SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

PROTOCOL

RULE 1111 NITROGEN OXIDES EMISSIONS COMPLIANCE TESTING FOR NATURAL GAS-FIRED, FAN-TYPE CENTRAL FURNACES

JULY 12, 1994

SOURCE TESTING AND ENGINEERING BRANCH

APPLIED SCIENCE AND TECHNOLOGY

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

PROTOCOL

RULE 1111 NITROGEN OXIDES EMISSIONS COMPLIANCE TESTING FOR NATURAL GAS-FIRED, FAN-TYPE CENTRAL FURNACES

JULY 12, 1994

SOURCE TESTING AND ENGINEERING BRANCH

APPLIED SCIENCE AND TECHNOLOGY

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS

RULE 1111 NITROGEN OXIDES EMISSIONS COMPLIANCE TESTING FOR NATURAL GAS-FIRED, FAN-TYPE CENTRAL FURNACES

PROTOCOL

1.0 OVERVIEW AND APPLICABILITY

The South Coast Air Quality Management District adopted Rule 1111, Control of Nitrogen Oxides from Natural Gas-Fired, Fan-Type Central Furnaces on July 8, 1983. This rule imposes an emission limit of 40 nanograms of NOx (calculated as NO_2) per joule of useful heat delivered to the heated space. Natural gas-fired, fan-type central furnaces (furnaces) require testing to certify compliance with the 40 nanograms of NOx per joule emission limit before they can be supplied, offered for sale or sold within the jurisdiction of the South Coast Air Quality Management District.

This protocol has been developed to ensure standardization of compliance certification test procedures including the use of: specified test conditions, required test methods, specifications for test equipment, data collection/reporting and quality assurance requirements.

An independent testing laboratory, approved by the South Coast Air Quality Management District, shall conduct the testing and prepare a report of findings, including all raw data sheets/charts and laboratory analytical data. This report and a request for product certification must be submitted to the Executive Officer. The testing must demonstrate to the satisfaction of the Executive Officer that emissions from the operation of a furnace meets the requirements of Rule 1111 before product compliance certification is granted.

When a furnace does not fall within the testing guidelines of this protocol, written modification to the protocol must be submitted for review, prior to written approval by the Executive Officer, along with supporting documents which demonstrate equivalency to the existing protocol.

2.0 ENVIRONMENTAL CRITERIA

Testing shall be conducted indoors with the ambient air temperature of the test room maintained between 65^{O}F and 85^{O}F at all times during the test. The ambient air temperature during these tests shall not vary more than $\pm$ 7^{O}F from the average ambient air temperature determined as the arithmetic average of the air temperatures measured periodically at intervals no greater than 15 minutes throughout the duration of the test.

The ambient temperature shall be monitored and recorded before, during, and after the tests in accordance with Section 7.3 of this protocol.

The relative humidity shall be between 20% and 65% during the test. It shall be recorded before and after the test.

The barometric pressure shall be monitored and recorded before and after each test.

3.0 DEFINITIONS

For the purposes of this test protocol, the following definitions shall apply:

3.1 INDEPENDENT TESTING LABORATORY

A testing laboratory that meets the requirements of South Coast Air Quality Management District's Rule 304(k), and is approved by the SCAQMD to conduct testing under this protocol.

3.2 NATURAL GAS-FIRED, FAN-TYPE CENTRAL FURNACE

A self-contained space heater providing for circulation of heated air at pressures other than atmospheric through ducts more than 10 inches in length that have:

A) an input rate of less than 175,000 BTU/hr; or

B) for combination heating and cooling units, a cooling rate of less than 65,000 BTU/hr.

3.3 ANNUAL FUEL UTILIZATION EFFICIENCY (AFUE)

Defined in Section 4.6 of Code of Federal Regulations, Title 10, Part 430, Subpart B, Appendix N.

4.0 TEST CONDITIONS

4.1 AMBIENT AIR TEMPERATURE

The ambient air temperature shall be controlled to a value between 65^{o}F and 85^{o}F on a continuous basis.

4.2 NATURAL GAS PRESSURE

Maintain the supply pressure in accordance with the manufacturer's specifications. If the supply pressure is not specified, maintain a supply pressure of 7-10 inches of water column. Use natural gas with a dry or higher heating value of 1040 $\pm$ 25 BTU per standard cubic foot (14.73 psia and 60^{o}F). Higher heating value shall be measured according to procedures described in Section 5.7.

4.3 INSTALLATION REQUIREMENTS

Tests shall be performed with the furnace and instrumentation installed in accordance with Section 7.

5.0 INSTRUMENTATION

All instrumentation within this section and pertaining to this protocol shall be calibrated as a minimum within the requirements set forth in SCAQMD Source Test Methods Chapter III, Calibrations.

5.1 PRESSURE MEASUREMENT

Pressure measurement instruments shall have an error no greater than the following values:

Measurement	Accuracy	Precision
Gas Pressure	± 0.1" of water column	± 0.05" of water column
Atmospheric Pressure	± 0.1" of Hg column	± 0.05" of Hg column

5.2 TEMPERATURE MEASUREMENTS

Temperature measuring instruments shall have an error no greater than the following values:

Accuracy	Precision
± 1^{o}F	± 1^{o}F

The time constant of instruments measuring inlet and outlet water temperatures shall be 5 seconds or less.

5.3 BAROMETRIC PRESSURE

Use a mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 0.1 in. Hg.

5.4 NATURAL GAS FLOW

The quantity of fuel used by the furnace shall be measured in cubic feet with dry gas meter and associated readout device that is accurate within ± 1% of the reading. The dry gas meter reading shall be corrected for gas pressure and temperature.

5.5 TIME

The elapsed time measurement shall be measured with an instrument that is accurate within ± 0.5 seconds per hour.

5.6 FLUE GAS ANALYSIS

5.6.1 NOx CONCENTRATION A chemiluminescence NOx Analyzer shall be employed to measure NOx in flue gas. Performance specifications of the analyzer shall be in accordance with SCAQMD Method 100.1 (Appendix A).

5.6.2 CO CONCENTRATION A non-dispersive infrared analyzer shall be employed to measure CO in flue gas. Performance specifications of the analyzer shall be in accordance with SCAQMD Method 100.1 (Appendix A).

5.6.3 CO_2 CONCENTRATION A non-dispersive infrared analyzer shall be employed to measure CO_2 in flue gas. Performance specifications of the analyzer shall be in accordance with SCAQMD Method 100.1 (Appendix A).

5.6.4 <u>SAMPLE CONDITIONING SYSTEM</u> The NOx, CO, and CO_2 analyzers shall sample flue gas delivered by a single sample conditioning system. The gases shall be measured simultaneously after undergoing identical sample conditioning. Figures 1 and 2 show acceptable sample conditioning systems. Additional components may be added at the user's discretion. However, deviations from the basic design must be approved by the Executive Officer.

5.6.4.1 <u>Sample Probe</u>

5.6.4.1.1 <u>Integrating Sample Probes</u> Integrating sample probes may be used with vents less than 12 inches in diameter. Figure 3 shows an acceptable hole layout for an integrating sample probe. The probe shall be of 316 stainless steel construction.

5.6.4.1.2 <u>Open Ended Sample Probes</u> Open ended sample probes shall be used to sample vents 12 inches in diameter and larger.

5.6.4.2 <u>Sample Lines</u> The sample line shall be of Teflon construction. It shall be electrically heated. The allowable temperature range is $175^{o}F$ - $300^{o}F$. The use of self-limiting heated sample line is permitted.

5.6.4.3 Moisture Removal System The moisture removal system shall be comprised of a permeation-type dryer, or a refrigerated condenser/separator, or a combination of the two moisture removal methods. The dew point of the dry gas shall be less than $35^{O}F$.

5.6.4.3.1 Permeation-Type Dryers A Permapure permeation-type dryer may be employed to dry the sample gas. The air to the dryer shall be dried with a heat-less dryer, which includes a colored moisture indicator.

5.6.4.3.2 Refrigerated Condenser/Separator A refrigerated condenser/separator designed to minimize contact between the condensate and the sample gas may be used to dry the sample gas. An example would be a knock-out system consisting of a series of empty bubblers immersed in an ice bath.

5.6.4.4 Sample Pump The sample pump shall be a diaphragm type. The diaphragm shall be Viton A; other wetted parts of the pump shall be 316 stainless steel. An equivalent type of sample pump may be used upon approval by the Executive Officer.

5.6.4.5 Flow Indicators Because the flow indicators in the sample conditioning system are for the operators convenience, they do not have to be calibrated. Water shall not be allowed to collect in the indicator tubes.

5.6.4.6 Pressure Indicators Because the pressure indicators in the sample conditioning system are for the operators convenience, they do not have to be calibrated.

5.6.4.7 Sample Vent The analyzers shall have an unrestricted atmospheric sample vent.

5.7 NATURAL GAS COMPOSITION

Heating value or gas composition of the fuel must be measured. If the heating value is measured, the accuracy of the measurement device shall be ± 1% of full scale. The precision of the device shall be ± 2 Btu/dscf. Calibration shall be conducted weekly using the device manufacturer's directions.

If the composition of the fuel is measured, it shall be measured with a gas chromatograph having a TC detector. Ethane, Propane, C4+, CO_2, and permanent gases will be measured directly. Methane may be determined by difference. The reproducibility of the gas chromatograph shall be ± 1% of full scale for each measured component.

6.0 ANALYTICAL METHODS

6.1 START UP

6.1.1 ANALYZERS Allow analyzers to warm up according to manufacturer's instructions. It is recommended that the analyzers be allowed to run overnight before testing.

6.1.2 SAMPLE CONDITIONING SYSTEM Energize the sample pump and sample line; allow temperatures and flows to come to equilibrium.

6.2 CALIBRATION AND PERFORMANCE TESTING

6.2.1 ANALYZER CALIBRATION Use calibration gases which are certified according to EPA Traceability Protocol Number 1. CO calibration gases may be certified to an accuracy of ± 2%. A high span calibration gas shall be selected such that the emission concentrations will be greater than 20% and less than 95% of the high span calibration gas value for the duration of each test run. Calibrate the analyzers according to the manufacturer's instructions and SCAQMD Method 100.1. It is recommended that the calibration of each analyzer be checked after each test run. A 2% drift invalidates the analysis. SCAQMD Method 100.1 is included as Appendix A.

6.2.2 SAMPLING SYSTEM BIAS TEST A sampling system bias test must be performed in accordance with SCAQMD Method 100.1

before and after each day of testing. The sample bypass flowrate shall not be altered during this test.

6.2.3 RESPONSE TIME The system response time test must be performed before each day of testing if NOx concentrations are to be determined by multi-point traverse. The response time test may be performed in conjunction with the sampling system bias test.

To determine response time, first introduce zero gas into the sample probe until all readings are stable; then switch to high-level calibration gas until a stable reading is obtained. Record the upscale response time, which is defined as the amount of time for the system to display 95% of the step change. Next re-introduce zero gas until all readings are stable. Record the downscale response time. The greater time is the "response time" for the system. An acceptable response time shall be less than, or equal to 4 minutes.

6.2.4 NO_2 TO NO CONVERSION EFFICIENCY The converter efficiency shall be measured in accordance with EPA Method 20 at least once a month. If the efficiency does not meet the requirements listed in Form F, the converter must be replaced, and all data acquired since the last converter efficiency test shall be considered suspect. The conversion efficiency test is included as Appendix B.

6.3 ANALYSIS

6.3.1 SAMPLE POINT

6.3.1.1 Appliances with Vents Less Than 12 Inch Diameter An integrating sample probe of the proper length is installed six inches from the upper end of the vent pipe. The probe must pass through the center of the vent and contact the opposite side. A system bias check and leak check shall be performed after changing integrating sample probes.

6.3.1.2 Appliances With Vents 12 Inch Diameter or Greater An open ended sample probe will be used to traverse the vent pipe at 1/2 vent diameter below its upper end. Three traverse points shall be located along the diameter of the highest expected stratification. The traverse points shall be 16.7, 50.0, and 83.3 percent of the diameter. The sample probe will be progressively inserted into the vent pipe along the diameter until each of the three points have been sequentially sampled.

6.3.2 SAMPLING PERIOD

6.3.2.1 Integrating Sample Probes When sampling with an integrating sample probe, the analytical system shall operate continuously during the testing of the appliance.

6.3.2.2 Sample Traverses When sample traverses are required, sampling shall begin after the appliance has reached steady state as defined in Section 8. Each traverse point shall be sampled for five minutes.

6.3.3 DATA RECORDING The output of each analyzer shall be recorded on a strip chart recorder having a minimum width of ten inches. Alternately, the outputs may be recorded with a data logger. The sampling rate of the logger must allow each point to be read at least once every 5 seconds.

7.0 INSTALLATION

7.1 Furnace Mounting Mounting of the furnace shall be in accordance with the manufacturer's instructions.

7.2 Fuel Consumption Install one or more instruments to measure the quantity of natural gas consumed in accordance with Section 5.4 of this protocol.

7.3 Inlet/ Ambient Temperature The inlet/ ambient air temperature shall be measured using a single thermocouple, shielded from direct radiation, at the center of the inlet air duct.

7.4 Outlet Air Temperature Measurements An outlet air sensor shall be located as close to the plenum as is practical with no thermocouple being able to see any part of the heating surface, or within 6 inches (152 mm) downstream from this location.

7.5 Vent Requirements For furnaces having a vertically discharging draft hood outlet, a 5 foot vertical vent pipe extension having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. For furnaces having a horizontally discharging draft hood outlet, a 90^{o} elbow having diameter equal to the largest collar size of the draft hood shall be connected to the draft hood outlet and a vertical 5 feet of length of vent pipe shall be connected to the elbow. If necessary to prevent condensation, the vent pipe must be insulated with an (R) value not less than 4 hr-ft^{2}-^{o}F/Btu.

7.6 Natural Gas Sample Valving and a tap shall be provided in the natural gas supply to allow collecting a sample of fuel for composition analysis.

8.0 TEST PROCEDURE

8.1 Power Input Burners shall be adjusted to their BTU input rates at ± 10% of the stated manifold pressure. The furnace shall be tested within ± 2% of the manufacturer's specified normal hourly BTU input rate, in accordance with Paragraph 2.5.4 of ANSI Z21.47 (1990).

8.2 Static Pressure and Air Flow Adjustments Static pressure and air throughputs shall be adjusted according to Section 2.6 of ANSI Z21.47 (1990).

8.3 Emission Testing Allow the heater to operate until equilibrium conditions are attained. Equilibrium is defined by the following conditions during a 15 minute interval:

A) Temperature changes in the flue gas of not more than ± 5^{o}F between readings 15 minutes apart when the flue gas temperature thermocouple is located in the center position of the flue;

B) NOx changes in the flue gas of not more than ± 2 ppm from the mean sampled over the 15 minute interval;

C) CO_2 changes in the flue gas of not more than ± 0.25 percent (± 2500 ppm) from the mean sampled over the 15 minute interval.

While establishing the equilibrium conditions above, gas measurements shall be made using an integrating sampling probe for vents less than 12 inches in diameter, and with an open ended probe located at the center of the vent for vent diameters greater than, or equal to 12 inches.

At the start of the test, record the time and gas meter reading. Do not interrupt the flow to the furnace. Record the inlet and outlet air temperatures at 60 second intervals throughout the duration of the test. Temperature rise cannot change by more than 5^{o}F during the test. Continuously record the NOx, CO, and CO_2 emissions during a five minute test interval. If an integrating sampling probe is employed, record the gas meter reading at the end of sampling. Determine the arithmetic mean of CO_2 and NOx concentration measured during the five minute test period. Record the maximum CO concentration during the test. Collect a sample of fuel for composition analysis.

If a sample traverse is required, identify the traverse point being sampled on the strip chart recorder and record the concentration of NOx and CO_2 at each point. Continuously record the NOx, CO, and CO_2 emissions during each five minute test interval. When the traverse is complete, record the gas meter reading. Determine the arithmetic mean of CO_2 and NOx concentration measured during each five minute test interval. Collect a sample of fuel for composition analysis.

9.0 CALCULATIONS

Calculations should be carried out to at least one significant digit beyond that of the acquired data and then should be rounded off after final calculation to three significant digits for each run. All rounding off of numbers should be in accordance with the ASTM E380-82 procedures.

9.1 CARBON NUMBER

The carbon number of the fuel can be determined from the measured heating value or determined from gas composition analysis.

Carbon number based on measured heating value is determined from the equation below[1]:

$$Cf = \frac{2 \times \text{Heating Value (Btu/scf)}}{1771} - 0.130 \qquad (1)$$

Carbon number based upon gas composition analysis of the fuel is determined as follows:

$$Cf = \frac{C_1 + 2C_2 + 3C_3 + 4C_4 + C_o}{100} \qquad (2)$$

Where C_f is a dimensionless number;

[1] Rule 1121 Nitrogen Oxides Emissions Compliance Testing For Natural Gas-Fired Water Heaters and Small Boilers

C_1 is concentration of methane in fuel, percent;

C_2 is concentration of ethane in fuel, percent;

C_3 is concentration of propane in fuel, percent;

C_4 is concentration of butane in fuel, percent;

C_o is concentration of CO_2 in fuel, percent.

9.2 HEATING VALUE

If heating value is measured, H equals that value in Btu/dscf. If gas composition analysis is performed, determine heating value as follows[2]:

First compute the compressibility (Z) of the fuel:

$$Z = 1.0 - .001473(C_1 \times .0116 + C_2 \times .0239 + C_3 \times .0344 + C_4 \times .0480 + C_o \times .0197 + I \times .0044)^2 \quad (3)$$

Where "I" is the concentration of Nitrogen in fuel, percent;

Then calculate the heating value (H) of the fuel as follows:

$$H = (C_1 \times 10.120 + C_2 \times 17.737 + C_3 \times 25.221 + C_4 \times 32.70) / Z \quad (4)$$

[2] Rule 1121 Nitrogen Oxides Emissions Compliance Testing For Natural Gas-Fired Water Heaters and Small Boilers

Where H is the heating value of the fuel in BTU per cubic foot at base conditions of 14.73 pounds per square inch absolute and 60 degrees Fahrenheit.

9.3 CO_2 FOR STOICHIOMETRIC COMBUSTION

For stoichiometric combustion of natural gas, the percent CO_2 in the flue may be calculated from the following relation:

$$U = \frac{41.8 \times Cf}{279.1 \times Cf + 79.1} \times 100 \qquad (5)$$

Where:

U = volume percent CO_2 in water-free flue gas for stoichiometric combustion;

Cf = the carbon number, determined from Equation (1) or Equation (2).

9.4 EMISSION OF NOx

Compute using the following:

$$N = \frac{4.566 \times 10^4 \times P \times U}{H \times C \times E} \qquad (6)$$

Where:

N = emissions of NOx as NO_2, nanograms/joule (output);

P = NOx concentration in flue gas, ppm (vol);

U = volume percent CO_2 in water-free flue gas for stoichiometric combustion, determined from Equation (5);

H = the gross heating value of the fuel;

C = concentration of CO_2 measured in flue gas, percent;

E = Annual Fuel Utilization Efficiency (AFUE), obtained from the Gas Appliance Manufacturer's Association (GAMA) Efficiency Certification Directory[3], percent.

[3] The GAMA Efficiency Certification Directory is available from GAMA at: 1901 N. Moore Street; Arlington, VA 22209

10.0 REPORT

10.1 TEST RESULTS

The following forms may be used in reporting test results:

Form A. General Information

Form B. Appliances with vents less than 12 inches in diameter.

Form C. Appliances with vents 12 inches in diameter and larger.

Form D. Gas composition analysis and average carbon number

Form E. Daily calibration check and sampling system bias test

Form F. Monthly NO_2 converter efficiency test

10.2 FORMS USED FOR PERFORMING THE CALCULATIONS

Form G. Correction of gas meter reading and determination of firing rate.

Form H. Calculation of NOx Emissions

10.3 REPORT FORMAT

The following information is to be included in the test report:

1. All chart traces, or digital printouts, must be included in the final report and must be clearly identified as to:

-location/source	-range changes
-operator initials	-range of measurement
-date/running times	-calibrations
-actual test interval	-cal gas concentration/cyl. no.
-contaminant/diluent	-range of calibration

   When more than one gas trace is shown on a chart, the individual traces must be distinguishable by color coding or some other means (original charts may be submitted, and returned following evaluation). If a gas measurement range has been "offset" from zero, or zero has been "transposed to the right side of the recorder chart, it must be clearly identified.

2. A summary of the Source Test results, including applicable rules and permit conditions (show allowable standards) and source test data computed so as to satisfy these requirements.

3. A brief process description. Indicate equipment operation during testing; as well as any other information which may influence the final report.

4. A simple schematic diagram of the process, showing the sampling location, with respect to the upstream and downstream flow disturbances.

5. The sampling and analytical procedures. Be specific about all aspects of sampling and analysis. Include diagrams of test equipment and methods.

6. Complete raw field data, including production data indicative of the testing interval, lab analyses, and the test results (show all calculations).

7. Calibration data regarding all sampling and measuring equipment utilized during testing (see District Source Testing Manual, Chapter III or "Quality Assurance Handbook For Air Pollution Measurement Systems", Vol. III, U.S. EPA-600/4-77-0276).

FIGURES AND DATA FORMS

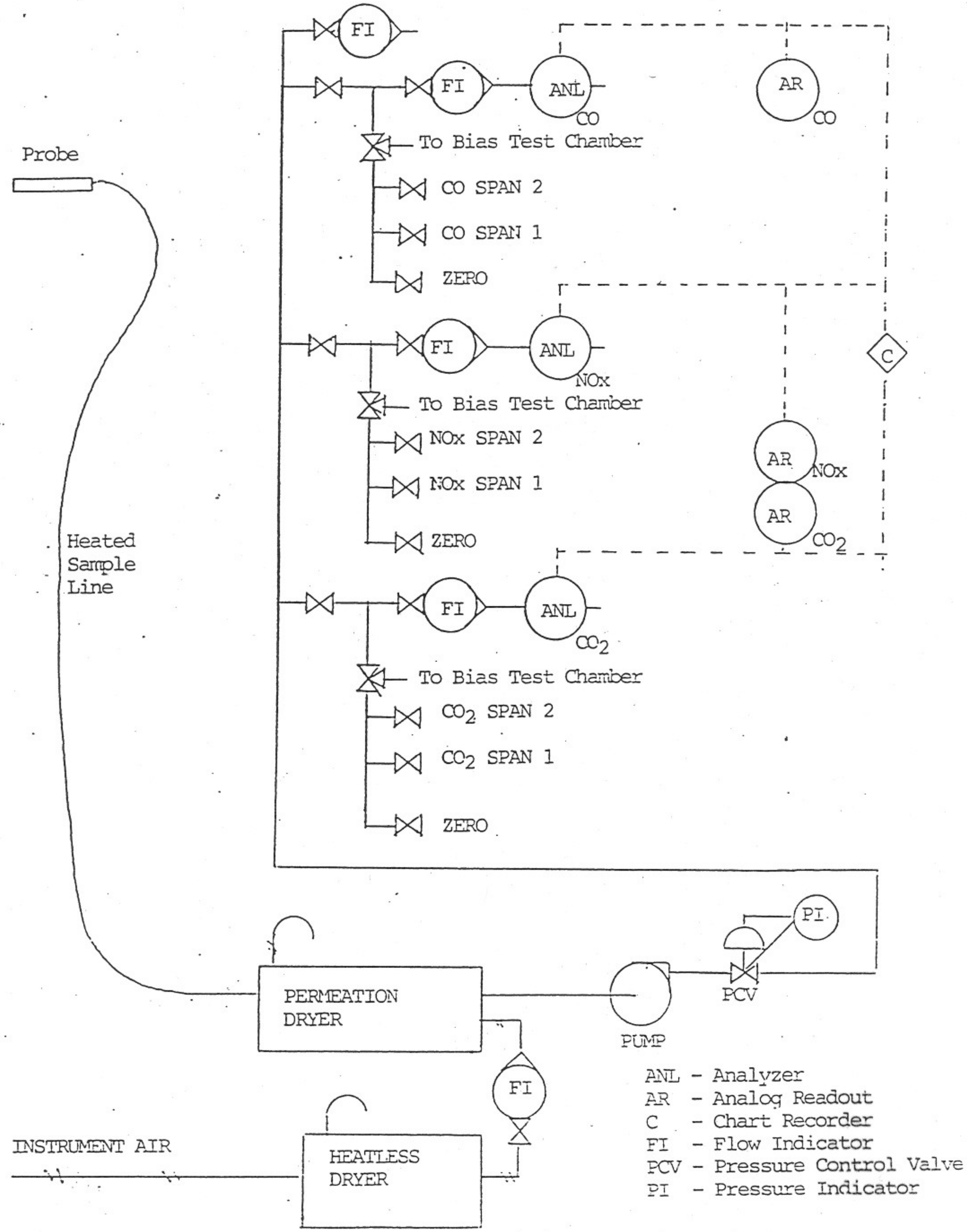
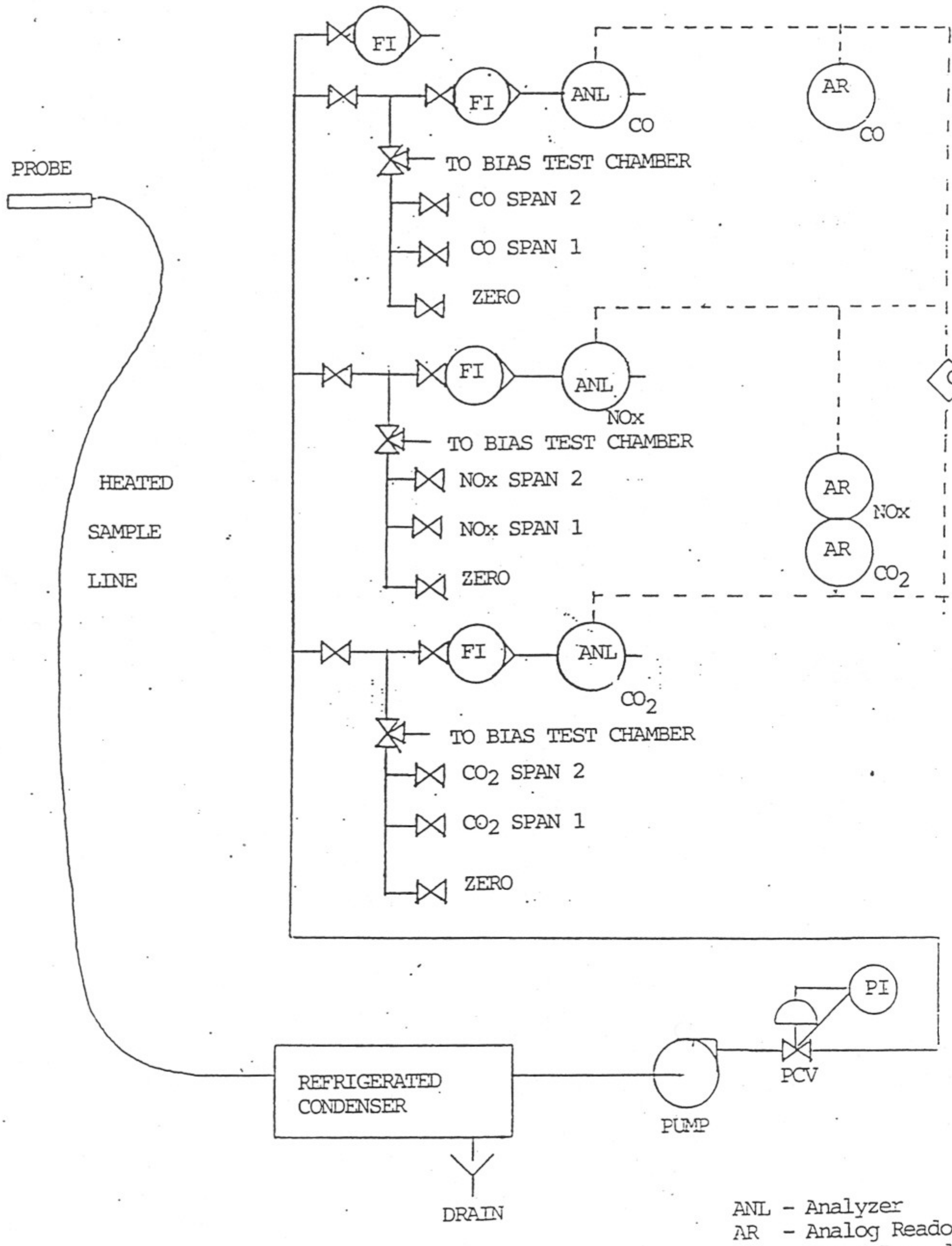


FIGURE 1

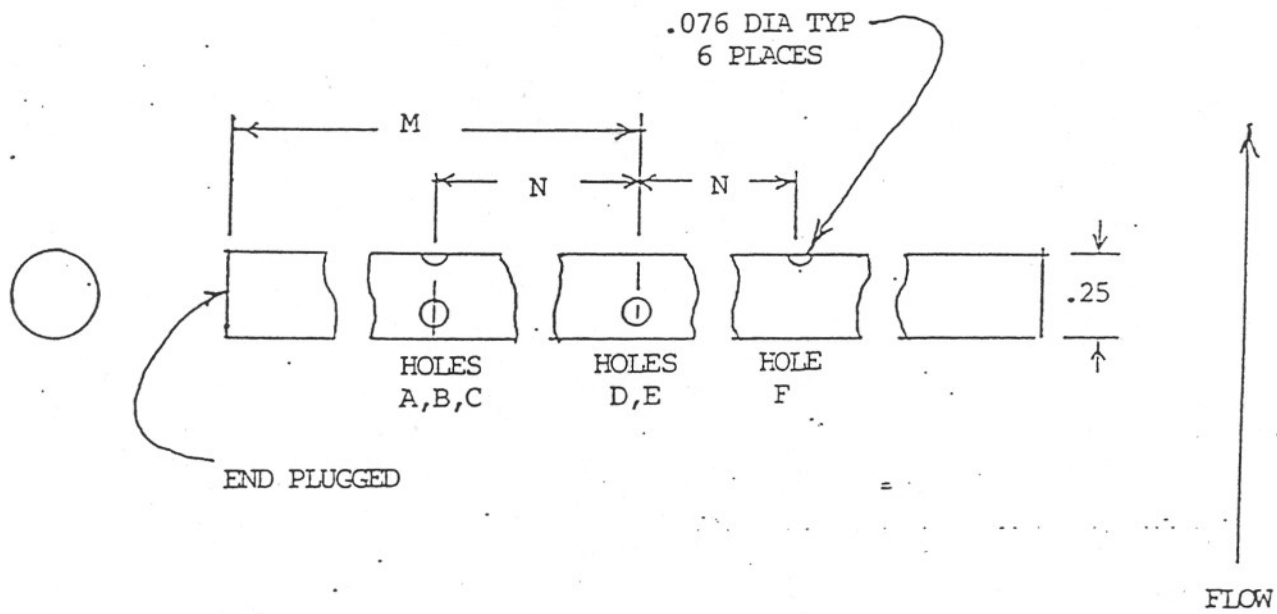
SAMPLE CONDITIONING SYSTEM



ANL - Analyzer
AR - Analog Readout
C - Chart Recorder
FI - Flow Indicator
PCV - Pressure Control Valve
PI - Pressure Indicator

FIGURE 2

ALTERNATE SAMPLE CONDITIONING SYSTEM



HOLE ORIENTATION		VENT DIA	M	N
A	0	3.0	1.50	0.50
B	120	4.0	2.00	1.00
C	240	5.0	2.50	1.36
D	240	6.0	3.00	1.62
E	120	7.0	3.50	1.90
F	0	8.0	4.00	2.17
		9.0	4.50	2.43
		10.0	5.00	2.72
		11.0	5.50	2.98

** Hole orientation in degrees; all other dimensions in inches.

FIGURE 3
SAMPLE PROBE

Run No.: ________________ Date: _____________

Form A. FURNACE INFORMATION/ AMBIENT CONDITIONS

<u>FURNACE</u>

Manufacturer ________________; Model No.___________; Serial No.___________

Input Rating: _______BTU/HR

	START	FINISH
Ambient Temperature	_______ ^{o}F	_______ ^{o}F
Relative Humidity	_______ %	_______ %
Barometric Pressure	_______ in Hg	_______ in Hg
Gas Meter Reading	_______ cu ft	_______ cu ft
Gas Pressure	_______ in H_20	_______ in H_20
Gas Temperature	_______ ^{o}F	_______ ^{o}F
Manifold Pressure	_______ in H_20	_______ in H_20
Outlet Air Temperature	_______ ^{o}F	_______ ^{o}F

Heating Value of Gas (optional) _______ BTU/Cu.Ft.

Start Time _______

Run No.: ________________ Date: _____________

Form B. EMISSION MEASUREMENTS - Appliances with vents less than 12 inches in diameter.

FURNACE

Type ____________________; Manufacturer ______________________;

Model No._________________; Serial No. ________________________.

				ZERO GAS		SPAN GAS	
ANALYZERS	Manufacturer	Model	Serial No.	Value	Reading	Value	Reading
CO_2	__________	_____	________	_____	______	_____	______
NOx	__________	_____	________	_____	______	_____	______
CO	__________	_____	________	_____	______	_____	______

CONCENTRATION MEASUREMENTS CO_2 - %; NOx - ppm; CO - ppm

	CO_2	NO_X	CO
First Minute	_____	_____	____
Second minute	_____	_____	____
Third minute	_____	_____	____
Fourth minute	_____	_____	____
Fifth minute	_____	_____	____

Run No.: ________________ Date: _____________

Form C. EMISSION MEASUREMENTS - Appliances with vents 12 inches in diameter and larger.

FURNACE

Type_________; Manufacturer____________; Model No.________; Serial No.________

				ZERO GAS		SPAN GAS	
ANALYZERS	Manufacturer	Model	Serial No.	Value	Reading	Value	Reading
CO_2	___________	_____	_________	_____	_______	_____	_______
NO_X	___________	_____	_________	_____	_______	_____	_______
CO	___________	_____	_________	_____	_______	_____	_______

CONCENTRATION MEASUREMENTS CO_2 - %; NOx - ppm; CO - ppm

Traverse Point	CO_2	NOx	CO
1	____ (%)	____ ppm	____ ppm
2	____ (%)	____ ppm	____ ppm
3	____ (%)	____ ppm	____ ppm

Run No.: ________________ Date of Run: __________________

Date of Analysis: _____________

Form D. GAS COMPOSITION ANALYSIS

ANALYZER: Manufacturer______________; Model No._________; Serial No.__________

Heating Value Measurement if Performed:

Measured Heating Value: _____________

Cf based on Heating Value (from Section 9.1): ______________

Gas Chromatograph Analysis if Performed:

	Span Gas		Sample Reading			
COMPONENT	Value	Reading	#1	#2	#3	Average
Ethane (C2)	_____%	_______%	_____%	_____%	_____%	_______%
Propane (C3)	_____%	_______%	_____%	_____%	_____%	_______%
Butane+ (C4)	_____%	_______%	_____%	_____%	_____%	_______%
Nitrogen (I)	_____%	_______%	_____%	_____%	_____%	_______%
Carbon Dioxide (Co)	_____%	_______%	_____%	_____%	_____%	_______%
TOTAL			_____%	_____%	_____%	_______%
Methane (C1) (100%-Total)			_____%	_____%	_____%	_______%

Cf CALCULATION

1.	Methane Contribution	C1/100.0	__________
2.	Ethane Contribution	C2/50.0	__________
3.	Propane Contribution	C3/33.33	__________
4.	Butane Contribution	C4/25.0	__________
5.	CO_2 Contribution	C0/100.0	__________
6.	Total is Cf		__________

Date: __________________

Form E. CALIBRATION CHECK AND SAMPLING SYSTEM BIAS TEST.
Must be conducted before and after each day of testing
(Page 1 of 2)

START OF DAY
Time: _______________

		Analyzer Response			System Response			BIAS
	Value	CO_2	NOx	CO	CO_2	NOx	CO	% of Range
Zero Gas	_____	___	___	___	___	___	___	___________
CO_2 Span	_____	___	X	X	___	X	X	___________
NOx Span	_____	X	___	X	X	___	X	___________
CO Span	_____	X	X	___	X	X	___	___________

END OF DAY
Time: _______________

		Analyzer Response			System Response			BIAS
	Value	CO_2	NOx	CO	CO_2	NOx	CO	% of Range
Zero Gas	_____	___	___	___	___	___	___	___________
CO_2 Span	_____	___	X	X	___	X	X	___________
NOx Span	_____	X	___	X	X	___	X	___________
CO Span	_____	X	X	___	X	X	___	___________

DRIFT (% of range)
Zero _________
CO_2 _________
NOx _________
CO _________

If system bias and/or drift for either the CO_2 or NOx analysis exceeds the ranges specified in this protocol, all tests for the day are void.

Date: ___________________

Form E. CALIBRATION CHECK AND SAMPLING SYSTEM BIAS TEST.
Must be conducted before and after each day of testing
(Page 2 of 2)

Analyzer:_________________

Range:_____________________

	Cylinder Value (Indicate Units)	Analyzer Calibration Response (Indicate Units)	Absolute Difference (Indicate Units)	Difference (Percent of Range)
Zero Gas				
Mid-Range Gas				
High-Range Gas				

Linearity Error _____________ percent range

Date: __________________

Form F. NO_2 CONVERTER EFFICIENCY TEST. Must be performed monthly.

ANALYZER CALIBRATION

	Value	Analyzer Reading
Zero Gas	_______	________
Span Gas	_______	________

CONVERTER TEST

	Time	Analyzer Reading
Start	_______	________
Max Reading	_______	________
Finish	_______	________

If final analyzer reading is more than 2.0% less than the maximum analyzer reading, the converter must be repaired or replaced.

Run No.: _______________ Date: ____________

Form G. CORRECTION OF GAS METER READING AND DETERMINATION OF FIRING RATE

A. CORRECTION OF GAS METER READING

1.	Final Gas Meter Reading (Form A)	_______	cu.ft.
2.	Initial Gas Meter Reading (Form A)	_______	cu.ft.
3.	Uncorrected Volume of Gas Burned (Line 1 - Line 2)	_______	cu.ft.
4.	Gas Pressure (Form A)*	_______	in H_20
5.	Barometric Pressure (Form A)	_______	in Hg
6.	Pressure Correction to 30 in Hg is ((Line 5 + (Line 4 / 13.57)) / 30.0	_______	No Units
7.	Gas Temperature (Form A)*	_______	^oF
8.	Temperature Correction to 60^oF is: 519.7 / (Line 7 + 459.7)	_______	No Units
9.	Meter Correction Factor (from Meter Calibration Curves)	_______	No Units
10.	Corrected Volume of Gas Burned (Line 3 x Line 6 x Line 8 x Line 9)	_______	cu.ft.

B. FIRING RATE

11.	Time of Burner Operation From Form A	_______	minutes
12.	Heating Value of Fuel from Form A, or compute using equations in Section 9.2	_______	BTU
13.	Firing Rate Line 12 x Line 10 x (60/Line 11)	_______	BTU/HR

* If initial and final values are different, record the average.

Run No.: ________________ Date: _____________

Form H. CALCULATION OF NOx EMISSIONS

1. P, is part per million NOx measured. Use the average of the NOx readings from the sample points which were used to determine the average CO_2 reading in Line 4. ________ ppm

2. U is volume percent CO_2 in water-free flue gas for stoichiometric combustion from Equation (5) ________ %

3. H is the gross heating value of the fuel from direct measurement, or from Equation (4) ________ BTU/cf

4. C, percent of CO_2 measured. If an integrating sample probe was used, the percent CO_2 is the average of the five measurements from Form B. If a traverse was required, the percent CO_2 is the average of the eight highest readings recorded in Form C. ________ %

5. E is AFUE, obtained from the GAMA Efficiency Certification Directory. ________ %

6. N is the NOx emissions

$$N = \frac{4.566 \times 10^4 \times P \times U}{H \times C \times E}$$

Substituting the corresponding line numbers gives

$4.566 \times 10^4 \times 1 \times 2 / (3 \times 4 \times 5)$ ________ nanograms per joule

APPENDIX A

SCAQMD METHOD 100.1

Method 100.1 can be found at this location:
http://www.aqmd.gov/tao/methods/stm/stm-100-1.pdf

APPENDIX B

NO_2 to NO Conversion Efficiency

NO_2 to NO Conversion Efficiency

Add gas from the mid-level NO in N_2 calibration gas cylinder to a clean, evacuated, leak-tight Tedlar bag. Dilute this gas approximately 1:1 with 20.9 percent O_2 purified air. Immediately attach the bag outlet to the calibration valve assemble and begin operation of the sampling system. Operate the sampling system, recording the NOx response, for at least 30 minutes. If the NO_2 to NO conversion is 100 percent, the instrument response will be stable at the highest peak value observed. If the response at the end of 30 minutes decreases more than 2.0 percent of the highest peak value, the system is not acceptable and corrections must be made before repeating the check.