APPENDIX O TO SUBPART B OF PART 430—UNIFORM TEST METHOD FOR MEASURING THE ENERGY CONSUMPTION OF VENTED HOME HEATING EQUIPMENT

1.0 Definitions

1.1 “Air shutter” means an adjustable device for varying the size of the primary air inlet(s) to the combustion chamber power burner.

1.2 “Air tube” means a tube which carries combustion air from the burner fan to the burner nozzle for combustion.

1.3 “Barometric draft regulator or barometric damper” means a mechanical device designed to maintain a constant draft in a vented heater.

1.4 “Draft hood” means an external device which performs the same function as an integral draft diverter, as defined in section 1.17 of this appendix.

1.5 “Electro-mechanical stack damper” means a type of stack damper which is operated by electrical and/or mechanical means.

1.6 “Excess air” means air which passes through the combustion chamber and the vented heater flues in excess of that which is theoretically required for complete combustion.

1.7 “Flue” means a conduit between the flue outlet of a vented heater and the integral draft diverter, draft hood, barometric damper or vent terminal through which the flue gases pass prior to the point of draft relief.

1.8 “Flue damper” means a device installed between the furnace and the integral draft diverter, draft hood, barometric draft regulator, or vent terminal which is not equipped with a draft control device, designed to open the venting system when the appliance is in operation and to close the venting system when the appliance is in a standby condition.

1.9 “Flue gases” means reaction products resulting from the combustion of a fuel with the oxygen of the air, including the inerts and any excess air.

1.10 “Flue losses” means the sum of sensible and latent heat losses above room temperature of the flue gases leaving a vented heater.

1.11 “Flue outlet” means the opening provided in a vented heater for the exhaust of the flue gases from the combustion chamber.

1.12 “Heat input” (Q\textsubscript{in}) means the rate of energy supplied in a fuel to a vented heater operating under steady-state conditions, expressed in Btu’s per hour. It includes any input energy to the pilot light and is obtained by multiplying the measured rate of fuel consumption by the measured higher heating value of the fuel.

1.13 “Heating capacity” (Q\textsubscript{hm}) means the rate of useful heat output from a vented heater, operating under steady-state conditions, expressed in Btu’s per hour. For room and wall heaters, it is obtained by multiplying the “heat input” (Q\textsubscript{in}) by the steady-state efficiency (\eta\textsubscript{st}) divided by 100. For room and wall furnaces, it is obtained by multiplying (A) the “heat input” (Q\textsubscript{in}) by (B) the steady-state efficiency divided by 100, minus the quantity (2.8)(L\textsubscript{c}) divided by 100, where L\textsubscript{c} is the jacket loss as determined in section 3.2 of this appendix.

1.14 “Higher heating value” (HHV) means the heat produced per unit of fuel when complete combustion takes place at constant pressure and the products of combustion are cooled to the initial temperature of the fuel and air and when the water vapor formed during combustion is condensed. The higher heating value is usually expressed in Btu’s per pound, Btu’s per cubic foot for gaseous fuel, or Btu’s per gallon for liquid fuel.

1.15 “Induced draft” means a method of drawing air into the combustion chamber by mechanical means.

1.16 “Infiltration parameter” means that portion of unconditioned outside air drawn into the heated space as a consequence of loss of conditioned air through the exhaust system of a vented heater.

1.17 “Integral draft diverter” means a device which is an integral part of a vented heater, designed to: (1) Provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft diverter, (2) prevent a back draft from entering the vented heater, and (3) neutralize the stack action of the chimney or gas vent upon the operation of the vented heater.

1.18 “Manually controlled vented heaters” means either gas or oil fueled vented heaters equipped without thermostats.

1.19 “Modulating control” means either a step-modulating or two-stage control.

1.20 “Power burner” means a vented heater burner which supplies air for combustion at a pressure exceeding atmospheric pressure, or a burner which depends on the draft induced by a fan incorporated in the furnace for proper operation.

1.21 “Reduced heat input rate” means the factory adjusted lowest reduced heat input rate for vented home heating equipment equipped with either two stage thermostats or step-modulating thermostats.

1.22 “Single stage thermostat” means a thermostat that cycles a burner at the maximum heat input rate and off.

1.23 “Stack” means the portion of the exhaust system downstream of the integral draft diverter, draft hood or barometric draft regulator, designed to open the venting system when the appliance is in operation and to
close off the venting system when the appliance is in the standby condition.

1.25 "Stack gases" means the flue gases combined with dilution air that enters at the intake of draft diverter, draft hood or barometric draft regulator.

1.26 "Steady-state conditions for vented home heating equipment" means equilibrium conditions as indicated by temperature variations of not more than 5 °F (2.8°C) in the flue gas temperature for units equipped with draft hoods, barometric draft regulators or direct vent systems, in three successive readings taken 15 minutes apart or not more than 3 °F (1.7°C) in the stack gas temperature for units equipped with integral draft diverters in three successive readings taken 15 minutes apart.

1.27 "Step-modulating control" means a control that either cycles a burner at the reduced heat input rate and off or cycles a burner at the maximum heat input rate and off or cycles a burner at the reduced heat input rate and off or cycles a burner at the maximum heat input rate and off.

1.30 "Vaporizing-type oil burner" means a device with an oil vaporizing bowl or other receptacle designed to operate by vaporizing liquid fuel oil by the heat of combustion and mixing the vaporized fuel with air.

1.31 "Vent/air intake terminal" means a device in the installation. Use the minimum length of pipe possible for this section. Use stack, elbow, and horizontal section with same cross sectional area as the diverter outlet.

Attach to the outlet of vented heaters having a horizontally discharging draft diverter or draft hood outlet a 90 degree elbow, and a five (5) foot long test stack having a cross sectional area the same size as the draft diverter outlet.

1.32 "Vent limiter" means a device which limits the flow of air from the atmospheric diaphragm chamber of a gas pressure regulator to the atmosphere. A vent limiter may be a limiting orifice or other limiting device.

1.33 "Vent pipe" means the passages and conduits in a direct vent system through which gases pass from the combustion chamber to the outdoor air.

2.0 Testing conditions.

2.1 Installation of test unit.


2.1.2 Vented floor furnaces. Install vented floor furnaces for test as specified in sections 35.1 through 35.5 of UL–729–1976.

2.1.3 Vented room heaters. Install in accordance with manufacturer's instructions.

2.2 Flue and stack requirements.

2.2.1 Gas fueled vented home heating equipment employing integral draft diverters and draft hoods (excluding direct vent systems). Add to, and vertically above the outlet of gas fueled vented home heating equipment employing draft diverters or draft hoods with vertically discharging outlets, a five (5) foot long test stack having a cross sectional area the same size as the draft diverter outlet.

2.2.2 Oil fueled vented home heating equipment (excluding direct vent systems). Use flue connections for oil fueled vented floor furnaces as specified in section 35 of UL-729-1976, sections 34.10 through 34.18 of UL 730-1974 for oil fueled vented wall furnaces and sections 36.2 and 36.3 of UL 896-1973 for oil fueled vented room heaters.

2.2.3 Direct vent systems. Have the exhaust/air intake system supplied by the manufacturer in place during all tests. Test units intended for installation with a variety of vent pipe lengths with the minimum length recommended by the manufacturer. Do not connect a heater employing a direct vent system to a chimney or induced draft source. Vent the gas solely on the provision for venting incorporated in the heater and the vent/air intake system supplied with it.

2.3 Fuel supply.

2.3.1 Natural gas. For a vented heater utilizing natural gas, maintain the gas supply to the unit under test at a normal inlet test pressure immediately ahead of all controls at 7 to 10 inches water column. Maintain the regulator outlet pressure at normal test pressure approximately at that recommended by the manufacturer. Use natural gas having a specific gravity of approximately 0.65 and a higher heating value within ±5 percent of 1.025 Btu's per standard cubic foot. Determine the actual higher heating value in Btu's per standard cubic foot for the natural gas to be used in the test with an error no greater than one percent.

2.3.2 Propane gas. For a vented heater utilizing propane gas, maintain the gas supply
to the unit under test at a normal inlet pressure of 11 to 13 inches water column and a specific gravity of approximately 1.53. Maintain the regulator outlet pressure, on units so equipped, at a temperature at that recommended by the manufacturer. Use propane having a specific gravity of approximately 1.53 and a higher heating value within ±5 percent of the Btu's per standard cubic foot for the propane to be used in the test with an error no greater than one percent.

2.3.3 Other test gas. Use other test gases with characteristics as described in section 2.4.2 of ANSI Standard Z21.11.1–1974. Use gases with a measured higher heating value within ±5 percent of the values specified in the above ANSI standard. Determine the actual higher heating value of the gas used in the test with an error no greater than one percent.

2.3.4 Oil supply. For a vented heater utilizing fuel oil, use No. 1, fuel oil (kerosene) for vaporizing-type burners and either No. 1 or No. 2 fuel oil, as specified by the manufacturer, for mechanical atomizing type burners. Use No. 1 fuel oil with a viscosity meeting the specifications as described in UL-730-1974, section 36.9. Use test fuel conforming to the specifications given in tables 2 and 3 of ANSI Standard Z21.1–1972 for No. 1 and No. 2 fuel oil. Measure the higher heating value of the test fuel with an error no greater than one percent.

2.3.5 Electrical supply. For auxiliary electric components of a vented heater, maintain the electrical supply to the test unit within one percent of the nameplate voltage for the entire test cycle. If a voltage range is used for nameplate voltage, maintain the electrical supply within one percent of the mid-point of the nameplate voltage range.

2.4 Burner adjustments.

2.4.1 Gas burner adjustments. Adjust the burners of gas fueled vented heaters to their maximum Btu ratings at the test pressure specified in section 2.3 of this appendix. Correct the burner volumetric flow rate to 60 °F (15.6°C) and 30 inches of mercury barometric pressure, set the fuel flow rate to obtain a heat rate of within ±2 percent of the hourly Btu rating specified by the manufacturer as measured after 15 minutes of operation starting with all parts of the vented heater at room temperature. The primary air shutters in accordance with the manufacturer's recommendations to give a good flame at this adjustment. Do not allow the deposit of carbon during any test specified herein.

If a vent limiting means is provided on a gas pressure regulator, have it in place during all tests.

For gas fueled heaters with modulating controls adjust the controls to operate the heater at the maximum fuel input rate. Set the thermostat control to the maximum setting. Start the heater by turning the safety control valve to the “on” position. In order to prevent modulation of the burner at maximum input, place the thermostat sensing element in a temperature control bath which is held at a temperature below the maximum set point temperature of the control.

For gas fueled heaters with modulating controls adjust the controls to operate the heater at the reduced fuel input rate. Set the thermostat control to the minimum setting. Start the heater by turning the safety control valve to the “on” position. If ambient test room temperature is above the lowest control set point temperature, initiate burner operation by placing the thermostat sensing element in a temperature control bath that is held at a temperature below the minimum set point temperature of the control.

2.4.2 Oil burner adjustments. Adjust the burners of oil fueled vented heaters to give the CO reading recommended by the manufacturer and an hourly Btu input, during the steady-state performance test described below, which is within ±2 percent of the heater manufacturer's specified normal hourly Btu input rating. On units employing a power burner do not allow smoke in the flue to exceed a No. 1 smoke during the steady-state performance test as measured by the procedure in ANSI Standard Z21.182–1965 (R1971) (ASTM D 2156–65 (1970)). If, on units employing a power burner, the smoke in the flue exceeds a No. 1 smoke during the steady-state test, readjust the burner to give a lower smoke reading, and, if necessary a lower CO reading, and start all tests over. Maintain the average draft over the fire and in the flue during the steady-state performance test at a temperature below that recommended by the manufacturer within ±0.005 inches of water gauge. Do not make additional adjustments to the burner during the required series of performance tests. The instruments and measuring apparatus for this test are described in section 6.3 of ANSI standard Z81.1–1972.

2.5 Circulating air adjustments.

2.5.1 Forced air vented wall furnaces (including direct vent systems). During tests maintain the air flow through the heater as specified by the manufacturer and operate the vented heater with the outlet air temperature between 80 °F and 130 °F above room temperature. If adjustable air discharge registers are provided, adjust them so as to provide the maximum possible air restriction. Measure air discharge temperature as specified in section 2.14 of ANSI Z21.49–1975.

2.5.2 Fan type vented room heaters and floor furnaces. During tests on fan type furnaces and heaters, adjust the air flow through the heater as specified by the manufacturer. If adjustable air discharge registers are provided, adjust them to provide the maximum possible air restriction.

2.6 Location of temperature measuring instrumentation.
2.6.1 Gas fueled vented home heating equipment (including direct vent systems). For units employing an integral draft diverter, install nine thermocouples, wired in parallel, in a horizontal plane at points one third and two thirds of the distance between the center of the stack and the stack wall.

For units which employ a direct vent system, locate at least one thermocouple at the center of each flue way exiting the heat exchanger. Provide radiation shields if the thermocouples are exposed to burner radiation.

For units which employ a draft hood or units which employ a direct vent system which does not significantly preheat the incoming combustion air, install nine thermocouples, wired in parallel, in a horizontal plane located within 12 inches (304.8 mm) of the heater outlet and upstream of the draft hood on units so equipped. Locate one thermocouple in the center of the pipe and five thermocouples along imaginary lines intersecting at right angles in this horizontal plane at points one third and two thirds of the distance between the center of the pipe and the pipe wall.

For units which employ a direct vent system that significantly preheat the incoming combustion air, install nine thermocouples, wired in parallel, in a horizontal plane located within 6 inches (152.4 mm) of the vent/air intake terminal. Equalize the length of all thermocouple leads before paralleling. Locate one thermocouple in the center of the pipe and eight thermocouples along imaginary lines intersecting at right angles in this horizontal plane at points one third and two thirds of the distance between the center of the pipe and the pipe wall.

Use bead-type thermocouples having a wire size not greater than No. 24 AWG. If there is a possibility that the thermocouples could receive direct radiation from the fire, install radiation shields on the fire side of the thermocouples only and position the shields so that they do not touch the thermocouple junctions.

Install thermocouples for measuring the conditioned warm air temperature as described in sections 35.12 through 35.17 of UL 730–1974. Establish the temperature of the inlet air by means of a single No. 24 AWG bead-type thermocouple, suitably shielded from direct radiation and located in the center of the plane of each inlet air opening.

2.7 Combustion measurement instrumentation. Analyze the samples of stack and flue gases for vented heaters to determine the concentration by volume of carbon dioxide present in the dry gas with instrumentation which will result in a reading having an accuracy of ±0.1 percentage points.

2.8 Energy flow instrumentation. Install one or more instruments, which measure the rate of gas flow or fuel oil supplied to the vented heater, and if appropriate, the electrical energy with an error no greater than one percent.

2.9 Room ambient temperature. During the time period required to perform all the testing and measurement procedures specified in section 3.0 of this appendix, maintain the room temperature within ±5 °F (±2.8°C) of the value T_BA measured during the steady-state performance test. At no time during these tests shall the room temperature exceed 100 °F (37.8°C) or fall below 65 °F (18.3°C).

Temperature (T_BA) shall be the arithmetic average temperature of the test area, determined by measurement with four No. 24 AWG bead-type thermocouples with junctions shielded against radiation, located approximately at 90-degree positions on a circle circumscribing the heater or heater enclosure under test, in a horizontal plane approximately at the vertical midpoint of the appliance or test enclosure, and with the junctions approximately 24 inches from sides of the heater or test enclosure and located so as not to be affected by other than room air. Locate a thermocouple at each elevation of draft relief inlet opening and combustion air.

2.6.2 Oil fueled vented home heating equipment (including direct vent systems). Install nine thermocouples, wired in parallel and having equal length leads, in a plane perpendicular to the axis of the flue pipe. Locate this plane at the position shown in Figure 34.4 of UL 730–1974, or Figures 35.1 and 35.2 of UL 729–1976 for a single thermocouple, except that on direct vent systems which significantly preheat the incoming combustion air, it shall be located within 6 inches (152.5 mm) of the outlet of the vent/air intake terminal. Locate one thermocouple in the center of the pipe and eight thermocouples along imaginary lines intersecting at right angles in this plane at points one third and two thirds of the distance between the center of the pipe and pipe wall.

Use bead-type thermocouples having a wire size not greater than No. 24 AWG. If there is a possibility that the thermocouples could receive direct radiation from the fire, install radiation shields on the fire side of the thermocouples only and position the shields so that they do not touch the thermocouple junctions.

Install thermocouples for measuring the conditioned warm air temperature as described in sections 35.12 through 35.17 of UL 730–1974. Establish the temperature of the inlet air by means of a single No. 24 AWG bead-type thermocouple, suitably shielded from direct radiation and located in the center of the plane of each inlet air opening.
Inlet opening at a distance of approximately 24 inches from the inlet openings. The temperature of the air for combustion and the air for draft relief shall not differ more than ±5°F from room temperature as measured above.

2.10 Equipment used to measure mass flow rate in flue and stack. The tracer gas chosen for this task should have a density which is less than or approximately equal to the density of air. Use a gas reactive with the environment to be encountered. Using instrumentation of either the batch or continuous type, measure the concentration of tracer gas with an error no greater than 2 percent of the value of the concentration measured.

3.0 Testing and measurements.

3.1 Steady-state testing.

3.1.1 Gas fueled vented home heating equipment (including direct vent systems). Set up the vented heater as specified in sections 2.1, 2.2, and 2.3 of this appendix. The draft diverter shall be in the normal open condition and the stack shall not be insulated. (Insulation of the stack is no longer required for the vented heater test.) Begin the steady-state performance test by operating the burner and the circulating air blower, on units so equipped, with the adjustments specified by sections 2.4.1 and 2.5 of this appendix, until steady-state conditions are attained as indicated by a temperature variation of not more than ±3°F (1.7°C) in the stack gas temperature for vented heaters equipped with draft diverters or ±5°F (2.8°C) in the flue gas temperature for vented heaters equipped with either draft hoods or direct vent systems; in three successive readings taken 15 minutes apart.

On units employing draft diverters, measure the room temperature (T<sub>R</sub>), as described in section 2.9 of this appendix and measure the steady-state stack gas temperature (T<sub>SS</sub>) using the nine thermocouples located in the 5 foot test stack as specified in section 2.6.1 of this appendix. Secure a sample of the stack gases in the plane where T<sub>SS</sub> is measured or within 3.5 feet downstream of this plane. Determine the concentration by volume of carbon dioxide (X<sub>CO2</sub>), present in the dry stack gas.

Determine the steady-state heat input rate, as defined in section 2.4.1 of this appendix, and the reduced fuel input rate, as specified in section 2.4.1 of this appendix.

For manually controlled gas fueled vented heaters, with various input rates determine the steady-state efficiency at the maximum fuel input rate, as specified in section 2.4.1 of this appendix.

For gas fueled vented heaters equipped with either two stage thermostats or step-modulating thermostats, determine the steady-state efficiency at the maximum fuel input rate, as specified in section 2.4.1 of this appendix, and at the reduced fuel input rate, as specified in section 2.4.1 of this appendix.

For manually controlled gas fueled vented heaters, with various input rates determine the steady-state efficiency at a fuel input rate that is within ±5 percent of 50 percent of the maximum fuel input rate. If the heater is designed to use a control that precludes operation at other than maximum output (single firing rate) determine the steady-state efficiency at the maximum input rate only.
Do not allow smoke in the flue, for units equipped with power burners, to exceed a No. 1 smoke during the steady-state performance test as measured by the procedure described in APIStandard 2156–65 (1970). Maintain the average draft over the fire and in the breeching during the steady-state performance test at that recommended by the manufacturer 40.005 inches of water gauge.

Measure the room temperature (T_{RA}) as described in section 2.9 of this appendix and measure the steady-state flue gas temperature (T'_{RA}) using nine thermocouples located in the flue pipe as described in section 2.6.2 of this appendix. Secure a sample of the flue gas in the plane of temperature measurement and determine the concentration by volume of CO₂(\times_{CO2}) present in dry flue gas. Measure and record the steady-state heat input rate (Q_i).

For manually controlled oil fueled vented heaters, determine the steady-state efficiency at a fuel input rate that is within 15 percent of 50 percent of the maximum fuel input rate.

3.1.3 Auxiliary Electric Power Measurement. Allow the auxiliary electrical system of a gas or oil vented heater to operate for at least five minutes before recording the maximum auxiliary electric power measurement from the wattmeter. Record the maximum electric power (P_{A}) expressed in kilowatts. For vented heaters with modulating controls, the recorded (P_{A}) shall be maximum measured electric power multiplied by the following factor (R). For two stage controls, R=1.3. For step modulating controls, R=1.4 when the ratio of minimum-to-maximum fuel input is greater than or equal to 0.7, R=1.7 when the ratio of minimum-to-maximum fuel input is less than 0.7 and greater than or equal to 0.5, and R=2.2 when the ratio of minimum-to-maximum fuel input is less than 0.5.

3.2 Jacket loss measurement. Conduct a jacket loss test for vented floor furnaces. Measure the jacket loss (L_j) in accordance with the ANSI standard Z21.48–1976 section 2.12.

3.3 Measurement of the off-cycle losses for vented heaters equipped with thermal stack dampers. Install the thermal stack damper according to the manufacturer’s instructions. Unless specified otherwise, the thermal stack damper should be at the draft diverter exit collar. Attach a five foot length of bare stack to the outlet of the damper. Install thermocouples as specified in section 2.6.1 of this appendix.

For vented heaters equipped with single stage thermostats, measure the off-cycle losses at the maximum fuel input rate. For vented heaters equipped with two stage thermostats, measure the off-cycle losses at the maximum fuel input rate and at the reduced fuel input rate. For vented heaters equipped with step-modulating thermostats, measure the off-cycle losses at the reduced fuel input rate.

Let the vented heater heat up to a steady-state condition. Feed a tracer gas at a constant metered rate into the stack directly above and within one foot above the stack damper. Record tracer gas flow rate and temperature. Measure the tracer gas concentration in the stack at several locations in a horizontal plane through a cross section of the stack at a point sufficiently above the stack damper to ensure that the tracer gas is well mixed in the stack.

Continuously measure the tracer gas concentration and temperature during a 10 minute cool down period. Shut the burner off and immediately begin measuring tracer gas concentration in the stack, stack temperature, room temperature, and barometric pressure. Record these values as the midpoint of each one-minute interval between burner shut down and ten minutes after burner shut down. Meter response time and sampling delay shall be considered in timing these measurements.

3.4 Measurement of the effectiveness of electro-mechanical stack dampers. For vented heaters equipped with electro-mechanical stack dampers, measure the cross sectional area of the stack (A_s), the net area of the damper plate (A_p), and the angle that the damper plate makes when closed with a plane perpendicular to the axis of the stack (\theta). The net area of the damper plate means the area of the damper plate minus the area of any holes through the damper plate.

3.5 Pilot light measurement.

3.5.1 Measure the energy input rate to the pilot light (Q_p) with an error no greater than 3 percent for vented heaters so equipped.

3.5.2 For manually controlled heaters where the pilot light is designed to be turned off by the user when the heater is not in use, that is, turning the control to the OFF position will shut off the gas supply to the burner(s) and to the pilot light, the measurement of Q_p is not needed. This provision applies only if an instruction to turn off the unit is provided on the heater near the gas control valve (e.g. by label) by the manufacturer.

3.6 Optional procedure for determining D_p, D_f, and D_e for systems for all types of vented heaters. For all types of vented heaters, D_p, D_f, and D_e can be measured by the following optional cool down test.

Conduct a cool down test by letting the unit heat up until steady-state conditions are reached, as indicated by temperature variation of not more than 5 °F (2.8 °C) in the flue gas temperature in three successive readings taken 15 minutes apart, and then shutting the unit off with the stack or flue damper controls by-passed or adjusted so that the stack or flue damper remains open during the resulting cool down period. If a
draft was maintained on oil fueled units in the flue pipe during the steady-state performance test described in section 3.1 of this appendix, maintain the same draft (within a range of +0.003 to -0.005 inches of water gauge of the average steady-state draft) during this cool down period.

Measure the flue gas mass flow rate ($\dot{m}_{\text{fuel}}$) during the cool down test described above at a specific off-period flue gas temperature and corrected to obtain its value at the steady-state flue gas temperature ($T_{\text{F,SS}}$), using the procedure described below. Within one minute after the unit is shut off to start the cool down test for determining $D_{\text{f}}$, begin feeding a tracer gas into the combustion chamber at a constant flow rate of $V_T$, and at a point which will allow for the best possible mixing with the air flowing through the chamber. (On units equipped with an oil fired power burner, the best location for injecting this tracer gas appears to be through a hole drilled in the air tube.) Periodically measure the value of $V_T$ with an instantaneous reading flow meter having an accuracy of ±3 percent of the quantity measured. Maintain $V_T$ at less than 1 percent of the air flow rate through the furnace. If a combustible tracer gas is used, there should be a delay period between the time the burner gas is shut off and the time the tracer gas is first injected to prevent ignition of the tracer gas.

Between 5 and 6 minutes after the unit is shut off to start the cool down test, measure at the exit of the heat exchanger the average flue gas temperature, $T^*_{\text{F,off}}$ At the same instant the flue gas temperature is measured, also measure the percent volumetric concentration of tracer gas $C_T$ in the flue gas in the same plane where $T^*_{\text{F,off}}$ is determined. Obtain the concentration of tracer gas using an instrument which will result in an accuracy of ±2 percent in the value of $C_T$ measured. If use of a continuous reading type instrument results in a delay time between drawing of a sample and its analysis, this delay should be taken into account so that the temperature measurement and the measurement of tracer gas concentration coincide. In addition, determine the temperature of the tracer gas entering the flow meter ($T_T$) and the barometric pressure ($P_B$).

The rate of the flue gas mass flow through the vented heater and the factors $D_\phi$, $D_S$, and $D_X$ are calculated by the equations in sections 4.5.1 through 4.5.3 of this appendix.

4.0 Calculations.

4.1 Annual fuel utilization efficiency for gas or oil fueled vented home heating equipment equipped without manual controls and without thermal stack dampers. The following procedure determines the annual fuel utilization efficiency for gas or oil fueled vented home heating equipment equipped without manual controls and without thermal stack dampers.

4.1.1 System number. Obtain the system number from Table 1 of this appendix.

4.1.2 Off-cycle flue gas draft factor. Based on the system number, determine the off-cycle flue gas draft factor ($D_F$) from Table 1 of this appendix.

4.1.3 Off-cycle stack gas draft factor. Based on the system number, determine the off-cycle stack gas draft factor ($D_S$) from Table 1 of this appendix.

4.1.4 Pilot fraction. Calculate the pilot fraction ($P_f$) expressed as a decimal and defined as:

$$P_f = Q_p/Q_{\text{in}}$$

where:

$Q_p$ as defined in 3.5 of this appendix
$Q_{\text{in}}$ as defined in 3.1 of this appendix at the maximum fuel input rate

4.1.5 Jacket loss for floor furnaces. Determine the jacket loss ($L_{\text{j}}$) expressed as a percent and measured in accordance with section 3.2 of this appendix. For other vented heaters $L_{\text{j}}=0.0$.

4.1.6 Latent heat loss. Based on the fuel, obtain the latent heat loss ($L_{\text{CO2,}}$) from Table 2 of this appendix.

4.1.7 Ratio of combustion air mass flow rate to stoichiometric air mass flow rate. Determine the ratio of combustion air mass flow rate to stoichiometric air mass flow rate ($R_{\text{CT}}$), and defined as:

$$R_{\text{CT}} = A + B \times X_{\text{CO2}}$$

where:

$A$ as determined from Table 2 of this appendix
$B$ as determined from Table 2 of this appendix
$X_{\text{CO2}}$ as defined in 3.1 of this appendix

4.1.8 Ratio of combustion and relief air mass flow rate to stoichiometric air mass flow rate. For vented heaters equipped with either an integral draft diverter or a draft hood, determine the ratio of combustion and relief air mass flow rate to stoichiometric air mass flow rate ($R_{\text{RT}}$), and defined as:

$$R_{\text{RT}} = A + B \times X_{\text{CO2}}$$

where:

$A$ as determined from Table 2 of this appendix
$B$ as determined from Table 2 of this appendix
$X_{\text{CO2}}$ as defined in 3.1 of this appendix

4.1.9 Sensible heat loss at steady-state operation. For vented heaters equipped with either an integral draft diverter or a draft hood, determine the sensible heat loss at steady-state operation ($L_{\text{SS,RT}}$) expressed as a percent and defined as:

$$L_{\text{SS,RT}} = C \times R_{\text{RT}} \times D (T_{\text{F,SS}} - T_{\text{RA}})$$
4.1.10 Steady-state efficiency. For vented heaters equipped with single stage thermostats, calculate the steady-state efficiency (excluding jacket loss, \(h_{SS}\), expressed in percent and defined as:

\[ h_{SS} = \frac{T_{L,A}}{T_{C}} \]

where:

- \(T_{L,A}\) as defined in 4.1.6 of this appendix
- \(T_{C}\) as defined in 4.1.13 of this appendix

4.1.11 Reduced heat output rate. For vented heaters equipped with either two stage thermostats or with step-modulating thermostats, calculate the steady-state efficiency at the reduced fuel input rate, \(\eta_{SS-L}\), expressed in percent and defined as:

\[ \eta_{SS-L} = 100 - \frac{L_{L,A}}{L_{SS}} \]

where:

- \(L_{L,A}\) as defined in 4.1.6 of this appendix
- \(L_{SS}\) as defined in 4.1.9 of this appendix

4.1.12 Maximum heat output rate. For vented heaters equipped with either two stage thermostats or step-modulating thermostats, calculate the maximum heat output rate \(Q_{max-out}\) defined as:

\[ Q_{max-out} = \frac{\eta_{SS-H}}{\eta_{SS-L}} \]

where:

- \(\eta_{SS-H}\) as defined in 4.1.10 of this appendix
- \(\eta_{SS-L}\) as defined in 4.1.10 of this appendix

4.1.13 Ratio of reduced to maximum heat output rates. For vented heaters equipped with
either two stage thermostats or step-modulating thermostats, calculate the ratio of reduced to maximum heat output rates (R) expressed as a decimal and defined as:

\[ R = \frac{Q_{\text{out}}}{Q_{\text{max-out}}} \]

where:

- \( Q_{\text{out}} \) as defined in 4.1.11 of this appendix
- \( Q_{\text{max-out}} \) as defined in 4.1.12 of this appendix

4.1.14 Fraction of heating load at reduced operating mode. For vented heaters equipped with either two stage thermostats or step-modulating thermostats, determine the fraction of heating load at the reduced operating mode (\( X_1 \)) expressed as a decimal and listed in Table 3 of this appendix or obtained from Figure 2 of this appendix.

4.1.15 Fraction of heating load at maximum operating mode or noncycling mode. For vented heaters equipped with two stage thermostats or step-modulating thermostats, determine the fraction of heating load at the maximum operating mode (\( X_2 \)) expressed as a decimal and listed in Table 3 of this appendix or obtained from Figure 2 of this appendix.

4.1.16 Weighted-average steady-state efficiency. For vented heaters equipped with single stage thermostats, the weighted-average steady-state efficiency (\( \eta_{\text{SS-WT}} \)) is equal to \( \eta_{\text{SS}} \), as defined in section 4.1.10 of this appendix. For vented heaters equipped with two stage thermostats, \( \eta_{\text{SS-WT}} \) is defined as:

\[ \eta_{\text{SS-WT}} = X_1 \eta_{\text{SS-L}} + X_2 \eta_{\text{SS-H}} \]

where:

- \( X_1 \) as defined in 4.1.14 of this appendix
- \( \eta_{\text{SS-L}} \) as defined in 4.1.10 of this appendix
- \( \eta_{\text{SS-H}} \) as defined in 4.1.10 of this appendix

For vented heaters equipped with step-modulating thermostats, \( \eta_{\text{SS-WT}} \) is defined as:

\[ \eta_{\text{SS-WT}} = X_1 \eta_{\text{SS-L}} + X_2 \eta_{\text{SS-MOD}} \]

where:

- \( X_1 \) as defined in 4.1.14 of this appendix
- \( \eta_{\text{SS-L}} \) as defined in 4.1.10 of this appendix
- \( \eta_{\text{SS-MOD}} \) as defined in 4.1.10 of this appendix

4.1.17 Annual fuel utilization efficiency. Calculate the annual fuel utilization efficiency (AFUE) expressed as percent and defined as:

\[ \text{AFUE} = (0.968 \theta_{\text{HHV-wt}} - 1.78D_h - 1.89D_s - 129P_f - 2.8 L_d + 1.61 \]

where:

- \( \theta_{\text{HHV-wt}} \) as defined in 4.1.16 of this appendix
- \( D_h \) as defined in 4.1.3 of this appendix
- \( D_s \) as defined in 4.1.4 of this appendix
- \( P_f \) as defined in 4.1.5 of this appendix
- \( L_d \) as defined in 4.1.7 of this appendix

4.2 Annual fuel utilization efficiency for gas or oil fueled vented home heating equipment equipped with manual controls. The following procedure determines the annual fuel utilization efficiency for gas or oil fueled vented home heating equipment equipped with manual controls.

4.2.1 Average ratio of stack gas mass flow rate to flue gas mass flow rate at steady-state operation. For vented heaters equipped with either direct vents or direct exhaust or are outdoor units, the average ratio of stack gas mass flow rate to flue gas mass flow rate at steady-state operation (\( S/F \)) shall be equal to unity. (\( S/F = 1 \)). For all other types of vented heaters, calculate (\( S/F \)) defined as:

\[ S/F = 1.3R_x X_c \]

where:

- \( R_x \) as defined in 4.1.8 of this appendix
- \( X_c \) as defined in 4.1.7 of this appendix

4.2.2 Multiplication factor for infiltration loss during burner on-cycle. Calculate the multiplication factor for infiltration loss during burner on-cycle (\( K_{\text{LON}} \)) defined as:

\[ K_{\text{LON}} = 100(0.24) (S/F) (0.7) [1 + R_x (A/F)] / HHV \]

where:

- \( 100 \) converts a decimal fraction into a percent
- \( 0.24 \) specific heat of air
- \( A/F \) stoichiometric air/fuel ratio, determined in accordance with Table 2 of this appendix

4.2.3 On-cycle infiltration heat loss. Calculate the on-cycle infiltration heat loss (\( L_{\text{LON}} \)) expressed as a percent and defined as:

\[ L_{\text{LON}} = K_{\text{LON}} (70-45) \]

where:

- \( K_{\text{LON}} \) as defined in 4.2.2 of this appendix
- \( 70 \) average indoor temperature
- \( 45 \) average outdoor temperature

4.2.4 Weighted-average steady-state efficiency.

4.2.4.1 For manually controlled heaters with various input rates the weighted average steady-state efficiency (\( \eta_{\text{SS-WT}} \)), is determined as follows:

1. at 50 percent of the maximum fuel input rate as measured in either section 3.1.1 of this appendix for manually controlled gas vented heaters or section 3.1.2 of this appendix for manually controlled oil vented heaters, or
2. at the minimum fuel input rate as measured in either section 3.11 to this appendix for manually controlled gas vented heaters or section 3.12 to this appendix for...
manually controlled oil vented heaters if the design of the heater is such that the ±5 percent of 50 percent of the maximum fuel input rate cannot be set, provided this minimum rate is no greater than 2/3 of maximum input rate of the heater.

4.2.4.2 For manually controlled heater with one single firing rate the weighted average steady-state efficiency is the steady-state efficiency measured at the single firing rate.

4.2.5 Part-load fuel utilization efficiency. Calculate the part-load fuel utilization efficiency ($h_u$) expressed as a percent and defined as:

$$h_u = \frac{HSS-WT}{L_{I,ON}}$$

where:

- $HSS-WT$ as defined in 4.2.4 of this appendix
- $L_{I,ON}$ as defined in 4.2.3 of this appendix

4.2.6 Annual Fuel Utilization Efficiency.

4.2.6.1 For manually controlled vented heaters, calculate the AFUE expressed as a percent and defined as:

$$AFUE = \frac{2,950 \eta_{SS} Q_{in-max}}{2,950 \eta_{SS} Q_{in-max} + 2.083(4,600) \eta_u Q_p}$$

where:

- 2,950=average number of heating degree days
- $\eta_{SS}$ as defined as $\eta_{SS-WT}$ in 4.2.4 of this appendix
- $Q_{in}$ at the maximum fuel input rate, as defined in 3.1 of this appendix
- 4,600=average number of non-heating season hours per year
- $Q_p$ as defined in 3.5 of this appendix
- 65=degree day base temperature, °F
- 15=national average outdoor design temperature for vented heaters as defined in section 4.1.10 of this appendix

24=number of hours in a day

4.2.6.2 For manually controlled vented heaters where the pilot light can be turned off by the user when the heater is not in use as described in section 3.5.2, calculate the AFUE expressed as a percent and defined as:

$$AFUE = \eta_u$$

where:

$\eta_u$ as defined in section 4.2.5 of this appendix

4.3 Annual fuel utilization efficiency by the tracer gas method. The annual fuel utilization efficiency shall be determined by the following tracer gas method for all vented heaters equipped with thermal stack dampers. All other types of vented heaters can elect to use the following tracer gas method, as an optional procedure.

4.3.1 On-cycle sensible heat loss. For vented heaters equipped with single stage thermostats, calculate the on-cycle sensible heat loss ($L_{SS,ON}$) expressed as a percent and defined as:

$$L_{SS,ON} = \eta_{SS} \frac{L_{S,SS,A}}{L_{S,SS,A-red}} + X_1 L_{S,SS,A-red} + X_2 L_{S,SS,A-max}$$

where:

- $X_1$ as defined in 4.1.14 of this appendix
- $L_{S,SS,A-red}$ as defined in 4.3.1 of this appendix
- $L_{S,SS,A-max}$ as defined as $L_{S,SS,A}$ in 4.1.9 of this appendix at the maximum fuel input rate

4.3.2 For vented heaters equipped with two stage thermostats, calculate $L_{SS,ON}$ defined as:

$$L_{SS,ON} = X_1 L_{S,SS,A-red} + X_2 L_{S,SS,A-max}$$

where:

- $X_1$ as defined in 4.1.14 of this appendix
- $X_2$ as defined in 4.1.15 of this appendix

4.3.3 For vented heaters with step-modulating thermostats, calculate $L_{SS,ON}$ defined as:

$$L_{SS,ON} = X_1 L_{S,SS,A-red} + X_2 L_{S,SS,A-avg}$$

where:

- $X_1$ as defined in 4.1.14 of this appendix
- $L_{S,SS,A-avg}$ as defined in 4.3.1 of this appendix
- $X_2$ as defined in 4.1.15 of this appendix

4.3.4 Average sensible heat loss for step-modulating vented heaters operating in the modulating mode.

$$L_{SS,SS,A-avg} = \left[ L_{SS,SS,A-max} - L_{SS,SS,A-red} \right] \frac{T_C - T_{OA}}{T_C - 15} + L_{SS,SS,A-red}$$
where:
\[ L_{SA,avg} = \text{as defined in 4.3.1 of this appendix} \]
\[ T_{CA} = \text{as defined in 4.1.10 of this appendix} \]
\[ T_{OA} = \text{as defined in 4.1.10 of this appendix} \]

4.3.2 On-cycle infiltration heat loss. For vented heaters equipped with single stage thermostats, calculate the on-cycle infiltration heat loss \( L_{I,ON} \) expressed as a percent and defined as:
\[ L_{I,ON} = K_{I,ON}(70 – 45) \]
where:
\[ K_{I,ON} = \text{as defined in 4.2.2 of this appendix} \]
\[ 70 = \text{as defined in 4.2.3 of this appendix} \]
\[ 45 = \text{as defined in 4.2.3 of this appendix} \]

For vented heaters equipped with two stage thermostats, calculate \( L_{I,ON} \) defined as:
\[ L_{I,ON} = X_1 K_{I,ON,max} (70 – T_{OA*}) + X_2 K_{I,ON,red} (70 – T_{OA}) \]
where:
\[ X_1 = \text{as defined in 4.1.14 of this appendix} \]
\[ X_2 = \text{as defined in 4.1.15 of this appendix} \]
\[ K_{I,ON,max} = \text{as defined as } K_{I,ON} \text{ in 4.2.2 of this appendix at the maximum heat input rate} \]
\[ T_{OA} = \text{as defined in 4.3.4 of this appendix} \]
\[ T_{OA*} = \text{as defined in 4.3.4 of this appendix} \]
\[ K_{I,ON,red} = \text{as defined as } K_{I,ON} \text{ in 4.2.2 of this appendix at the minimum heat input rate} \]

4.3.3 Off-cycle sensible heat loss. For vented heaters equipped with single stage thermostats, calculate the off-cycle sensible heat loss \( L_{S,OFF} \) at the maximum fuel input rate. For vented heaters equipped with step-modulating thermostats, calculate \( L_{S,OFF} \) defined as:
\[ L_{S,OFF} = X_1 L_{S,OFF,red} \]
where:
\[ X_1 = \text{as defined in 4.1.14 of this appendix} \]
\[ L_{S,OFF,red} = \text{as defined as } L_{S,OFF} \text{ in 4.3.3 of this appendix at the reduced fuel input rate} \]

For vented heaters equipped with two stage thermostats, calculate \( L_{S,OFF} \) defined as:
\[ L_{S,OFF} = X_1 L_{S,OFF,red} + X_2 L_{S,OFF,Max} \]
where:
\[ X_1 = \text{as defined in 4.1.14 of this appendix} \]
\[ X_2 = \text{as defined in 4.1.15 of this appendix} \]
\[ L_{S,OFF,Max} = \text{as defined as } L_{S,OFF} \text{ in 4.3.3 of this appendix at the maximum fuel input rate} \]

Calculate the off-cycle sensible heat loss \( L_{S,OFF} \) expressed as a percent and defined as:
\[ L_{S,OFF} = \frac{100(0.24)}{Q_m t_{on}} \sum m_{S,OFF} (T_{S,OFF} – T_{RA}) \]
where:
\[ 100 = \text{conversion factor for percent} \]
\[ 0.24 = \text{specific heat of air in Btu per pound per } ^\circ \text{F} \]
\[ Q_m = \text{fuel input rate, as defined in 3.1 of this appendix in Btu per minute (as appropriate for the firing rate)} \]
\[ t_{on} = \text{average burner on-time per cycle and is 20 minutes} \]
\[ \sum m_{S,OFF}(T_{S,OFF} – T_{RA}) = \text{summation of the twenty values of the quantity,} \]
\[ m_{S,OFF}(T_{S,OFF} – T_{RA}) = \text{measured in accordance with 3.3 of this appendix} \]
\[ m_{S,OFF} = \text{stack gas mass flow rate pounds per minute} \]
\[ m_{S,OFF} = \frac{1.325 P_B V_I (100 – C_T)}{C_T (T_T + 460)} \]
\[ T_{S,OFF} = \text{stack gas temperature measured in accordance with 3.3 of this appendix} \]
\[ L_{1,\text{OFF}} = 100 \left( \frac{0.24}{1.3} \cdot 0.7 \cdot \left( 70 - T_{OA} \right) \right) \sum m_{S,\text{OFF}} \]

where:
- 100 = conversion factor for percent
- 0.24 = specific heat of air in Btu per pound \(^{\circ}\)F
- 1.3 = dimensionless factor for converting laboratory measured stack flow to typical field conditions
- 0.7 = infiltration parameter
- 70 = assumed average indoor air temperature, \(^{\circ}\)F
- \( T_{OA} \) = average outdoor temperature as defined in 4.3.4 of this appendix
- \( Q_{in} \) = fuel input rate, as defined in 3.1 of this appendix in Btu per minute (as appropriate for the firing rate)
- \( t_{on} \) = average burner on-time per cycle and is 20 minutes
- \( \Sigma m_{S,\text{OFF}} \) = summation of the twenty values of the quantity, \( m_{S,\text{OFF}} \), measured in accordance with 3.3 of this appendix

4.3.6 Part-load fuel utilization efficiency.
Calculate the part-load fuel utilization efficiency (\( \eta_u \)) expressed as a percent and defined as:

\[ \eta_u = 100 - L_{L,A} - C_j L_j \left( \frac{t_{on}}{t_{on} + P_{F\text{off}}} \right) + \left[ L_{s,\text{on}} + L_{s,\text{OFF}} + L_{L,\text{on}} + L_{S,\text{OFF}} \right] \]

where:
- \( C_j = 2.8 \), adjustment factor
- \( L_{L,A} \) = jacket loss as defined in 4.1.5
- \( L_{L,\text{on}} \) = as defined in 4.1.6 of this appendix
- \( L_{S,\text{on}} \) = as defined in 4.3.3 of this appendix
- \( L_{S,\text{OFF}} \) = as defined in 4.3.3 of this appendix
- \( L_{L,\text{OFF}} \) = as defined in 4.1.6 of this appendix
- \( P_{F\text{off}} \) = as defined in 4.1.4 of this appendix

\( L_{S,\text{OFF}} \) = as defined in 4.3.3 of this appendix

\( L_{L,\text{OFF}} \) = as defined in 4.1.6 of this appendix

\( P_{F\text{off}} \) = as defined in 4.1.4 of this appendix
where:

\( t_{b,OFF} \) = average burner off-time per cycle and is 20 minutes

4.3.7 Annual Fuel Utilization Efficiency.

\[
AFUE = \frac{2.950 \eta_{SS-WT} \eta_u Q_{in-max}}{2.950 \eta_{SS-WT} Q_{in-max} + 2.083(4.600) \eta_u Q_p}
\]

where:

\( 2,950 = \) average number of heating degree days

\( \eta_u = \) as defined in 4.1.6 of this appendix

\( Q_{in-max} = \) as defined in 4.2.6 of this appendix

\( Q_p = \) as defined in 3.5 of this appendix

4.4 Stack damper effectiveness for vented heaters equipped with electro-mechanical stack dampers. Determine the stack damper effectiveness for vented heaters equipped with electro-mechanical stack dampers (\( D_r \)), defined as:

\[ D_r = 1.62 \left[ 1 - A_D \cos \Omega A_S \right] \]

where:

\( A_D = \) as defined in 3.4 of this appendix

\( \Omega = \) as defined in 3.4 of this appendix

\( A_S = \) as defined in 3.4 of this appendix

4.5 Addition requirements for vented home heating equipment using indoor air for combustion and draft control. For vented home heating equipment using indoor air for combustion and draft control, \( D_r \), as described in section 4.1.2 of this appendix, and \( D_s \), as described in section 4.1.3 of this appendix, shall be determined from Table I of this appendix.

4.5.1 Optional procedure for determining \( D_r \) for vented home heating equipment. Calculate the ratio (\( D_r \)) of the rate of flue gas mass through the vented heater during the off-period, \( M_{F,OFF}(T_{F,SS}) \), to the rate of flue gas mass flow during the on-period, \( M_{E,SS}(T_{F,SS}) \), and defined as:

\[ D_r = \frac{M_{F,OFF}(T_{F,SS})}{M_{E,SS}(T_{F,SS})} \]

For vented heaters in which no draft is maintained during the steady-state or cool down tests, \( M_{E,OFF}(T_{F,SS}) \) is defined as:

\[
M_{F,OFF}(T_{F,SS}) = M_{F,OFF}(T_{F,OFF}) \left[ \frac{T_{F,OFF} - T_{RA}}{T_{F,OFF} - T_{RA}} \right]^{0.56} \left[ \frac{T_{F,OFF} + 460}{T_{F,SS} + 460} \right]^{-1.19}
\]

For oil fueled vented heaters in which an imposed draft is maintained, as described in section 3.5 of this appendix, \( M_{E,OFF}(T_{F,SS}) \) is defined as:

\[ M_{E,OFF}(T_{F,SS}) = M_{E,OFF}(T_{F,OFF}) \]

where:

\( T_{F,OFF} = \) as defined in 3.1.1 of this appendix

\( T_{RA} = \) flue gas temperature during the off-period measured in accordance with 3.6 of this appendix in degrees Fahrenheit

\( T_{F,OFF} = \) as defined in 2.9 of this appendix

\[
M_{F,OFF}(T_{F,OFF}) = 1.325 P_B V_T \left( 100 - C_T \right) / C_T \left( T_T + 460 \right)
\]

\( P_B = \) barometric pressure measured in accordance with 3.6 of this appendix in inches of mercury

\( V_T = \) flow rate of tracer gas through the vented heater measured in accordance with 3.6 of this appendix in cubic feet per minute

\( C_T = \) concentration by volume of tracer gas present in the flue gas sample measured in accordance with 3.6 of this appendix in percent

\( C_T = \) concentration by volume of the active tracer gas in the mixture in percent and is 100 when the tracer gas is a single component gas

\( T_T = \) the temperature of the tracer gas entering the flow meter measured in accordance with 3.6 of this appendix in degrees Fahrenheit

\( (T_T + 460) = \) absolute temperature of the tracer gas entering the flow meter in degrees Rankine

\( M_{E,SS}(T_{F,SS}) = Q_a [R_T \left( A/F \right) + 1]/[60HHV_a] \]

\( Q_a = \) as defined in 3.1 of this appendix

\( R_T = \) as defined in 4.1.7 of this appendix

\( A/F = \) as defined in 4.2.2 of this appendix

\( HHV_a = \) as defined in 4.2.2 of this appendix

4.5.2 Optional procedure for determining off-cycle draft factor for flue gas flow for vented
heaters. For systems numbered 1 thru 10, calculate the off-cycle draft factor for flue gas flow (Df) defined as:

\[ D_f = D_r \]

For systems numbered 11 or 12: \[ D_f = D_r \]

where:
\[ D_r \] as defined in 4.5.1 of this appendix
\[ D_f \] as defined in 4.4 of this appendix

4.5.3 Optional procedure for determining off-cycle draft factor for stack gas flow for vented heaters. Calculate the off-cycle draft factor for stack gas flow (Df) defined as:

For systems numbered 1 or 2: \[ D_f = 1.0 \]
For systems numbered 3 or 4: \[ D_f = (D_r + 0.79)/1.4 \]
For systems numbered 5 or 6: \[ D_f = D_r \]
For systems numbered 7 or 8 and if \[ D_r(S/F) \] is less than 1: \[ D_f = D_r \]
For systems numbered 7 or 8 and if \[ D_r(S/F) > 1 \]: \[ D_f = (D_r(S/F) - 1)/(S/F - 1) \]

where:
\[ D_r \] as defined in 4.5.1 of this appendix
\[ D_f \] as defined in 4.4 of this appendix

4.6 Annual energy consumption.
4.6.1 National average number of burner operating hours. For vented heaters equipped with single stage controls or manual controls, the national average number of burner operating hours (BOH) is defined as:

\[ \text{BOH}_{\text{avg}} = 1,416 A_{\text{DHR}} \]

where:
\[ 1,416 \] = national average heating load hours for vented heaters based on 2,950 degree days and 15°F outdoor design temperature
\[ A_{\text{DHR}} \] = 0.7607, adjustment factor to adjust the calculated design heating requirement and heating load hours to the actual heating load experienced by the heating system

4.6.1.1 For vented heaters equipped with two stage or step modulating controls the national average number of burner operating hours is increased by the factor R, which is defined in 4.1.15 of this appendix.
\[ R = 1.3 \]

4.6.1.2 For vented heaters equipped with two stage controls
\[ R = 1.4 \]

4.6.1.3 For vented heaters equipped with step modulating controls
\[ R = 1.7 \]

4.6.1.4 For step modulating controls when the ratio of minimum-to-maximum fuel input is greater than or equal to 0.7
\[ R = 0.7 \]

4.6.1.5 For step modulating controls when the ratio of minimum-to-maximum fuel input is less than 0.7 and greater than or equal to 0.5
\[ R = 2.2 \]

4.6.1.6 For step modulating controls when the ratio of minimum-to-maximum fuel input is less than 0.5
\[ R = 0.5 \]

4.6.1.7 For two stage controls
\[ R = 1.3 \]

4.6.1.8 For step modulating controls
\[ R = 1.7 \]

4.6.1.9 For step modulating controls
\[ R = 2.2 \]

4.6.1.10 For step modulating controls
\[ R = 4.6 \]

4.6.1.11 For vented heaters equipped with two stage or step modulating controls based on Q_{\text{red-in}}, from Table 4 of this appendix.

\[ Q_{\text{red-in}} = (\eta_{\text{sec}} 100) - C_{\text{L}} (L_{\text{DHR}} 100) Q_{\text{in}} \]

100 = jacket loss as defined in 4.1.5 of this appendix
\[ C_{\text{L}} \] = 2.8, adjustment factor as defined in 4.3.6 of this appendix
\[ \eta_{\text{sec}} \] = steady-state efficiency as defined in 4.1.10 of this appendix, percent
\[ Q_{\text{in}} \] = as defined in 3.1 of this appendix at the maximum fuel input rate
\[ A_{\text{DHR}} \] = 0.7607, adjustment factor to adjust the calculated design heating requirement and heating load hours to the actual heating load experienced by the heating system

4.6.1.12 For vented heaters equipped with single stage controls or manual controls, the national average number of burner operating hours (BOH) is defined as:

\[ \text{BOH}_{\text{avg}} = X_{\text{sec}} E_{\text{ann}} Q_{\text{in}} \]

where:
\[ X_{\text{sec}} \] = as defined in 4.1.14 of this appendix
\[ E_{\text{ann}} \] = average annual energy used during the heating season
\[ Q_{\text{in}} \] = as defined in 3.1 of this appendix at the maximum fuel input rate
\[ \text{BOH}_{\text{avg}} \] = as defined in 4.6.1 of this appendix, in which the term \[ P_f \] in the factor A is increased by the factor R, which is defined in 3.1.3 of this appendix as:
\[ R = 1.3 \]

4.6.1.13 For vented heaters equipped with two stage controls
\[ R = 1.4 \]

4.6.1.14 For step modulating controls
\[ R = 1.7 \]

4.6.1.15 For step modulating controls
\[ R = 2.2 \]

4.6.1.16 For step modulating controls
\[ R = 4.6 \]

4.6.1.17 For two stage controls
\[ R = 1.3 \]

4.6.1.18 For step modulating controls
\[ R = 1.7 \]

4.6.1.19 For step modulating controls
\[ R = 2.2 \]
4.6.2 Average annual fuel energy for gas or oil fueled vented heaters. For vented heaters equipped with single stage controls or manual controls, the average annual fuel energy consumption \( (E_F) \) is expressed in Btu per year and defined as:

\[ E_F = BOH_{avg} (Q_a - Q_e) + 8,760 Q_e \]

where:

- \( BOH_{avg} \) as defined in 4.6.1 of this appendix
- \( Q_a \) as defined in 3.1 of this appendix
- \( Q_e \) as defined in 3.5 of this appendix
- 8,760 as specified in 4.6.1 of this appendix

4.6.2.1 For vented heaters equipped with either two stage or step modulating controls \( E_F \) is defined as:

\[ E_F = E_{AE} + 4,600 Q_e \]

where:

- \( E_{AE} \) as defined in 4.6.1.2 of this appendix
- 4,600 as specified 4.2.6 of this appendix
- \( Q_e \) as defined in 3.5 of this appendix

4.6.3 Average annual auxiliary electrical energy consumption for vented heaters. For vented heaters with single stage controls or manual controls the average annual auxiliary electrical consumption \( (E_{AE}) \) is expressed in kilowatt-hours and defined as:

\[ E_{AE} = BOH_{avg} P_F \]

where:

- \( BOH_{avg} \) as defined in 4.6.1 of this appendix
- \( P_F \) as defined in 3.1.3 of this appendix

4.6.3.1 For vented heaters equipped with two stage or modulating controls \( E_{AE} \) is defined as:

\[ E_{AE} = BOH_{avg} + BOH_{SS} P_F \]

where:

- \( BOH_{avg} \) as defined in 4.6.1 of this appendix
- \( BOH_{SS} \) as defined in 4.6.1 of this appendix

4.6.4 Average annual energy consumption for vented home heaters located in a different geographic region of the United States and in buildings with different design heating requirements. For gas or oil fueled vented heaters in a different geographic region of the United States and in buildings with different design heating requirements the average annual fuel energy consumption \( (E_{FAE}) \) is expressed in Btu per year and defined as:

\[ E_{FAE} = (E_F - 8,760 Q_e) (HLH/1,416) + 8,760 Q_e \]

where:

- \( E_F \) as defined in 4.6.2 of this appendix
- 8,760 as specified in 4.6.1 of this appendix
- \( Q_e \) as defined in 3.5 of this appendix
- HLH = heating load hours for a specific geographic region
determined from the heating load hour map in Figure 3 of this appendix
- 1,416 as specified in 4.6.1 of this appendix

4.6.4.2 Average annual auxiliary electrical energy consumption for gas or oil fueled vented home heaters located in a different geographic region of the United States and in buildings with different design heating requirements. For gas or oil fueled vented home heaters the average annual auxiliary electrical energy consumption \( (E_{AFAE}) \) is expressed in kilowatt-hours and defined as:

\[ E_{AFAE} = E_{AE} \cdot HLH/1,416 \]

where:

- \( E_{AE} \) as defined in 4.6.3 of this appendix
- HLH = as defined in 4.6.4.1 of this appendix
- 1,416 as specified in 4.6.1 of this appendix

### TABLE 1—OFF-CYCLE DRAFT FACTORS FOR FLUE GAS FLOW (\( D_s \)) AND FOR STACK GAS FLOW (\( D_s \)) FOR VENTED HOME HEATING EQUIPMENT EQUIPPED WITHOUT THERMAL STACK DAMPERS

<table>
<thead>
<tr>
<th>System number</th>
<th>( D_s )</th>
<th>( D_s )</th>
<th>Bumer type</th>
<th>Venting system type (^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
<td>Atmospheric</td>
<td>Draft hood or diverter.</td>
</tr>
<tr>
<td>2</td>
<td>0.4</td>
<td>1.0</td>
<td>Power</td>
<td>Draft hood or diverter.</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>1.0</td>
<td>Atmospheric</td>
<td>Barometric draft regulator.</td>
</tr>
<tr>
<td>4</td>
<td>0.4</td>
<td>0.85</td>
<td>Power</td>
<td>Barometric draft regulator.</td>
</tr>
<tr>
<td>5</td>
<td>1.0</td>
<td>D.</td>
<td>Atmospheric</td>
<td>Draft hood or diverter with damper.</td>
</tr>
<tr>
<td>6</td>
<td>0.4</td>
<td>D.</td>
<td>Power</td>
<td>Draft hood or diverter with damper.</td>
</tr>
<tr>
<td>7</td>
<td>1.0</td>
<td>D.</td>
<td>Atmospheric</td>
<td>Barometric draft regulator with damper.</td>
</tr>
<tr>
<td>8</td>
<td>0.4</td>
<td>D. D.</td>
<td>Power</td>
<td>Barometric draft regulator with damper.</td>
</tr>
<tr>
<td>9</td>
<td>1.0</td>
<td></td>
<td>Atmospheric</td>
<td>Direct vent.</td>
</tr>
<tr>
<td>10</td>
<td>0.4</td>
<td></td>
<td>Power</td>
<td>Direct vent.</td>
</tr>
<tr>
<td>11</td>
<td>D.</td>
<td></td>
<td>Atmospheric</td>
<td>Direct vent with damper.</td>
</tr>
<tr>
<td>12</td>
<td>0.4 D.</td>
<td></td>
<td>Power</td>
<td>Direct vent with damper.</td>
</tr>
</tbody>
</table>

\(^1\)Venting systems listed with dampers means electro-mechanical dampers only.
### Table 2—Values of Higher Heating Value (HHV(A)), Stoichiometric Air/Fuel (A/F), Latent Heat Loss (L,A) and Fuel-Specified Parameters (A, B, C, and D) for Typical Fuels

<table>
<thead>
<tr>
<th>Fuels</th>
<th>HHVₐ (Btu/lb)</th>
<th>A/F</th>
<th>L,A</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1 oil</td>
<td>19,800</td>
<td>14.56</td>
<td>6.55</td>
<td>0.0679</td>
<td>14.22</td>
<td>0.0179</td>
<td>0.167</td>
</tr>
<tr>
<td>No. 2 oil</td>
<td>19,500</td>
<td>14.49</td>
<td>6.50</td>
<td>0.0667</td>
<td>14.34</td>
<td>0.0181</td>
<td>0.167</td>
</tr>
<tr>
<td>Natural gas</td>
<td>20,120</td>
<td>11.81</td>
<td>9.55</td>
<td>0.0919</td>
<td>10.96</td>
<td>0.0175</td>
<td>0.235</td>
</tr>
<tr>
<td>Manufactured gas</td>
<td>18,500</td>
<td>11.34</td>
<td>7.99</td>
<td>0.0841</td>
<td>12.62</td>
<td>0.0177</td>
<td>0.151</td>
</tr>
<tr>
<td>Propane</td>
<td>21,500</td>
<td>15.58</td>
<td>7.99</td>
<td>0.0841</td>
<td>12.62</td>
<td>0.0177</td>
<td>0.151</td>
</tr>
<tr>
<td>Butane</td>
<td>20,000</td>
<td>15.36</td>
<td>7.79</td>
<td>0.0808</td>
<td>12.93</td>
<td>0.0180</td>
<td>0.143</td>
</tr>
</tbody>
</table>

### Table 3—Fraction of Heating Load at Reduced Operating Mode (X1) and at Maximum Operating Mode (X2), Average Outdoor Temperatures (TOA and TOA*), and Balance Point Temperature (TC) for Vented Heaters Equipped With Either Two-Stage Thermostats or Step-Modulating Thermostats

<table>
<thead>
<tr>
<th>Heat output ratio</th>
<th>X1</th>
<th>X2</th>
<th>TOA</th>
<th>TOA*</th>
<th>TC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20 to 0.24</td>
<td>.12</td>
<td>.88</td>
<td>57</td>
<td>40</td>
<td>53</td>
</tr>
<tr>
<td>0.25 to 0.29</td>
<td>.16</td>
<td>.84</td>
<td>56</td>
<td>39</td>
<td>51</td>
</tr>
<tr>
<td>0.30 to 0.34</td>
<td>.20</td>
<td>.80</td>
<td>54</td>
<td>38</td>
<td>49</td>
</tr>
<tr>
<td>0.35 to 0.38</td>
<td>.30</td>
<td>.70</td>
<td>53</td>
<td>36</td>
<td>46</td>
</tr>
<tr>
<td>0.40 to 0.44</td>
<td>.36</td>
<td>.64</td>
<td>52</td>
<td>35</td>
<td>44</td>
</tr>
<tr>
<td>0.45 to 0.49</td>
<td>.43</td>
<td>.57</td>
<td>51</td>
<td>34</td>
<td>42</td>
</tr>
<tr>
<td>0.50 to 0.54</td>
<td>.52</td>
<td>.48</td>
<td>50</td>
<td>32</td>
<td>39</td>
</tr>
<tr>
<td>0.55 to 0.59</td>
<td>.60</td>
<td>.40</td>
<td>49</td>
<td>30</td>
<td>37</td>
</tr>
<tr>
<td>0.60 to 0.64</td>
<td>.67</td>
<td>.30</td>
<td>48</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>0.65 to 0.69</td>
<td>.76</td>
<td>.24</td>
<td>47</td>
<td>27</td>
<td>32</td>
</tr>
<tr>
<td>0.70 to 0.74</td>
<td>.84</td>
<td>.16</td>
<td>46</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>0.75 to 0.79</td>
<td>.88</td>
<td>.12</td>
<td>46</td>
<td>22</td>
<td>27</td>
</tr>
<tr>
<td>0.80 to 0.84</td>
<td>.94</td>
<td>.06</td>
<td>45</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>0.85 to 0.89</td>
<td>.96</td>
<td>.04</td>
<td>45</td>
<td>18</td>
<td>21</td>
</tr>
<tr>
<td>0.90 to 0.94</td>
<td>.98</td>
<td>.02</td>
<td>44</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>0.95 to 0.99</td>
<td>.99</td>
<td>.01</td>
<td>44</td>
<td>13</td>
<td>17</td>
</tr>
</tbody>
</table>

*The heat output ratio means the ratio of minimum to maximum heat output rates as defined in 4.1.13.
FIGURE 1
Average Outdoor Air Temperature vs. Balance Point Temperature for Modulating Vented Heaters

This figure is based on 4500 degree-days and 15°F outdoor design temperature.
FIGURE 2
Fraction of Total Annual Heating Load Applicable to Reduced Operating Mode ($X_1$) and to Maximum Operating Mode or Modulating Mode ($X_2$) vs. Balance Point Temperature for Modulating Vented Heaters

This figure is based on 4500 degree-days and 15°F outdoor design temperature.
This map is reasonably accurate for most parts of the United States but is necessarily
generalized, and consequently not too accurate in mountainous regions, particularly in
the Rockies.