lb/hr CO = (ppm CO<sub>corrected</sub>) (7.27x10<sup>-8</sup>) (F Factor<sub>Note 1</sub>) ( 20.9 ) (Heat Input / hr<sub>Note 2</sub>)**  

$$\frac{20.9 - O_2 \% \text{ corrected}}{20.9 - O_2 \% \text{ corrected}}$$

**gm/hp-hr NOx = (lb/hr NOx) (454)**  
**(Tested Horsepower<sub>Note 3</sub>) or (Calculated Engine Horsepower<sub>Note 4</sub>)**

**gm/hp-hr CO = (lb/hr CO) (454)**  
**(Tested Horsepower<sub>Note 3</sub>) or (Calculated Engine Horsepower<sub>Note 4</sub>)**

Note 1: Use "F-factor" unless calculated based on the actual fuel gas composition and the higher heating value of the fuel.  
 Note 2: Heat input / hr. (MMBtu/hr) shall be based on the average hourly fuel usage during the test and the higher heating value of the fuel consumed.  
 Note 3: Tested Horsepower is directly determined during test.  
 Note 4: Calculated Engine Horsepower =  $\frac{(\text{Heat Input per Hour}_{\text{Note 2}}) (10^6)}{(\text{Specific Fuel Consumption} - \text{See default below}^*)}$

\* use 9,400 Btu/hp-hr (as default) for 4-cycle and 2-cycle lean burn engines  
 \* use 11,000 Btu/hp-hr (as default) for 2-cycle non-lean burn engines

**For combustion turbine horsepower that cannot be determined during testing, the emissions shall be reported in terms of concentration (ppm by volume, dry basis) corrected to 15 percent O<sub>2</sub>. Calculation to corrected to 15% O<sub>2</sub> is shown below:**

ppm NOx @ 15% O<sub>2</sub> = ppm NOx corrected ( 5.9 ) ppm CO @ 15% O<sub>2</sub> = ppm CO corrected ( 5.9 )

**NOx (NO + NO<sub>2</sub>) Results**

Ave. Tested NO ppm	NO ppm (corrected)	Ave. Tested NO <sub>2</sub> ppm	NO <sub>2</sub> ppm (corrected)	NOx ppm (corrected)	As Tested	Allowable
					gm/hp-hrs =	gm/hp-hrs =
					lb/hr =	lb/hr =

**O<sub>2</sub> Results**

**CO Results**

Ave. Tested O <sub>2</sub> %	O <sub>2</sub> % (corrected)	Ave. Tested CO ppm	CO ppm (corrected)	As Tested	Allowable
				gm/hp-hrs =	gm/hp-hrs =
				lb/hr =	lb/hr =

## F-Factors

An “F-Factor” is the ratio of the gas volume of the products of combustion to the heat content of the fuel.

$F_d$  - Dry Factor, Includes all components of combustion less water.

$F_w$  - Wet Factor, Includes all components of combustion.

$F_c$  - Carbon Factor, Includes only carbon dioxide

Note: Since F-Factors include water resulting only from combustion of hydrogen in the fuel, The procedures using  $F_w$  factors are not applicable for computing emissions from steam generating units with wet scrubbers or with other processes that add water (e.g. steam injection).

<b>F- Factors for Various Fuels <sup>1</sup></b>						
<b>Fuel Type</b>	<b><math>F_d</math></b>		<b><math>F_w</math></b>		<b><math>F_c</math></b>	
	<b>dscm / J</b>	<b>dscf /10<sup>6</sup> Btu</b>	<b>wscm / J</b>	<b>wscm /10<sup>6</sup> Btu</b>	<b>scm / J</b>	<b>scf /10<sup>6</sup> Btu</b>
<b>Coal:</b>						
Anthracite <sup>2</sup>	$2.71 * 10^{-7}$	10000	$2.83 * 10^{-7}$	10540	$0.530 * 10^{-7}$	1970
Bituminus <sup>2</sup>	$2.63 * 10^{-7}$	9780	$2.86 * 10^{-7}$	10640	$0.484 * 10^{-7}$	1800
Lignite	$2.65 * 10^{-7}$	9860	$3.21 * 10^{-7}$	11950	$0.513 * 10^{-7}$	1910
<b>Oil<sup>3</sup></b>	$2.47 * 10^{-7}$		$2.77 * 10^{-7}$	10320	$0.383 * 10^{-7}$	1420
<b>Gas:</b>						
Natural	$2.43 * 10^{-7}$	8710	$2.85 * 10^{-7}$	10610	$0.287 * 10^{-7}$	1040
Propane	$2.34 * 10^{-7}$	8710	$2.74 * 10^{-7}$	10200	$0.321 * 10^{-7}$	1190
Butane	$2.34 * 10^{-7}$	8710	$2.79 * 10^{-7}$	10390	$0.337 * 10^{-7}$	1250
<b>Wood</b>	$2.48 * 10^{-7}$	9240			$0.492 * 10^{-7}$	1830
<b>Wood bark</b>	$2.58 * 10^{-7}$	9600			$0.516 * 10^{-7}$	1920
<b>Municiple</b>	$2.57 * 10^{-7}$	9570			$0.488 * 10^{-7}$	1820
<b>Solid Waste</b>	*****					

<sup>1</sup> Determined at standard conditions : 20° C (68° F) and 760 mm (29.92 in Hg).

<sup>2</sup> As classified according to ASTM D388-77.

<sup>3</sup> Crude, residual, or distillate.

Reader note: F-Factor table copied from US EPA 40 CFR, Pt 60, Appendix A, Method 19 -Determination of Sulfur Dioxide Removal efficiency and Particulate Marter, Sulfer Dioxide and Nitrogen Oxides Emissions Rates.

**APPENDIX B**

## ICAC Test Method For Periodic Monitoring

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### Batch Testing of Portable Gas Analyzer Flow Rate.

#### **Background**

In order to meet the requirements of Section 5.1.8 for sample flow rate, the manufacturer has the option of providing the user with a maximum and minimum allowable sample flow rate (outside of the method specified  $\pm 10$  percent) provided that the manufacturer performs a batch certification of flow rate vs. gas reading shift.

#### **Procedure**

##### Size of Batch

The manufacturer must randomly sample a portable gas analyzer once every three months or every 50 units, whichever comes first, from a production batch.

##### Testing

The manufacturer must monitor the flow rate of the sample and the gas concentration of the calibration (pollutant) gas continuously. Once the analyzer has reached a stable gas reading. The flow rate and concentration are recorded. The sample flow rate is then changed to the minimum recommended flow rate in 0.1 liter increments / min, through the full range of certified flow. The manufacturer must record the gas readings for each increment and compare these against the initial analyzer reading.

Each test must consist of three (3) identical runs. Each error band must include a standard deviation at 95 percent confidence level interval (per US EPA 40 CFR 60 Appendix B, PS1).

##### Documentation

The manufacturer must provide a certificate with each analyzer indicating conformance with the requirements of Section 5.1.8.