SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

PROTOCOL

NITROGEN OXIDES EMISSIONS COMPLIANCE TESTING FOR NATURAL GAS-FIRED WATER HEATERS AND SMALL BOILERS

MARCH 1995

(AMENDED JANUARY 1998)

SOURCE TESTING AND ENGINEERING BRANCH

APPLIED SCIENCE AND TECHNOLOGY

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**NITROGEN OXIDES EMISSIONS COMPLIANCE TESTING
FOR NATURAL GAS-FIRED WATER HEATERS & BOILERS**

PROTOCOL

1.0   OVERVIEW AND APPLICABILITY

The South Coast Air Quality Management District adopted Rule 1121, Control of Nitrogen Oxides from Residential Type, Natural Gas-Fired Water Heaters, on December 1, 1978. This rule imposes an emission limit of 40 nanograms of NO_x (calculated as NO_2) per joule of heat output for residential type, natural gas-fired water heaters. Natural gas-fired water heaters require testing to certify compliance with the 40 nanograms of NO_x 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.

Proposed Rule 1146.2, which applies to equipment larger than those regulated by Rule 1121, seeks to limit NOx emissions from commercial water heaters, small industrial boilers, and process heaters. These combustion equipment must also be tested and certified before they can be supplied, offered for sale or sold within the jurisdiction of the South Coast Air Quality Management District. Compliance will be based either on a nanogram per joule of heat output basis, or a concentration basis (parts per million, or pounds per million Btu heat input).

This protocol has been developed to support Rules 1121 and 1146.2 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 natural gas-fired water heater or boiler meets the requirements of Rules 1121 and 1146.2 before product compliance certification is granted.

When a natural gas-fired water heater or boiler does not fall within the testing guidelines of this protocol, the protocol may be modified following an equivalency determination and written approval of the Executive Officer.

2.0   ENVIRONMENTAL CRITERIA

Testing shall be conducted indoors with the ambient air temperature of the test room maintained between 65^OF and 85^OF at all times during the test. The ambient air temperature during these tests shall not vary more than $\pm$ 7^OF 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 7.1.6 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,
Paragraph (K), and is approved by the SCAQMD to conduct
testing under this protocol.

3.2   NATURAL GAS-FIRED WATER HEATER

A closed vessel, in which water is heated by the
combustion of natural gas and is withdrawn for use
external to the vessel at pressures not exceeding 160
psig, including the apparatus by which heat is generated
and all controls and devices necessary to prevent water
temperatures from exceeding $210^{O}F$.

3.3   NATURAL GAS-FIRED BOILER

A self-contained gas burning appliance for supplying
steam or hot water. A boiler can be of the following
types:

3.3.1   HOT WATER HEATING BOILER A boiler in which no steam is
generated, from which hot water is circulated for
heating purposes and then returned to the boiler.

3.3.2   <u>HOT WATER SUPPLY BOILER</u> A boiler, completely filled
with water, which furnishes hot water to be used
externally to itself, and which operates at water
pressures not exceeding 160 psig (1.10 MPa) and at water
temperatures not exceeding 250°F (121°C) at or near the
boiler outlet.

3.3.3   <u>STEAM HEATING BOILER</u> A boiler in which steam is
generated and/or produced.

3.4   **NATURAL GAS-FIRED POOL HEATER**
An appliance designed for heating non-potable water
stored at atmospheric pressure, such as water in
swimming pools, spas, hot tubs and similar applications.

4.0   TEST CONDITIONS

4.1   AMBIENT AIR TEMPERATURE

The ambient air temperature shall be controlled to a value between 65^OF and 85^OF on a continuous basis.

4.2   SUPPLY WATER TEMPERATURE

4.2.1   STORAGE, INSTANTANEOUS, AND CIRCULATING WATER HEATERS
The temperature of water being supplied to the water heater shall be maintained at 72 ± 4^OF throughout the test. Instantaneous and circulating water heaters may use a recirculating line with pump to control inlet water temperature as specified by the manufacturer. The specified inlet water temperature for circulating water heaters shall not be more than 120^OF.

4.2.2   POOL HEATERS The supply water temperature shall not be less than 65^OF and the outlet water temperature not more than 115^OF with a rise of 40^OF. When specified by the manufacturer the water temperature rise may be adjusted to a lower value, but not less than 10^OF with the average temperature of the inlet and outlet being $90^O \pm 5^O$F.

4.2.3   STEAM AND HOT WATER BOILERS The temperature of make-up water shall be $70^O \pm 2^O$F. If required, a recirculating pump may be used to provide feedwater at the manufacturer's specified temperature.

4.3   SUPPLY WATER PRESSURE

4.3.1   WATER HEATERS During tests when water is not being
         withdrawn, the supply pressure shall be maintained
         between 40 psig and the maximum allowable pressure
         specified by the appliance manufacturer. When water is
         being withdrawn, the supply pressure shall be adequate
         to maintain the specified test flows.

4.3.2   POOL HEATERS The supply pressure shall be adequate to
         maintain the specified test flows.

4.3.3   STEAM AND HOT WATER BOILERS The supply pressure shall
         be in accordance with the manufacturer's instructions.

4.4   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°F).

4.5   INSTALLATION REQUIREMENTS

         Tests shall be performed with the water heater and
         instrumentation 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	$\pm$ 0.1" of water column	$\pm$ 0.05" of water column
Atmospheric Pressure	$\pm$ 0.1" of Hg column	$\pm$ 0.05" of Hg column
Water and Steam Pressure	$\pm$ 1.0 psi	$\pm$ 0.50 psi

5.2   TEMPERATURE MEASUREMENTS

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

	Accuracy	Precision
Inlet/outlet water temperatures	$\pm$ 0.2^{O}F	$\pm$ 0.1^{O}F
Storage Tank Temperature	$\pm$ 0.5^{O}F	$\pm$ 0.25^{O}F
Ambient Temperature	$\pm$ 0.2^{O}F	$\pm$ 0.1^{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   LIQUID FLOW MEASUREMENTS

The accuracy of liquid flow measurements, using calibration curves if furnished, shall be equal to or less than $\pm$ 2% of the measured value.

5.5   NATURAL GAS FLOW

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

5.6   MASS MEASUREMENT

Mass shall be measured with instruments that are accurate within $\pm$ 1%.

5.7   TIME

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

5.8 **FLUE GAS ANALYSIS**

5.8.1 $\underline{NO_x \text{ CONCENTRATION}}$ A chemiluminescence NO_x Analyzer

shall be employed to measure NO_x in flue gas.

Performance specifications of the analyzer shall be in

accordance with SCAQMD Method 100.1 (Appendix A).

5.8.2 $\underline{CO \text{ CONCENTRATION}}$ 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).

5.8.3 $\underline{CARBON \text{ } DIOXIDE \text{ } OR \text{ } OXYGEN \text{ } ANALYSIS}$

5.8.3.1 $\underline{CO_2 \text{ CONCENTRATION}}$ 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).

5.8.3.2 $\underline{O_2 \text{ CONCENTRATION}}$ As an alternative to measuring CO_2 for

emission limits which require an oxygen correction, an

electrochemical type analyzer shall be employed to

measure O_2 in flue gas.   Performance specifications of

the analyzer shall be in accordance with SCAQMD Method

100.1 (Appendix A).

5.8.4 $\underline{SAMPLE \text{ } CONDITIONING \text{ } SYSTEM}$ The NO_x, CO, and CO_2 (or O_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.

5.8.4.1 <u>Sample Probe</u>

5.8.4.1.1 <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.

5.8.4.1.2 <u>Open Ended Sample Probes</u> Open ended sample probes shall be used to sample vents 12 inches in diameter and larger. They shall also be used to measure emissions from heaters and boilers designed for outdoor use which do not have vents.

5.8.4.2 <u>Sample Lines</u> The sample line shall be of Teflon construction. It shall be electrically heated. The allowable temperature range is 175^OF - 300^OF. The use of self-limiting heated sample line is permitted.

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5.8.4.3   Moisture Removal System

5.8.4.3.1 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.

5.8.4.3.2 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. The dew point of the dry gas
          shall be less than 35°F.

5.8.4.4   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.

5.8.4.5   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.

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

5.8.4.7   Sample Vent   The analyzers shall have an unrestricted

atmospheric sample vent.

5.9   NATURAL GAS COMPOSITION

Heating value or gas composition of the fuel must be

measured.   If the heating value is measured, the

reproducibility of the measurement device shall be $\pm$ 1%

of full scale.   The precision of the device shall be

$\pm$ 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 $\pm$ 1% of full scale for each

measured component.

6.0   ANALYTICAL METHODS

6.1   START UP

6.1.1   <u>ANALYZERS</u> 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   <u>SAMPLE CONDITIONING SYSTEM</u> Energize sample pump and
sample line. Allow temperatures and flows to come to
equilibrium.

6.2   CALIBRATION AND PERFORMANCE TESTING

6.2.1   <u>ANALYZER CALIBRATION</u> Use calibration gases which are
certified according to EPA Traceability Protocol Number
1. CO calibration gases may be certified to an accuracy
of $\pm$ 2%. Select analytic ranges so that measured gas
concentrations are between 20% and 95% of full scale
during the last 10 minutes of each test. 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.
A 2% drift invalidates the analysis. SCAQMD Method
100.1 is included as Appendix A.

6.2.2   <u>SAMPLING SYSTEM BIAS TEST</u> 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 NO_x
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.

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 I, 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. The
          traverse will be conducted along two diameters
          perpendicular to the axis of the vent and to each other.
          Eight points will be sampled on each diameter. The
          distance of the sample points from the inside surface of
          the vent pipe are given in inches in the following
          table:

VENT	----------------SAMPLE POINT---------------------						
DIAMETER	1	2	3	4	5	6	7	8
12	0.5	1.3	2.3	3.9	8.1	9.7	10.7	11.5
13	0.5	1.4	2.5	4.2	8.8	10.5	11.6	12.5
14	0.5	1.5	2.7	4.5	9.5	11.3	12.5	13.5
15	0.5	1.6	2.9	4.8	10.2	12.1	13.4	14.5
16	0.5	1.7	3.1	5.2	10.8	12.9	14.3	15.5
17	0.5	1.8	3.2	5.5	11.5	13.8	15.2	16.5
18	0.6	1.9	3.5	5.8	12.2	14.5	16.1	17.4
19	0.6	2.0	3.7	6.1	12.9	15.3	17.0	18.4
20	0.6	2.1	3.9	6.5	13.5	16.1	17.9	19.4

The sample probe will be progressively inserted into the vent pipe along one diameter and then the other until all 16 points have been sequentially sampled.

6.3.1.3 Appliances Which Do Not Have Vents Appliances designed for outdoor use which do not have vents shall be sampled by traverse with an open ended probe. The vent guard will be divided into 16 rectangles of equal area on a 4x4 matrix. The sample probe shall be sequentially inserted through the vent guard at the center of each rectangle and the emissions analyzed.

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 complete test cycle of
           the appliance. Sampling during appliance warm-up is not
           required for storage-type water heaters.

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 for each water
           heater or boiler. Each traverse point shall be sampled
           for at least one minute plus the system response time.

6.3.3   DATA RECORDING The output of each analyzer shall be
           recorded on a strip chart recorder having a minimum
           width of six 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   **STORAGE TANK WATER HEATERS WITH INPUT RATINGS BELOW 75,000 BTU/HR**

7.1.1   WATER HEATER MOUNTING Mounting shall be in accordance with the manufacturer's instructions.

7.1.2   WATER SUPPLY The water supply shall be capable of delivering water at conditions as specified in Sections 4.2 and 4.3 of this protocol.

7.1.3   WATER INLET AND OUTLET CONFIGURATION Inlet and outlet piping connections shall be configured as illustrated in Figures 4, 5, or 6, except a water heater 36 inches high or less intended for installation either beneath, adjacent to, or in conjunction with a counter shall have the inlet and outlet connections configured as illustrated in Figures 7a and 7b. Type "L" hard copper tubing, the same size as the connections on the water heater, shall be connected to the tank and extend 24 inches in length. If a water heater 36 inches high or less is not equipped with pipe to extend the field connection point of the water heater lines to outside the jacket or cabinet, type "L" hard copper tubing shall be used to extend the water line horizontally to the exterior of the jacket or cabinet. Unions may be used to facilitate installation and removal. A pressure

gauge shall be installed in the supply at a location upstream of the 24 inch cold water inlet pipe. An appropriately rated pressure and temperature relief valve shall be installed on all water heaters at the port specified by the manufacturer. Discharge piping for the relief valve shall be non-metallic. All energy conservation accessories which are supplied with the water heater shall be installed for testing.

7.1.4   FUEL CONSUMPTION Install one or more instruments to measure the quantity of natural gas consumption in accordance with section 5.5 of this protocol.

7.1.5   INTERNAL STORAGE TANK TEMPERATURE MEASUREMENTS Install six temperature measurement sensors inside the water heater tank with a vertical distance of at least four inches between successive sensors. A temperature sensor shall be positioned at the vertical midpoint of each of the six equal volume nodes within the tank. Nodes designate the equal volumes used to evenly partition the total volume of the tank. As much as possible, the temperature sensors should be positioned away from any anodic protective devices, tank walls, and flue pipe walls. If the tank cannot accommodate six temperature sensors and meet the installation requirements, install the maximum number of sensors which comply with the installation requirements. The temperature sensors

shall be installed either through: (1) the anodic device opening; (2) the relief valve opening; or (3) the hot water outlet. If installed through the relief valve opening or the hot water outlet, a tee fitting and elbow shall be installed such that the outlet piping is as close as possible to its original location. If the hot water heater includes a heat trap, the tee fitting shall be between the heat trap and the storage tank. Fittings added to accommodate the temperature sensors shall be covered with thermal insulation having a thermal resistance (R) value not less than 4 hr-ft^2-$^{\circ}$F/BTU.

7.1.6   <u>AMBIENT TEMPERATURE</u> The ambient temperature shall be measured at the approximate vertical mid-point of the heater and approximately 2 feet from the surface of the water heater. The sensor shall be shielded against radiation.

7.1.7   <u>INLET AND OUTLET WATER TEMPERATURE MEASUREMENTS</u> Install temperature sensors in the cold-water inlet pipe and hot-water outlet pipe as shown in Figures 4, 5, 6, or 7, as applicable and in accordance with ASHRAE STD 41.1-1986.

7.1.8   <u>FLOW CONTROL</u> A flow control valve shall be installed to provide flow as specified within Section 8 of this protocol.

7.1.9   <u>VENT REQUIREMENTS</u> Establish a natural draft in the
         following manner. For water heaters having a vertically
         discharging draft hood outlet, a five foot vertical vent
         pipe extension having a diameter equal to the largest
         flue collar size of the draft hood outlet shall be
         installed. For water heaters having a horizontally
         discharging draft hood outlet, a 90° elbow having a
         diameter equal to the largest flue collar size of the
         draft hood shall be connected to the draft hood outlet.
         A five foot length of standard double walled vent pipe
         (Type B vent) shall be connected to the elbow and
         oriented to discharge vertically upward. Optionally, a
         five foot length of single walled vent pipe may be
         installed if it is insulated up to the sampling port
         with glass fiber having a thermal resistance (R) value
         of not less than 4 $\text{hr-ft}^{2}\text{-}^{\circ}\text{F/Btu}$.

         Direct vent water heaters shall be installed with
         venting equipment specified in the manufacturers
         instructions using the minimum vertical and horizontal
         lengths of vent pipe recommended by the manufacturer.

7.1.10   <u>NATURAL GAS SAMPLE</u> Valving and a tap shall be provided
         in the natural gas supply to allow collecting a sample
         of fuel for composition analysis.

7.2   **STORAGE TANK WATER HEATERS WITH INPUT RATINGS ABOVE 75,000 BTU PER HOUR; CIRCULATING AND INSTANTANEOUS WATER HEATERS.**

.7.2.1 WATER HEATER MOUNTING Mounting shall be in accordance with the manufacturer's instructions.

7.2.2   WATER SUPPLY The water supply shall be capable of delivering water at conditions as specified in 4.2 and 4.3 of this protocol.

7.2.3   WATER INLET AND OUTLET CONNECTIONS

7.2.3.1 Storage Tank Water Heaters Storage tank water heaters which are not equipped with integral heat traps shall have inlet and outlet piping connections configured as illustrated in Figures 4, 5, or 6. Storage tank water heaters which incorporate integral heat traps may have the inlet and outlet piping installed in any convenient fashion. Unions may be utilized to facilitate installation and removal.

If the manufacturer has not provided a temperature and pressure relief valve, one shall be installed on the water heater at the port specified by the manufacturer. Discharge piping for the relief valve shall be non-metallic.

The relief valve and the inlet and outlet piping including heat traps shall be insulated with a material having a thermal resistance (R) value not less than 4 hr-ft^2-^{O}F/Btu. The insulation on the inlet and outlet piping shall extend four feet from the connection with the appliance.

7.2.3.2   <u>Instantaneous and Circulating Water Heaters</u> Inlet and outlet piping shall be installed as shown in Figure 8. If the manufacturer has not provided a temperature and pressure relief valve, one shall be installed for test purposes.

The inlet and outlet piping including recirculating loop, if used, shall be insulated with material having a thermal resistance (R) value not less than 4 hr-ft^2-^{O}F/Btu.

7.2.4   <u>FUEL CONSUMPTION</u> Install one or more instruments to measure the quantity of natural gas consumption in accordance with Section 5.5 of this protocol.

7.2.5   <u>INTERNAL STORAGE TANK TEMPERATURE MEASUREMENTS</u> Internal tank temperature measurements are not required.

7.2.6   AMBIENT TEMPERATURE The ambient temperature shall be
         measured in accordance with Section 7.1.6 of this
         protocol.

7.2.7   INLET AND OUTLET WATER TEMPERATURE MEASUREMENTS

7.2.7.1 Storage Tank Water Heater The inlet and outlet
         temperature sensors shall be installed as shown in
         Figures 4,5, and 6 as applicable and in accordance with
         ASHRAE STD 41.1-1986.

7.2.7.2 Instantaneous and Circulating Water Heaters Install
         temperature sensors as shown in Figure 8 and in
         accordance with ASHRAE STD 41.1-1986. Supply and outlet
         water sensors shall be located as close to the appliance
         as is practical.

7.2.8   FLOW CONTROL A flow control valve shall be installed to
         provide flow as specified within Section 8 of this
         protocol.

7.2.9   VENT REQUIREMENTS

7.2.9.1 Appliances Equipped With Draft Hoods A water heater
         having a vertically discharging draft hood shall have
         attached to and vertically above the outlet, five feet
         of vent pipe the same size as the draft hood outlet. A
         water heater having a horizontally discharging draft

hood shall have attached a 90° elbow and five feet of vent pipe the same size as the draft hood outlet. 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.

7.2.9.2   Direct Vent Appliances The appliance shall be installed with the venting arrangement specified in the manufacturer's instructions. The venting must be insulated if the inlet flow of combustion air is not restricted.

7.2.10   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.

7.3   POOL HEATERS

7.3.1   Pool Heater Mounting Mounting of the pool heater shall be in accordance with the manufacturer's instructions.

7.3.2   Water Supply The water supply shall be capable of delivering water at conditions as specified in 4.2 and 4.3 of this protocol.

7.3.3   Water Inlet and Outlet Connections Piping connections shall be as shown in figure 8. Heat traps, insulation,

and other conservation equipment supplied with the
heater shall be installed for testing. When required to
achieve temperature rise and minimum flow as specified
by the manufacturer, a recirculating loop of minimum
length and a pump shall be provided by the manufacturer.
The recirculating loop shall be insulated with material
having a thermal resistance (R) value of at least 4 hr-
ft^2-^oF/Btu.

Any device provided to maintain water flow rate shall be
removed or adjusted to prevent bypassing of water around
the heat exchanger.

7.3.4   Fuel Consumption Install one or more instruments to
measure the quantity of natural gas consumed in
accordance with Section 5.5 of this protocol.

7.3.5   Internal Storage Tank Temperature Measurements Internal
tank temperature measurements are not required.

7.3.6   Ambient Temperature The ambient air temperature shall
be measured in accordance with Section 7.1.6 of this
protocol.

7.3.7   Inlet and Outlet Water Temperature Measurements Install
temperature sensors as shown in Figure 8. Supply and
outlet water sensors shall be located as close to the

appliance as is practical and in accordance with ASHRAE
STD 41.1-1986.

7.3.8   Flow Control A flow control valve shall be installed to
provide flow as specified within Section 8 of this
protocol.

7.3.9   Vent Requirements For pool heaters 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 heaters having a
horizontally discharging draft hood outlet, a 90° 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}-$^{\circ}$F/Btu.

An appliance for outdoor installation with the venting
system provided as part of the appliance shall be tested
with the venting system in place.

7.3.10   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.

7.4   STEAM AND HOT WATER BOILERS

7.4.1   <u>STEAM BOILERS</u>

7.4.1.1 <u>Boiler Installation</u> The boiler shall be installed in
         accordance with the manufacturer's instructions and all
         applicable safety codes.

         Feed water to the boiler shall be automatically
         controlled to maintain a constant water level in the
         boiler.

7.4.1.2 <u>Water Supply</u> The water supply shall be capable of
         delivering water at conditions as specified in 4.2 and
         4.3 of this protocol.

7.4.1.3 <u>Water Inlet and Outlet Connection</u> Piping connections
         shall be in accordance with the manufacturers
         instructions and have the general arrangement shown in
         Figure 9. All conservation equipment supplied with the
         boiler shall be installed for testing.

7.4.1.4 <u>Water Consumption</u> Install one or more instruments to
         measure the quantity of water delivered to the boiler in
         accordance with Section 5.4 of this protocol.

7.4.1.5 Fuel Consumption Install one or more instruments to
measure the quantity of natural gas consumed in
accordance with Section 5.5 of this protocol.

7.4.1.6 Ambient Temperature The ambient air temperature shall
be measured in accordance with Section 7.1.6 of this
protocol.

7.4.1.7 Inlet and Outlet Temperature Measurements Install a
temperature sensor in the water inlet pipe approximately
24 inches from the boiler inlet. Install a temperature
sensor in the steam outlet pipe within 24 inches of the
boiler outlet in accordance with ASHRAE STD 41.1-1986.

7.4.1.8 Vent Requirements The boiler shall be connected to a
sheet-metal vent pipe the same size as the draft hood
outlet. When the flue gases are vented horizontally, a
90-degree, four-piece, sheet metal elbow and five feet
of vertical stack shall be attached to and above the
outlet. When the flue gases are vented vertically, five
feet of vertical stock shall be attached to and
vertically above the outlet. The vent pipe shall be
insulated with a thermal resistance (R) value not less
than 4 hr-ft^2-$^{\circ}$F/Btu.

A boiler with a power burner or direct vent system shall have vent pipe installed in accordance with the manufacturer's instructions.

An appliance for outdoor installation with the venting system provided as part of the appliance shall be tested with the venting system in place.

7.4.1.9 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.

7.4.2   HOT WATER BOILERS

7.4.2.1   Boiler The boiler shall be installed in accordance with the manufacturer's instructions and all applicable safety codes.

7.4.2.2   Water Supply The water supply shall be capable of delivering water at conditions specified in Sections 4.2 and 4.3 of this protocol.

7.4.2.3   Water Inlet and Outlet Connections Piping connections shall be in accordance with the manufacturer's instructions and have the general arrangement shown in Figure 8. Any conservation equipment supplied with the heater shall be installed for testing. When required, a recirculating loop of minimum length and a pump shall be

provided by the manufacturer. The recirculating loop
shall be insulated with material having a thermal
resistance (R) value of at least 4 hr-ft^2-^{o}F/Btu.

7.4.2.4   <u>Water Consumption</u> Install one or more instruments to
measure the quantity of water delivered to the boiler in
accordance with Section 5.4 of this protocol.

7.4.2.5   <u>Fuel Consumption</u> Install one or more instruments to
measure the quantity of natural gas consumed in
accordance with Section 5.5 of this protocol.

7.4.2.6   <u>Ambient Temperature</u> The ambient air temperature shall
be measured in accordance with Section 7.1.6 of this
protocol.

7.4.2.7   <u>Inlet and Outlet Water Temperature Measurement</u> Install
temperature sensors in the water inlet and outlet piping
approximately 24 inches from the boiler and in
accordance with ASHRAE STD 41.1-1986. The outlet piping
between the boiler and the temperature sensor shall be
insulated with material having a thermal resistance (R)
value of not less than 4 hr-ft^2-^{o}F/Btu.

7.4.2.8   <u>Flow Control</u> A flow control valve shall be installed in
the outlet piping downstream of the temperature sensor

to provide flow as specified in Section 8 of this protocol.

7.4.2.9 <u>Vent Requirements</u> The boiler shall be connected to a sheet-metal vent pipe the same size as the draft hood outlet. When the flue gases are vented horizontally, a 90-degree, four-piece, sheet-metal elbow and five feet of vertical stack shall be attached to and above the outlet. When the flue gases are vented vertically, five feet of vertical stack shall be attached to and vertically above the outlet. The vent pipe shall be insulated with a thermal resistance (R) value not less than 4 hr-ft^2-$^{\circ}$F/Btu.

A boiler using a power burner with positive vent pressures, or with a direct vent system shall have vent pipe installed in accordance with the manufacturer's instructions.

An appliance for outdoor installation with the venting system provided as part of the appliance shall be tested with the venting system in place.

7.4.2.10 <u>Natural Gas Sample</u> Valving and a tap shall be provided in the natural gas supply to allow collecting a sample of fuel for composition or heating value analysis.

8.0   TEST PROCEDURE

8.1   **STORAGE TANK WATER HEATERS WITH INPUT RATINGS OF 75,000 BTU PER HOUR OR LESS**

8.1.1   <u>POWER INPUT</u> Burners shall be adjusted to their BTU input rates at $\pm$ 10% of the stated manifold pressure. The heater shall be tested within $\pm$ 2% of the manufacturer's specified normal hourly BTU input rate.

8.1.2   <u>DETERMINATION OF STORAGE TANK VOLUME</u> Determine the storage tank capacity, VST, of the water heater, in gallons, by subtracting the tare weight - measured while the tank is empty - from the gross weight of the storage tank completely filled with water with all air eliminated and dividing the resulting net weight by the density of water at the temperature.

8.1.3   <u>SETTING THE THERMOSTAT</u> The thermostat dial shall be adjusted so that the maximum mean temperature after cut-out is $135^{O}F \pm 5^{O}F$.

8.1.4   <u>EMISSION TESTING</u> With the water heater turned off, fill the water heater with supply water and apply pressure as described in Section 4.3.1. Turn on the water heater and allow heater to come to operational temperature. The water heater may be allowed to come to temperature overnight.

Initiate burner cut-in by withdrawing 10 gallons of water; wait until cut-out occurs. Measure the mean tank temperature using the temperature sensors described in section 7.1.5 every minute until the maximum mean storage tank temperature is achieved. This is the start of the test. Record the time, the mean tank temperature (To), and the gas meter reading. Note the test start on the analyzer recorders.

Draw water from the tank at the rate of 3.0 $\pm$ 0.25 gallons per minute until 10.7 $\pm$ 0.5 gallons are withdrawn. If burner cut-in has not occurred when 10.7 gallons have been withdrawn, continue withdrawal until cut-in occurs.

Measure the inlet and outlet water temperature beginning 15 seconds after the draw is initiated and at subsequent 5 second intervals through the duration of the draw. Record the time of cut-in and cut-out. The arithmetic mean of the hot water discharge temperature and the cold water inlet temperature shall be determined for the draw. Record the weight or volume of water withdrawn. At the end of the recovery period, record the maximum tank temperature observed after cut-out, Tmax and the volume of fuel consumed. Collect a sample of fuel for composition analysis. Determine the arithmetic mean of the CO_2 and NO_x concentrations measured during each of the last three one-minute periods prior to cut-out;

record the maximum CO concentration measured during the
test.

8.2   **STORAGE TANK WATER HEATERS WITH INPUT RATINGS ABOVE
75,000 BTU PER HOUR; CIRCULATING AND INSTANTANEOUS WATER
HEATERS**

.8.2.1   POWER INPUT Burners shall be adjusted to their BTU
input rates at $\pm$ 10% of the stated manifold pressure.
The heater shall be tested within $\pm$ 2% of the
manufacturer's specified normal hourly BTU input rate.

8.2.2   SETTING THE THERMOSTAT The thermostat shall be placed
in the maximum position, or bypassed if the device
cycles.

8.2.3   EMISSION TESTING

8.2.3.1   Instantaneous Water Heaters with Input Ratings of
200,000 BTU per Hour or Less The water flow shall be
adjusted to provide a discharge temperature of 135 $\pm$
5°F. After the outlet temperature has become constant,
as indicated by no variation in excess of 1^{O}F over a
three minute period, record the time, water meter and
gas meter reading. Do not interrupt fuel to the water
heater. Record the inlet and outlet temperatures at
every 15 seconds interval throughout the test.
Temperature rise cannot change by more than 2^{O}F during

the test. Continuously record the NO_x, CO and CO_2 (or O_2) emissions. After 15 minutes or twice the water residence time, whichever is longer, record the water meter and gas meter readings. Determine the arithmetic mean of the hot water discharge temperature and the cold water inlet temperature during the draw. Collect a sample of fuel for composition analysis. Determine the arithmetic mean of CO_2 (or O_2) and NO_x concentrations measured during the last three minutes of the test. Record the maximum CO concentration measured.

8.2.3.2   <u>Storage with Input Ratings Above 75,000 BTU per Hour, Instantaneous with Input Ratings Above 200,000 BTU per Hour, and Circulating Water Heaters</u> The water flow shall be adjusted to provide a discharge temperature of $140^O \pm 2^O$F. After the outlet temperature has become constant, as indicated by no variation in excess of 1^OF over a three minute period, record the time, gas meter and water meter readings. Do not interrupt the flow of fuel to the water heater. Record the inlet and outlet temperatures at every 15 second interval throughout the test. Temperature rise cannot change by more than 2^OF during the test. Continuously record the NO_x, CO and CO_2 (or O_2) emissions. After 15 minutes or twice the water residence time, whichever is longer, record the water meter and gas meter readings.

If a sample traverse is required, identify the traverse point being sampled on the strip chart recorder and record the concentration of NO_x and CO_2 (or O_2) at each point. When the traverse is complete or after 15 minutes, whichever is longer, record the gas and water meter readings.

Determine the arithmetic mean of the hot water discharge temperature and the cold water inlet temperature during the test. Collect a sample of fuel for composition analysis. If an integrating sample probe was employed, determine the arithmetic mean of CO_2 (or O_2) and NO_x concentrations measured during each of the last three one-minute periods of the test. Record the highest CO concentration during the test.

8.3   POOL HEATERS

8.3.1   <u>Power Input</u> Burners shall be adjusted to their BTU input rates at $\pm$ 10% of the stated manifold pressure. The heater shall be tested within $\pm$ 2% of the manufacturer's specified normal hourly BTU input rate.

8.3.2   <u>Outlet Water Temperature</u> The outlet water temperature shall not be more than 115^OF, with a temperature rise of 40^OF. When specified by the manufacturer, the water temperature rise may be adjusted to a lower value, but

not less than 10^OF, with the average of the inlet and outlet water temperature being $90^O \pm 5^O$F.

8.3.3   <u>Emission Testing</u> Allow the heater to operate until equilibrium conditions are attained. Equilibrium is defined as no variation in excess of 2^OF over a three minute period.

Record the time, gas meter and water meter readings. Do not interrupt the flow to the heater. Record the inlet and outlet temperatures at every 15 second interval throughout the duration of the test. Temperature rise cannot change by more than 2^OF during the test. Continuously record the NO_x, CO, and CO_2 (or O_2) emissions. If a sample traverse is required, identify the traverse point being sampled on the strip chart recorder and record the concentration of NO_x and CO_2 (or O_2) at each point. When the traverse is complete or after 15 minutes, whichever is longer, record the water and gas meter readings. Determine the arithmetic mean of the hot water discharge temperature and the cold water inlet temperature during the test. Collect a sample of fuel for composition analysis. Determine the arithmetic mean of CO_2 (or O_2) and NO_x concentration measured during each of the last three one-minute periods of the test. Record the maximum CO concentration during the test.

8.4   STEAM AND HOT WATER BOILERS

8.4.1   STEAM BOILERS

8.4.1.1   Power Input   Burners shall be adjusted to their BTU

          input rates at $\pm$ 10% of the stated manifold pressure.

          The boiler shall be tested within $\pm$ 2% of the

          manufacturer's specified normal hourly BTU input rate.

8.4.1.2   Outlet Steam Pressure   The boiler shall be tested at

          atmospheric pressure.

8.4.1.3   Emission Testing   Allow the boiler to operate until

          equilibrium conditions are attained but not less than

          one hour.

          When equilibrium conditions are attained, begin

          monitoring CO_2 (or O_2) and NO_x emissions. Record the

          time, water and fuel meter readings. Record the inlet

          water and outlet steam temperatures at 15 second

          intervals throughout the test. If a sample traverse is

          required, identify the traverse point being sampled on

          the strip chart recorder and record the concentration of

          NO_x and CO_2 (or O_2) at each point. When the traverse is

          complete or after 30 minutes, whichever is longer,

          record the water and gas meter readings. Determine the

          arithmetic mean of the steam discharge temperature and

          the cold water inlet temperature during the test.

Collect a sample of fuel for composition analysis. If
an integrating sample probe is employed, determine the
arithmetic mean of CO_2 (or O_2) and NO_x concentration
measured during each of the last three one-minute
periods of the test.

8.4.2   HOT WATER BOILER

8.4.2.1 Power Input Burners shall be adjusted to their BTU
         input rates at $\pm$ 10% of the stated manifold pressure.
         The boiler shall be tested within $\pm$ 2% of the
         manufacturer's specified normal hourly BTU input rate.

8.4.2.2 Outlet Water Temperature The outlet water temperature
         shall be $180^O \pm 2^O F$. The water temperature limiting
         device shall be set to its maximum temperature.

8.4.2.3 Emission Testing Allow the boiler to operate until the
         equilibrium conditions are attained, but not less than
         one hour. Equilibrium conditions are indicated by no
         change in outlet water temperature in excess of $5^O F$ over
         a 5 minute period.

         After equilibrium conditions are attained, begin
         monitoring CO, CO_2 (or O_2) and NO_x emissions. Record
         water and fuel meter readings and time. Record the
         inlet and outlet water temperatures at 15 second
         intervals throughout the duration of the test.

Temperature rise cannot change by more than 5^OF during the test. If a sample traverse is required, identify the traverse point being sampled on the strip chart recorder and record the concentration of NO_x and CO_2 (or O_2) at each point. When the traverse is complete or after 15 minutes, whichever is longer, record the water and gas meter readings. After 30 minutes record the gas and water meter readings. Determine the arithmetic mean of the inlet and outlet water temperatures during the test. Measure the heating value of the fuel or collect a sample of fuel for composition analysis. If an integrating sample probe is employed, determine the arithmetic mean of CO_2 (or O_2) and NO_x concentrations measured during each of the last three one-minute periods of the test.

9.0   CALCULATIONS

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:

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

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

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

Where C_f is a dimensionless number;

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:

First compute the compressibility (Z) of the fuel:

$$Z = 1.0 - .001473(C_1 \times .0116 + C_2 \times .0239 +$$
$$C_3 \times .0344 + C_4 \times .0480 + C_O \times .0197 +$$
$$I \times .0044)^2 \hspace{4cm} (3)$$

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

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

$$H = (C_1 \times 10.120 + C_2 \times 17.737 + C_3 \times 25.221$$
$$+ C_4 \times 32.70) / Z \hspace{4cm} (4)$$

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   HEAT OUTPUT

9.3.1   STORAGE TANK WATER HEATERS WITH INPUT RATINGS OF 75,000

          BTU/HR OR LESS

9.3.1.1   Storage Tank Capacity Storage tank capacity is computed

          with the following:

$$V_{st} = (W_f - W_t)/D_s \qquad (5)$$

          Where V_{st} is the storage capacity of the water heaters,

               gallons;

          W_f is the weight of the water heater completely filled

            with water, pounds;

          W_t is the weight of the empty water heater, pounds;

          D_s is the density of water at the appropriate

            temperature, lbs/gallon.

9.3.1.2   Computation Heat output is computed using the

          following:

$$H_o = MC_{pi}(T_{del} - T_{in}) + V_{st}D_nC_{p2}(T_{max} - T_o) \qquad (6)$$

          Where H_o is heat output, BTU;

          M is the mass of the water withdrawn, pounds;
          C_{pi} is the specific heat of water at the average

               temperature $(T_{del} + T_{in})/2$, BTU/pound ^{O}F;

          T_{del} is average delivery temperature, ^{O}F;

          T_{in} is average inlet temperature, ^{O}F;

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V_{st} is storage tank capacity, gallons (Section 9.3.1.1);

D_n is the density of water at the average temperature

$(T_{max} + T_o)/2$, pounds/gallon;

C_{p2} is the specific heat of water at the average

temperature $(T_{max} + T_o)/2$, Btu/pound ^{O}F;

T_{max} is the maximum mean tank temperature recorded after

cutout following the test draw, ^{O}F;

T_o is the maximum mean tank temperature recorded prior

to the test draw, ^{O}F.

9.3.2   STORAGE TANK WATER HEATERS WITH INPUT RATINGS ABOVE

75,000 BTU PER HOUR, CIRCULATING, AND INSTANTANEOUS

WATER HEATERS, AND POOL HEATERS

Heat output is computed using the following:

$$H_o = Cp_{avg} \times (T_{del} - T_{in}) \times V \times D_i \qquad (7)$$

Where H_o is heat output, BTU;

T_{del} is the average delivery temperature, ^{O}F;

Cp_{avg} is the specific heat of water at $(T_{del} + T_{in})/2$,

BTU/pound ^{O}F;

T_{in} is the average inlet temperature, ^{O}F;

temperature, BTU/pound ^{O}F;

V is the volume of water withdrawn, gallons;

D_i is the density of water at the average inlet

temperature, pounds/gallon.

9.3.3   <u>STEAM BOILERS</u> Heat output is computed using the
following:

$$H_O = VD \times (H_s - H_w) \tag{8}$$

Where H_O is heat output, BTU;

V is volume of feed water during test, gallons;

D is density of water at average delivery temperature,
     pounds/gallon;

H_s is the enthalpy of saturated steam at the

average delivery temperature, Tdel; Btu/lb;

H_w is the enthalpy of water at the average

 inlet temperature, Tin; Btu/lb.

9.3.4   <u>HOT WATER BOILERS</u>

Heat output is computed using the following:

$$H_O = Cp_{avg} \times (T_{del} - T_{in}) \times V \times D_i \tag{9}$$

Where H_O is heat output, BTU;

T_{del} is the average delivery temperature, ^OF;

Cp_{avg} is the specific heat of water at $(T_{del} + T_{in})/2$.
     BTU/pound ^OF;

T_{in} is the average inlet temperature, $^O F$;

V is the volume of water withdrawn, gallons;

D_i is the density of water at the average inlet

temperature, pounds/gallon.

9.4 EMISSION OF NO$_X$

9.4.1 NOx EMISSION (ng/J Heat Output)

Compute using the following:

$$N = \frac{5211 \times Cf \times P \times F}{Ho \times C} \qquad (10)$$

Where N is emissions of NO_X as NO_2, nanograms/joule

(output);

P is NO_X concentration in flue gas, ppm (vol);

C_f is carbon number of fuel, from Section 9.1;

F is volume of fuel burned, cubic feet (30 in.Hg, $60^O F$);

C is concentration of CO_2 measured in flue gas, percent

H_O, as determined in Section 9.3.

9.4.2 NOx EMISSION (Concentration at 3% O_2)

Compute using the following:

$$N = P \frac{20.9 - 3}{20.9 - \%O2} \qquad (11)$$

Where N is emissions of NO_x as NO_2, concentration

corrected to 3% oxygen;

P is NO_x concentration in flue gas, ppm (vol);

%O2 is the concentration of oxygen measured in flue gas, percent. Note that the CO_2 concentration (C) in the flue may be related to %O2 using the following relation:

%O2 = 20.9 - 1.75 (C)

9.4.3   NOx EMISSION (lb/MMBtu)

Compute using the following:

$$N = 1.194 \times 10^{-7} (P)(1040) \frac{100}{C} \qquad (12)$$

Where N is emissions of NO_x as NO_2, lb/MMBtu

(input);

P is NO_x concentration in flue gas, ppm (vol);

C is concentration of CO_2 measured in flue gas, percent. The O_2 concentration (%O2) in the flue may be related to (C) using the following relation:

C = 0.5713 (20.9 - %O2)

10.0   REPORT

10.1   TEST RESULTS

The following forms may be used in reporting test
results:

10.1.1   ENVIRONMENT AND HOT WATER PRODUCTION

Form A. Storage tank water heaters with input rating of
75,000 Btu/Hr or less

Form B. Storage tank water heaters with input rating
above 75,000 Btu/Hr, instantaneous and
circulating water heaters, pool heaters, and hot
water boilers.

Form C. Steam boilers.

10.1.2   EMISSION MEASUREMENTS

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

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

Form F. Appliances without vents.

10.1.3   GAS COMPOSITION ANALYSIS

       Form G.   Gas composition analysis and average carbon
                     number

10.1.4   ANALYZER CALIBRATION AND SAMPLING SYSTEM BIAS TEST

       Form H.   Daily sampling system analyzer calibration
                     and bias test

10.1.5 NO_2 CONVERTER EFFICIENCY TEST

       Form I.   Monthly NO_2 converter efficiency test

10.2   **FORMS USED FOR PERFORMING THE CALCULATIONS**

10.2.1   CALCULATION OF HEAT OUTPUT

Form J. Storage tank water heaters with input rating of
75,000 Btu/hr or less.

Form K. Storage tank water heaters with input rating
above 75,000 Btu/Hr, Instantaneous and circulating water
heaters, pool heaters, and hot water boilers.

Form L. Steam boilers.

10.2.2   CORRECTION OF GAS METER READING AND DETERMINATION OF
         FIRING RATE

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

10.2.3   CALCULATION OF NO_x EMISSIONS
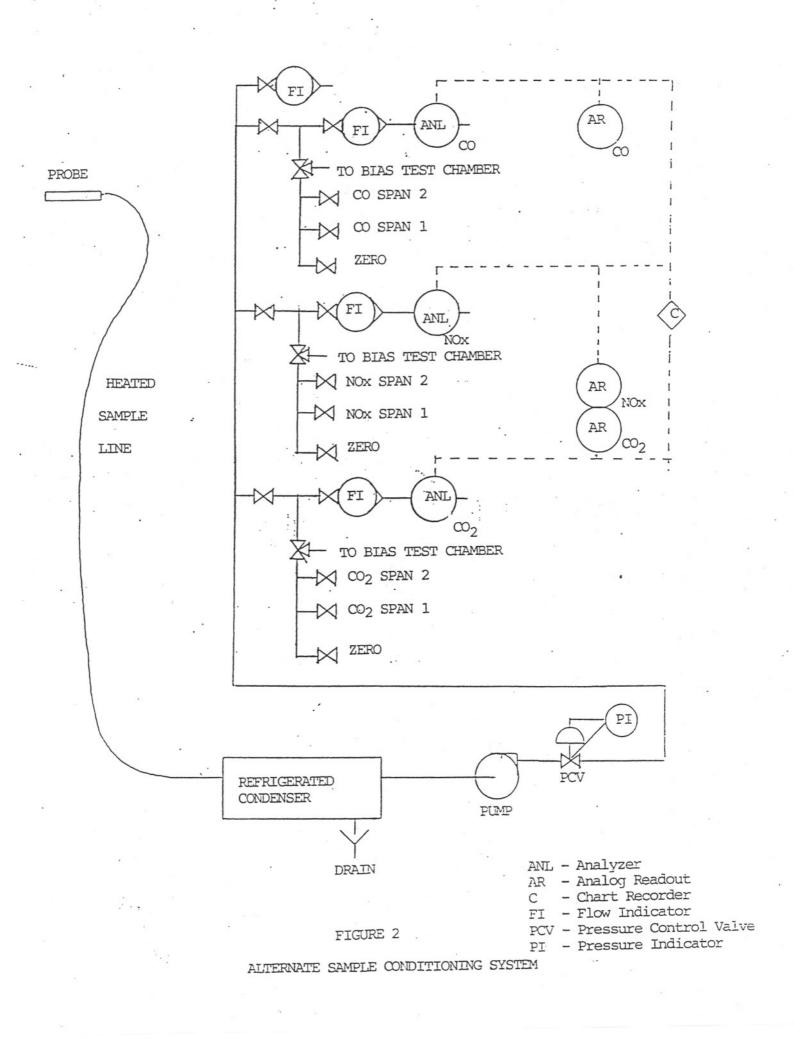
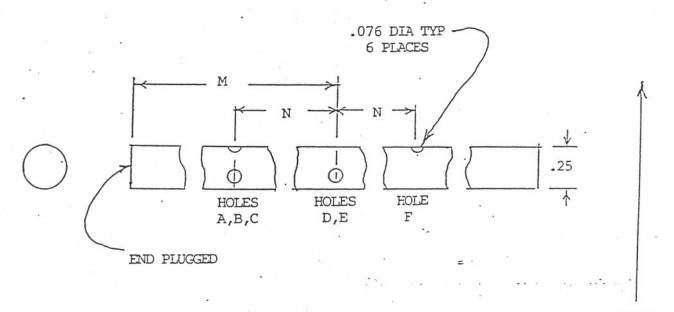   Form N. Calculation of NOx Emissions (ng/J Heat Output)

         Form O. Calculation of NOx Emissions (at 3% Oxygen)

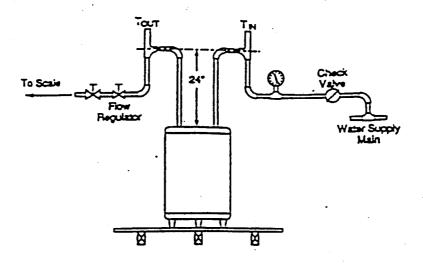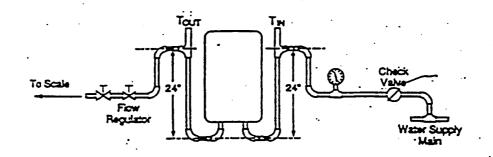   Form P. Calculation of NOx Emissions (lb/MMBtu)

FIGURE 1

SAMPLE CONDITIONING SYSTEM

PROBE

HEATED

SAMPLE

LINE

FI

FI   ANL
          CO

TO BIAS TEST CHAMBER

CO SPAN 2

CO SPAN 1

ZERO

FI   ANL
          NOx

TO BIAS TEST CHAMBER

NOx SPAN 2

NOx SPAN 1

ZERO

FI   ANL
          CO_2

TO BIAS TEST CHAMBER

CO_2 SPAN 2

CO_2 SPAN 1

ZERO

AR
   CO

C

AR
   NOx

AR
   CO_2

REFRIGERATED
CONDENSER

DRAIN

PUMP

PCV

PI

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

FIGURE 2

ALTERNATE SAMPLE CONDITIONING SYSTEM

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.076 DIA TYP
6 PLACES

M

N   N

.25

HOLES
A,B,C

HOLES
D,E

HOLE
F

END PLUGGED

FLOW

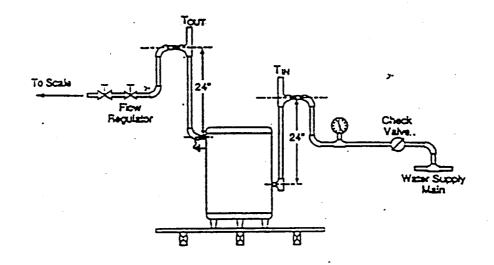| HOLE ORIENTATION		VENT DIA	M	N
A	0	3.0	1.50	0.50
B	120	4.0	2.00	1.00
C	240	5.0	2.50	1.36
D	240	6.0	3.00	1.62
E	120	7.0	3.50	1.90
F	0	8.0	4.00	2.17
		9.0	4.50	2.43
		10.0	5.00	2.72
		11.0	5.50	2.98

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

FIGURE 3

SAMPLE PROBE

Figures 4, 5, and 6

Arrangement for storage tank water heaters

Figures 7a and 7b

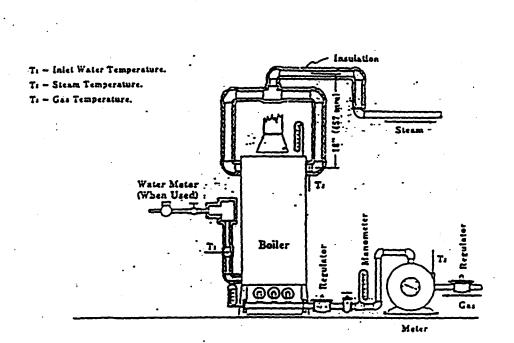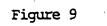Arrangement for "under counter" water heater

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Figure 8

Arrangement for Instantaneous and Circulating Water Heaters,

Pool Heaters, and Hot Water Boilers

T₁ — Inlet Water Temperature.
T₂ — Steam Temperature.
T₃ — Gas Temperature.

Figure 9

Arrangement for Steam Boilers

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Form A.   STORAGE TANK WATER HEATERS WITH INPUT RATING OF 75,000 BTU/HR OR LESS.

WATER HEATER

Manufacturer _____; Model No._____; Serial
No._____

Input Rating: _____BTU/HR

Water Heater Weight: Full (Wf) _____ ;   Empty (Wt) _____ pounds.

Collection Tank: After Draw _____ ;   Empty _____ pounds

	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_2O	_____ in H_2O
Gas Temperature	_____ ^{O}F	_____ ^{O}F

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

Mean Tank Temperature at Start of Draw (To)   _____ ^{O}F

Maximum Mean Temperature Following Draw (Tmax) _____ ^{O}F

Start Time _____

Burner Cut-In   _____

Burner Cut-Out   _____

Water Inlet (Tin); Hot Water Delivery (Tdel); Temperature (^{O}F).

Min:Sec	Tin	Tdel	Min:Sec	Tin	Tdel	Min:Sec	Tin	Tdel
0:15	____	____	1:25	____	____	2:35	____	____
0:20	____	____	1:30	____	____	2:40	____	____
0:25	____	____	1:35	____	____	2:45	____	____
0:30	____	____	1:40	____	____	2:50	____	____
0:35	____	____	1:45	____	____	2:55	____	____
0:40	____	____	1:50	____	____	3:00	____	____
0:45	____	____	1:55	____	____	3:05	____	____
0:50	____	____	2:00	____	____	3:10	____	____
0:55	____	____	2:05	____	____	3:15	____	____
1:00	____	____	2:10	____	____	3:20	____	____
1:05	____	____	2:15	____	____	3:25	____	____
1:10	____	____	2:20	____	____	3:30	____	____
1:15	____	____	2:25	____	____	3:35	____	____
1:20	____	____	2:30	____	____	3:40	____	____

Run No.: _____   Date: _____

Form B. STORAGE TANK WATER HEATERS WITH INPUT RATINGS ABOVE 75,000 BTU/HR, INSTANTANEOUS AND CIRCULATING WATER HEATERS, POOL HEATERS AND HOT WATER BOILERS.

Manufacturer _____; Model No._____; Serial No._____

Type _____;   Input Rating: _____BTU/HR

	S T A R T	F I N I S H
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_2O	_____ in H_2O
Gas Temperature	_____ ^{O}F	_____ ^{O}F
Water Meter Reading	_____ gal	_____ gal
Heating Value of Gas (optional)	_____ BTU/Cu.Ft.	

Start Time _____

Water Inlet (T_{in}); Hot Water Delivery (T_{del}); Temperature (^{O}F).

Min:Sec	T_{in}	T_{del}	Min:Sec	T_{in}	T_{del}	Min:Sec	T_{in}	T_{del}
0:15	____	____	5:15	____	____	10:15	____	____
0:30	____	____	5:30	____	____	10:30	____	____
0:45	____	____	5:45	____	____	10:45	____	____
1:00	____	____	6:00	____	____	11:00	____	____
1:15	____	____	6:15	____	____	11:15	____	____
1:30	____	____	6:30	____	____	11:30	____	____
1:45	____	____	6:45	____	____	11:45	____	____
2:00	____	____	7:00	____	____	12:00	____	____
2:15	____	____	7:15	____	____	12:15	____	____
2:30	____	____	7:30	____	____	12:30	____	____
2:45	____	____	7:45	____	____	12:45	____	____
3:00	____	____	8:00	____	____	13:00	____	____
3:15	____	____	8:15	____	____	13:15	____	____
3:30	____	____	8:30	____	____	13:30	____	____
3:45	____	____	8:45	____	____	13:45	____	____
4:00	____	____	9:00	____	____	14:00	____	____
4:15	____	____	9:15	____	____	14:15	____	____
4:30	____	____	9:30	____	____	14:30	____	____
4:45	____	____	9:45	____	____	14:45	____	____
5:00	____	____	10:00	____	____	15:00	____	____

Run No.: _____   Date: _____

Form C.   __STEAM BOILERS (Page 1 of 2)__

<u>STEAM BOILER</u>

Manufacturer _____; Model No._____; Serial

No._____

Input Rating: _____BTU/HR

	S T A R T	F I N I S H
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_2O	_____ in H_2O
Gas Temperature	_____ ^{O}F	_____ ^{O}F
Water Meter Reading	_____ gal	_____ gal
Steam Drum Pressure	_____ psig	_____ psig
Manifold Pressure	_____ in H_2O	_____ in H_2O

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

Start Time _____

Record inlet and outlet temperatures on Page 2.

Run No.: _____   Date: _____

Form C.   STEAM BOILERS (Page 2 of 2)

Water Inlet (T_{in}); Steam Delivery (T_{del}); Temperature (^{O}F).

Min:Sec	T_{in}	T_{del}	Min:Sec	T_{in}	T_{del}	Min:Sec	T_{in}	T_{del}
0:15	____	____	10:15	____	____	20:15	____	____
0:30	____	____	10:30	____	____	20:30	____	____
0:45	____	____	10:45	____	____	20:45	____	____
1:00	____	____	11:00	____	____	21:00	____	____
1:15	____	____	11:15	____	____	21:15	____	____
1:30	____	____	11:30	____	____	21:30	____	____
1:45	____	____	11:45	____	____	21:45	____	____
2:00	____	____	12:00	____	____	22:00	____	____
2:15	____	____	12:15	____	____	22:15	____	____
2:30	____	____	12:30	____	____	22:30	____	____
2:45	____	____	12:45	____	____	22:45	____	____
3:00	____	____	13:00	____	____	23:00	____	____
3:15	____	____	13:15	____	____	23:15	____	____
3:30	____	____	13:30	____	____	23:30	____	____
3:45	____	____	13:45	____	____	23:45	____	____
4:00	____	____	14:00	____	____	24:00	____	____
4:15	____	____	14:15	____	____	24:15	____	____
4:30	____	____	14:30	____	____	24:30	____	____
4:45	____	____	14:45	____	____	24:45	____	____
5:00	____	____	15:00	____	____	25:00	____	____
5:15	____	____	15:15	____	____	25:15	____	____
5:30	____	____	15:30	____	____	25:30	____	____
5:45	____	____	15:45	____	____	25:45	____	____
6:00	____	____	16:00	____	____	26:00	____	____
6:15	____	____	16:15	____	____	26:15	____	____
6:30	____	____	16:30	____	____	26:30	____	____
6:45	____	____	16:45	____	____	26:45	____	____
7:00	____	____	17:00	____	____	27:00	____	____
7:15	____	____	17:15	____	____	27:15	____	____
7:30	____	____	17:30	____	____	27:30	____	____
7:45	____	____	17:45	____	____	27:45	____	____
8:00	____	____	18:00	____	____	28:00	____	____
8:15	____	____	18:15	____	____	28:15	____	____
8:30	____	____	18:30	____	____	28:30	____	____
8:45	____	____	18:45	____	____	28:45	____	____
9:00	____	____	19:00	____	____	29:00	____	____
9:15	____	____	19:15	____	____	29:15	____	____
9:30	____	____	19:30	____	____	29:30	____	____
9:45	____	____	19:45	____	____	29:45	____	____
10:00	____	____	20:00	____	____	30:00	____	____

Run No.: _____   Date: _____

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

Type _____; Manufacturer _____;
Model No._____; Serial No. _____.

| | | | | ZERO GAS | | SPAN GAS | |
ANALYZERS	Manufacturer	Model	Serial No.	Value	Reading	Value	Reading
CO_2 (O_2)	_____	_____	_____	_____	_____	_____	_____
NOx	_____	_____	_____	_____	_____	_____	_____
CO	_____	_____	_____	_____	_____	_____	_____

CONCENTRATION MEASUREMENTS CO_2 (or O_2) - %; NOx - ppm; CO - ppm

	CO_2/O_2	NO_X	CO
Last minute before cut-out or end of test	_____	_____	_____
Next to last minute	_____	_____	_____
Preceding minute	_____	_____	_____

Run No.: _____   Date: _____

Form E. <u>EMISSION MEASUREMENTS</u> - Appliances with vents 12 inches in diameter and larger.

Type_____; Manufacturer_____; Model No._____; Serial No._____

				ZERO GAS		SPAN GAS	
ANALYZERS	Manufacturer	Model	Serial No.	Value	Reading	Value	Reading
CO_2 (or O_2)	_____	_____	_____	_____	_____	_____	_____
NO_X	_____	_____	_____	_____	_____	_____	_____
CO	_____	_____	_____	_____	_____	_____	_____

CONCENTRATION MEASUREMENTS CO_2 (or O_2) - %; NO_X - ppm; CO - ppm

Point	CO_2/O_2	NO_X	CO	Point	CO_2	NO_X	CO
1	_____	_____	_____	9	_____	_____	_____
2	_____	_____	_____	10	_____	_____	_____
3	_____	_____	_____	11	_____	_____	_____
4	_____	_____	_____	12	_____	_____	_____
5	_____	_____	_____	13	_____	_____	_____
6	_____	_____	_____	14	_____	_____	_____
7	_____	_____	_____	15	_____	_____	_____
8	_____	_____	_____	16	_____	_____	_____

Circle the eight highest CO_2 concentrations.

Traverse Points
Ref: 6.3.1.2

Run No.: _____   Date: _____

Form F. APPLIANCES WITHOUT VENTS

Type_____; Manufacturer_____; Model No._____; Serial No._____

				Z E R O G A S		S P A N G A S	
ANALYZERS	Manufacturer	Model	Serial No.	Value	Reading	Value	Reading
CO_2 (or O_2)	_____	_____	_____	_____	_____	_____	_____
NO_X	_____	_____	_____	_____	_____	_____	_____
CO	_____	_____	_____	_____	_____	_____	_____

CONCENTRATION MEASUREMENTS CO_2 (or O2) – %; NO_X – ppm; CO – ppm

Point	CO_2/O_2	NO_X	CO	Point	CO_2	NO_X	CO
1	____	____	____	9	____	____	____
2	____	____	____	10	____	____	____
3	____	____	____	11	____	____	____
4	____	____	____	12	____	____	____
5	____	____	____	13	____	____	____
6	____	____	____	14	____	____	____
7	____	____	____	15	____	____	____
8	____	____	____	16	____	____	____

Circle the eight highest CO_2 concentrations.

Traverse Points
Ref: 6.3.1.2

Run No.: _____   Date of Run: _____

                                 Date of Analysis: _____

Form G.   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:

| | S p a n   G a s | | S a m p l e   R e a d i n g | | | |
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		_____

Form H. 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* _____   * CO_2 or O_2 Analyzer
     NOx   _____
     CO   _____

If system bias and/or drift for the CO_2, O_2, or NOx analysis exceeds the ranges specified in this protocol, all tests for the day are void.

Date: _____

Form H. 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

Form I. 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.

Form J. CALCULATION OF HEAT OUTPUT – STORAGE TANK WATER HEATERS WITH INPUT RATING OF 75,000 BTU/HR OR LESS (Page 1 of 2).

A.   STORAGE TANK CAPACITY
  1. W_f, weight of water heater filled with
          water (Form A)   _____ pounds

  2. W_t, weight of empty water heater (Form A) _____ pounds

  3. D_s, density of water at the temperature
          weighted [*]   _____ pounds/gal

  4. V_{st}, storage tank capacity is:
          $V_{st} = (W_f - W_t) / D_s$
          Substituting the corresponding line
           numbers gives:
          (1 - 2)/3   _____ gallons

B.   HEAT OUTPUT
  5.   Weight of collection tank and water
          at end of test (Form A)   _____ pounds

  6.   Tare weight of collection tank (Form A)   _____ pounds

  7.   M, mass of water withdrawn (lines 5-6)   _____ pounds

  8. T_{del}, average delivery temperature, sum
          of all outlet temperatures on Form A
          divided by number of measurements   _____ ^{o}F

  9. T_{in}, average inlet temperature, sum of
          all inlet temperatures on Form A divided
          by number of measurements   _____ ^{o}F

  10.   Average of inlet and outlet temperature is
          $(T_{del} + T_{in})/2.0$
          substituting the corresponding line
          numbers gives
          (8 + 9)/2.0   _____ ^{o}F

[*]   The values of these parameters may be found in handbooks such as
Perry's Chemical Engineers Handbook. Use correct units.

11. Cpi, specific heat of water at temperature
        in line 10*   _____ BTU/lb^{O}F

12. Tmax, maximum mean tank temperature after
        cut-out (Form A)   _____ ^{O}F

13. To, initial mean tank temperature
     (Form A)   _____ ^{O}F

14. Average tank temperature is (Tmax + To)/2 _____ ^{O}F

15. Dn, density of water at the temperature
        in line 14.*   _____ lb/gal

16. Cp2, specific heat of water at the
        temperature in line 14.*   _____ BTU/lb^{O}F

17. Ho, heat output is
     Ho = M x Cpi x (Tdel-Tin) + Vst x Dn x Cp2 x (Tmax-To),
     substituting the corresponding line numbers gives:
   Ho = 7 x 11 x (8-9) + 4 x 15 x 16 x (12-13) _____ BTU

*   The values of these parameters may be found in handbooks such as
     Perry's Chemical Engineers Handbook. Use correct units.

Run No.: _____ Date: _____

Form K. CALCULATION OF HEAT OUTPUT - Storage Tank Water Heaters With Input Rating Above 75,000 BTU/HR, Instantaneous and Circulating Water Heaters, Pool Heaters and Hot Water Boilers.

A. HEAT OUTPUT
1. Tdel, average delivery temperature, sum of all delivery temperatures in Form B divided by number of measurements (60 if 15 min. test) _____ ^{O}F

2. Tin, average inlet temperature, sum of all inlet temperatures in Form B divided by number of measurements (60 if 15 min. test) _____ ^{O}F

3. Tavg, (Tdel + Tin) / 2 _____ ^{O}F

4. Cp_{avg}, specific heat of water at the temperature in line 3.* _____ $BTU/lb^{O}F$

5. V, volume of water withdrawn, final water meter reading - initial water meter reading (Form B) _____ gallons

6. Di, density of water at the average inlet temperature (line 2)* _____ lbs/gal

7. Ho, heat output is:
   Ho= Cp_{avg} x (Tdel - Tin) x V x Di
   substituting the corresponding line number gives:
   4 x (1 - 2) x 5 x 6 _____ BTU

* The values of these parameters may be found in handbooks such as Perry's Chemical Engineers Handbook. Use correct units.

Run No.: _____   Date: _____

Form L.   CALCULATION OF HEAT OUTPUT - STEAM BOILERS.

A.   HEAT OUTPUT - STEAM BOILERS

1.   V, volume of feed water during test, final
      water meter reading - initial water meter
      reading (Form B)   _____ gallons

2.   Tdel, average delivery temperature, sum of
      all delivery temperatures in Form C
      divided by number of measurements (120 if

      30 minute test)   _____ ^{O}F

3.   Tin, average inlet temperature, sum of all
      inlet temperatures in Form C divided by

      number of measurements(120 if 30 min.test)   _____ ^{O}F

4.   Hs, enthalpy of saturated steam at
      the average delivery temperature, line 2*.   _____ BTU/lb

5.   Hw, the enthalpy of water at the
      average inlet temperature, line 3*.   _____ BTU/lb

6.   D, density of water at the average inlet
      temperature (line 3)*   _____ lbs/gal

7.   Ho, heat output is:

          Ho= V x D x (Hs - Hw)

      substituting the corresponding line number
      gives:
          1 x 6 x (4 - 5)   _____ BTU

*   The values of these parameters may be found in handbooks such as
Perry's Chemical Engineers Handbook. Use correct units.

Run No.: _____   Date: _____

**Form M.   CORRECTION OF GAS METER READING AND DETERMINATION OF FIRING
            RATE**

A.   CORRECTION OF GAS METER READING

    1.   Final Gas Meter Reading (Form A, B, or C)   _____ cu.ft.

    2.   Initial Gas Meter Reading (Form A, B, or C)   _____ cu.ft.

    3.   Uncorrected Volume of Gas Burned
       (Line 1 - Line 2)   _____ cu.ft.

    4.   Gas Pressure (Form A, B, or C)*   _____ in H_2O

    5.   Barometric Pressure (Form A, B, or C)   _____ 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, B, or C)*   _____ $^O F$

    8.   Temperature Correction to $60^O F$ 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,B, or C _____ minutes

    12. Heating Value of Fuel from Form A, B, or C, 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 N.   CALCULATION OF NOx EMISSIONS (ng/J Heat Output Basis)

1.   Cf, average carbon number of fuel (Form G)   _____ No Units

2.   C, percent of CO_2 measured. If an integrating
       sample probe was used, the percent CO_2 is the

       average of the three measurements from Form D.
       If a traverse was required, the percent CO_2 is

       the average of the eight highest readings
       recorded in Form E or F.   _____ %

3.   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 2.   _____ ppm

4.   F is the corrected fuel burned (Form M)   _____ cu.ft.

5.   Ho is the heat output (Form J, K, or L)   _____ BTU

6.   N is the NOx emissions

$$N = \frac{5211 \times Cf \times P \times F}{Ho \times C}$$

       Substituting the corresponding line numbers
       gives

       5211.0 x 1 x 3 x 4/(5 x 2)   _____ nanograms
                                                                   per joule

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Form O.   CALCULATION OF NOx EMISSIONS (Corrected to 3% Oxygen)

1.   C, percent of CO_2 measured. If an integrating
         sample probe was used, the percent CO_2 is the

         average of the three measurements from Form D.
         If a traverse was required, the percent CO_2 is

         the average of the eight highest readings
         recorded in Form E or F.   _____ %

2.   %O2, percent of O_2 measured. If an integrating
         sample probe was used, the percent O_2 is the

         average of the three measurements from Form D.
         If a traverse was required, the percent O_2 is

         the average of the eight lowest readings
         recorded in Form E or F. If %O2 is calculated
         from CO_2 measurements, use the following equation:

             %O2 = 20.9 - 1.75 (C)
         where C is the reading from Line 1   _____ %

3.   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 2.   _____ ppm

4.   N is the NOx emissions Corrected to 3% Oxygen

$$N = P \times \frac{20.9 - 3}{20.9 - \%O2}$$

         Substituting the corresponding line numbers
         gives

             (Line 3) x (17.9)/(20.9 - Line 2)   _____ ppm @ 3%
                                                                 oxygen

Run No.: _____   Date: _____

Form P.   CALCULATION OF NOx EMISSIONS (lb/MMBtu)

1.   C, percent of CO_2 measured. If an integrating
         sample probe was used, the percent CO_2 is the

         average of the three measurements from Form D.
         If a traverse was required, the percent CO_2 is

         the average of the eight highest readings
         recorded in Form E or F. If C is calculated
         from O_2 measurements, use the following equation:

             %CO2 = 0.5713 (20.9 - %O2)
         where %O2 is the averaged reading from
         Form O, Line 2.   _____ %

2.   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 (or O_2) reading in Line 2.   _____ ppm

3.   N is the NOx emissions

$$N = 1.194 \times 10^{-7} (P)(1040) \frac{100}{C}$$

         Substituting the corresponding line numbers
         gives

             0.01242 (Line 2/ Line 1)   _____ lb/MMBtu

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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 NO$_x$ 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.