Testing Protocol for Particulate Emissions from Masonry Fireplaces

Northern Sonoma County APCD
Healdsburg, California

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TESTING PROTOCOL FOR PARTICULATE EMISSIONS FROM MASONRY FIREPLACES

Northern Sonoma County-APCD, Healdsburg, California

1.0 SCOPE. This protocol covers the procedures necessary to conduct particulate emissions testing of masonry fireplace model lines. In order for testing to be considered valid for certification purposes in the Northern Sonoma County-APCD (NSCAPCD) the testing must be conducted by an EPA Accredited-Laboratory which has received its accreditation in accordance 40 CFR Part 60 Subpart AAA.. This Protocol is comprised of two parts. Part I constitutes the test firing and particulate sampling protocols. Part II is comprised of the calculations necessary to determine particulate emissions and report these findings to the Northern Sonoma County Air Pollution Control District for Certification Purposes.

2.0 DEFINITIONS. For the purpose of this protocol, certain terms are defined as follows:

2.1 Analyzer Calibration Error is the difference between the gas concentration exhibited by the gas analyzer and the known concentration of the calibration gas when the calibration gas is introduced directly to the analyzer.

2.2 Approved Fireplace is a fireplace that meets the certification and emission standards of NSCAPCD Regulation 4 when tested according to this Protocol.

2.3 Burn Rate is the average rate at which test-fuel is consumed in a fireplace during a test-burn period measured in kilograms of wood (dry basis) burned per hour (kg/hour).

2.4 Calibration Drift is the difference in the analyzer reading from the initial calibration response at a mid-range calibration value after a stated period of operation during which no maintenance, repair, or adjustment took place.

2.5 Calibration Gas is a known concentration of Carbon Dioxide (CO_2), Carbon Monoxide (CO), or Oxygen (O_2) in Nitrogen (N_2).

2.6 Certification or Certification Audit Test is the completion of at least one, three-fuel-load test-bum or test period in accordance with the fireplace operating and sampling procedures of this Protocol.

2.6.1 Equivalent Flue/Chimney Diameter is a calculated distance based on flue/chimney size. Where the flue is circular the measured diameter of the flue constitutes this distance. If the flue is rectangular the equivalent distance (ED) is calculated as follows:

ED= 2 x (L x W) / (L + W) where: L = Flue rectangular length. W = Flue rectangular width.

2.7 **Firebox** is the chamber in the fireplace in which test-fuel charges are placed and burned.

2.7.1 **Firebox** Height is the vertical dimension measured from the fireplace hearth to the horizontal plane that intersects and is perpendicular to the top edge of the firebox opening.

2 8 **Fireplace** Design is the construction and/or fabrication specifications including all dimensions and materials required for manufacturing or building a fireplace.

2.9 **Fireplace Hearth** is the firebox floor area, within the firebox of a fireplace upon which a fire may be, or is intended to be built (see Section 2.21 of this Protocol.)

2.10 **Fireplaces, Masonry** are wood fired appliances as defined in Regulation 4 of the NSCAPCD and which are exempt from Title 40 of the Code of Federal Regulations (CFR) Part 60, Subpart AAA and are not cookstoves, boilers, furnaces, or pellet stoves as defined in 40 CFR Part 60, Subpart AAA.

2.10.1 **Flue-gas Exhaust Duct** is the connector pipe, chimney, or other duct form that conveys exhaust gases from the firebox to the atmosphere. The flue gas exhaust duct is considered to be a portion of the fireplace model line configuration for purposes of model line certification. Flue-gas exhaust duct cross-sectional area is calculated using duct dimensions measured at the narrowest point downstream from the horizontal plane which intersects the top most edge of the firebox.

2.11 **Fireplace Model Line** is **a series** of fireplace models which all have the same internal assembly, including flue-gas exhaust ducting and grate height above hearth. Each model in a model line can have different facade designs and external decorative features.

2 11.1 **Grate Height** Above Hearth is the measure distance between hearth floor and bbttom of grate. It is the space under which combustion air can pass under and through the fuel load held by the grate. The grate height above hearth is considered to be a portion of the of the fireplace model line configuration for purposes of model line certification.

2 11.2 Hearth Grate is a non-combustible structure capable of elevating a fuel load above the hearth of a fireplace while offering no impedance to the passage of combustion air up to and through the fuel load.

2.12 Internal Assembly is the core construction and firebox design which produces the same combustion function, particulate emissions factor, particulate emissions rate, and overall thermal efficiency of a fireplace model line.

2.13 **Maximum Flue-Gas Oxygen Depression Value** is the difference between the baseline air supply 02 concentration ~~(20.9%)~~and the lowest 5-minute data point oxygen concentration data point measured and recorded for each specific test-fuel charge.

2 14 **Response Time is the amount** of time required for a gas measurement system to respond and display 90 percent of a step change in gas concentration.

2.15 **Sampling System Bias** is the difference between the gas concentrations displayed by an analyzer when a gas of known concentration is introduced at the inlet of the sampling probe and the gas concentration displayed when the gas of known concentration is introduced directly to the analyzer.

2.16 **Span** is the upper limit of the gas concentration measurement range. (Usually 25 percent for CO_2, O_2 and 5 percent for CO.)

2.17 **Test-Burn or Test Period** is the time required to consume at least 90% of the mass of three consecutively burned test-fuel charges.

2.18 **Test Facility** is the building enclosure in which the fireplace is installed, operated, and sampled for emissions.

2.19 Test-Fuel Charge is one of three batches of test fuel burned during a test period as determined using the test fuel loading factor.

2.20 Test-Fuel Loading Factor is **7.0** pounds of test fuel per square foot of usable fireplace hearth area.

2.21 **Usable Firebox or Hearth Area** is the firebox floor (or hearth) area, within the fire chamber of a fireplace upon which a fire may be, or is intended to be built. Usable firebox area is calculated using the following definitions:

2.21.1 Length. The longest horizontal fire chamber dimension along the floor of the firebox that is parallel to a wall of the fire chamber.

2.21.2 Width. The shortest horizontal tire chamber dimension along the floor of the firebox that is parallel to a wall of the fire chamber.

2.21.3 For angled or curved firebox walls and/or sides, the effective usable firebox area shall be determined by calculating the sum of standard geometric areas or sub-areas of the firebox floor.

2.21 .4 If a fireplace has a larger floor area within the fire chamber than the area upon which it is intended that fuel be placed and burned, the usable frrebox area shall be calculated as the sum of standard geometric areas or sub-areas of the area intended for fuel placement and burning.

2.21.5 For fireplace grates which elevate the fuel above the frrebox floor, the useable firebox area includes all geometric sub-areas within the total grate area or "foot print circumscribed by the connection of all of the outer most grate projections. Usable firebox hearth areas-determined in this manner shall be multiplied by a factor of 1.5. The weight of test-fuel charges for fireplace-grate useable-firebox-area tests shall not exceed the weight of test-fuel charges determined for the entire available fireplace floor/hearth area.

2.22 **Zero Drift** is the difference between the initial calibration response at the zero concentration level and the calibration response at the zero concentration level after a stated period of instrument operation during which no maintenance, repair, or adjustment took place.

2.23 **Thermal** Efficiency.

2.23.1 Combustion Efficiency is a measure of the completeness of the chemical oxidizing and reducing reactions which take place within the fuel and between the fuel and oxygen. Combustion efficiency is expressed as the percentage of the total heat potential of the fuel which is converted to heat,

2.23.2 Heat Transfer Efficiency is a measure of how much of the heat produced by the chemical combustion reaction process is transferred from a firebox into the mass of the fireplace and/or into the room in which the fireplace is located. Heat transfer efficiency is expressed as **a** percentage of the heat produced in the firebox which is transferred into the mass of the fireplace and/or the room in which the fireplace is located, and

2.23.3 Overall Thermal Efficiency is a measure of how much of the heat Potential of the fuel is absorbed into the mass of the fireplace and/or reaches the room in which the fireplace is located. It is expressed as that percentage of the total heat potential of the fuel which is absorbed into the mass of the fireplace and/or reaches the room in which the fireplace is located. Overall thermal efficiency is calculated as the multiplication product of the Combustion Efficiency and the Heat Transfer Efficiency.

PART I.

3.0 Testing.

3.1 Applicability. The methods described in this section are applicable to the sampling of particulate emissions and establishing thermal efficiency for masonry fireplaces.

3.1.1 Alternative Sampling Systems. Upon' approval by the NSCAPCD, qualified alternative emissions sampling and/or thermal efficiency measuring methods may be used as equivalent methods to those described in this Protocol. To qualify as equivalent, candidate alternative method(s) testing shall be performed by an EPA accredited laboratory in accordance with the U.S. EPA Method 301 Field Validation Procedure (Federal Register, December 12, 1992; Volume 57, Number 250, page 11998). In order to qualify for alternative sampling system approval, the results of these qualifying tests shall comply with the U.S. EPA Field Validation acceptance criteria.

3.2 .Principle. Emissions and thermal efficiency measurements are performed on a fireplace installed and operated in accordance with the specific methods of this Protocol. Emissions are sampled from fireplace flue gases using an emission sampling system (ESS) described in Section 4.3.11 of this Protocol. Flue gases are drawn through a heated fiberglass filter and a sorbent resin for determining non-volatile as well as semi-volatile particulate emissions fractions. Sampled combustion gases are also analyzed for oxygen (O_2) carbon dioxide (CO_2). and carbon monoxide (CO) concentrations for use in the determination of emission factors, emission rates and overall thermal efficiency. Overall fireplace thermal efficiency is determined by measuring flue-gas chemical, sensible, and latent heat losses. A total combustible carbon (TCC) analysis of flue gases is used to measure chemical losses (i.e., incompletely burned volatile, semi-volatile, and solid carbonaceous materials). Direct temperature measurements and calculated flue-gas moisture content are used to determine sensible and latent heat losses.

3.3 Test Apparatus. The following test equipment is required to facilitate the performance of the emissions sampling and thermal efficiency measurement procedures contained in this Protocol:

3.3.1 Fireplace Temperature Monitors. Device(s) capable of measuring flue-gas temperature to within 1.5 percent of expected absolute temperature values. These monitors are to be sited in accordance with Section 3.3.11.2.3

3.3.2 Test Facility Temperature Monitor. A device located centrally in a vertically oriented pipe shield 6 inches (150 mm) long and 2 inches (50 mm) in diameter that is open at both ends and capable of measuring air temperature to within 1 .O percent of expected absolute temperature values. These monitors are to be sited in accordance with Section 3.10.

33.3 Analytical Balance. An analytical balance capable of weighing sample filters, and sorbent-resin and equipment-rinse particulate residues to the nearest 0.1 mg.

3.3.4 Desiccator. A desiccator for maintaining all particulate sample residues at constant room temperature and the relative humidity levels required in 40 CFR Part 60 Appendix A, Method 5.

3.3.5 Soxhlet Extractors. Soxhlet extractors for extracting particulate emission, residues from XAD-2 sorbent-resin.

3.3.6 Balance. Balance capable of weighing the test-fuel charge(s) to within 0.1 pound (0.05 kg).

3.3.7 Wood-Fuel Moisture Meter. Calibrated electrical resistance meter for measuring test-fuel moisture to within 1 percent moisture content (dry basis).

3.3.8 Anemometer. Device capable of detecting air velocities less than 20 feet/minute (0.10 m/second), for measuring air velocities near the fireplace being tested.

3.3.9 Barometer. Mercury barometer, capable of measuring atmospheric pressure to within 0.1 inch Hg (2.5 mm Hg).

3.3.10 Draft Gauge. Electromanometer or inclined liquid manometer for the determination of flue draft (i.e., static pressure) readable to within 0.01 inches of water column (0.50 Pa).

3.3.11 Emissions Sampling System.

3.3.11 .1 Principle. Figure 3.3.11 .1.1 shows a schematic of an ESS used for sampling wood fired masonry fireplace emissions. Except as specified in 3.1 .1 of this Protocol, an ESS in this configuration shall be used to sample and quantify particulate emissions from all fireplaces submitted to the NSCAPCD for approval. The ESS for this Protocol draws sampled flue gas through a heated probe inserted into the flue-gas stream being generated by the operation of a fireplace being tested. Sampled gases are drawn through a heated sample line and filter for solid particulate, a cooled XAD-2 sorbent-resin trap for semi-volatile particulate, a condensate trap/gas dryer to remove moisture, an oxygen concentration measurement cell, and then into a gas sample bag for later detailed measurement and verification of combustion-gas constituent concentrations.

The ESS flue-gas sampling rate is controlled by a critical orifice designed for a nominal flow in the range of one (1) to three (3) liters per minute. The ESS filter catch is processed in accordance with U.S. Environmental Protection Agency (EPA) Method 5 protocols (Title 40 Code of Federal Regulations, Part 60, Appendix A). The XAD-2 sorbent-resin trap and the sample line and probe-wall catches are processed by solvent extractions and rinsing.

After the particulate sample processing is complete and the gas-bag-collected combustion gases have been analyzed, the results are processed to obtain carbon monoxide and particulate emission factors and rates.

3.3.11.2 Specifications.

3.3.11.2.1 Particulate Sampling Train Specifications. The ESS shall draw flue gases-through a, heated 3/8-inch (10 mm) O.D. stainless-steel probe and Teflon@ sampling line that is temperature monitored. The heated probe and Teflon@ sample line shall not be longer than 15 feet and shall be maintained in a temperature range between 225 deg F to 300 deg F during all sample periods. The probe shall be fitted with a stainless steel 3/8-inch diameter leading edge button hook nozzle to provide a 90 degree turn of the probe into the direction from which the flue-gas stream flows. The probe is to be located near the center of the flue at an elevation which is at least 4.0 equivalent flue/chimney diameters upstream from the flue exit to the atmosphere, or 8 feet (2.44m) above the floor of the firebox (i.e., the hearth) whichever is lower. Exact probe location within this area of the flue is to be determined from the pre-test flue gas stratification check conducted under Section 3.8.3. The location of the sampling probe must also be sited at least 4.0 equivalent chimney diameters downstream of any flow disturbance such as a emissions control device bend, expansion joint, smoke chamber, or visible flame that might exist in the range identified above. The location of this sampling train for particulate and gas sampling shall be known as the primary sampling location,

The flue-gas sample shall travels through the heated sample line where it is conducted through a heated U.S. EPA Method 5-type glass-fiber filter (40 CFR Part 60 Appendix A) for collection of solid particulate matter. The filter shall be followed by a cooled in-line flow-through cartridge containing 20 to 25 grams of XAD-2 sorbent resin for collecting semi-volatile hydrocarbons. Excess water vapor shall be then be removed from the sampled flue-gases by a cooled condensate trap with a volume of no more than 75 ml. The XAD-2 cartridge and the condensate trap shall be maintained at temperatures between 40 to 50 degrees F during all sampling periods.

3.3.11.2.2 Flue Gas Oxygen Monitoring Specifications. Flue-gas oxygen concentrations are measured within the ESS system by an electrochemical cell meeting the performance specifications presented in Section 3.3.12 of this Protocol.

3.3.11.2.3 Flue Gas Temperature Monitoring Specifications. There may need to be up to three temperature probes present to obtain required flue gas temperature data.

A primary temperature probe is to be located within one equivalent flue/chimney diameter of the primary sampling location established in Section 3.3.11.2.1. Where flue gas temperature probes are sufficiently small as to not interfere with particulate sampling, the primary tremperature probe may be located in the the primary sampling location cross section. Temperature readings taken from this location will be referred to as primary temperature readings.

A thermal efficiency temperature probe is to be located at the 8 foot (2.44m) level of the fireplace in order to obtain data which is representative of where the last possible thermal donation would occur in a standard 8 foot (2.44m) high room. This shall be reffered to as the thermal efficiency temperature probe and thermal efficiency temperature readings. It is conceivable and allowable that the primary temperature probe could be substituted for the thermal efficiency temperature probe when the primary sampling location is within one equivalent flue/chimney diameter of the 8 foot (2.44m) level in the flue exhaust duct.

A secondary temperature probe shall be required if the fireplace is equipped with an emissions control device which is located in the flue, downstream from the fireplace firebox. This probe shall be positioned one equivalent flue/chimney diameter upstream from the flue-gas inlet to the emission control device. This shall be referred to as the secondary sampling location and these measurements shall be referred to as secondary temperature readings.

3.3.11.3 ESS Operating Criteria.

3.3.11.3.1 The ESS shall use a critical orifice to maintain a nominal flue-gas sampling rate in the range of 0.035 cfm (1 .O liter per minute) to 0.0875 cfm (2.5 liters per minute) **±10%.** The actual flow rate through the critical orifice shall be determined to within 0.0007 cubic feet (0.02 liters) per minute before and after each test-bum with a standardized volumetric bubble-type flow meter to document sampling rates.

Post-test-bum critical-orifice flow-rate determinations shall be performed before the ESS is dismantled for sample recovery and clean-up. Pre-test-burn and post-test-burn critical-orifice flow-rate measurements shall be within 0.0007 cubic feet (0.02 liters) per minute of each other or the test-bum emissions results shall be invalid.

3.3.11.3.2 A constantly proportional_sub-sample of the flue-gas sample stream exiting the ESS unit, shall be pumped into a 1 cubic-foot (28-liter minimum-size) gas sampling bag for measuring the average carbon dioxide and carbon monoxide and confirmation of average ESS-measured oxygen concentrations for the test period.

Flow to the sub-sample gas bag shall be controlled by a fine-adjust needle-controlled flow valve. The sub-sample flue gas shall be pumped into the gas bag at all times when the ESS sample pump is on. The rate of flow into the bag shall be controlled by the fine-adjust metering needle-valve which is adjusted during pretest preparation so that approximately 0.8 to 1 .0 cubic feet (22.5 to 28.3 liters) of gas is collected over the entire test period without over-pressurizing the gas sample bag;

Note: It is recommended that the ESS return its particle-free and dry exhaust gas to the flue via a %-inch (6 mm) Teflon@ line and a 15-inch (380 mm) stainless-steel probe inserted into the flue downstream from the primary sampling location.

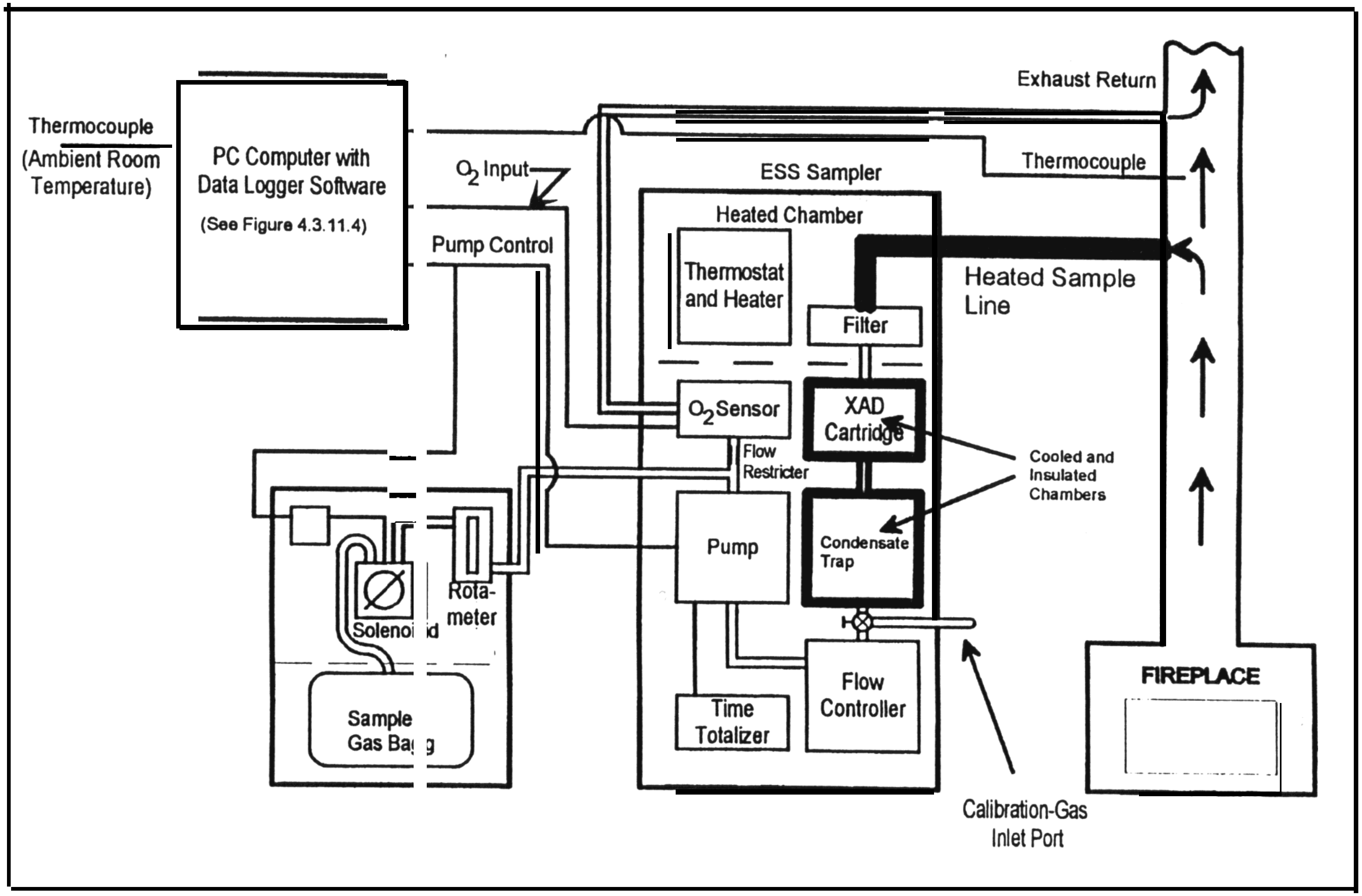

Figure 3.3.11.1.1 Schematic Diagram of Emissions Sampling System (ESS)

3.3.11.4 The ESS Data Acquisition and Sampler Control System. A diagram of the data acquisition and ESS control system shown in Figure 3.3.11.4-l This system consists of a personal computer (PC with 80486DX2 processor or better) containing an analog-to-digital data processing board (12-bit precision), a terminal (connection) box, and data acquisition and system control software.

The data logger and system control hardware and software shall be configured to control, collect, and store the following test information and data:

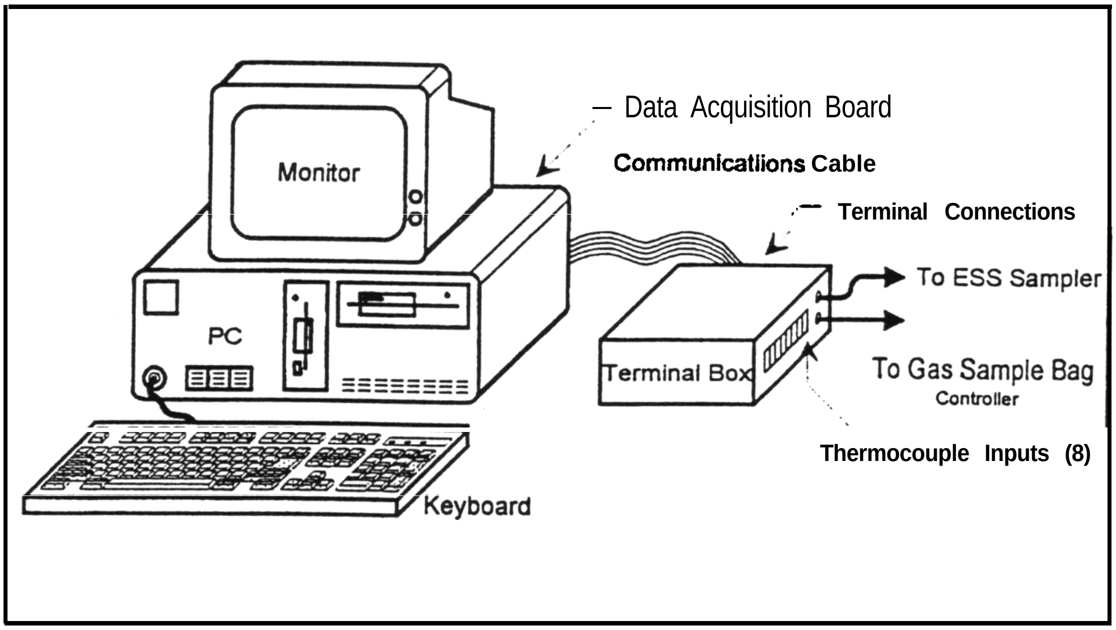

Figure 3.3.11.4-l
The ESS Data Acquisition and Sampler Control System

3.3.11.4.1 Test-period starting and ending times and dates and total length of sampling period,

3.3.11.4.2 Temperature measurements , including flue-gas temperatures at all applicable locations, and ambient test facility temperature, Temperature measurements shall be recorded at least once per minute and averaged for recording at each 5-minute test interval throughout the test period,

3.3.11.4.3 Date, times, and weights of each added fuel load,

3.3.11.4.4 Flue-gas oxygen concentrations. Flue gas oxygen sensor measurements shall be recorded at least once per minute and averaged for recording at each 5-minute test interval throughout the test period.

3.3.11.4.5 During testing, instantaneous readings of real-time data shall be displayed on the system status screen. These data shall include the date, time, temperatures for each of the thermocouples and flue-gas oxygen concentrations. The most recent 10 sets of 5-minute average recorded data shall also be displayed.

3.3.11.4.6 Test Period Initiation-Flue-gas sampling and the recording of flue-gas oxygen concentrations shall begin and continue only after flue-gas temperatures as measured at the lowest temperature monitoring point in the flue duct are 25°F (14°C) greater than the pre-test flue-gas temperature determined in Section 3.9.5. After test initiation, all average temperatures, average flue-gas concentrations, and fueling events shall be recorded at five-minute intervals throughout the test period until the test is terminated as provided in Section 3.11.9 of this Protocol.

3.3.11.5 ESS Sampling-Pump Operation . The ESS sampling-pump operation shall be set for continuous flow in the ranges established in Section 3.3.11.3.1.

3.3.11.6 Minimum Sample Quantities.

3.3.11.6.1 For each complete test period, the ESS must catch a minimum total particulate material mass of at least 15 mg.

3.3.11.6.2 Alternatively, the ESS must sample a minimum of 150 liters during each test-bum period. If this volume cannot be sampled in the test-bum time period, two ESS samplers must be utilized to sample fireplace emission simultaneously during each test-bum. If emissions results from the two ESSs are different by more than IO percent of the lower emissions-factor result, the test-bum results shall be invalid. An arithmetic average is calculated for test-bum results when two ESSs are utilized.

3.3.11.7 ESS Preparation and Sample Processing Procedures. Prior to emissions testing, the ESS unit shall be prepared with a new, tared glass-fiber filter and a clean XAD-2 sorbent-resin cartridge. Within 1 hour after testing is completed, the stainless steel sampling probe, Teflon@ sampling line, filter holder, and XAD-2 sorbent-resin cartridge(s) shall be placed in a container that maintains temperatures less than 70 degrees F (20 degrees C) before it is-removed from the test site and transported to the laboratory for processing. Each component of the ESS shall be processed as follows:

3.3.11.7.1 Filter: The glass-fiber filter (4 inches (102 mm) in diameter) shall be removed from the ESS filter housing and placed in a petri dish for desiccation and gravimetric analysis.

3.3.11.7.2 XAD-2 sorbent-resin cartridge: The sorbent-resin cartridge shall be extracted in a Soxhlet extractor with dichloromethane for 24 hours. The extraction solution shall be transferred to a tared glass beaker and evaporated in a filtered ambient-air dryer. The beaker with dried residue shall then be desiccated to constant weight (less than ±0.5 mg change within a 2-hour period), and the dichloromethane-extractable residue shall be weighed.

3.3.11.7.3 ESS hardware: All hardware components which are in the flue-gas sample stream (stainless steel probe, Teflon@ sampling line, stainless steel filter housing, and all other Teflon@ and stainless steel fittings) through the top of the sorbent-resin cartridge, shall be cleaned with a solvent mixture of 50 percent dichloromethane and 50 percent methanol. The cleaning solvent solutions shall be placed in tared glass beakers, evaporated in an ambient-air dryer, desiccated to constant weight (less than ±0.5 mg change within a 2-hour period), and weighed. Blank values shall be determined for the amount of each solvent used for cleaning ESS components and these blank values shall be subtracted from the total measured particulate residues determined in this Section.

3.3.11.7.4 The EPA Method 5 procedures (40 CFR Part 60 Appendix A) for desiccation and weighing time intervals shall be followed for the residues processed in Section 3.3.11.7. of this Protocol.

3.3.11.7.5 The ESS shall be serviced both at the start and end of a fireplace testing period. During test preparation, leak checks shall be performed; the thermocouples, fuel-weighing scale, and oxygen-cell shall be calibrated, and the data logger shall be programmed. At the end of the test period, final calibration, and leak-check procedures shall again be performed and recorded, and the ESS sampling line, filter housing, XAD-2 cartridge, sampling probe, and Tedlar® bag shall be removed, sealed, and transported to the laboratory for analysis. If the pre-test and/or post-test leak checks of the ESS system exceed 0.05 liters per minute, the test-burn emission results shall be invalid. The average of the starting critical orifice calibration and ending critical orifice calibration sampling rates is used to determine the sample rate.

3.3.12 Gas Analyzers. A combustion gas analyzer for measuring carbon dioxide (CO_2), carbon monoxide (CO) and oxygen (O_2) in sampled flue-gas samples and a low-level carbon dioxide analyzer for measuring ambient carbon dioxide in the range of 0 to 2000 ppm CO_2 will be used. These gas analyzers must meet the following measurement system performance specifications:

3.3.12.1 Analyzer Calibration Error. Shall be less than ±2 percent of the span value for the zero, mid-range, and high-range calibration gases.

3.3.12.2 Sampling System Bias. Shall be less than ±3 percent of the span value for the zero, mid-range, and high-range calibration gases.

3.3.12.3 Zero Drift. Shall be less than ±2 percent of the span value over the time of each test period.

3.3.12.4 Calibration Drift. Shall be less than ±2 percent of the span value over the time of each test period.

3.3.12.5 Response Time. Shall be less than 1.5 minutes.

3.3.12.6 Interferences & Limitations. CO_2 interference in the CO analyzer shall be determined by sampling CO_2 calibration gas through the CO analyzer. CO_2 calibration gas in the IO to 12 % range shall be used for this purpose. An analyzer shall be rejected for use if its response indicates more than 0.1% carbon monoxide under such testing.

Unless measurement of flue-gas carbon dioxide (C02) and carbon monoxide (CO) can be accomplished on a continuous basis at an accuracy of +/- 50 parts per million, this Protocol can not be used to measure emissions and efficiency of those masonry fireplaces that produce less than 1 .O% average total CO2 plus CO volume in the flue gases during a bum cycle performed as prescribed in this Protocol.

3.3.13 Total Combustible Carbon (TCC) Thermal Efficiency Measurement System Specifications flue-gas incinerator (Figure 3.3.13.1), direct flue-gas (Figure 3.3.13.2), and ambient air (Figure 3.3.13.3) sampling trains consist of the following components:

3.3.13.1 Flue Gas Sample Bag. A gas sample bag (recommended Tedlar®) of 1 cubic-foot minimum size and equipped with a screw type inlet/outlet port valve. The bag shall be purged with nitrogen and completely evacuated before each test.

3.3.13.2 Flue-Gas Sample Probe. Heated Stainless steel with 3/8-inch (10 mm) O.D. Sited at the primary sampling location in accordance with Particulate Sampling Train Section 3.3.11.2.

3.3.13.3 Incinerator. A tube furnace capable of maintaining a continuous minimum temperature of 1202°F (650°C) in a flow-through 150 ml quartz tube. During the collection of samples for measuring efficiency the TCC incinerator system shall provide a minimum sample-gas residence time in the heated incinerator tube of 2 seconds. The tube shall contain 150 ml of catalyst-coated (e.g., platinum and palladium) ceramic beads or pellets (1 O-12 mesh). (A 50/50 mixture of Englehard® #2253701 and #1243801 catalyst beads is recommended.)

3.3.13.3.1 Incinerator Performance Specifications.

3.3.13.3.2 Zero-Gas Response. When CO2-free air is passed through the incinerator sampling train (introduced at the sample probe/nozzle end), at a flow rate that is plus or minus 20% of the flow rate used during sampling (Section 3.5.2), the CO2 concentration at the output of the incinerator shall be less than 0.05 percent.

3.3.13.3.3 Mid-Level Gas Response. When mid-level incinerator-check gas is passed through the incinerator, at a flow rate that is plus or minus 20% of the flow rate used during sampling, the measured change in CO2 concentrations shall be at least 90 percent of the theoretical value, based upon the actual composition of the mid-level incinerator-check gas used.

3.3.13.4 Flowmeters. Rotameter with flow-control valve in the 0 to 200 ml per minute (0.5 cf/hour) range.

3.3.13.5 Condenser/Dryers. At least 2, low-volume (e.g., 50 ml) ice-cooled impingers.

3.3.13.6 Filter. An in-line filter to remove solids from the sampled gas stream. The filter can be fiberglass or glass wool. Disposable filter cartridges may be used.

3.3.13.7 Lung-Sampler Enclosures with Evacuation Pumps. Lung sampler enclosures of approximately 2 to 3 cubic feet (57 -85 liters) of volume each with an evacuation pump capable of pumping 0.42 cubic feet per hour (200 ml/hr) @ 20 inches (520mm) of Hg vacuum.

3.3.13.8 Heated Teflon@ Tubing for the TCC System. Heated Teflon tubing, 3/8-inch (10 mm) ID, not to exceed- 15 feet (4.6 meters) in length, shall be used to make the connection between the heated stainless-steel sampling probe and the incinerator. Connection between the furnace and cooler should be made with either quartz or borosilicate glass. Non-heated 3/8-inch (10mm O.D.) Teflon@ tubing shall be used to make all other connections shown in Figure 3.3.13-1.

3.3.13.9 Pressure Dampener (optional).. A glass flask or similar device about 200ml in size may placed in the sample line between the pump and flow meter to pressure fluctuations.

3.3.13.10 Vacuum Gages. Vacuum gage with a range of 0 to 30 inches of mercury.

3.3.13.11 Tees and Valves (optional). To permit withdrawal of a portion of the gas-sample stream during a test period for optional, on-line, real time instrumental analysis of carbon dioxide.

3.3.13.12 Three-Way Valve. For purging and evacuating gas sample bags, for isolating the sample bag once evacuated, and for permitting withdrawal of sample from the bag for analysis.

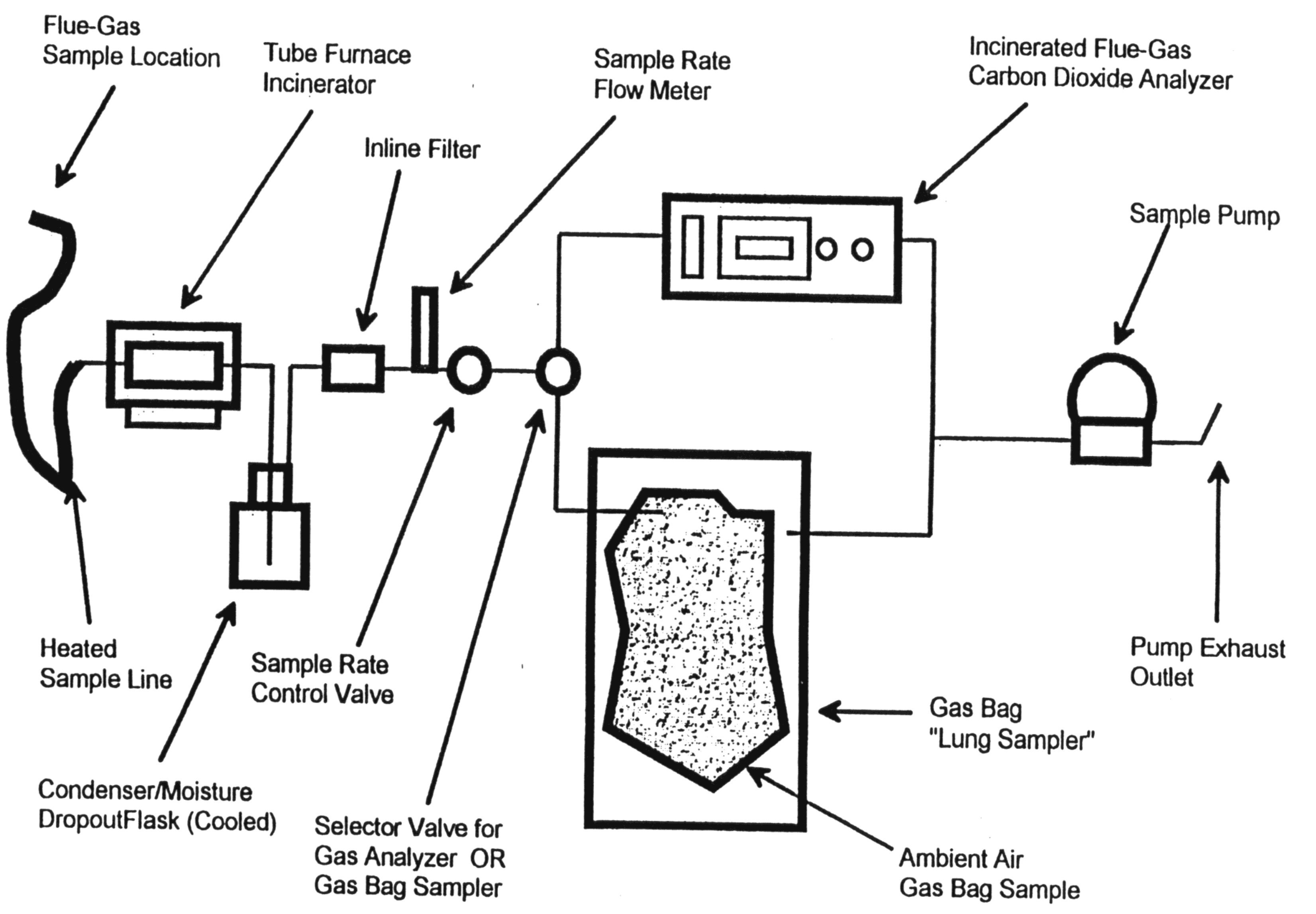

Figure 3.3.13.1 Flue-Gas Incinerator Sampling Train.

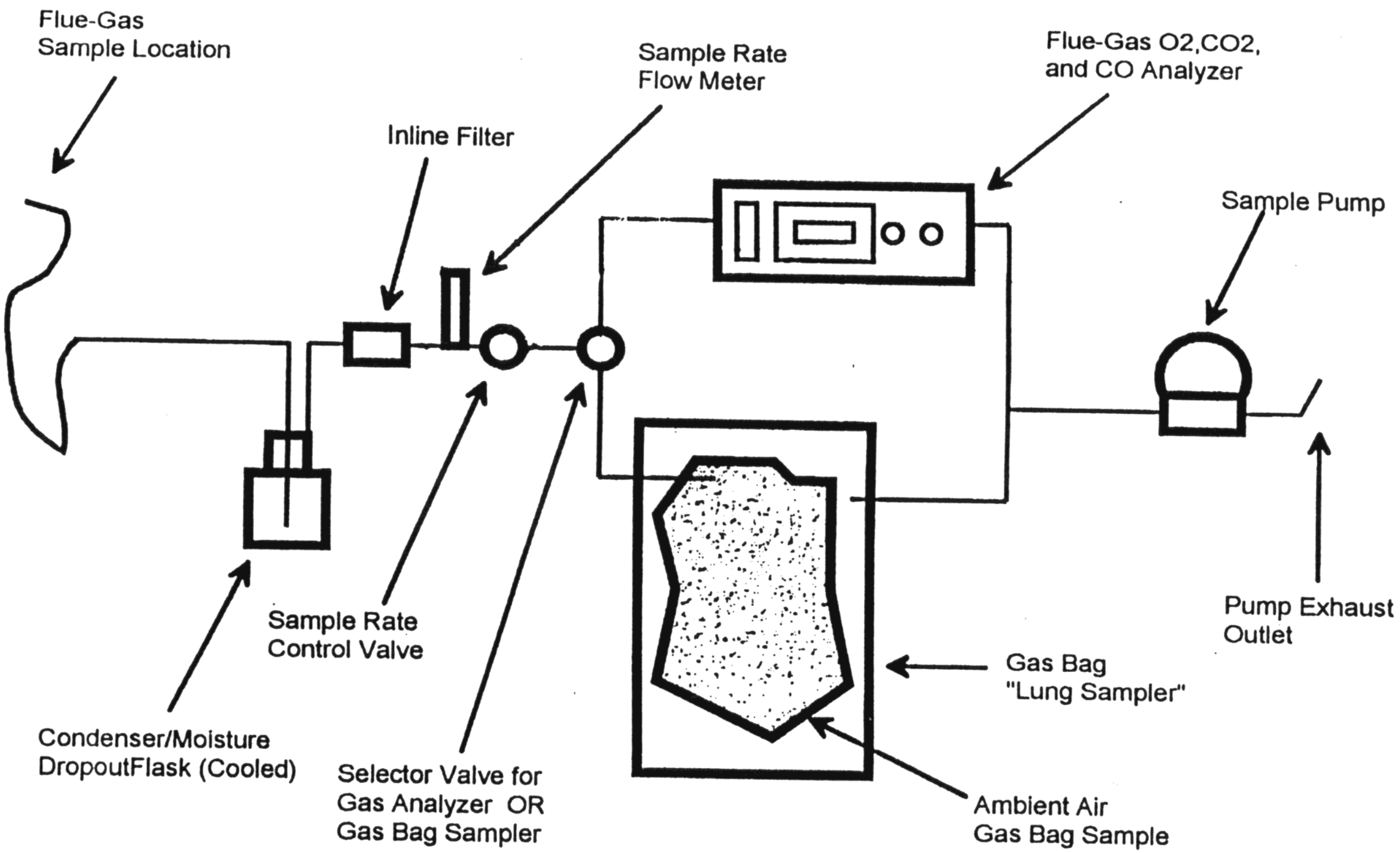

Figure 3.3.13.2 Flue-Gas Sampling Train.

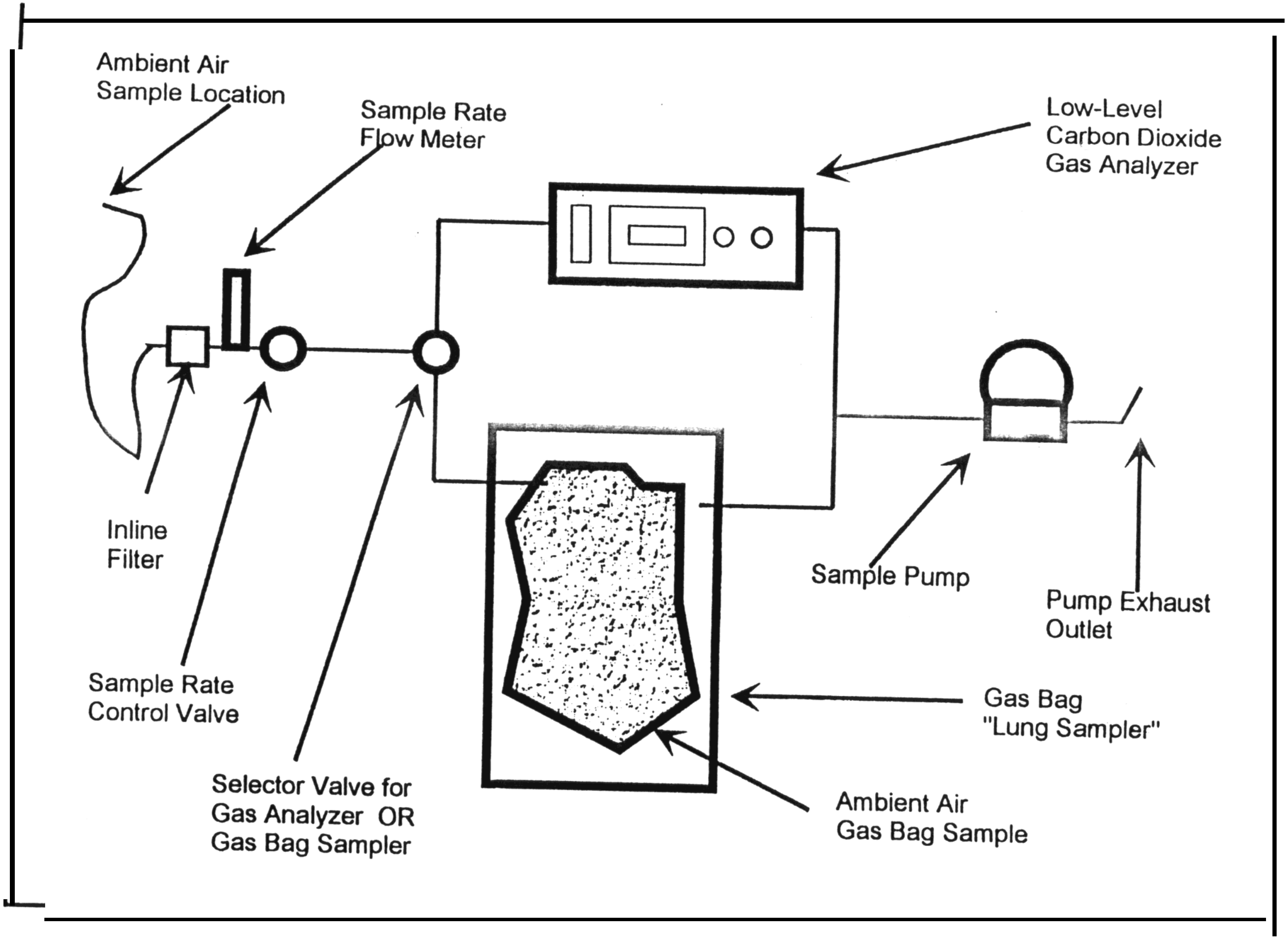

Figure [illegible] Ambient Air/Carbon Dioxide Sampling Train.

3.4 Supplies and Reagents.

3.4.1 Calibration Gases. Calibration gases for each flue-gas constituent to be measured shall have concentrations at each of the nominal levels indicated in Table 3.4.1. Mixtures or combinations of calibration gases may be used in place of separate cylinders for each calibration constituent.

Table 3.4.1
Nominal Calibrations-Gas Constituent Levels
(Each Constituent may be in Separate or Combined **Cylinders.)**

Gas Level	**Concentrations (Volume Percent)**		
Combustion Gas Analyzer/ESS O_2 Cell	CO_2	O_2	c o
High	**10**	**20**	1.0
Mid	**4**	**14**	**0.3**
Zero	**0**	**0**	**0**
Low-Level CO_2 Analyzer	CO_2	O_2	c o
High	**2.0**	NRe	NRe
Mid	1.0	NRe	NRe
Zero	**0** (<10 ppm)	NRe	NRe

Note 1: All calibration gas mixtures shall be' certified by the calibration gas supplier or the NSCAPCD-approved test laboratory using the reference methods contained in the Title 40 Code of Federal Regulations, Part 60, Appendix A: Methods 3 and 10.

Note 2: NRe = Not Required.

3.4.2 Incinerator Performance Gases. Two gas mixtures are required for testing the destruction efficiency of the incinerator. Required constituents and their concentrations are presented in Table 3.4.2.

Table 3.4.2
Required Incinerator
Performance-Gas Compositions and Concentrations.

Gas Level	**Compositions (Volume Percent)**
Mid	**0.1% CO; 0.1%** CH,; Balance in CO,-Free Air
Zero	CO,-Free Air

Note: The purpose of the incinerator check gases is not to validate the incinerator, but to check that it effectively oxidizes combustible gases, and to check that there is no residual CO2 being emitted from the oxidation of any carbonaceous matter lodged in the incinerator. The first of the two gas levels listed above is labeled “Mid” because higher and lower actual combustible gas concentrations may be encountered.

3.4.3 Dichloromethane. Reagent Grade or better. (Report blanks for each supply batch.)

3.4.4 Methanol. Reagent Grade or better. (Report blanks for each supply batch.)

3.4.5 Type A/E glass-fiber filters. Rated at 99.9% removal of particulate matter 0.3 m aerodynamic diameter: 102 mm diameter.

3.4.6 Amberlite. XAD-2 adsorbent resin.

3.5 **Operation of Thermal Efficiency Gas-Sampling Trains.** For the measurement of efficiency, three gaseous samples are collected concurrently and continuously throughout a test period. One sample is withdrawn directly from the fireplace flue/chimney. The second sample is withdrawn from an incinerator that oxidizes combustible gases as they are withdrawn from the fireplace flue/chimney and the third sample is collected from ambient air. After a test period is completed, the carbon dioxide (C02) concentration in each gas sample is measured using a CO2 gas analyzer. Chemical energy losses are determined by using an estimated combustibles-heating-value equal to the lower-heating-value of the fuel and the difference in CO2 concentrations between the incinerated and non-incinerated flue-gas samples. Ambient CO2 concentrations are used to correct the flue-gas sample concentrations for local background variations. Sensible energy losses are determined using flue-gas temperature and flue-gas flow. Total flue-gas flow is calculated by using the fuel-carbon/flue-gas-carbon balance relationship. Latent energy losses are determined as a theoretical latent loss, as if combustion were complete. Once all of the energy losses are determined, the method-defined overall thermal energy efficiency of the fireplace is calculated.

3.5.1 Response Time. The amount of time it takes for sampled gases to travel from the end of each sample probe (in the flue/chimney or ambient air) to the gas-sample bag shall be determined by injecting a high-level calibration gas (CO or CO_2) into the end of each of the flue-gas sample probes and measuring how much time it takes to be measured at the gas-sample bag-port to 90% or greater of the calibration-gas value with a calibrated gas analyzer. During this determination of “response time”, each sampling train shall be operated at its ‘normal” sampling rate.

351.1 The determination of response time for each gas sampling train shall be conducted once every six months or at the time when sampling train components or sampling rates are changed.

3.5.1.2 At the end of each test-period, each of the three gas sampling trains shall be operated past the time that the test is terminated as provided in Section 3.11.9 of this Protocol, for a period equal to the respective response time for each of the three sampling trains.

3.52 Gaseous Sampling Rates. The sampling rate into each gas-sample bag shall be constant to within ±10% of the test-period average, from the beginning of a test period to the end, and high enough to insure that the total volume of each collected sample is greater than 10 liters (or .35 ft^3). If it turns out that the resulting flow rate is more than the desired bag-filling rate, vent the excess sample at a constant rate continuously during the entire test period, using a selector valve tee and control valve as shown in Figures 3.3.13.1, 3.3.13.2, and 3.3.13.3.

3.53 Data Recording. During the test period, record the sampling rate for each sampling train, the vacuum of each sampling system, and the incinerator temperature, once every 5 minutes.

3.5.4 Sample Analysis.

3.5.4.1 Leak Checks. A pre-analysis leak check of the CO2 analyzer train is recommended but not required. A post-analysis leak check is mandatory at the conclusion of the sample analysis.

3.5.4.1.1 Leak-Check Procedure. Seal the sample inlet probe to the CO2 analyzer train. Use the CO2-train sampling pump controls to create a vacuum greater than, either twice the maximum vacuum encountered during the test period, or 125 mm Hg (5 inches), whichever is greater. Record the resulting sample flow rate indicated by the CO2 instrument flowmeter when the required vacuum is achieved, corrected for pressure, if applicable.

3.5.4.1.2 Acceptance Criterion. If the vacuum leakage rate is found to be in excess of 2 percent of the average test-period sampling rate the test results are invalid.

3.5.4.2 Concentration Measurements. Measure the CO_2 concentration in each of the three gas sample bags at least twice. After preparation of the CO2 analyzer train(s) as described in Section 3.6.10, analyze the three sample bags in quick succession and in the following order: ambient air, direct flue-gas, and then incinerated flue-gas. Next, re-zero the CO_2 analyzer (optional). Then re-analyze the three gas-sample bags a second time in quick succession and in the same order. If the two measurements for each gas-sample bag agree to within the acceptance criteria presented in Table 3.5.4.2.1, the analysis is complete. If the two analyses for any one sample do not satisfy the acceptance criteria, re-zero the analyzer (optional) and re-analyze all three gas-sample bags a third time using the same procedure. If, for each of the three gas-sample bags, at least two of the three analyses satisfy the respective acceptance criterion, the analysis is complete

3.5.4.2.1 Use the average of the two analyses which fall within the acceptance criteria in. all subsequent calculations. If, after three analyses, the acceptance criteria are still not met, efficiency results for the test period are not valid.

Table 3.5.4.2.1 Acceptance Criteria for CO_2 Concentration Measurements.	
Sample	**Acceptance Criterion (percent of the paired-average value[1])**
Ambient	**15%**
Incinerated Flue-Gas	**3%**
Direct Flue-Gas	**2%**

[1] For example, a paired set of direct flue-gas CO_2 analyses which result in measurements of 9.9 and 10.1 mole-percent passes, and a paired set which results in measurements of 9.9 and 10.2 mole-percent, fails.

3.5.4.2.2 For clean-burning appliances, if the inexactness of the measurement process results in a measured flue-gas CO_2 concentration exceeding the measured incinerated flue-gas concentration by more than 2 percent of the incinerated flue-gas concentration value, efficiency results for the test period are invalid.

Note: If the direct flue-gas CO2 concentration is between 100 and 102 percent of the incinerated flue-gas CO2 concentration, record all the actual measured values, but for subsequent calculations, use a direct flue-gas concentration that is 99 percent of the incinerated flue-gas value.

3.6 Calibrations and Audits.

3.6.1 Scale. Before each certification test, the scale used for weighing test-fuel charges shall be audited by weighing at least one calibration weight (Class F) that corresponds to 20 percent to 80 percent of the expected test-fuel charge weight. If the scale cannot reproduce the value of the calibration weight within 0.1 pound (0.05 kg) or 1 percent of the expected test-fuel charge weight, whichever is greater, re-calibrate the scale before use with at least five calibration weights spanning the operational range of the scale.

3.6.2 Temperature Monitor. Calibrate the Temperature Monitor before the first certification test and semiannually thereafter.

3.6.3 Fuel Moisture Meter. Calibrate the Fuel Moisture Meter as per the manufacturer's instructions before each certification test.

3.6.4 Anemometer. Calibrate the Anemometer as specified by the manufacturer's instructions before the first certification test and semiannually thereafter.

3.6.5 Barometer. Calibrate the Barometer against a mercury barometer before the first certification test and every month thereafter.

3.6.6 Draft Gauge. Calibrate the Draft Gauge as per the manufacturer's instructions; an inclined liquid manometer does not require calibration but must be checked for level (zero tilt).

3.6.7 Sample Gas Flowmeters. Sample Gas Flowmeters shall be calibrated once every six months or once after every 10 tests whichever occurs first.

3.6.8 Combustion Gas and Ambient CO2 Analyzers. Combustion Gas and Ambient CO2 Analyzers shall be calibrated before and after each test to check potential accuracy and drift errors.

3.6.9 Emission Sampling System (ESS). The ESS sample flow rate and oxygen sensor cell shall be calibrated before and after each test as specified in Section 3.3.11.7.5. Before each test the XAD-2 cartridge shall be processed as described in Section 3.3.11.7.2 for the determination of an XAD-2 resin blank. No XAD-2 resin blank that exceeds 2mg per 25 gram batch of XAD-2 resin shall be used for any test.

3.6.10 CO_2 Analyzer Train. Upon assembly of the CO_2 analyzer sampling train, perform a three-point, (multi-point) calibration check of the analyzer train. If at any time during the test and analysis procedures, a single-point audit fails (using the criteria set forth in Section 3.5.4.2), re-perform the multi-point calibration.

3.6.10.1 Set up the CO_2 analyzer train and allow the instrument to operate for a sufficient time to stabilize, as recommended by the manufacturers recommended operating procedures.

3.6.10.2 Introduce zero gas into the inlet at a "normal" sample flow rate, and zero the analyzer output. Then introduce the high-level calibration gas and span the analyzer output.

3.6.10.3 Introduce, in the same manner as described in Section 3.5.4.2, the level calibration gas, and record the instrument response when no further change in the analyzer response can be detected.

3.6.10.4 Calculate and plot a linear least-squares calibration curve, forcing the curve to pass through the origin.

3.6.11 CO_2 Analyzer Train Audit. Within 15 minutes of analyzing the three gas samples from a test, zero and span the CO_2 analyzer train with the zero- and high-level calibration gases. Then introduce a mid-level calibration gas. Using the most recent calibration curve for the analyzer, compare the measured concentration of the mid-level calibration gas to its actual concentration. If the values do not agree to within 5 percent the average of their values, recalibrate the analyzer train, and start the analyzer audit procedure over again.

3.6.12 Sampling Rate Constancy. For each of the gas-sampling trains, calculate the average sampling rate during the entire test period from the data recorded as described in Section 3.53. Then calculate the percentage deviation of each recorded sampling rate from its test period average. The sampling rate is adequately constant and valid if the average magnitude of the deviations is less than 10 percent and if no single deviation is larger than 15 percent.

3.6.13 Efficiency Data Quality. Conformance with data quality criteria shall be required for validating thermal efficiency measurement results. Measurement values outside of the following indicated ranges shall be considered invalid for supporting fireplace approval applications:

$$0.03\ \% < CO_{2A}\ \% < 0.10\ \%$$

$$0\ \% < CO_{2A}\ \% < CO_{2FD}\ \% < CO_{2FI}$$

WHERE:

CO_{2A} = Ambient CO2

CO_{2FD} = Direct Flue-Gas CO_2

CO_{2FI} = Incinerated Flue-Gas CO_2

3.7 Fireplace Installation and Test Facility Requirements. The fireplace being tested must be constructed, on site, in accordance with the designers/manufacturer's written instructions. The chimney shall have a total vertical height above the hearth of not less than 15 feet (4.6 m). The fireplace flue/chimney exit to the atmosphere must be freely communicating with the fireplace combustion makeup-air source. There shall be no artificial atmospheric pressure differential imposed between the chimney exit to the atmosphere and the fireplace make-up air inlet. The flue/chimney configuration and grate height above hearth shall be noted for purposes of model line identification.

3.8 Fireplace Aging and Curing. A fireplace of any type shall be aged before certification testing begins. The aging procedure shall be conducted and documented by the testing laboratory.

3.8.1 Catalyst-Equipped Fireplaces. Operate the fireplace with a new catalytic combustor in place for a period of at least 50 hours using fuel as described in Section 3.11.1. Record and report hourly catalyst exit temperatures, the hours of operation, and the weight of all fuel burned during the aging and curing period.

3.8.2 Non-Catalyst-Equipped Fireplaces. Operate the fireplace using the fuel described in Section 3.11.1 for at least 10 hours. Record and report the hours of operation and weight of all fuel burned during the aging and curing period.

3.8.3 Flue-Gas Stratification Check. During the last five hours of the aging and curing period specified here, use the carbon dioxide analyzer and sampling system specified in Section 3.3.12 to determine whether flue gases become stratified in the flue/chimney cross-section of the proposed ESS and TDD sampling points. Stratification of flue-gas carbon dioxide concentrations shall be determined by first sampling at the center of the flue/chimney for at least one minute and then moving the sampling probe to within 1 inch (25.4mm) of the flue chimney wall for an additional minute. This procedure is to be repeated on at least two traverses of the flue/chimney that are 90° from each other. Flue-gas carbon dioxide concentration changes of more than 15% (ie, 15% of the carbon dioxide concentration measured when sampling at the center of the flue/chimney) when the sample probe is moved from the center of the flue/chimney to within 1 inch (25.4 mm) of the flue/chimney wall shall be considered stratified. The presence of stratified flue-gases at the flue/chimney sampling location shall be remedied by either changing the flue/chimney duct design, changing the flue-gas sampling location, or changing the flue-gas sampling probe to equally and simultaneously sample the flue-gases in the center of at least 4 separate equal areas of the flue/chimney cross-section.

3.9 Pretest Preparation.

3.9.1 Record measurements. Record test-fuel charge dimensions, moisture content, and weights. The fireplace description shall include photographs showing all externally observable features and drawings showing all internal and external dimensions needed for fabrication and/or construction. The drawings must be verified as representing the fireplace being tested and signed by an authorized representative of the testing laboratory.

3.9.2 Record descriptions. Record fireplace and catalyst descriptions, if equipped.

3.9.3 Sample-Bag Evacuation. Evacuate each of the gas sample bags. If necessary, roll the bag up'toward the inlet/outlet port-valve fitting from the opposite comer and complete evacuation with a vacuum pump. Flush each bag with zero-air before evacuation.

3.9.4 Fireplace Cooling Period. No fuel shall be burned in the test fireplace and no ether means for heating the fireplace may be used within 12 hours preceding the start of a test period.

3.9.5 Pre-Test Flue Temperature. At least one hour before initiating a test period (.i.e., ignition of **a** fire in the fireplace), close all air supply controls and fireplace door(s). If the fireplace is not equipped with **a** door(s), use other means for closing the open face area of the fireplace. After one hour of closure and within 5.0 minutes prior to opening the fireplace for test-fire ignition, measure and record the pre-test flue-gas temperature at the thermal efficiency temperature location or the secondary sampling location whichever is closer to the hearth floor.

3.10 **Test** Facility Conditions **and Monitoring Specifications. The** test facility ambient temperature probe shall be located no closer than 3 feet nor farther than 6 feet from the vertical plane created by the opening of the fireplace. The probe must be located within 45 degrees of a line drawn perpendicular to the center of the vertical plane. Test facility ambient temperatures shall be maintained between 65 and 95°F (16 and 32°C) during test periods.

Using an anemometer measure and record the room-air velocity within 2 feet (0.6 meters) of the test fireplace before test initiation and once immediately following the test-burn completion. Air velocity within 2 feet (0.6 meters) of the test fireplace shall be less than 50 feet/minute (250 mm/second) without the fireplace operating. Measure and record the barometric pressure before and after each test-bum period.

3.11 Fireplace Operating Protocol and Test Requirements.

3.11.1 Test Fuel. Test fuel shall be air-dried Douglas fir dimensional lumber or air dried cordwood without bark. Fuel pieces shall not be less than ½ nor more than $^5/_6$ of the length of the average fire chamber width or not more than 1.5 times the average grate width if a grate is used in the firebox. Fuel shall be split or cut into pieces with no cross-sectional dimension greater than 6 inches (152 mm) or less than 1 .O inches (2.5 cm). Spacers, if used, shall not exceed ¾ inches (19 mm) in thickness and 4 inches (100 mm) in length and shall not be more than 15 percent of the test-fuel charge weight. The test fuel moisture for each piece of fuel, as measured at a depth of one inch, shall be in the range of 16 to 20 percent (wet basis) or 19 to 25 percent (dry basis).

3.11.2 Test-Fuel Loading . The wet (with moisture) minimum weight of each test-fuel charge shall be calculated by multiplying the useable firebox or hearth area (see definition in Section 2.0), in square feet, by 7.0 pounds per square foot (square meters of hearth area x 0.30 kg/m2). Three equal (± 5%) test-fuel charges shall be prepared for each test-bum.

3.11.3 Test-Fuel Placement. All testing is to be performed using a grate. Spacer and fuel arrangement shall follow the methods identified in 40 CFR Part 60 Subpart AAA, Appendix A Method 28A & 28. If the manufacturer's or builder's written operating instructions require the stacking of fuel pieces in a non-conventional configuration (i.e., the long axes of the fuel pieces are not horizontal or do not approximate horizontal placements parallel to the hearth floor), the NSCAPCD shall approve the fuel placement configuration_ to be used for performing an additional set of tests for each applicable fireplace configuration in Section 3.11 .1 3 of this Protocol. The NSCAPCD shall base its determination for fuel placement configuration on a reasonable expectation of consumer practices.

To determine compliance with Section 1 .1.1.2 of this Protocol, the results of the test bums performed with NSCAPCD-specified fuel placement configuration shall be arithmetically averaged with the results from the test bums performed with the manufacturers or builder's specified fuel placement configuration.

3.11.4 Kindling. Kindling fuel shall be air-dried Douglas fir dimensional lumber or split cordwood with moisture contents of 16 to 20 percent (wet basis) or 19 to 25 percent (dry basis). The initial test-fuel charge of each three test-fuel-charge test-bum may be started by using a kindling-fuel charge which is up to 25 percent of the first test-fuel charge weight. Kindling-fuel pieces can be any size needed to start the fire or whatever is recommended in the manufacturers (builder's) instructions to consumers. The first kindling-fuel charge weight is not part of the initial test-fuel charge weight but is in addition to it and is used in calculating total fuel for the test period.

3.115 Test-Bum Ignition. No burning or heating by other means shall take place in the test fireplace for 12 hours before test-burn ignition. The test fire can be started with or without paper. If used, the weight of the paper shall not be included in test-fuel charge weight. The remainder of the test-fuel charge must be added within 10 minutes after test initiation.

Prior to fuel charge ignition in a masonry heater, it may be necessary to first establish an operational flue draft so that combustion gases exit properly through the convoluted venting path and out the chimney exit. Otherwise, initial firebox combustion gases might vent out the fuel loading door or extinguish. Establish sufficient operating draft by first heating the venting path by burning paper and/or kindling, so that flue draft is at least 0.02" H_2O measured at the 8-foot (2.44 meter) sampling level. Test measurements and sampling shall be initiated when flue temperatures reach 25°F above pre-test flue-gas temperature as specified in Section 3.11.6. The weight of paper and/or kindling used to initiate a draft for nominal fireplace operation are not considered part of the fuel load charges and are not included in total fuel weight determinations.

3.116 Test Initiation. Emissions and flue-gas sampling are initiated after the kindling has been ignited and within 30 seconds of when flue-gas temperature at the center of the flue at an elevation of 8 feet (2.44 meters) above the hearth, or the upstream flue-gas measurement location of an emissions control device reaches 25°F (14°C) greater than the pre-test flue-gas temperature. Once all test sampling and measurements have been initiated, all test sampling and measurements shall continue without interruption until the test is terminated in accordance with Section 3.11.9 of this Protocol.

3.11.7 Measuring Parameters. Sampling shall include:

3.11.7.1 Particulate Emissions.

3.11.7.2 Carbon Dioxide (C02).

3.11.7.3 Carbon Monoxide (CO)

3.11.7.4 Oxygen (02)

3.11.7.5 Temperature.

The required sample gases may be measured on-line (real-time) using analyzers meeting the requirements of Section 3.3.12 of this Protocol and recorded by the ESS data logger at a frequency of not less than once every minute during the test-bum period. These l-minute readings are to be arithmetically averaged over the test-bum period.

3.11.8 Test-Fuel Additions. The second and third test-fuel charges for a test-bum period shall be placed and burned in the fire chamber only after flue-gas oxygen concentrations, as measured by the ESS Oxygen sensor (or an alternative oxygen analyzer as provided for in Section 3.11.7 of this Protocol), have recovered (i.e., increased) to at least 90% of the maximum flue-gas oxygen depression value resulting from combustion of the previous test-fuel charge. 20.9 percent is to always be used as the baseline air supply oxygen concentration. For example, if the maximum flue-gas oxygen depression from the burning of a precedent fuel charge was 2.50% (i.e., the minimum flue-gas oxygen was 18.40%: 20.90 - 18.40 = 2.50%) the next fuel charge may only be loaded after the flue-gas oxygen concentration has returned to 20.65% or greater: (0.90 x 2.50) + 18.4 = 20.65%.

3.11.8.1 If the coal bed remaining after flue-gas oxygen concentrations are recovered (i.e., increased) to at least 90% of the preceding maximum flue-gas oxygen depression value, is not sufficient or adequate for restarting the next test-fuel charge within 5.0 minutes after loading the test-fuel charge, newspaper and/or kindling may be added and the test-fuel charge re-positioned in order to facilitate reasonable ignition of the added test-fuel charge.

3.11.8.1.1 The addition of all newspaper and/or kindling and repositioning the entire test-fuel charge must be completed within 10.0 minutes from the time the first piece of fuel is first added.

3.11.8.1.2 The weight of newspaper and/or kindling added under 3.11.8.1 shall be weighed to the nearest 0.1 lb (0.05 kg) and recorded.

3.11.8.1.3 The weight of the newspaper and/or kindling added under 3.11.8.1 shall not be included in the total test-fuel weight for the test period.

3.11.9 Test Completion. A test (i.e., a three test-fuel charge test-bum period) is completed and all sampling and test-period measurements are stopped at the time flue-gas oxygen concentrations, as measured by the ESS oxygen sensor (or an alternative oxygen analyzer as provided for in Section 3.11.7 of this Protocol), have recovered (i.e., increased) to at least 95% but not more than 97% of the maximum flue-gas oxygen depression value resulting from combustion of the third test-fuel charge.

3.11.9.1 Within 5 minutes after the test-bum is completed and all measurements and sampling has stopped, the remaining coals and/or unburned fuel, and ash shall be removed from the firebox and weighed to the nearest 0.1 pound (0.05 kg). (It is recommended that the coals first be extinguished with carbon dioxide.) The weight of these unburned materials and ash shall be carefully removed from the total test-bum fuel weight when calculating the test-bum bum rate. A test-bum shall be invalid if less than 90 percent of the weight of the total test-fuel charges plus the kindling weight have been consumed in the fireplace firebox.

3.11.10 Test-Fuel Charge Adjustments. Test-fuel charges may be adjusted (i.e., repositioned) once during the burning of each test-fuel charge. The time used to make this adjustment shall be less than 15 seconds.

3.11.11 Air Supply Adjustment. Any means for controlling combustion air supplies may only be adjusted during the first 10 minutes after the addition of each test-fuel charge. After the first 10 minutes, after the addition of each test-fuel charge, all air supply control settings must be set to the lowest level and shall remain at the lowest setting throughout the remaining burning time for each test-fuel charge.

3.11.12 Auxiliary Fireplace Equipment Operation. Only auxiliary fireplace equipment that are a permanently installed and integrated into the design and construction of the fireplace may be allowed during testing. Where allowed heat exchange blowers shall be operated during all test bums following the manufacturers written instructions. If no manufacturers written instructions are available, operate the heat exchange blower in the "high" or maximum position. (Automatically operated blowers shall be operated as designed.) Shaker grates, by-pass controls, afterburners, or other auxiliary equipment allowed under this section may be adjusted only once during the period that each test-fuel charge bums and the adjustment shall be in accordance with the manufacturers written instructions. Record and report all adjustments on a fireplace operational written-record. Overall efficiency is to be reduce by the amount of electrical energy used by the blowers during the course of the testing.

3.11.13 Fireplace Configurations. One, three-test-fuel-charge test-bum shall be conducted for each of the following fireplace operating configurations:

3.11.13.1 Door(s) closed, with hearth grate;

3.11.13.2 Door(s) open, with hearth grate;

3.11.14 Closed-Door(s) Testing. For all closed-door test configurations, the fuel loading door(s) shall be closed within 10 minutes after the addition of the first test-fuel piece of each test-fuel charge in a test-bum. During a test-bum period, the fuel loading door(s) shall not be re-opened except during test-fuel reload and adjustment as specified in Section 3.11.8 of this Protocol.

3.11.15 Additional Test-Bums. The testing laboratory may conduct more than one test-bum series for each of the applicable configurations specified in Section 3.11.13 of this Protocol. If more than one test burn is conducted for specified configuration, the results from at least two thirds of the test bums for that configuration shall be used in calculating the emissions for that configuration. The measurement data and results of all tests conducted shall be reported regardless of which values are used in calculating the emissions for that configuration.