SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

PROTOCOL FOR THE PERIODIC MONITORING OF NITROGEN OXIDES, CARBON MONOXIDE, AND OXYGEN FROM STATIONARY ENGINES SUBJECT TO SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT RULE 1110.2

November 2007

ENGINEERING AND COMPLIANCE DIVISION
INDUSTRIAL BRANCH

SOURCE TEST ENGINEERING BRANCH
MONITORING & ANALYSIS

PROTOCOL FOR THE PERIODIC MONITORING OF NITROGEN OXIDES, CARBON MONOXIDE, AND OXYGEN FROM SOURCES SUBJECT TO SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT RULE 1110.2

1.0 OVERVIEW AND APPLICABILITY

This protocol is applicable to the determination of nitrogen oxides (NO and NO_2), carbon monoxide (CO), and oxygen (O_2) concentrations in emissions from engines subject to South Coast Air Quality Management District (AQMD) Rule 1110.2 using portable electrochemical analyzers. This protocol is limited to engines that use fuels such as natural gas, propane, butane, gasoline, landfill gas, digestor gas, refinery gas and fuel oils and relies upon EPA Conditional Test Method CTM-030 (see Attachment I). Deviations from CTM-030 have been adopted in order to simplify the procedure, while still providing a reasonable assurance of compliance. When CTM-030 and this protocol are in disagreement, this protocol shall supercede. This protocol is not intended to replace the EPA reference methods of 40 CFR Part 60, Appendix A, or AQMD source test methods, but rather to facilitate the measurement of emissions on a periodic monitoring schedule. These test results, along with other pertinent information, may be considered by AQMD as credible evidence of compliance or non-compliance with Rule 1110.2. AQMD reserves the right to modify this protocol without advance notice.

When engines subject to Rule 1110.2 cannot be tested using this protocol, the protocol may be modified following written approval of the Executive Officer. The latest version of the protocol can be found on the AQMD web site.

2.0 MEASUREMENT SYSTEM PEFORMANCE SPECIFICATIONS AND APPARATUS

Use any measurement system that meets the performance and design specifications in Sections 4 and 5 of CTM-030 and the requirements of this protocol. The measurement system shall maintain the gas sample at conditions that will prevent condensation in the lines or when it contacts the electrochemical cells. Additions to, or modifications of, vendor supplied electrochemical analyzers (e.g. heated sample lines, thermocouples, flow meters, etc.) may be required to meet the specifications indicated in this protocol.

For gas streams where the NO_2 portion of total NO_x is less than or equal to 10 percent (based on average test data collected according to an approved source test or this protocol), use of the NO_2 electrochemical cell is voluntary.

2.1 SENSITIVITY

The minimum detectable limit depends on the nominal range and resolution of the electrochemical cell and signal to noise ratio of the measurement system. For the CO, NO, and NO_2 electrochemical cells, the minimum detectable limit shall be less than or equal to 3 percent of the selected range or 1 ppm, whichever is less restrictive. For the O_2

electrochemical cell, the minimum detectable limit shall be less than or equal to 0.3 percent O_2.

2.2 INTERFERENCE RESPONSE

The CO, NO, and NO_2 interference response must be less than or equal to ± 5 percent of the span gas concentration. Refer to Section 7.7 of CTM-030 for the calculation method. Analyzers that have been verified for interference response by a recognized agency (e.g. ETV or TUV), or as approved by EPA Method 301 verification, shall be considered in compliance with this interference check specification.

Notwithstanding the interference checks required by CTM-030, an annual interference check of the NO and NO_2 electrochemical cells shall be performed for combustion devices which have a potential to emit SO_2 concentrations greater than 10 ppm. The interference check procedure shall consider both positive and negative biases in the data, and shall demonstrate (using an equation similar to that in Section 6.3.1 of CTM-030) that the combined NO and NO_2 interference responses due to SO_2 contribute less than 5 percent of the NO_x concentration in the emissions. The facility shall justify the SO_2 concentration selected for interference verification using historical data or mass balance calculations.

The potential for interference from other flue gas constituents should be reviewed with the electrochemical analyzer manufacturer based on site-specific data.

2.3 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 NO_2 portion of NO_x (based on average test data collected according to an approved source test or this protocol) is greater than 10 percent. Alternatively, for gas streams with less than 10 percent NO_2 a device that uses ambient means to condense moisture from the gas stream before the electrochemical cells is acceptable for this protocol. All sampling system components shall be non-reactive with nitrogen dioxide.

2.4 ELECTROCHEMICAL CELL TEMPERATURE INDICATOR

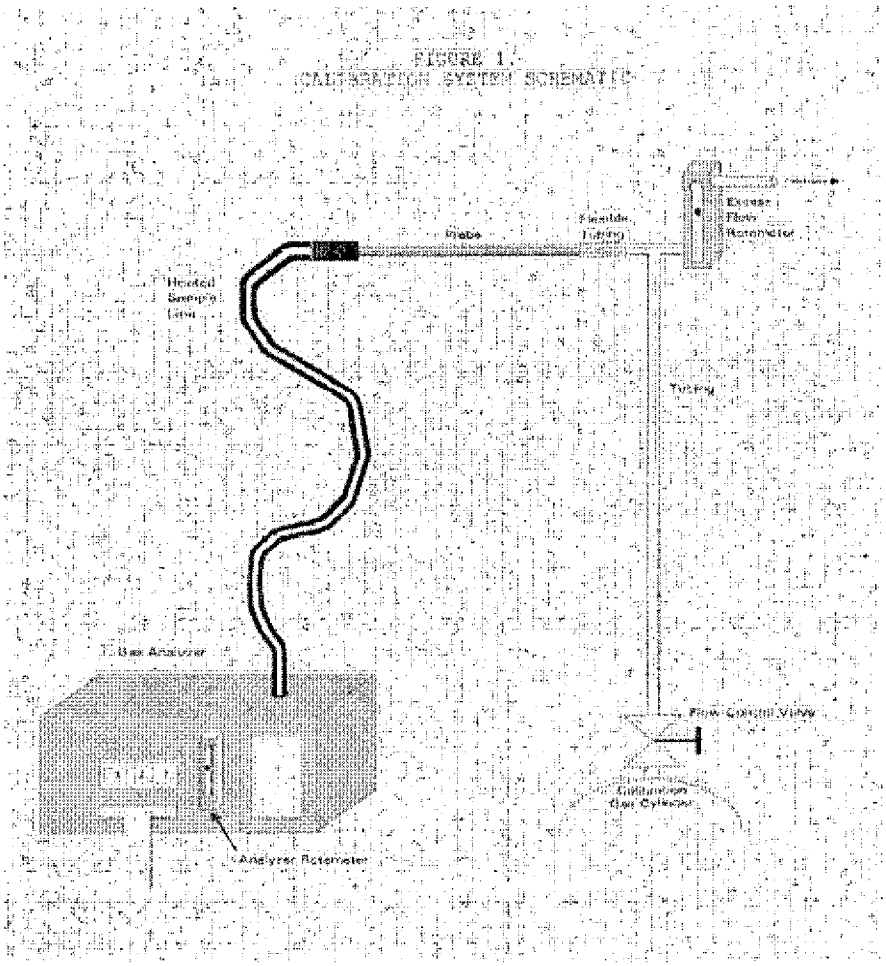
The analyzer shall be equipped with a temperature measurement device to monitor the electrochemical cell temperature. The temperature may be monitored at the surface, within the cell, or in close proximity to the cells such that it indicates the operating temperature of the cells. At no time shall the analyzer be used outside the manufacturer's recommended operating range.

2.5 DATA RECORDER

The data shall be recorded using procedures in Section 5.1.10 of CTM-030. The data recorder must allow each data point to be read at least once every 15 seconds.

2.6 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. Figure 1 is a diagram of the calibration assembly.



2.6 CALIBRATION GAS

Use EPA Protocol 2 gases which are certified to a minimum accuracy of ± 2 percent, or NIST traceable calibration gases. Fresh air, which is defined as air free from ambient CO, NO_x, and other pollutants, is permitted for O_2 calibration, at 20.9% O_2, and as a zero gas for CO and NO_x. The instrument and the electrochemical cell design will determine the analytical range for each gas component.

Select a span calibration gas concentration, span gas, that is within the analytical range for each of the CO, NO, and NO_2 electrochemical cells, such that the expected average stack gas readings for each test are between 25 and 150 percent of the span gas selected. The nominal range is defined as zero to the span gas selected.

3.0 MEASUREMENT SYSTEM PERFORMANCE CHECK PROCEDURES

The following procedures define the steps to follow in order to verify measurement system performance and accuracy. For each set of field emissions tests, perform a successful pre-test (Section 3.1) and post-test calibration check (Section 3.2) within ten calendars days of each other. Conduct a linearity check (Section 3.3), stability check (Section 3.4), and interference test (Section 3.5) every 12 months, or more often, as necessary, to ensure proper operation of the electrochemical cells.

For gas streams where the NO_2 portion of NO_x is less than or equal to 10 percent (based on average test data collected according to an approved source test or this protocol), use of the NO_2 electrochemical cell is voluntary.

3.1 PRE-TEST 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 by plugging the probe tip and observing that the sample flow rate goes to zero, and verify the gas scrubbing agent is not depleted. Energize sample pump and allow portable electrochemical analyzer to warm up to ambient temperature. Conduct the following procedures for each electrochemical cell within 10 calendar days of the field emissions tests and the post-test calibration check.

3.1.1 Zero Calibration Check

Calibrate the O_2 electrochemical cell at 20.9 percent using fresh air free from ambient CO, NO_x, and other pollutants. Next, introduce the O_2, CO, NO, and NO_2 zero calibration gas at the probe tip using the calibration assembly shown in Figure 1. During this check, do not make adjustments to the system except those necessary to achieve the correct calibration gas flow rate at the analyzer. Set the flow rate to the value recommended by the manufacturer. Allow the electrochemical cell response to stabilize for at least thirty seconds, before recording the result. After achieving a stable response, disconnect the gas and briefly purge with fresh air.

The zero level reading for CO, NO, and NO_2 shall be less than or equal to ± 3 percent of the span gas value or ± 1 ppm, whichever is less restrictive, and less than or equal to ± 0.3 percent O_2 for the O_2 electrochemical cell.

3.1.2 Span Calibration Check

Individually inject each span gas into the analyzer at the probe tip using the calibration assembly. Allow the electrochemical cell response to stabilize within ± 5 percent of the mean reading, for at least thirty seconds, before recording the result. If the analyzer response for the CO, NO, or NO_2 electrochemical cells must be re-set during the pre-test calibration check, never during the post-test calibration check, follow manufacturer's instructions. After achieving a stable response, disconnect the gas and briefly purge with fresh air. Repeat these steps for each span gas.

The span gas reading for the CO, NO and NO_2 electrochemical cells shall be within ± 5 percent of the span gas value and within ± 0.5 percent O_2 for the O_2 electrochemical cell.

3.2 POST-TEST CALIBRATION CHECK

After the field emission tests, and within 10 calendar days of the last successful pre-test calibration check, perform the post-test calibration check in the same manner as the pre-test calibration check, Section 3.1. If the emission test results are within 5 percent of engine's emission limits, then the post-test calibration must be performed immediately after the test period to verify compliance. Make no changes to the sampling system or analyzer calibration until the post-test calibration check has been recorded.

The difference between the pre-test calibration and post-test calibration span gas readings, which is defined as drift, shall not exceed ± 5 percent for CO, NO, NO_2 and O_2. If the post-test calibration drift is greater than ± 5 percent but less than ± 10 percent for CO, NO, NO_2 and/or O_2 and the corrected concentration is less than 75% of the emission limit, then the test is considered valid for demonstrating compliance. Otherwise, the testing does not meet the specifications, all test data for that component are null and void, and re-calibration and re-testing are required.

3.3 LINEARITY CHECK

Conduct the following procedure once for each nominal range that is to be used on each electrochemical cell, CO, NO, O_2 and NO_2. Repeat the linearity check if an electrochemical cell is replaced. Linearity may be checked using a gas divider if it is calibrated according to EPA Method 205.

3.3.1 Linearity Check Procedure

Select mid-level calibration gases for CO, O_2, NO, and NO_2 that are 40 to 60 percent of the nominal range. Follow the procedure for the Pre-Test Calibration Check, Section 3.1, and then introduce the mid-level calibration gas for each electrochemical cell at the probe tip using the calibration assembly. During this check, do not make adjustments to the system except those necessary to achieve the correct calibration gas flow rate at the analyzer. Set the flow rate to the value recommended by the manufacturer. Allow each reading to stabilize within ± 5 percent of the mean reading, for at least thirty seconds, before recording the result. After achieving a stable response, disconnect the gas and briefly purge with fresh air.

The mid-level analyzer response shall be within ± 3 percent of the mid-lever span gas concentrations for NO, O_2, CO and NO_2 cells.

3.4 STABILITY CHECK

Conduct the following procedure once for each nominal range that is to be used on each electrochemical cell, CO, NO, and NO_2. Repeat the stability check if an electrochemical cell is replaced or exposed to gas concentrations greater than the analytical range of electrochemical cell specified by the manufacturer.

3.4.1 Stability Check Procedure

Energize sample pump and allow portable electrochemical analyzer to warm up to ambient temperature. Introduce the span gas for each electrochemical cell at the probe tip using the calibration assembly and record the analyzer response at least once per minute until the conclusion of the test. During this check, do not make adjustments to the system except those necessary to achieve the correct calibration gas flow rate at the analyzer. Set the flow rate to the value recommended by the manufacturer. After the analyzer response has stabilized, continue to flow the gas for at least 30-minutes. At the end of the check, disconnect the gas and briefly purge with fresh air.

The analyzer response to CO, NO, and NO_2 span gases shall be within ± 2.5 percent of the span gas value over a 30-minute period. As an alternative, the system will pass a stability check if it is within ± 1 percent of the span gas value over a 15-minute period.

3.5 INTERFERENCE CHECK

An NO and NO_2 interference response of the CO electrochemical cell shall be performed once for each CO electrochemical cell, and repeated if the cell is replaced, by using the CO interference response procedure listed in CTM-030 Section 6.3. The interference response check shall be performed by injecting a NO span gas, balance nitrogen, to determine the positive response by the CO electrochemical cell. Then a NO_2 span gas in either balance nitrogen or air is inserted into the CO electrochemical cell to determine the positive interference response by the CO cell.

3.6 CALCULATIONS

a. The following equation shall be used to determine the calibration error (E_{CAL}) for the zero and span calibration checks (Sections 3.1.1 and 3.1.2):

$$E_{CAL} = \left(\frac{\text{Analyzer Response} - \text{Cal. Gas Concentration}}{\text{Cal. Gas Concentration}} \right) \times 100\%$$

b. The following equation shall be used to determine the drift between the pre-test calibration and post-test calibration checks (Section 3.2):

$$\text{Drift} = \left(\frac{\text{Post Test Analyzer Response} - \text{Pre Test Analyzer Response}}{\text{Pre Test Analyzer Response}} \right) \times 100\%$$

c. The following equations shall be used to determine the linearity (E_{LIN}) (Section 3.3):

$$E_{LIN} = \left(\frac{\text{Mid-Span Analyzer Response} - \text{Mid. Span Gas Value}}{\text{Mid. Span Gas Value}} \right) \times 100\%$$

4.0 EMISSION TEST PROCEDURE

All engines shall be tested "as-found." No tuning or maintenance for the purpose of lowering tested emissions is allowed within 24 hours prior to testing or during testing.

4.1 SELECTION OF SAMPLING SITE AND SAMPLING POINTS

Select a sampling point located at least two stack diameters downstream of any disturbance (e.g. turbocharger exhaust, crossover junction, or recirculation take-off) and at least one-half stack diameter upstream of the gas discharge to the atmosphere. Typically, the existing sampling port will satisfy these conditions. Use a sample location at a single point near the center of the duct. If previous test data demonstrates that the stack gas concentration varies significantly across the duct diameter, greater than 10 percent, then traverse sampling shall be performed along one cross-sectional axis of the stack, using three points located at positions of 16.7, 50, and 83.3 percent of the stack diameter.

4.2 ELECTROCHEMICAL CELL TEMPERATURE AND FLOW MONITORING

Do not interrupt the flow to the portable analyzer and maintain a constant sampling rate (± 15 percent of the analyzer flow rate value experienced during the Pre-Test Calibration Check) during the entire test run. At no time shall the electrochemical cells be used outside the manufacturer's recommended operating range.

4.3 SAMPLE COLLECTION

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. Zero the electrochemical analyzer with fresh air. Energize sample pump and allow portable electrochemical analyzer to warm up to ambient temperature.

Sample the stack gas for an equal period of time at each test point. At the start of the test, record the time, ambient temperature, and operating condition of the engine. Record emission data at least every 15-seconds for a minimum of 15-minutes using procedures in Section 5.1.10 of CTM-030. Note that although at least 15-minutes of testing will be conducted, the actual sampling time will be greater, depending on the response time or stability time of the analyzer. Record the general operating conditions and load of the engine during the test. Operating conditions include the parameters required to be monitored by the Inspection and Monitoring Plan.

At the end of the test, conduct a post-test leak check of the measurement system, and then disconnect the gas and briefly purge with fresh air. If multiple engines are to be tested at a single facility, the post-test leak check may be postponed until after the last unit is tested. However, the analyzer shall be purged with fresh air between units, and if the measurement system fails the final post-test leak check, then all of the testing after the last successful leak check is null and void and re-testing is required.

4.4 CALCULATIONS AND DETERMINATION OF COMPLIANCE

The following procedure will determine the mean concentration of NO_x and CO, adjusted for calibration results and corrected to 15 percent O_2, to determine compliance with Rule 1110.2 and equipment permit condition emission limits for each test.

a. Determine the arithmetic mean of each gas concentration (NO, NO_2, CO and O_2) measured during the test period.

b. The mean of each measured concentration (NO, NO_2, CO and O_2) shall be corrected using the following equation to give values adjusted for the pre-test calibration and post-test calibration results (C_{ADJ}):

$$C_{ADJ} = (C_{MEAS} - C_{CZ}) \times \left(\frac{C_{CAL}}{C_{CM} - C_{CZ}} \right)$$

Where: C_{ADJ} = pollutant concentration adjusted for calibration, parts per million dry and by volume (ppmdv)

C_{MEAS} = measured pollutant concentration, ppmdv

C_{CAL} = span gas concentration, ppmdv

C_{CZ} = average concentration of the pre-test and post-test analyzer responses to zero gas, ppmdv

C_{CM} = average concentration of pre-test and post-test analyzer responses to span gas, ppmdv

c. Add NO and NO_2, together to determine NO_x.

d. Compute the corrected concentrations with the following formula using adjusted concentrations (C_{ADJ}) to determine compliance with emission limits for NO_x and CO:

$$N = (C_{ADJ}) \times \left(\frac{20.9 - 15}{20.9 - O_2} \right)$$

Where: N = NO_x or CO concentration corrected to 15% O_2, ppmdv

C_{ADJ} = pollutant concentration of NO_x or CO adjusted per Section 4.4(b), ppmdv

O_2 = oxygen concentration (%), dry basis, measured in the flue gas and adjusted per Section 4.4(b)

5.0 TESTING UNDER NON-IDEAL CONDITIONS

The following is a discussion of some common non-ideal testing conditions and their solutions in source testing:

5.1 LOAD CHANGES

If there are fluctuations in the process or operating conditions, such as changes in load, the testing may continue as long as the operating conditions are recorded to show each fluctuation. If the engine shuts down completely or if there are severe fluctuations during sampling, testing must be repeated for a minimum of 15 continuous minutes during

acceptable operating conditions. All changes in process and operating conditions and test interruptions must be noted with the beginning and ending times of each occurrence on the field data sheets.

5.2 BYPASS STACK

If there are dampers or bypass stacks present, testing shall be conducted as follows:

a. If excess air is frequently introduced to the exhaust stack at a variable rate, concentration testing shall be performed while no excess air is introduced to the exhaust stack.

5.3 MULTIPLE STACKS

For multiple stacks, perform sampling at each of the stacks during acceptable testing conditions. Sampling at each stack need not be performed simultaneously.

5.4 OTHER NON-IDEAL TESTING CONDITIONS

If other non-ideal testing conditions exist (e.g. stack gas oxygen concentration greater than 19 percent), the facility must submit a source test protocol for review and written approval by the Executive Officer prior to testing.

6.0 RECORDKEEPING REQUIREMENTS

6.1 MEASUREMENT SYSTEM LOG

Maintain a bound log, available upon request, for each individual measurement system that includes the following records for 5 years. Electronically stored records are acceptable alternatives for 'hard copies' only if reproducible electronic and/or hard copies are retrievable upon request.

a. Linearity and Stability Tests Recordkeeping Form (Form 1), which must be completed and signed by trained personnel.

b. Calibration Recordkeeping Form (Form 2), which must be completed and signed by trained personnel.

c. Certificates of analysis for all calibration gases listed on Forms 1 and 2.

d. All maintenance and service records, including but not limited to dates that electrochemical cells and filters were replaced, and replacement parts purchase records.

6.2 ENGINE COMPLIANCE LOG

Maintain a bound log on-site, available for inspection at any time, which includes the following records for 5 years, as required by Rule 1110.2. Electronically stored records are acceptable alternatives for 'hard copies' only if reproducible electronic and/or hard copies are immediately retrievable for inspection at any time.

a. Periodic Monitoring Recordkeeping Form (Form 3), which must be completed and signed by trained personnel.

b. Source test reports, including those required per Rule 1110.2.

c. Inspection and Monitoring Plan.records.

d. Operating log.

7.0 REPORTING REQUIREMENTS

If any testing conducted according to this protocol determines that emission concentrations have exceeded either Rule 1110.2 or equipment permit condition emission limits, the operator shall comply with the following requirements:

a. For excess emissions caused by a breakdown, notify AQMD at 1-800-CUT-SMOG within one hour of learning of the breakdown in the same manner required by paragraph (b)(1) of Rule 430. This report is not required if there is no breakdown.

b. Immediately correct the noncompliance or shut down the engine within 24 hours or the end of an operating cycle, whichever is sooner; and

c. Comply with all other requirements of Rule 1110.2 (f)(1)(H) if there was a breakdown.

d. Title V facilities must also notify AQMD at 1-800-CUT-SMOG within 72 hours of learning of learning of any emission exceedance and submit a written report with 14 days using Form 500-N Deviations, Emergencies & Breakdowns.

e. Submit to AQMD the quarterly report required by Rule 1110.2 (f)(1)(H)(iii) within 15 days of each of each calendar quarter.

FORM 1

Linearity and Stability Tests Recordkeeping Form

FORM 1 -- Linearity and Stability Tests Recordkeeping Form For Portable Analyzers

RULE 1110.2 Emissions from Gaseous- and Liquid-Fueled Engines

ANALYZER(Make/Model)	**Analyzer S/N:**
OPERATOR	
Date of Last Linearity Check	Date of Last Stability Check
Requirement: Linearity less than or equal to 3% of the mid span gas concentration	Requirement: Response within 1% of Span start for 15 min or 2.5% for 30 min.
A linearity check must be conducted each time a cell is replaced	A stability check must be conducted each time a cell is replaced.

Linearity Check

Date of Linearity Check

Constituent	CO (ppm)	NO (ppm)	NO_2 (ppm)	O_2 (ppm)
Zero Gas				
Mid Span Gas				
High Span Gas				
Reading, Zero				
Reading, Mid				
Reading, High				
Linearity, E_{LIN}, %				

Calculations for Linearity are described in Section 3.6 of the Periodic Monitoring Protocol

Stability Check

Date of Stability Check:

Constituent	CO (ppm)	NO (ppm)	NO_2 (ppm)	O_2 (ppm)
Reading, Span Start				
Reading, 15 min				
Reading, 30 min				
Stability, %, 15 min				
Stability, %, 30 min				

Stability fraction is the absolute difference between the initial and final reading divided by the start reading. The stability percentage is the stability fraction times 100.

CERTIFICATION: Based on the information and belief formed after reasonable inquiry, I certify that the statements and information contained in this report are true, accurate, complete and representative of the emissions from this source.

Test Conducted By

Signature

Title

Date

FORM 2

Calibration Recordkeeping Form

FORM 2 CALIBRATION RECORDKEEPING ☐ Pre-Test Calibration ☐ Post-Test Calibration

RULE 1110.2 Emissions from Gaseous- and Liquid-Fueled Engines

DATE: _____ TIME (start/stop): _____ / _____ NAME: _____

MONITOR: _____

Gas Constituent	Cylinder	Expiration Date	Cylinder Conc.	Reading 1	Reading 2	Reading 3	Reading 4

**If the reading is re-calibrated, then put an "R" next to it in the box*

FORM 3

Periodic Monitoring Recordkeeping Form

FORM 3 -- Periodic Monitoring Recordkeeping Form For Portable Analyzers

RULE 1110.2 Emissions from Gaseous- and Liquid-Fueled Engines

FACILITY NAME:

ANALYZER (Make/Model):

Facility ID Number:

Analyzer S/N:

Engine Name:

Date of Last Stability Check[1]:

Permit to Operate:

Date of Last Linearity Check[2]:

Application No.:

1. Stability check must be conducted within 12 months of test date
2. Linearity check must be conducted within 12 months of test date

"As Found" PM Test Results

Time Start: Date:

Time End:

Constituent	CO (ppm)	NO (ppm)	NO_2 (ppm)	O_2 (ppm)
Measured, C_{MEAS}				
Cal Adjusted, C_{CORR}				

Example Calculation: $$C_{ADJ} = (C_{MEAS} - C_{CZ}) \times \left(\frac{C_{CAL}}{C_{CM} - C_{CZ}} \right)$$

Constituent	CO (ppm)	NO_x (ppm)
C_{ADJ} @ 15% O_2, N		
Compliance Limit		
Difference		

In Compliance?

☐Yes ☐No, Call 1-800-CUT-SMOG within 1 hr. if a breakdown. See Protocol for other reporting

Calibration Results

Date of Pre-Test Calibration:

Date of Post-Test Calibration:

Constituent	CO (ppm)	NO (ppm)	NO_2 (ppm)	O_2 (ppm)
Pre-Test Zero				
Post-Test Zero				
Mean Zero, C_{CZ}				
Span Gas, C_{CAL}				
Pre-Test Span				
Post-Test Span				
Mean Span, C_{CM}				
Drift, %				

Drift Calculation is listed in Section 3.6, Periodic Monitoroing Protocol

CO Interference Response, NO Gas		

"As Left" PM Test Results

Time Start: Date:

Time End:

Constituent	CO (ppm)	NO (ppm)	NO_2 (ppm)	O_2 (ppm)
Measured, C_{MEAS}				
Cal Adjusted, C_{ADJ}				

Constituent	CO (ppm)	NO_x (ppm)
C_{ADJ} @ 15% O_2, N		
Compliance Limit		
Difference		

In Compliance?

☐Yes ☐No, Call 1-800-CUT-SMOG within 1 hr. if a breakdown. See Protocol for other reporting

Note engine parameters during test, and describe any measures taken after the "As Found" Test to bring the engine into compliance (attach additional documentation as necessary):

CERTIFICATION: Based on the information and belief formed after reasonable inquiry, I certify that the statements and information contained in this report are true, accurate, complete and representative of the emissions from this source.

Test Conducted By

Signature

Title

Date

ATTACHMENT I

EPA CONDITIONAL TEST METHOD

CTM-030

Determination of Nitrogen Oxides, Carbon Monoxide, and Oxygen Emissions from Natural Gas-Fired Engines, Boilers and Process Heaters Using Portable Analyzers

1. APPLICABILITY AND PRINCIPLE

1.1 Applicability. This method is applicable to the determination of nitrogen oxides (NO and NO_2), carbon monoxide (CO), and oxygen (O_2) 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 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 continuously extracted from a stack and conveyed to a portable analyzer for determination of NO, NO_2, CO, and O_2 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 (e.g. heated sample line, flow meters, etc.) may be required to meet the design specifications of this test method.

2. RANGE AND SENSITIVITY

2.1 Analytical Range. 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.

2.1.1 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 percent 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 percent of the span gas at any time during the sampling run then the test run for that channel is invalid.

2.1.2 NO_2 Span Gas. Choose a span gas concentration such that the average stack gas reading for each test run is greater than 25 percent 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_2 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 percent of the span gas at any time during the sampling run then the test run for that channel is invalid.

2.1.3 O_2 Span Gas. The difference between the span gas concentration and the average stack gas reading for each run shall be less than 10% O_2. Where the stack oxygen is high, dry ambient air (20.9% O_2) may be used.

2.2 Sensitivity. 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 percent of the nominal range.

3. DEFINITIONS

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

3.1.1 Sample Interface. 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.

3.1.2 External Interference Gas Scrubber. A tube filled with scrubbing agent used to remove interfering compounds upstream of some electrochemical cells.

3.1.3 Electrochemical Cell. That portion of the system that senses the gas to be measured and generates an output proportional to its concentration. Any cell that uses diffusion-limited oxidation and reduction reactions to produce an electrical potential between a sensing electrode and a counter electrode.

3.1.4 Data Recorder. A strip chart recorder, computer, or digital recorder for recording measurement data.

3.2 Nominal Range. The range of concentrations over which each cell is operated (25% to 125% of *span gas* value). Several nominal ranges may be used for any given cell as long as the linearity and stability check results remain within specification.

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

3.4 Zero Calibration Error. The gas concentration 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 Response Time. The amount of time required for the measurement system to display 95 percent of a step change in gas concentration on the data recorder.

3.7 Interference Check. A method of quantifying analytical interferences from components in the stack gas other than the analyte.

3.8 Linearity Check. A method of demonstrating the ability of a gas analyzer to respond consistently over a range of gas concentrations.

3.9 Stability Check. A 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.

3.10 Stability Time. As determined during the Stability check; the elapsed time from the start of the gas injection to the start of the 30-minute stability check period.

3.11 Initial NO Cell Temperature. The temperature of the NO cell that is recorded during the most recent pretest calibration error check. 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.

4. MEASUREMENT SYSTEM PERFORMANCE SPECIFICATIONS

4.1 Zero Calibration Error. Less than or equal to ±3 percent of the span gas value for NO, NO_2, and CO channels and less than or equal to ±0.3% O_2 for the O_2 channel.

4.2 Span Calibration Error. Less than ±5% of the span gas value for NO, NO_2, and CO channels and less than or equal to ±0.5% O_2 for the O_2 channel.

4.3 Interference Response. The CO and NO interference responses must be less than or equal to ±5 percent of the average stack concentration for each test run.

4.4 Linearity. For the zero, mid-level, and span gases; the absolute value of the difference between the gas value and the analyzer response shall not be greater than 2.5% of the span gas

concentration for NO, CO and O_2 cells and not greater than 3.0% of the span gas for NO_2 cells.

4.5 Stability Check Response. The analyzer responses to CO, NO, and NO_2 span gases shall not vary more than 2.0% of span gas value over a 30-minute period or more than 1.0 % of the span gas value over a 15-minute period.

5. APPARATUS AND REAGENTS

5.1 Measurement System. Use any measurement system that meets the performance and design specifications in Sections 4 and 5 of this method. 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 Figure 1. The essential components of the measurement system are described below:

5.1.1 Sample Probe. Glass, stainless steel, or other nonreactive material, of sufficient length to traverse the sample points. If necessary to prevent condensation, the sampling probe shall be heated.

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

5.1.3 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.

5.1.4 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. Alternatively use any other method that introduces calibration gases at the probe at atmospheric pressure.

5.1.5 Moisture Removal System. A chilled condenser or similar device (e.g., permeation dryer), to remove condensate continuously from the sample gas while maintaining minimal contact between the condensate and the sample gas.

5.1.6 Particulate Filter. 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.

5.1.7 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 may be constructed of any material that is nonreactive to the gas being sampled.

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

5.1.9 Gas Analyzer. A device containing electrochemical cells to determine the NO, NO_2, CO, and O_2 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. A means of controlling the analyzer flow rate and a device for determining proper sample flow rate (e.g., precision rotameter, pressure gauge downstream of all flow controls, etc.) shall be provided at the analyzer. (Note: 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 method.)

5.1.10 Data Recorder. A strip chart recorder, computer, or digital recorder, for recording measurement data. The data recorder resolution (i.e., readability) shall be at least 1 ppm for CO, NO, and NO_2; 0.1% O_2 for O_2; 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.

5.1.11 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 (i.e. color indication).

5.1.12 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.

5.2 Calibration Gases. The calibration gases for the gas analyzer shall be CO in nitrogen or CO in nitrogen and O_2, NO in nitrogen, NO_2 in air or nitrogen, and O_2 in nitrogen.

5.3.1 Span Gases. Used for calibration error, linearity, and interference checks of each nominal range of each cell. Select concentrations according to procedures in Section 2.1.

5.3.2 Mid-Level Gases. Select concentrations that are 40-60% of the span gas concentrations.

5.3.3 Zero Gas. Concentration of less than 0.25 percent of the span gas for each component. Ambient air may be used in a well ventilated area.

6. MEASUREMENT SYSTEM PERFORMANCE CHECK PROCEDURES

Perform the following procedures before measurement of emissions (Section 7).

6.1 Calibration Gas Concentration Verification. For the mid-level and span cylinder gases, use calibration gases certified according to EPA Protocol G1 or G2 procedures (see Bibliography). Alternative

certification techniques may be used if they are approved in writing by the applicable regulatory agency.

6.2 Linearity Check. Conduct the following procedure once for each nominal range that is to be used on each electrochemical cell (NO, NO_2, CO, and O_2) before each field test program. If a field test program lasts longer than five days, the linearity check shall be repeated before each five days of analyzer operation. Repeat the linearity check if a cell is replaced.

6.2.1 Linearity Check Gases. For each cell obtain the following gases: zero (0-0.25% of nominal range), mid-level (40-60% of span gas concentration), and span gas (selected according to Section 2.1).

6.2.2 Procedure. If the analyzer uses an external interference gas scrubber with a color indicator, using the analyzer manufacturer's recommended procedure, verify that the scrubbing agent is not depleted. After calibrating the analyzer with zero and span gases, 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. Purge the analyzer briefly with ambient air between gas injections. For each gas injection, verify that the flow rate is constant and that the analyzer responses have stabilized before recording all of the responses on a form similar to Figure 2.

6.3 Interference Check. Following each linearity check, use the results from the span gas injections to determine interference responses for the CO and NO cells.

6.3.1 CO Interference Response.

$$I_{CO} = [(R_{CO\text{-}NO} / C_{NOG} \times C_{NOS}/C_{COS}) + (R_{CO\text{-}NO2} / C_{NO2G} \times C_{NO2S}/C_{COS})] \times 100$$

where: I_{CO} = CO interference response (percent)

$R_{CO\text{-}NO}$ = 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-NO2} = CO response to NO_2 span gas (ppm CO)

C_{NO2G} = concentration of NO_2 span gas (ppm NO_2)

C_{NO2S} = concentration of NO_2 in stack gas (ppm NO_2)

6.3.2 NO Interference Response.

$$I_{NO} = (R_{NO-NO2} / C_{NO2G}) \times (C_{NO2S} / C_{NOxS}) \times 100$$

where:
- I_{NO} = NO interference response (percent)
- R_{NO-NO2} = NO response to NO_2 span gas (ppm NO)
- C_{NO2G} = concentration of NO_2 span gas (ppm NO_2)
- C_{NO2S} = concentration of NO_2 in stack gas (ppm NO_2)
- C_{NOxS} = concentration of NO_x in stack gas (ppm NO_x)

6.4 Stability Check. Conduct the following procedure once for each nominal range that is to be used on each pollutant electrochemical cell (NO, NO_2, and CO) before each field test program. If a field test program lasts longer than five days, the stability check shall be repeated before each five days of analyzer operation. Repeat the stability check if a cell is replaced or if a cell is exposed to gas concentrations greater than 125 percent of the highest span gas concentration.

6.4.1 Procedure. 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. After the analyzer response has stabilized, continue to flow the span gas for at least 30 minutes. Make no adjustments to the analyzer during the test except to maintain constant flow. Record the stability time as the number of minutes elapsed between the start of the gas injection and the start of the 30-minute stability check period. If the concentration reaches a peak value within five minutes, you may choose to record the data for at least 15 minutes following the peak.

6.4.2 Calculations. Determine the highest and lowest concentrations recorded during the 30-minute period and record the results on a form similar to Figure 3. The absolute value of the difference between the maximum and minimum values recorded during the 30-minute period must be less than 2.0% of the span gas concentration. Alternatively, record stability check data in the same manner for the 15-minute

period following the peak concentration. The difference between the maximum and minimum values for the 15-minute check must be less than 1.0% of the span gas concentration.

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 five stack diameters downstream of any turbocharger exhaust, crossover junction, or recirculation take-offs and upstream of any dilution air inlet. Locate the sampling site no closer than one meter or three stack diameters (whichever is less) upstream of the gas discharge to the atmosphere. Use a minimum of three sampling points located at positions of 16.7, 50, and 83.3 percent of the stack diameter. Alternatively, the tester may choose an alternative sampling location and/or sample from a single point in the center of the duct if previous test data demonstrate that the stack gas concentration does not vary significantly across the duct diameter.

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. Alternatively, the tester may choose an alternative sampling location and/or sample from a single point in the center of the duct if previous test data demonstrate that the stack gas concentrations of CO, NO_x, and O_2 does not vary significantly across the duct diameter.

7.2 Warm Up Period. 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.

7.3 Pretest Calibration Error Check. 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.

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

7.3.2 Inject the zero and span calibration gases at the probe tip using the calibration assembly. Ensure that the calibration gases flow through all parts of the sample interface (including any exhaust lines). During this check, make no adjustments to the system except those necessary to achieve the correct calibration gas flow rate at the analyzer. Set the analyzer flow rate to the value recommended by the analyzer manufacturer. Allow each reading to stabilize before recording the result on a form similar to Figure 4. The time allowed for the span gas to stabilize shall be no less than the stability time noted during the stability check. After achieving a stable response, disconnect the gas and briefly purge with ambient air.

7.3.3 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_2 span gas record the time required to respond to 90% of a step change.

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

7.3.5 If the zero and span calibration error test results are not within the specifications in Section 4, take corrective action and repeat the calibration error check until acceptable performance is achieved.

7.4 NO Cell Temperature Monitoring. Record the initial NO cell temperature during the pretest calibration error check and monitor

and record the temperature regularly (at least once each 5 minutes) during the sample collection period. If at any time during sampling the NO cell temperature is 85_F or greater and has increased or decreased by more than 5_F since the pretest calibration, stop sampling immediately and conduct a post test calibration error check per Section 7.6, re-zero the analyzer, and then conduct another pretest calibration error check before continuing.

7.5 Sample Collection. Position the sampling probe at the first measurement point and begin sampling at the same rate used during the calibration error check. Maintain constant rate sampling (i.e. ± 10 percent of the analyzer flow rate value used in section 7.3.2) during the entire test run. Sample for an equal period of time at each test point. Sample the stack 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. If recording emission data manually, record concentration values at least once each minute. If a computer or the analyzer record data automatically, the concentration data must be recorded either (1) at least once each minute, or (2) as a block average for the test run using values sampled at least once each minute. Do not break any seals in the sample handling system until after the post test calibration error test (this includes opening the moisture removal system to drain condensate).

7.6 Post Test Calibration Error Check. Immediately after the test run or set of test runs conduct span and zero calibration error checks using the procedure in Section 7.3. Conduct the calibration error check at the sampling location. Make no changes to the sampling system or analyzer calibration until all of the calibration error test results have been recorded. If the zero or span calibration error exceeds the specifications in Section 4 then all test data collected since the previous calibration error check are invalid. 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.

7.7 Interference Verification. The tester shall review the results of the post test calibrations and compare them to the results of the most recent interference test. Use the post test calibration results and average emission concentrations for the test to calculate interference responses (I_{NO} and I_{CO}) using the procedure in section 6.3. If an interference response exceeds 5%, all emission test results since the last successful interference test for that compound are invalid.

7.8 Re-Zero. At least once every three hours 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. 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.

8. CALIBRATION CORRECTIONS

8.1 The tester may choose to correct the emissions data for a test run using the pretest and post test calibration error results. Use the following formula to make the corrections:

$$C_{GAS} = (C_R - C_o) \frac{C_{MA}}{C_M - C_o}$$

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
C_{MA} = actual concentration of span gas

9. BIBLIOGRAPHY

1. "Appendix H to Part 75 - Revised Traceability Protocol No. 1," Federal Register, Vol. 58, No. 6, January 11, 1993, pp. 3750-3757.

FIGURE 1.
CALIBRATION SYSTEM SCHEMATIC

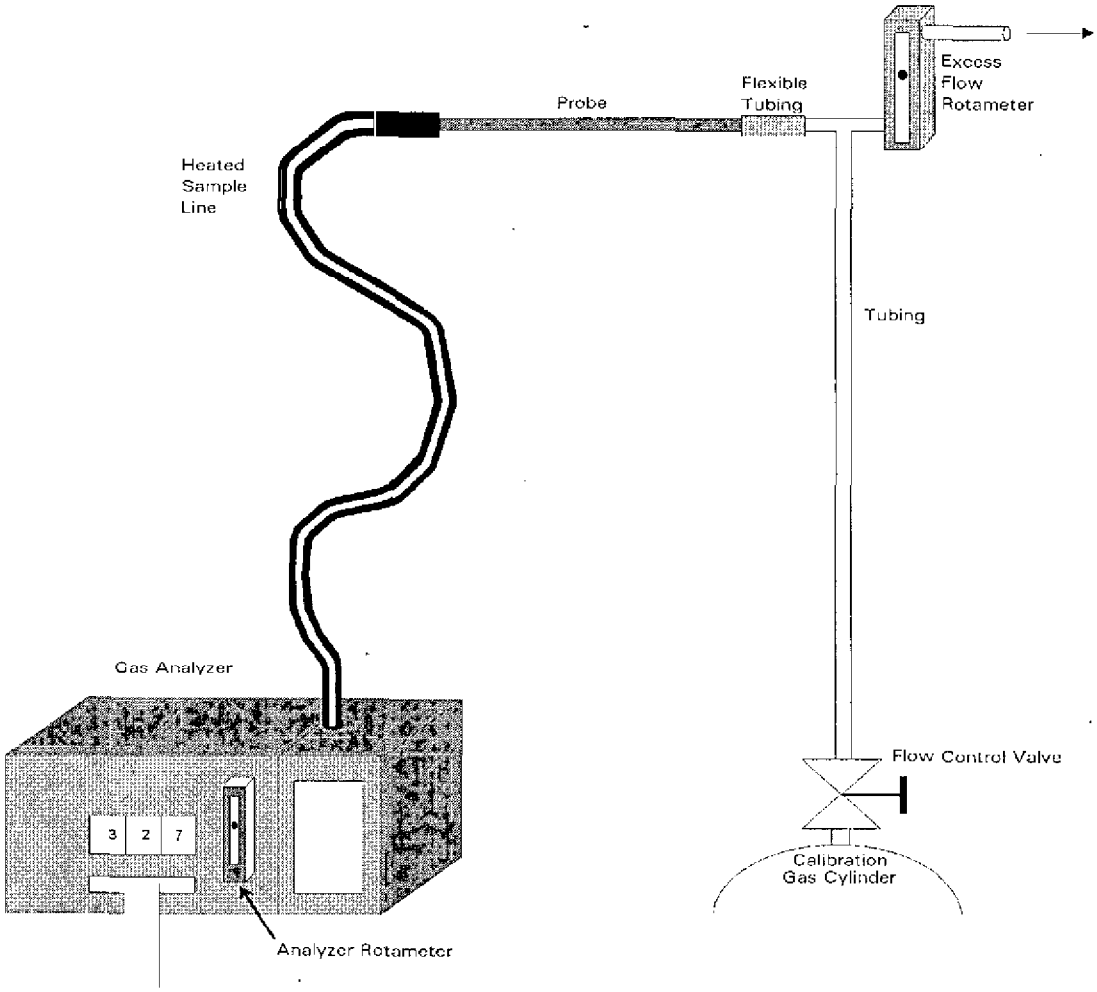


FIGURE 2.
LINEARITY CHECK DATA SHEET

Date____________________ Analyst________________________

Analyzer Manufacturer/Model No.______________________________

Analyzer Serial Number__________________________

Calibration Gas Conc.	ppm NO Response	ppm NO_2 Response	ppm CO Response	% Oxygen Response

FIGURE 3.
STABILITY CHECK DATA SHEET

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 x (max. - min.)/span gas conc. =_____

Stability Time_____

FIGURE 4.
CALIBRATION ERROR CHECK DATA SHEET

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 _____

Channel	Zero Gas Conc.	Zero Response	Zero Error (%)	Span Gas Conc.	Span Response	Span Error (%)
NO						
NO_2						
CO						
O_2						

Post Test Calibration Error Check Results:

Final NO cell temperature _____

Channel	Zero Gas Conc.	Zero Response	Zero Error (%)	Span Gas Conc.	Span Response	Span Error (%)
NO						
NO_2						
CO						
O_2						