BSR/ASHRAE Standard 124-2007 (RA 202X)

Public Review Draft

Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances

First Public Review (September 2025)

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BSR

~~ANSI~~/ASHRAE Standard 124-2007 (RA ~~2016~~)

202X

Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances

NOTE

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FOREWORD

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Insert foreword

1. PURPOSE

The purpose of this standard is to establish a method of test to rate the performance of a combination space-heating and water-heating appliance.

2. SCOPE

2.1 This test method is intended to cover electric, gas-fired, and oil-fired combination space-heating and water-heating appliances.

2.2 This standard covers appliances up to 300,000 Btu/h (87.9 kW) rated input.

3. DEFINITIONS AND NOMENCLATURE

3.1 Definitions

automatic vent damper: for purposes of this standard, an electrically operated or thermally actuated mechanical device installed downstream of the draft hood.

boiler, low-pressure steam or hot water: an electric, gas, or oil-burning appliance designed to supply low-pressure steam or hot water for space-heating applications. A low-pressure steam boiler operates at or below 15 psig (103.4 kPa) steam pressure; a hot water boiler operates at or below 160 psig (1102.4 kPa) water pressure and 250°F (121°C) water temperature.

combination space-heating and water-heating appliance: a unit that is designed to provide space heating and potable water heating from a single primary energy source.

control, single-stage: a control that cycles a burner between the maximum heat input rate and off.

control, modulating: a manual or automatic step-modulating control. Also referred to as a *two-stage control*.

control, two-stage: a modulating control that both cycles a burner between a reduced heat input rate and OFF and cycles a burner between the maximum heat input rate and OFF. It may also switch from OFF to reduced fire to high fire to OFF again under certain load conditions.

control, step modulating: a modulating control that cycles a burner between the reduced input rate and OFF if the heating load is light. If a higher heating load is encountered that cannot be met with the reduced input rate, the control goes into a modulating mode where it either gradually or incrementally increases the input rate to meet the higher heating load. At that point, if a lower heating load is encountered, the control either gradually or incrementally decreases to the reduced input rate.

(a) ***automatic modulating control:*** a step-modulating control that is capable of controlling the burner fuel input rate between maximum and the minimum adjustable input rate in response to a varying heating load.

(b) ***manually adjusted modulating control:*** a step-modulating control adjusted for reduced input at the time of installation of the furnace or boiler.

draft hood: a devise built into a gas-fired appliance, or external to it, that is designed to (a) provide for the ready escape of flue gases in the event of no draft, back draft, or stoppage beyond the draft hood, (b) prevent a back draft from entering the appliance, and (c) neutralize the effect of stack action of the chimney or gas vent on the operation of the appliance.

direct exhaust system: an appliance venting system supplied or recommended by the manufacturer through which the products of combustion pass directly from the appliance to the outside and that does not employ a means of draft relief. This system includes units with small air passages in the flue (air passages that do not have an opening area in excess of 10% of the cross-sectional area of the vent).

direct vent system: a manufacturer-supplied system that provides outdoor air directly to a unit for combustion and discharges all flue gases to the outside atmosphere.

first-hour rating: an estimate of the maximum volume of "hot" water that a storage-type water heater or an integrated heater can supply within an hour from the time that the water heater is fully heated (i.e., with all thermostats satisfied). This rating is a function of both the storage volume and the recovery rate.

flue: a conduit between the flue outlet of the appliance and the integral draft diverter, draft hood, barometric draft regulator, vent terminal, or any other point of draft relief.

flue collar: a projection or recess provided to accommodate the vent connector or draft hood.

flue gases: all gases in the flue during the duration of combustion in the combustion chamber, including reaction products, inerts, and any excess air.

flue outlet: the opening provided in an appliance for the escape of flue gases.

maximum gpm (L/s) rating: the maximum gallons per minute (liters per second) of domestic hot water that can be supplied continuously by an instantaneous water heater or a tankless heater while maintaining a nominal temperature rise of 77°F (42.8°C) during steady-state operation.

"shall": where "shall" or "shall not" is used, a provision is mandatory if compliance with this standard is claimed.

(This foreword is not a part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard.)

This is a reaffirmation of Standard 124-2007(RA2016). This standard was prepared under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). It may be used, in whole or in part, by an association or government agency with due credit to ASHRAE. Adherence is strictly on a voluntary basis and merely in the interests of obtaining uniform guidelines throughout the industry. This version of the reaffirmation has no changes.

"should," "it is recommended," or "it is not recommended": terms used to indicate provisions that are not mandatory but are desirable as good practice.

stack: the portion of the exhaust system downstream of the draft diverter, draft hood, or barometric draft regulator.

storage water heater: an appliance that heats and stores potable water within the appliance at a thermostatically controlled temperature for delivery on demand and has an input rate of less than 4,000 Btu/h per gallon (310W/L) of stored water.

tankless heater: a heat exchanger for indirect heating of domestic water. Designed to be used without a domestic water storage tank, it may be attached directly to the boiler or installed external to the boiler and connected by piping.

thermostat, tank: a device that senses changes in stored water temperature and that controls, by means of separate components, the flow of energy to maintain selected temperatures.

vent connector: the portion of the venting system that connects the gas appliance or its draft hood to the chimney or vent terminal.

vent pipe: passages and conduits in a direct vent or direct exhaust system through which gases pass from the combustion chamber to the outdoor air.

water temperature control: a device that senses boiler water temperature and controls burner operation.

3.2 Nomenclature

CAE = combined annual efficiency, %.

C_{aux} = auxiliary electric input associated with the production of domestic hot water, kWh (MJ).

$C_{aux\text{-}d}$ = auxiliary electric input during draw period, kWh (MJ).

$C_{aux\text{-}sb}$ = auxiliary electric input during standby loss test, kWh (MJ).

$C_{aux\text{-}r1}$ = auxiliary electric input during recovery from standby, kWh (MJ).

$C_{aux\text{-}r2}$ = auxiliary electric input during recovery from the draw period, kWh (MJ) .

CE_{hs} = combined heating season efficiency, %.

CE_{ns} = non-heating season efficiency, %.

D_h = average heating season days.

D_n = average non-heating season days.

EF = energy factor, water heating.

E_r = recovery efficiency, dimensionless.

$Effy_{hs}$ = space-heating seasonal efficiency, %.

$Effy_{ss}$ = space-heating steady-state efficiency, %.

F = first-hour rating of a storage-type water heater or an integrated heater, gal (L).

FR = flow rate for systems with storage of domestic water, gpm (L).

FR_{max} = steady-state flow rate at the rated input for an instantaneous water heater or tankless heater to give a discharge temperature of 135°F±5°F (57.2°C±2.8°C), gpm (L/s).

FR_{min} = flow rate at reduced output for an instantaneous water heater or tankless heater, gpm (L/s).

G = volume of water drawn during first hour test, gal (L).

HHV = fuel higher heating value, Btu/lb, Btu/ft^3, Btu/gal (kJ/kg, J/L, kJ/L).

c_p = specific heat of water, Btu/lb°F (kJ/kg K).

n = for storage-type water heaters or integrated heaters, total number of draws during the first-hour rating test.

NHF = non-heating season water-heating factor.

Q_1 = corrected standby energy consumption for 24 hours, Btu (kJ).

Q_2 = corrected draw period energy consumption for water drawn, Btu (kJ).

Q_d = draw period measured energy consumption, Btu (kJ).

q_{in} = energy input rate, Btu/h (W).

Q_{rs} = total energy input, Btu (kJ).

Q_{r1} = recovery energy after 18-hour standby test, Btu (kJ).

Q_{r2} = recovery energy after the draw period, Btu (kJ).

Q_{sb} = standby loss test energy input, Btu (kJ).

R = ratio of non-heating season days to heating season days.

S = standby loss, storage type, h^{-1}.

SHF = space-heating factor.

t_{fhr} = total time of first-hour draw test, min.

t_0 = start time of first-hour draw test.

t_{run} = burner operating time during draw period, min.

T_a = air temperature, °F (°C).

T_{avg} = average outdoor temperature during the heating season, °F (°C).

T_b = boiler water temperature at control location, °F (°C).

T_c = nominal cold water supply temperature, °F (°C).

$\overline{T}_{del}$ = For instantaneous water heaters or tankless heaters, average outlet water temperature during a 10-minute continuous draw interval in the maximum gpm (L/min) rating test, °F (°C).

T_i = inlet water temperature, °F (°C).

$\overline{T}_{in}$ = average inlet water temperature, °F (°C).

T_m = arithmetic mean of outlet water temperature, °F (°C).

T_{min} = nominal minimum temperature for usable hot water, °F (°C).

T_o = outlet water temperature, °F (°C).

$T_{o(max)}$ = maximum outlet water temperature, first-hour draw test, °F (°C).

T_r = nominal room temperature, °F (°C).

T_s = mean tank temperature, °F (°C).

T_t = nominal tank temperature for systems with storage of domestic hot water and nominal discharge temperature for instantaneous water heaters and tankless heaters, °F (°C).

$\overline{T}^*_{del,i}$ = for storage-type water heaters or integrated heaters, average outlet water temperature during the i-th draw (i =1 to n) of the first-hour rating test, °F (°C).

$T^*_{max,i}$ = for storage-type water heaters or integrated heaters, maximum outlet water temperature during the i-th

draw (i =1 to n) of the first-hour rating test, °F (°C).

$T^*_{min,i}$ = for storage-type water heaters or integrated heaters, minimum outlet water temperature during the i-th draw (i = 1 to n) of the first-hour rating test, °F (°C).

U = daily hot water consumption, gal (L). An assigned value, nominally 64.3 gal (243.3 L) for residential-sized water heaters and boilers and 120 gal (454 L) for commercial-sized water heaters and boilers, where input ratings covered by ASHRAE Standards 118.1 and 118.2 serve as a reasonable demarcation of residential and commercial units.

U_s = gallons (L) drawn during the 24 hours of the simulated-use test.

V^*_i = volume of water removed during the i-th draw (i =1 to n) during the first-hour rating test, gal (L).

V_{10m} = for instantaneous water heaters or tankless heaters, total volume of water drawn continuously over a 10-minute interval in the maximum gpm (L/s) rating test, gal (L).

V = storage volume, gal (L).

v_t = specific volume of water at a temperature of T_t, ft^3/lb (L/kg).

W = total weight of water drawn during first-hour draw test, lb (kg).

wc = water column, in. (Pa).

WHF = heating-season water-heating factor.

W^*_i = for storage-type water heaters or integrated heaters, mass of water removed during the ith draw (i =1 to n) during the first-hour rating test, lb (kg).

W_{10m} = for instantaneous water heaters or tankless heaters, total mass of water drawn continuously over a 10-minute interval in the maximum gpm (L/s) rating test, lb (kg).

4. CLASSIFICATIONS

Combination space-heating and water-heating appliances are classified as follows:

4.1 Type I Appliance. An appliance where the space-heating function is provided by heat exchange with low-pressure steam or recirculated nonpotable boiler water.

Subcategories include the following:

4.1.1 Tankless Heater Directly in Appliance. This includes a heat exchanger within the appliance for heating domestic water but does not have an external tank for storing domestic hot water. (See Figure 4-1.)

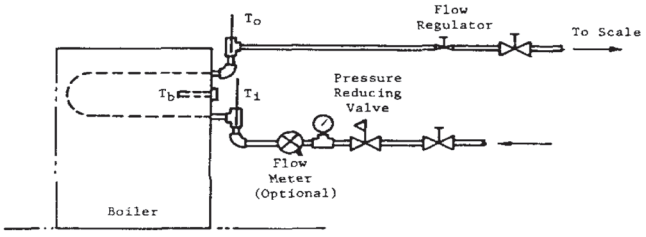

Figure 4-1 Type I appliances—typical piping arrangement, tankless heater in boiler.

4.1.2 Tankless Heater in External Tank. This includes an external tank within a tank for storing domestic hot water where the volume of low-pressure steam or boiler water is greater than the volume of domestic water. (See Figure 4-2.)

4.1.3 Integrated Heater. This includes an external tank within a tank for storing domestic hot water where the volume of domestic water is greater than the volume of low-pressure steam or boiler water. (See Figure 4-3.)

4.2 Type II Appliance. An appliance where the space-heating function is provided by heat exchange with recirculated potable domestic hot water.

Subcategories include the following:

a. Storage water heater

b. Instantaneous water heater

5. REQUIREMENTS

5.1 Space-Heating Performance

5.1.1 Type I Appliance. The space-heating performance shall be determined from tests conducted in accordance with *ASHRAE Standard 103-1993*, *Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*.[1]

5.1.2 Type II Appliance. Space-heating performance parameters shall be determined from tests conducted in accordance with *ASHRAE Standard 103-1993*, *Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*,[1] as supplemented by the additional provisions of Sections 6 through 11 of this standard.

5.2 Water-Heating Performance

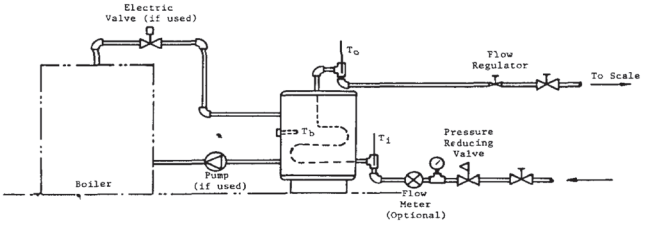

Figure 4-2 Type I appliances—typical piping arrangement, tankless heater, boiler water or low-pressure steam in external tank.

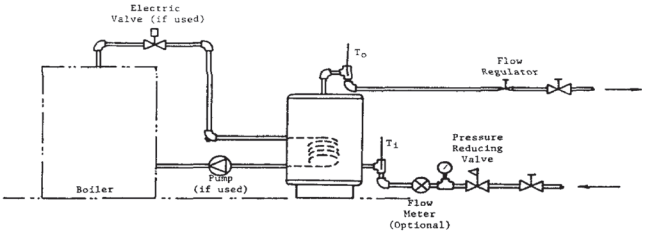

Figure 4-3 Type I appliances—typical piping arrangement, integrated heater, domestic water in external tank.

5.2.1 Type I Appliance. Water-heating performance parameters shall be determined from tests conducted in accordance with this standard.

5.2.2 Type II Appliance. The water-heating performance shall be determined from tests conducted in accordance with *ASHRAE Standard 118.2-1993*, *Method of Testing for Rating Residential Water Heaters*[2] or *ANSI/ASHRAE Standard 118.1-2003*, *Method of Testing for Rating Commercial Gas, Electric, and Oil Service Water Heating Equipment.*[3]

5.3 Combined Space-Heating and Water-Heating Performance. Combined space-heating and water-heating performance of the combination appliance shall be determined from calculations as prescribed in Section 11.

6. INSTRUMENTS

6.1 General. All instruments shall be in working order and be calibrated periodically. Records of periodic calibration shall be kept, and they shall contain, at a minimum, the date of calibration, method of calibration, and reference standard used.

6.2 Temperature

6.2.1 Space Heating Tests

6.2.1.1 Thermometers. Thermometers shall have an error no greater than ±2°F (±1°C).

6.2.1.2 Thermocouples. Thermocouples and their readout instrumentation shall have an error no greater than ±2.0°F (±1°C) Thermocouples shall be the bead type having a wire size no greater than No. 24 American Wire Gauge (AWG). Where there is a possibility that the thermocouple(s) could receive direct radiation from the flame, use of a radiation shield is required.

6.2.1.3 Thermocouple Grids. Thermocouple grids shall be constructed of thermocouples of the type described in Section 6.2.2. The grid shall be wired in parallel and located in a test plane perpendicular to the axis of the test flue, stack, or vent pipe, and the thermocouple leads shall be equalized in length before paralleling.

6.2.2 Water Heating Test. Temperature measuring devices and any associated readout instrumentation used for measuring domestic water temperatures shall be in accordance with *ANSI/ASHRAE Standard 41.1-1986 (RA 2006), Standard Method for Temperature Measurement.*[4]

6.3 Pressure. Gas, oil, air, water, and steam pressure measuring instruments shall be calibrated so that the error is no greater than the following:

6.3.1 Gas. ±0.2 in. water column (50 Pa).

6.3.2 Oil. ±0.5 psi (3.4 kPa).

6.3.3 Air. ±0.01 in. water column (2.5 Pa).

6.3.4 Steam. ±0.2 in. mercury column (0.7 kPa).

6.3.5 Water. ±1.0 psi (6.9 kPa)

6.4 Draft. Draft gauges shall have an accuracy of ±0.005 in. wc (1.2 Pa). The divisions on the draft gauge shall be 0.005 in. wc (1.2 Pa) or less.

6.5 Combustion Products. Stack and flue CO_2 (carbon dioxide) shall be determined with an instrument providing a reading with an error no greater than ±0.1 percentage points.

6.6 Weight or Volume. The error associated with the measuring instruments shall not exceed ±1.0% of the quantity measured.

6.7 Time. The error associated with timing instruments shall not exceed ±0.5 seconds per hour.

6.8 Smoke. Smoke-measuring instruments shall comply with requirements for smoke meters as outlined in ANSI/ASTM-D-2156-94 (2003), *Standard Test Method for Smoke Density in the Flue Gases from Burning Distillate Fuels.*[5]

6.9 Energy Flow Rate

6.9.1 Electricity. The error shall be no greater than 1%.

6.9.2 Gas. The error shall be no greater than 1%.

6.9.3 Oil. The error shall be no greater than 1%.

6.10 Energy Consumption

6.10.1 Electricity. The error shall be no greater than 1%.

6.10.2 Gas. The error shall be no greater than 1%.

6.10.3 Oil. The error shall be no greater than 1%.

6.11 Higher Heating Value

6.11.1 Gas. The error shall be no greater than 1%.

6.11.2 Oil. The error shall be no greater than 1%.

7. APPARATUS

7.1 General. Water heaters and boilers shall be installed in the test room in accordance with their manufacturer's instructions unless required otherwise by a specific method of test.

The apparatus described below is used in conjunction with Type I and Type II combination space-heating and water-heating appliances during the testing.

7.2 Type I Appliances

7.2.1 Space-Heating Function. The following is extracted from Section 7 of *ASHRAE Standard 103-1993*, *Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*[1] with some editing to clarify references to other parts of that standard.

7.2.1.1 General. The apparatus described below is used in conjunction with the boiler during the testing. Each piece of apparatus shall conform to the material and construction specifications and any noted reference standards. Test rooms containing equipment shall have suitable facilities for providing utilities necessary for performance of the test and be able to maintain conditions within the limits specified.

7.2.1.2 Piping. Piping arrangements for hot water and steam boilers shall be appropriate to maintain the required conditions.

7.2.1.3 Stacks and Flues without Stack Dampers

7.2.1.3.1 Boilers with Draft Hoods or Integral Draft Diverters. Low-pressure steam and hot water boilers equipped with draft hoods or integral draft diverters shall be provided with a 5 ft (1.52 m) stack of a cross-sectional area or perimeter the same size as the boiler outlet as described in Figure 7-1. For boilers equipped with an integral draft-diverter, cover the stack with insulation having an R-value of not less than R-7 $ft^2 \cdot h \cdot °F/Btu$ (1.23 $m^2 \cdot K/W$) and an outer layer of aluminum foil. For other boilers, provide the flue pipe with R-7 insulation and an outer layer of aluminum foil. Supply an elbow the same size as the boiler outlet on horizontal discharging draft diverters and cover the draft diverter elbow with not less than R-7 insulation and an outer layer of aluminum foil.

7.2.1.3.2 Boilers, Direct Vent and Direct Exhaust. Units not equipped with a draft hood or draft diverter shall be provided with the minimum-length vent configuration recommended by the manufacturer (see Figure 7-2).

7.2.1.3.3 Boilers, Oil-Fired or Power Gas-Fired. Provide oil-fired or power gas-fired steam and hot water boilers with a flue and elbows as described in Figure 7-3. The flue and elbows shall be of the same cross-sectional area, or perimeter, as the boiler outlet and covered with insulation having an R-value of not less than R-7 $ft^2 \cdot h \cdot °F/Btu$ (1.23 $m^2 \cdot K/W$) and an outer layer of aluminum foil. There shall be no opening between the boiler and the point where the flue gas sample is to be taken and the flue gas temperature is to be measured. Provide a means for adjusting the draft. Additional stack height or a mechanical draft inducer may be used.

7.2.1.3.4 Condensing Boilers, Additional Requirements. The flue pipe installation must not allow condensate formed in the flue pipe to flow back into the unit. An initial downward slope from the unit's exit, an offset with a drip leg, annular collection rings, or drain holes must be included in the flue pipe installation without disturbing normal flue gas flow. Flue gases should not flow out of the drain with the condensate.

7.2.1.4 Additional Requirements for Stacks and Flues on Units with Stack Dampers

7.2.1.4.1 Units with Draft Hoods or Draft Diverters. Install the stack damper connector in accordance with the manufacturer's instructions. Install 5 ft (1.52 m) of stack above the damper.

7.2.1.4.2 Units with Barometric Draft Control. Provide a means for adjusting the draft. Additional stack height or a mechanical draft inducer may be used.

7.2.1.5 Direct-Vent Systems, Insulation Requirements. For direct-vent systems that are not designed to significantly preheat the incoming air, only the first 18 in. (457 mm) of vent pipe downstream of the boiler outlet shall

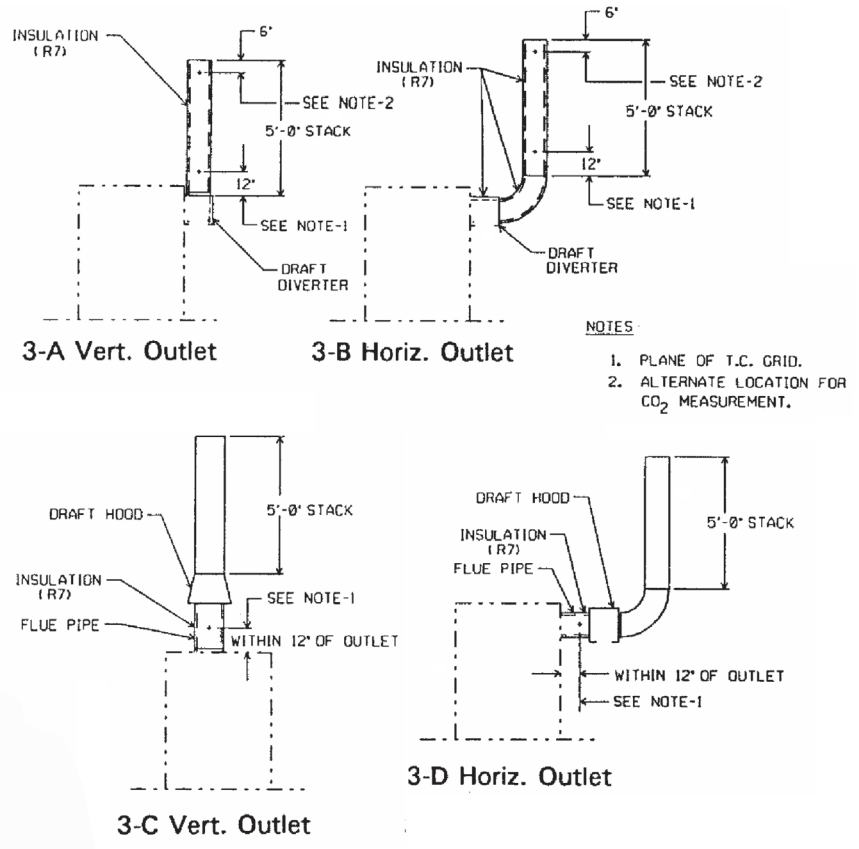

Figure 7-1 Test vents for boilers with draft hoods gas firing.

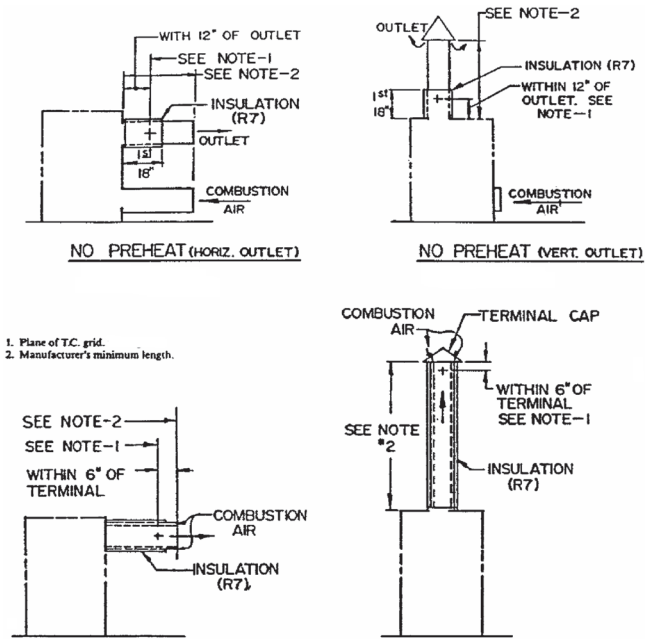

Figure 7-2 Test vent for direct vent and direct exhaust systems.

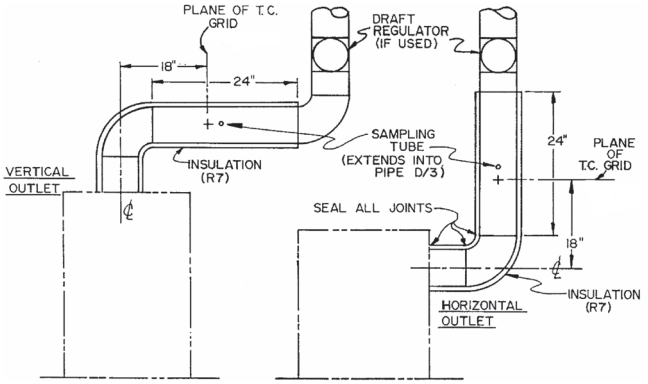

Figure 7-3 Test vent for oil or power gas firing.

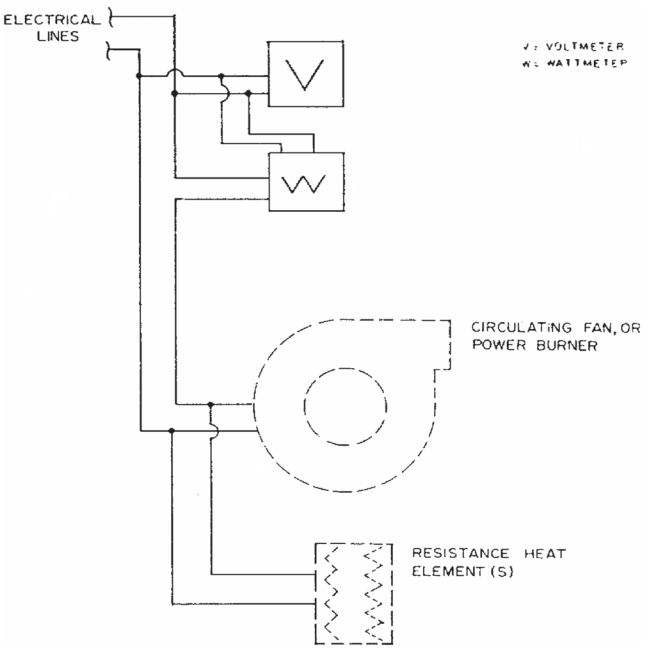

Figure 7-4 Electrical arrangements.

be insulated with a layer of insulation having an R-value of R-7 ft^2 h· °F/Btu (1.23 m^2· K/W) and a layer of aluminum foil. For units designed to significantly preheat the incoming combustion air, cover all surfaces of the vent/air intake system exposed to ambient air with insulation having an R-value not less than R-7 ft^2 h· °F /Btu (1.23 m^2· K/W) and a layer of aluminum foil where the combustion air temperature exceeds the room temperature by more than 30°F (16.7°C). Care should be taken not to block the air intake with insulation.

7.2.1.6 Thermocouple Grids. Thermocouple grids shall be constructed of either 5 or 9 thermocouples (17 optional) of the type described below. The grid shall be wired in parallel and located in a test plane perpendicular to the axis of the test stack or vent pipe (direct-vent system). The thermocouple leads shall be equalized in length before paralleling. Arrange the thermocouples in a grid with one thermocouple in the center of the test stack and the remaining on radial wires 90° apart. If there is a possibility that the thermocouples could receive direct radiation from the flame, install radiation shields on the flame side of the thermocouple only and position the shields so that they do not touch the thermocouple junctions. If there is an indication that condensation forming in the flue or stack is contacting the thermocouples, provide a means to protect the thermocouples from direct contact with the condensate.

7.2.1.7 Electrical Measurement. Electrical measurements shall be carried out in accordance with Figure 7-4.

7.2.2 Water-Heating Function Requirements

7.2.2.1 Flue and Stack Requirements for Type I Appliances. Type I appliances shall be equipped with flues and stacks that meet the requirements of Sections 7.3.2, 7.3.3, 7.4, and 7.5 of *ASHRAE Standard 103-1993*, *Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers.*[1]

7.2.2.2 Piping. See Figures 4-1, 4-2, and 4-3 for typical piping arrangements. Provision shall be made to ensure constant water temperature and pressure being supplied to the unit.

7.2.2.3 Water Flow Measurement. Provide appropriate weigh tanks and scales or calibrated meters to measure the water flow rate.

7.2.2.4 Energy Supply

7.2.2.4.1 Electrical Supply. For an electric Type I appliance and for the auxiliary electrical system, if any, of an oil or gas Type I appliance, maintain the electrical supply voltage to within ±1% of the center of the voltage range specified by the appliance manufacturer on the appliance nameplate throughout the entire operating portion of each test.

7.2.2.4.2 Natural Gas. For a gas Type I appliance using natural gas, maintain the gas supply at an normal inlet

test pressure of 7 to 10 in. wc (1.7 to 2.5 kPa) immediately ahead of all controls. Use natural gas with a higher heating value of approximately 1,025 Btu/standard ft^3 (38 kJ/L). Determine the actual higher heating value (HHV) in Btu/standard ft^3 for the natural gas to be used in the test with an error no greater than ±1%, and use that value for all calculations included herein. Alternatively, the test can be conducted using "bottled" natural gas with a higher heating value (HHV) of approximately 1,025 Btu/standard ft^3 (38 kJ/L) as long as the actual HHV of the bottled natural gas has been determined with an error no greater than ±1%, as certified by the supplier.

7.2.2.4.3 Propane Gas. For a gas Type I appliance using propane gas, maintain the gas supply at a normal test pressure of 11 to 13 in. wc (2.7 to 3.2 kPa) immediately ahead of all controls. Use propane with a higher heating value of approximately 2,500 Btu/standard ft^3 (9.25 kJ/L). Determine the actual HHV Btu/standard ft^3 (kJ/L) for the propane to be used in the test with an error no greater than ±1% and use that value for all calculations included herein. Alternatively, the test can be conducted using "bottled" propane of an HHV of approximately 2,500 Btu/standard ft^3 (92.5 kJ/L) as long as the actual HHV of the bottled propane has been determined with an error no greater than ±1%, as certified by the supplier.

7.2.2.4.4 Oil Supply. For an oil Type I appliance, use fuel oil with a heating value of approximately 138,500 Btu/gal at 70°F (41.5 MJ/L at 21°C). Determine the actual higher heating value (HHV) in Btu/gal (MJ/L) for the fuel oil to be used in the test with an error no greater than ±1% and use that value for all calculations included herein. Alternatively, the tests can be conducted using a tested fuel oil with a certified HHV other than 138,500 Btu/gal (41.5 MJ/L) as long as the actual HHV of the test fuel oil has been determined with an error of no greater than ±1%, as certified by the supplier.

7.2.2.4.5 Fuel or Energy Consumption Measurement. Install one or more instruments that measure, as appropriate, the quantity or rate of energy consumed by the appliance when heating water. Electrical energy consumption shall be expressed in units of kilowatt-hours. Natural gas and propane consumption shall be expressed in units of Btu (J). Fuel oil consumption shall be expressed in units of Btu (J). See Figures 7-5 and 7-6.

7.2.2.5 Thermocouple Installation

7.2.2.5.1 Room Temperature. Install a thermocouple to measure the ambient temperature with the junction shielded against direct radiation from any heat source and positioned at the vertical midpoint of the unit at a perpendicular distance of approximately 24 in. (610 mm) from the surface of the boiler (tankless heater) or 24 in. (610 mm) from both the boiler and tank jacket.

7.2.2.5.2 Thermocouple Installation for Domestic Water Storage Tanks of Integrated Heaters. Install six thermocouples inside the tank. Position each thermocouple-measuring junction along a vertical line at the level of the center horizontal plane of each of six non-overlapping sections of approximately equal volume from the top to the bottom of the tank. This placement should be such that each thermocouple is surrounded by water and as far as possible from any heat input device, anodic protective device, or tank wall. The anodic protective device may be removed in order to install the thermocouples, and all testing may be carried out with the device removed. Install thermocouples in both the cold-water inlet pipe and the hot-water outlet pipe not more than 24 in. (610 mm) from the connections to the water heater or, where these connections are inaccessible, at the closest accessible point to these connections. Locate the thermocouples downstream of two elbows, or downstream of a turbulator, to ensure good mixing. In boilers, for the purpose of recording boiler water temperature, install a thermocouple in the boiler limit control well, if provided; otherwise, install it in the outlet of the boiler.

7.2.2.5.3 Mean Tank Temperature Measurement. The mean tank temperature of the water in an integrated heater tank, wherever specified, shall be the mean of the temperatures determined by using the six heater tank thermocouples.

7.2.2.5.4 Thermocouple Installation for Gas-Fired and Oil-Fired Tankless Heaters. Install thermocouples in both the cold water inlet pipe and the hot water outlet pipe not more than 24 in. (610 mm) from the connections to the heat exchange unit. Locate the thermocouples downstream of two elbows, or a turbulator, to ensure good mixing. Install a thermocouple to measure the boiler water temperature in the location where the control well is normally installed. The thermocouple shall extend into the boiler water a distance equal to two-thirds the length of the control well supplied with the boiler. The thermocouple may be inside the well, or outside at the same level and within 1 in. (25 mm) of the well, but not touching the coil.

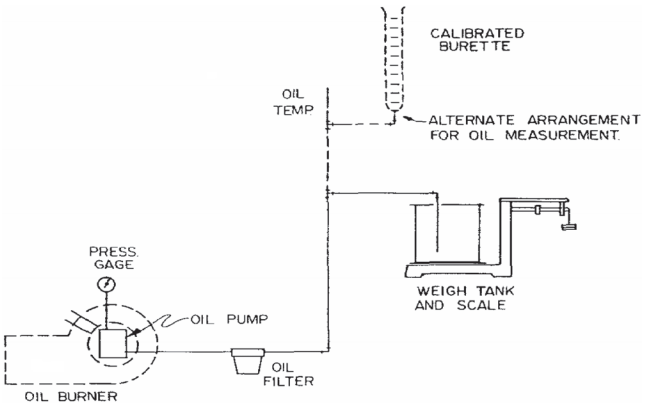

Figure 7-5 Suggested oil burner test setup.

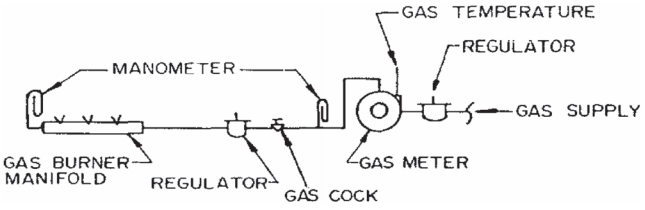

Figure 7-6 Suggested gas burner test setup.

7.3 Type II Appliances

7.3.1 Water-Heating Function Requirements. For Type II appliances with maximum inputs at or less than 75,000 Btu/h (22kW) for gas-fired storage type, 105,000 Btu/h (30.8 kW) for oil-fired storage types, 200,000 Btu/h (58.6 kW) for gas-fired non-storage types, 210,000 Btu/h (61.5kW) for oil-fired non-storage types, and 12kW for all electric types, use the procedures of *ASHRAE 118.2–1993*, *Method of Testing for Rating Residential Water Heaters*.[2] For all larger input Type II appliances, use the procedures found in A*NSI/ASHRAE 118.1-2003*, *Method of Testing for Rating Commercial Gas, Electric, and Oil Service Water Heating Equipment*.[3]

7.3.2 Space-Heating Function Requirements

7.3.2.1 Installation. Install the water heater according to the manufacturer's installation instructions on a 0.75 in. (19 mm) thick plywood platform elevated approximately 4 in. (102 mm) off the floor by three 2 × 4 in. (51 × 102 mm) runners. If the appliance is not approved for installation on a combustible floor, suitable noncombustible material shall be placed between it and the platform. Any piping components or insulation supplied with the heater shall be included. An appropriately rated pressure- and temperature-relief valve shall be installed in the location specified by the manufacturer and insulated with thermal insulation having a value of R-4. Provide a pressure gauge and, for storage tank type units, a diaphragm type expansion tank and check valve in the water supply line. See Figures 7-7a through 7-7h.

7.3.2.2 Flue and Stack Requirements

7.3.2.2.1 Gas-Fired Water Heaters. For a gas water heater having a vertically discharging draft hood outlet, a 5 ft (1.52 m) vertical stack having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. For a gas water heater having a horizontally discharging draft hood outlet, a 90-degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A 5 ft (1.52 m) length of stack shall be connected to the elbow and oriented to discharge vertically upward. Cover the stack with insulation having an R-value not less than R-7 ft^2 h· °F/Btu (1.23 m^2· K/W) and an outer layer of aluminum foil. Perform all tests with the natural draft established by this length of stack. See Figure 7-8a. Direct-vent gas water heaters shall be installed with venting equipment as specified by the manufacturer's instructions. If the manufacturer specifies optional or adjustable venting equipment, the flue loss test shall be conducted with the venting system utilizing the minimum lengths of vertical and horizontal vent pipe recommended by the manufacturer.

7.3.2.2.2 Oil-fired and power gas-fired water heaters. For an oil-fired or power gas-fired water heater, establish a draft at the flue collar equivalent to at least 0.02 in. wc (5 Pa) during periods of burner firing. For a water heater having a vertically discharging flue outlet, establish the draft by using a sufficient length of flue pipe connected to the water heater flue outlet and oriented to discharge vertically upward. For a water heater having a horizontally discharging flue outlet, a 90-degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the flue outlet. A length of flue pipe sufficient to establish the draft shall be connected to the elbow fitting and oriented to discharge vertically upward. See Figure 7-2. Cover the flue with insulation having an R-value not less than R-7 ft^2 h· °F/Btu (1.23 m^2· K/W) and an outer layer of aluminum foil. Direct-vent water heaters shall be installed with the minimum-length venting equipment as specified in the manufacturer's instructions.

7.3.2.3 Energy Supply. Same as Section 7.2.2.4.

7.3.2.4 Fuel or Energy Consumption Measurement. Install one or more instruments that measure, as appropriate, the quantity and rate of electrical energy, natural gas, propane, and fuel oil consumed by water heater and auxiliary devices. See Figures 7-3, 7-4, and 7-5.

7.3.2.5 Thermocouple Installation in Flue Pipe. For determining flue temperatures, install a 5 or 9 thermocouple grid 12 in. (305 mm) above the jacket top (see Section 6.2.3).

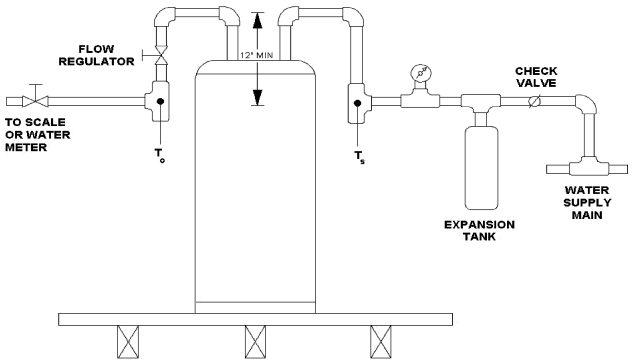

Figure 7-7a Vertical connections (top) (commercial water heaters).

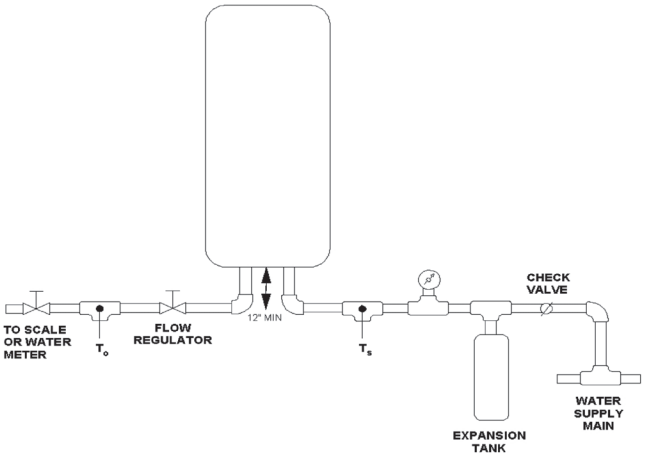

Figure 7-7b Vertical connections (bottom) (commercial water heaters).

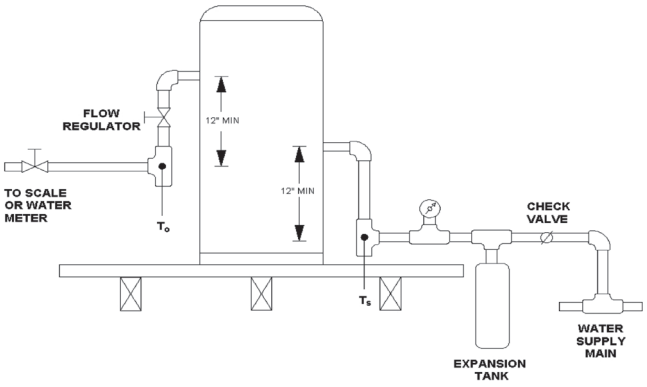

Figure 7-7c Horizontal connections (commercial water heaters).

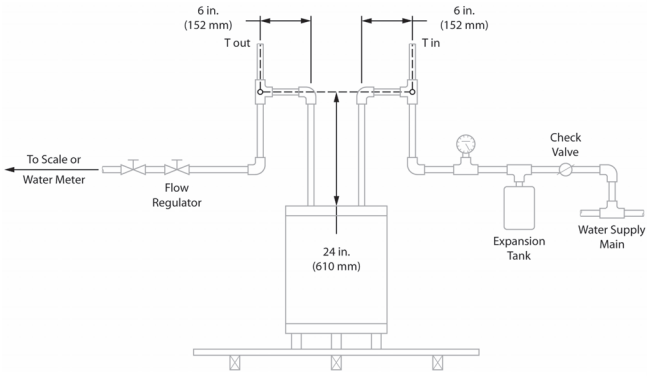

Figure 7-7d Top connections (residential water heaters).

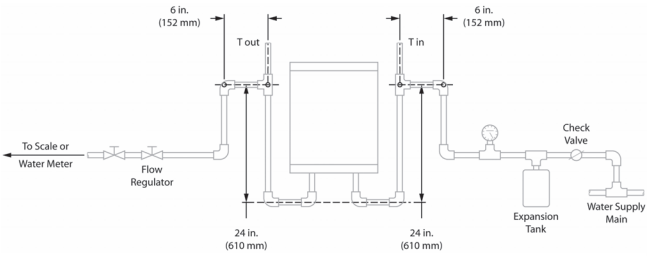

Figure 7-7e Bottom connections (residential water heaters).

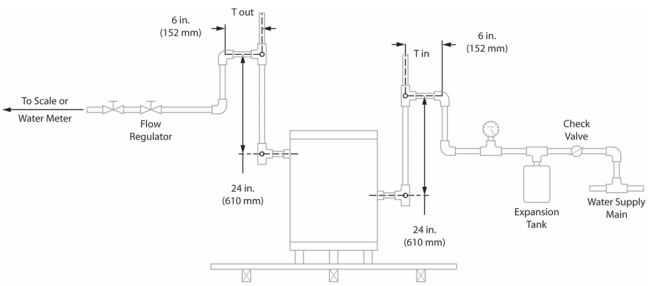

Figure 7-7f Side connections (residential water heaters).

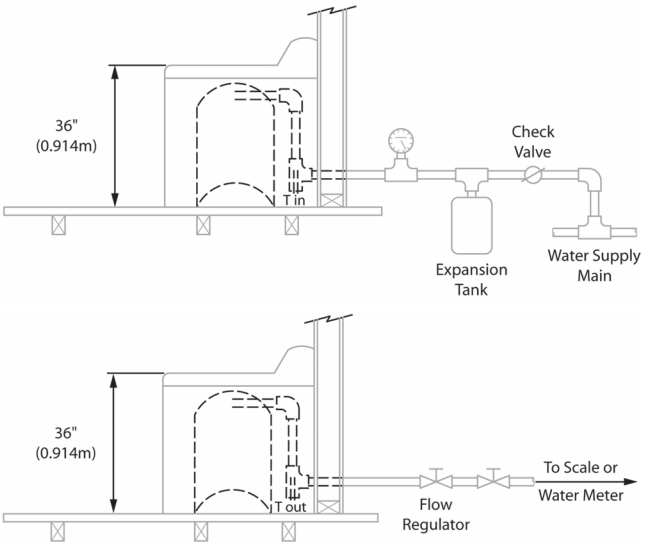

Figure 7-7g Connections for residential water heaters of 20 gal (75.7 L) or more that are 36 in. (914 mm) high or less.

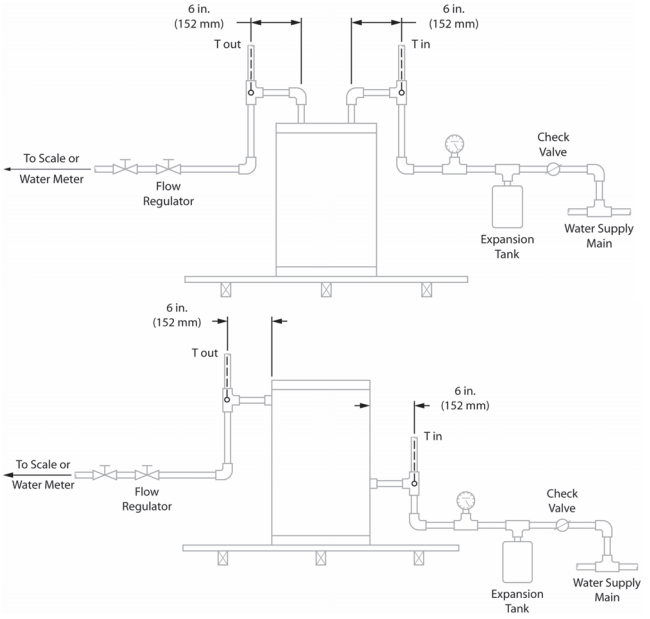

Figure 7-7h Connections for residential water heaters of less than 20 gal (75.7 L).

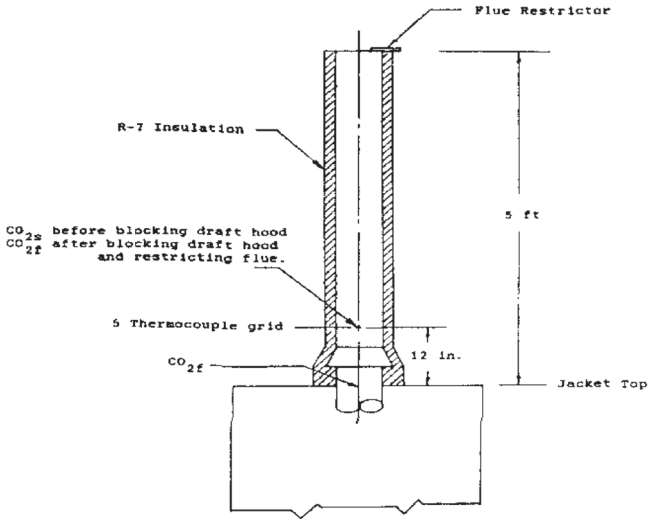

Figure 7-8a Type II combination space-heating and water-heating appliance.

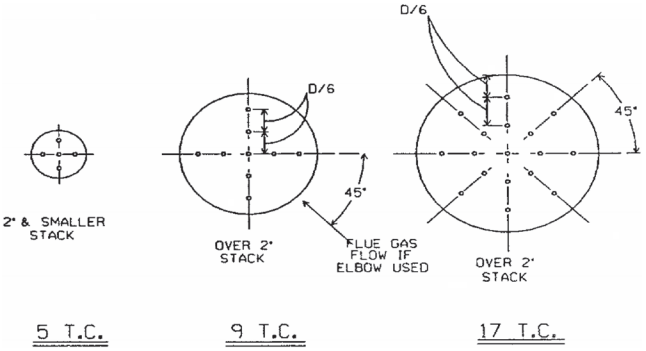

Figure 7-8b Thermocouple grid and arrangements.

Arrange the thermocouples in a grid with one thermocouple in the center of the test stack and the remaining as shown in Figure 7-8b. If there is a possibility that the thermocouples could receive direct radiation from the flame, install radiation shields on the flame side of the thermocouple only and position the shields so that they do not touch the thermocouple junctions. Alternatively, provide a test vent in accordance with Figure 7-2.

7.3.2.6 System Number for Atmospheric Burner Appliances. Appliances with atmospheric burners shall be deemed system number 1, 5, or 9 as appropriate in Table 6 of *ASHRAE Standard 103-1993*, *Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*[1] without regard to the presences of a burner inlet damper or flue damper.

8. TEST SETUP

8.1 General. Type I and Type II combination space-heating and water-heating appliances shall be equipped with the apparatus described in Section 7, and the instrumentation described in Section 6 shall be set up for recording data. Refer to Figures 4-1, 4-2, 4-3, 7-1, 7-2, 7-3, 7-4, 7-5, 7-6, 7-7, and 7-8 when equipping Type I and Type II appliances with the apparatus and instrumentation. The equipment shall be adjusted to the test requirements or conditions described in Section 8.4.

8.1.1 Test Unit Installation—Type I and II Combination Space-Heating and Water-Heating Appliances

8.1.1.1 Integrated Heater. If the manufacturer supplies an installation kit, install the unit according to the manufacturer's directions. Otherwise, install the connecting piping between the boiler and the storage tank using copper tube of the size and length recommended by the manufacturer. (See Figure 4-3.)

8.1.1.2 Tankless Heater. Tankless heaters shall be installed in the boiler or in the external tank containing boiler water. The boiler shall be equipped with a safety relief valve. Expansion of the water during the test shall be provided for. (See Figure 4-1 or 4-2.)

8.1.1.3 Storage Water Heater. Install the appliance according to the manufacturer's installation instructions. It shall be equipped with a pressure- and a temperature-relief valve.

8.1.1.4 Instantaneous Water Heater. Install the appliance according to the manufacturer's installation instructions.

8.1.2 Piping Insulation. Unless piping insulation is supplied by the manufacturer, none shall be installed.

8.2 Air, Water, and Electrical

8.2.1 Water Supply. During the entire test, maintain the water supply to the appliance inlet at the nominal cold water supply temperature T_c ±2°F (±1°C) and at a gauge pressure of between 30 psig (206.7 kPa) and the maximum pressure specified by the manufacturer for the appliance under test. If the water supply pressure varies outside of these limits during the first 18 hours of the tests, the heater shall be isolated by use of a shutoff valve in the supply line with an expansion tank installed in the supply line downstream of the shutoff valve. There shall be no shutoff means between the expansion tank and the water heater inlet.

8.2.2 Room Ambient Temperature. Maintain the ambient air temperature, T_a, of the test room at the nominal room temperature, T_r, ±5°F (±2.5°C) at all times during the test, as measured according to Section 7.2.2.5.

8.3 Power Input Determination. Initiate normal operation of the appliance and determine the power input, Q_{in}, to the main burners (including pilot light power, if any) or heating elements of the appliance under test in Btu/h (W) or kW, as appropriate. (See Section 8.3.3.)

8.3.1 Gas-Fired Appliances. Adjust the input rate to the burner(s) Btu/h (W) so that it will be within ±1% of the Btu/h (W) rating specified by the manufacturer as measured during the steady-state test, 15 minutes after starting with all parts at room temperature, corrected to 60°F (15.5°C) and 30 in. Hg (101.6 kPa) (using the correction-to-heating-value procedure below.) The manifold pressure shall be within ±10% of the manufacturer's specified manifold pressure. Do

not make additional adjustments to the burner during the required series of performance tests.

The following procedure is used for the correction applied to the heating value, H, for a fuel gas when it is metered at temperature and/or pressure conditions other than the standard conditions on which the value of H is based:

Dry gas utilizing a dry test meter,

$$C_{s-dry} = \frac{P_g \times (459.7 + T_s)}{P_s \times (459.7 + T_g)} \quad (8\text{-}1a)$$

$$\left[C_{s-dry} = \frac{P_g \times (273.15 + T_s)}{P_s \times (273.15 + T_g)} \right] \quad (8\text{-}1b)$$

Saturated gas utilizing a wet test meter,

$$C_{s-wet} = \frac{(P_g - P_{wv}) \times (459.7 + T_s)}{(P_s - P_{wvs}) \times (459.7 + T_g)} \quad (8\text{-}2a)$$

$$\left[C_{s-wet} = \frac{(P_g - P_{wv}) \times (273.15 + T_s)}{(P_s - P_{wvs}) \times (273.15 + T_g)} \right] \quad (8\text{-}2b)$$

where

P_g = absolute pressure of gas being metered (barometric pressure plus gas pressure inside meter), in. Hg (kPa)
P_s = standard absolute pressure, in. Hg (kPa)
T_g = temperature of gas inside meter, °F (°C)
T_s = standard temperature, °F (°C)
P_{wv} = water vapor pressure at T_g, in. Hg (kPa)
P_{wvs} = water vapor pressure at T_s, in. Hg (kPa)

For water vapor pressures, see the *2005 ASHRAE Handbook— Fundamentals*, Chapter 6, Table 3.[6]

If the value of H is based upon a dry condition and the gas is metered with a wet test meter, its value must also be reduced by a factor as determined by Equation 8-3:

$$C_f = \frac{(P_s - P_{wvs})}{P_s} \quad (8\text{-}3)$$

Conversely, if the value of H is based upon a saturated condition and the gas is metered dry, its value must also be increased by a factor as determined by Equation 8-4:

$$C_f = \frac{P_s}{(P_s - P_{wvs})} \quad (8\text{-}4)$$

EXAMPLE:

If the standard conditions are 30.00 in. Hg and 60°F, Equations 8-1 through 8-4 simplify to the following:

$$C_{s-dry} = \frac{17.323 \times P_g}{459.7 + T_g} \quad (8\text{-}5)$$

$$C_{s-wet} = \frac{17.63 \times (P_g - P_{wv})}{459.7 + T_g} \quad (8\text{-}6)$$

C_f (H dry, wet meter) = 0.9826,

C_f (H saturated, dry meter) = 1.0177.

8.3.2 Oil-Fired Appliances. Adjust the burner to give a CO_2 reading recommended by the manufacturer and a Btu/h (W) input during the tests described below that is within ±2% of the manufacturer's specified normal Btu/h (W) input rating. Smoke in the flue may not exceed a No. 1 smoke density during the tests as measured by the procedure in *ANSI/ASTM-D-2156-94 (1999), Standard Test Method for Smoke Density in the Flue Gases from Burning Distillate Fuels.*[5] Maintain the average draft over the fire and in the flue during the tests at the pressure recommended by the manufacturer. Do not allow draft fluctuations exceeding 0.005 in. wc (1.2 Pa). Do not make additional adjustments to the burner during the required series of performance tests.

8.3.3 Electric Appliances. For electric appliances with immersed heating elements, the power input, I_n, to the heating element shall be taken to be the design power rating of the heating element as indicated on the appliance rating plate. For an electric water heater with dual immersed heating elements, the power input, Q_{in}, to the heating elements shall be taken to be the arithmetic mean of the design power ratings of heating elements. This applies if, in characteristic operation of the appliance, only one heating element will be energized at any time; otherwise, Q_{in} shall be taken to be the sum of the design power ratings of the heating elements.

8.4 Setting the Tank Thermostat, Type II Appliances (where applicable)

8.4.1 Single Thermostat. Starting with a tank of supply water, initiate normal operation of the appliance. After cutout, determine whether the maximum value of the mean tank temperature T_s is equal to the nominal tank temperature T_t±5°F (±2.5°C). If not, turn off the appliance, adjust the thermostat, refill with supply water, initiate normal operation of the appliance, and once again determine the maximum mean temperature after cutout. Repeat this sequence until the maximum mean tank temperature after cutout is equal to the nominal tank temperature T_t±5°F (±2.5°C), at which time the thermostat is properly set.

8.4.2 Two Thermostats. If an appliance has two thermostats, the upper thermostat shall be set first to yield a maximum water temperature equal to T_t±5°F (±2.5°C), as measured by the topmost tank thermocouple, after cutout as described in Section 8.4.1. The lower thermostat shall then be set to yield a maximum mean tank temperature equal to T_t±5°F (±2.5°C) after cutout as described in Section 8.4.1.

8.4.3 Nonadjustable Thermostat. Remove the nonadjustable thermostat and replace it with an adjustable thermostat installed at the same location and follow the procedure described in Section 8.4.1 or 8.4.2.

8.5 Setting Control of Integrated Heater. Starting with a tank of unheated water, initiate normal operation of the unit. After thermostat cutout, determine whether the maximum mean tank water temperature T_s is equal to T_t±5°F (±2.5°C). If not, turn off the unit, adjust the thermostat, empty the tank and refill it with unheated water, initiate normal operation of the unit, and once again determine the maximum mean tank water temperature after cutout. Repeat this sequence until the maximum mean tank water temperature after thermostat cut-

out is equal to T_t±5°F (±2.5°C), at which time the thermostat is properly set. The boiler limit control shall not be set higher than T_t + 75°F (+41.7°C).

8.6 Setting Control of Tankless Heater. Starting with a boiler full of unheated water, initiate normal operation of the boiler. After cutout, determine whether the maximum temperature measured by the thermocouple installed at the control well T_b is equal to T_t + 45°F (T_t + 25°C) or to the nominal setting recommended by the manufacturer's installation instructions if this nominal setting is higher than (T_t + 45°F)±5°F [(T_t + 25°C)±2.5°C]. If not, turn off the boiler, adjust the water temperature control, empty the boiler and refill with unheated water, then initiate normal operation of the boiler, and once again determine the maximum temperature at the well after cutout.

Repeat this sequence until the maximum temperature at the control well after cutout is equal to T_t + 45°F (T_t + 25°C) or to the nominal setting recommended by the manufacturer's installation instructions if this nominal setting is higher than (T_t + 45°F)±5°F [(T_t + 25°C)±2.5°C], at which time the control is properly set. The differential setting of the control shall be set to 10°F (5.5°C), or to the setting nearest 10°F (5.5°C), when a 10°F (5.5°C) setting is not provided. The boiler limit control shall not be set higher than T_t + 75°F (T_t + 41.7°C).

8.7 Flow Rate for Simulated-Use Test. The simulated-use test specifies six equal draws of *U*/6 gallons (L) each during a 24-hour period.

8.7.1 Integrated Heater. The flow rate shall be FR±0.25 gpm (FR±0.015 L/s), and the outlet water temperature T_o shall not fall below T_s – 25°F (T_s – 13.9°C) at any time during a draw. If necessary, the flow rate may be adjusted to a lower value in order that the outlet water temperature does not fall below T_s – 25°F (T_s – 13.9°C).

8.7.2 Tankless Heater. The flow rate shall be set to achieve a difference between the average outlet water temperature (T_o) and average inlet water temperature (T_i) of (T_t – T_c)±3°F ([T_t – T_c]±1.5°C).

8.7.3 Systems with Modulating or Two-Stage Burners. If the system incorporates a controller that permits continuous burner operation at a reduced input rate, adjust the flow rate as necessary to maintain the minimum input rate. Record the corresponding flow rate, FR_{min}. If the outlet water temperature cannot be maintained within the lower limit specified above in Section 8.7.1 or 8.7.2, record the outlet water temperature, T_m, in order to determine the length of draw (see Section 9.1.2.3.2).

9. TEST PROCEDURE

9.1 Type I Appliances

9.1.1 Space Heating. Space heating tests shall be conducted in accordance with all the provisions of *ASHRAE Standard 103-1993, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers.*[1]

9.1.2 Water Heating. Water-heating tests shall be conducted in accordance with the following sections.

9.1.2.1 Tank Storage Capacity Determination. Determine the storage capacity, *V*, of the integrated heater tank, in gal (L), by subtracting the tare weight of the empty tank from the gross weight of the tank when full of water at temperature T_c with all air removed. Multiply the resulting net weight by the specific volume, in ft^3/lb (L/kg) of water at T_c, times 7.48055 gal/ft^3 (1L/L). No storage capacity measurement is necessary for tankless heaters.

9.1.2.2 First-Hour Rating for Integrated Heaters and Maximum GPM Rating for Tankless Heaters

9.1.2.2.1 First-Hour Draw Test for Type I Integrated Heaters

9.1.2.2.1.1 General. Using criteria described in Section 8.5, establish a maximum mean tank temperature within the specified range. During hot water draws, remove water at a rate of 3.0±0.25 gallons per minute (11.4±0.015 liters per second). Collect the water in a container that is large enough to hold the volume removed during an individual draw and suitable for weighing at the termination of each draw. Alternatively, a water meter may be used to directly measure the water volume(s) withdrawn.

9.1.2.2.1.2 Draw Initiation Criteria. Begin the first-hour draw test by imposing a draw on the storage tank. After completion of this first draw, initiate successive draws when the storage tank thermostat cuts out. For tanks with two thermostats, wait until the uppermost thermostat cuts out and then begin to draw water again.

9.1.2.2.1.3 Test Sequence. Establish normal water heater operation as specified in Section 9.1.2.2.1.1. If the water heater is not presently operating, initiate a draw. The draw may be terminated anytime after thermostat cut-in occurs. Wait until cutout occurs (i.e., all thermostats are satisfied). Initiate the first draw after a maximum mean tank temperature has been observed following cutout. Record the time when this draw is initiated and designate it as an elapsed time of zero ($t^* = 0$). (The superscript * is used to denote variables pertaining to the first-hour draw test.) Record the outlet water temperature beginning 15 seconds after the draw is initiated and at 5-second intervals thereafter until the draw is terminated.

Determine the maximum outlet temperature that occurs during this first draw, and record it as $T^*_{o(max),1}$. For the duration of this first draw and all successive draws, in addition, monitor the inlet temperature of the potable water to the storage tank to ensure that the required 58°F±2°F (14.4°C±1.1°C) test condition is met. Terminate the hot water draw when the outlet temperature decreases to $T^*_{o(max),1}$ – 25°F ($T^*_{o(max),1}$ – 13.9°C). Record this temperature as $T^*_{min,1}$. Following draw termination, determine the average outlet water temperature and the mass or volume removed during this first draw and record them as $T^*_{del,1}$ and W^*_1 or V^*_1, respectively.

Initiate a second and, if applicable, successive draw each time the applicable draw initiation criteria described in Section 9.1.2.2.1.2 are satisfied. As required for the first draw, record the outlet water temperature 15 seconds after initiating each draw and at 5-second intervals thereafter until the draw is terminated. Determine the maximum outlet temperature that occurs during each draw and record it as $T^*_{o(max),i}$, where the

subscript *i* refers to the draw number. Terminate each hot water draw when the outlet temperature decreases to $T^*_{o(max),i}$ – 25°F ($T^*_{o(max),i}$ – 13.9°C). Record this temperature as $T_{min,i}$. Calculate and record the average outlet temperature and the mass or volume removed during each draw ($\bar{T}^*_{del,i}$ and W^*_1 or V^*_1, respectively). Continue this sequence of draw and recovery until one hour has elapsed from t^*; then shut off the electrical power and/or fuel supplied to the integrated heater.

If a draw is occurring at an elapsed time of one hour, continue this draw until the outlet temperature decreases to $T^*_{o(max),n}$ – 25°F ($T^*_{o(max),n}$ – 13.9°C), at which time the draw shall be immediately terminated. (The subscript *n* shall be used to denote quantities associated with the final draw.) If a draw is not occurring at an elapsed time of one hour, a final draw shall be imposed at that time. This draw shall be immediately terminated when the outlet temperature first indicates a value less than or equal to the cutoff temperature used for the previous draw ($T^*_{min,n-1}$).

For cases where the outlet temperature is close to $T^*_{min,n-1}$, the final draw shall proceed for a minimum of 30 seconds. If an outlet temperature greater than $T^*_{min,n-1}$ is not measured within 30 seconds, the draw shall be immediately terminated, and zero additional credit shall be given toward first-hour rating (i.e., set $W^*_n = 0$ or $V^*_n = 0$).

After the final draw is terminated, calculate and record the average outlet temperature and the mass or volume removed during the draw ($\bar{T}^*_{del,n}$ and W^*_n or V^*_n, respectively).

9.1.2.2.2 Maximum GPM Rating for Tankless Heaters

9.1.2.2.2.1 Setting the Outlet Water Temperature. Using the criteria described in Section 8.6, set the boiler controls. Initiate normal operation of the water heater at the full input rating. Monitor the tankless heater outlet water temperature and set to a value of 135°F±5°F (57.2°C±2.8°C) in accordance with the manufacturer's instructions. If the tankless heater is not capable of providing this outlet temperature when the flow rate is 3.0 gallons±0.25 gallons per minute (0.2 liters±0.015 liters per second), then adjust the flow rate as necessary to achieve the specified outlet water temperature. Record the corresponding volume flow rate as V_{max}.

9.1.2.2.2.2 Maximum GPM Rating Test. Establish normal water heater operation at the maximum input rate with the tankless heater outlet water temperature set in accordance with Section 9.1.2.2.2.1. During the following ten-minute test, do not interrupt the electrical energy or fossil fuel supplied to the tankless heater. During the ten-minute test, either collect the withdrawn water for later measuring of the total mass removed or, alternatively, use a water meter to directly measure the water volume removed.

Begin with the water flow temporarily discontinued. Record the scale or water meter reading as appropriate. Turn on the hot water, recording the corresponding time. Record the inlet and outlet water temperatures beginning 15 seconds after the hot water is turned on and at every subsequent 5-second interval throughout the duration of the test. At the end of 10 minutes, turn off the water. Determine the mass of water collected, W_{10m}, in pounds (kilograms), or the volume of water, V_{10m}, in gallons (liters), with an error no greater than 2%.

9.1.2.3 Simulated-Use Test

9.1.2.3.1 Initial Conditions. Following the first-hour draw test, initiate normal operation of the boiler and heater with the controls set as specified in Section 8.5 or 8.6. After initial cutout, or any subsequent cutout, draw *U*/6 gal (L) at the rate determined in Section 8.7.1 or 8.7.2. Thirty minutes after initiating the first draw, draw *U*/6 gal (L) at the same rate.

9.1.2.3.2 Integrated Heater Simulated Use Test Conditions. When the burner and circulator (if used) shut off following the second draw as described in Section 9.1.2.3.1, start the 24-hour test clock. Record the initial scale, meter, or instrument readings for determining energy input and auxiliary electric input. At the beginning of the test and at each 15-minute interval throughout the 24-hour test, unless recovery or a draw is occurring, record the mean tank temperature, T_s, the air temperature, T_a, and the boiler water temperature, T_b. After 18 hours have elapsed, record the energy input, Q_{sb}, and auxiliary electrical input, $C_{aux\text{-}sb}$, for the standby period. Then electrically bypass the integrated heater thermostat and operate the burner until the mean tank and boiler water temperature return to the initial conditions, ±5°F (2.5°C), recorded at the start of the 24-hour test. Record the energy input, Q_{r1}, and auxiliary electric input, $C_{aux\text{-}r1}$, for this recovery. Interrupt the 24-hour clock during this recovery. After the recovery test, proceed as follows:

a. For systems with single-stage burners, disconnect the electrical bypass and conduct six equal draws of *U*/6 gal (L) initiated one hour apart at the draw rate determined in Section 8.7.2. Record the burner operating time, t_{run}. Collect or meter the water drawn.
b. For systems with modulating or two-stage burners that permit continuous burner operation at reduced input rate, disconnect the electrical bypass and conduct six draws. Record burner operating time, t_{run}. Collect or meter the water drawn. The first three draws initiated one hour apart shall be one-sixth of the daily hot water use, *U*/6. The second three draws shall be conducted at V_{min} as determined in Section 8.7.3. If the minimum outlet temperature as specified in Section 8.7.1 cannot be achieved at the minimum flow rate, the last three draws shall be lengthened such that the volume removed is equivalent to the following:

$$V_{4,5,6} = U/6 \times (T_t - T_c) / (T_m - T_c)$$

The quantity of water drawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn shall be equal to the following:

$$[U/2 + (3 \times V_{4,5,6})] \pm 1 \text{ gal (L)}$$

After 24 hours has elapsed, record the energy input, Q_d, and auxiliary electrical input, $C_{aux\text{-}d}$, for the draw period. Then electrically bypass the integrated heater thermostat and operate the burner until water temperatures return to the initial conditions, ±5°F (2.5°C), recorded at the start of the 24-hour test. Record the energy input, Q_{r2}, and auxiliary electrical input, $C_{aux\text{-}r2}$, for this recovery. Then, stop the test. Determine total input for the 24-hour test

period, Q_{rs}, including the recovery energy after completion of the 24-hour test, Q_{r2}, and the recovery energy after the 18-hour standby, Q_{r1}.

9.1.2.3.3 Tankless Heater Simulated-Use Test Conditions. When the burner shuts off following the second draw described in Section 9.1.2.3.1, start the 24-hour test clock. Record the initial scale, meter, or instrument readings for determining energy input and auxiliary electric input. At the beginning of the test and at each 15-minute interval throughout the 24-hour test, unless recovery or a draw is occurring, record the air temperature, T_a, and the boiler water temperature, T_b. After 18 hours have elapsed, record the energy input, Q_{sb}, and auxiliary electrical input, $C_{aux\text{-}sb}$, for the standby period. Then operate the burner until the boiler water temperature returns to the initial conditions, ±5°F (2.5°C), recorded at the start of the 24-hour test. Record the energy input, Q_{r1}, and auxiliary electric input, $C_{aux\text{-}r1}$, for this recovery. Interrupt the 24-hour clock during this recovery. After the recovery test, proceed as follows:

a. For systems with single-stage burners, disconnect the means used to manually operate the burner and conduct six equal draws of U/6 gal (L) initiated one hour apart at the draw rate determined in Section 8.7.1. Record the burner operating time, t_{run}. Collect or meter the water drawn.
b. For systems with modulating or two-stage burners that permit continuous burner operation at reduced input rate, conduct six draws as described below. Record burner operating time, t_{run}. Collect or meter the water drawn. The first three draws initiated one hour apart shall be one-sixth of the daily hot water use, U/6. The second three draws shall be conducted at V_{min} as determined in Section 8.7.3. If the minimum outlet temperature as specified in Section 8.7.1 cannot be achieved at the minimum flow rate, the last three draws shall be lengthened such that the volume removed is equivalent to the following:

$$V_{4,5,6} = U/6 \times (T_t - T_c) / (T_m - T_c)$$

The quantity of water drawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn shall be equal to the following:

$$[U/2 + (3 \times V_{4,5,6})] \pm 1 \text{ gal } (3.8\text{L})$$

After 24 hours has elapsed, record the energy input, Q_d, and auxiliary electrical input, $C_{aux\text{-}d}$, for the draw period. Then manually operate the burner until water temperature returns to the initial conditions, ±5°F (2.5°C), recorded at the start of the 24-hour test. Record the energy input, Q_{r2}, and auxiliary electrical input, $C_{aux\text{-}r2}$, for this recovery. Then, stop the test. Determine total input for the 24-hour test period, Q_{rs}, including the recovery energy after completion of the 24-hour test, Q_{r2}, and the recovery energy after the 18-hour standby, Q_{r1}.

9.1.2.3.4 Measurements During Draw Periods. Record supply water temperature, T_i, and the outlet water temperature, T_o, at 15 seconds after the start of the each draw and at continuing 5-second intervals during all draw periods. Determine the weighted average temperature difference ($T_o - T_i$) for all the water drawn.

9.2 Type II Appliances

9.2.1 Space Heating. Space-heating tests shall be conducted according to the requirements for boilers in *ASHRAE Standard 103-1993, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers,*[1] except as noted below.

9.2.1.1 Carbon Dioxide. During the steady-state test, determine the CO_2 in the flue, CO_{2f}, and in the stack, CO_{2s}, with the draft-control device supplied by the manufacturer in its normal position.

9.2.1.2 Flue and Stack Temperatures. For determining flue temperatures during the cool-down and heat-up tests, consider the units as having an integral draft diverter. This requires blocking the draft-control device after the steady-state test is done and then progressively blocking off the 5 ft (1.52 m) flue pipe until the CO_2 measured during the steady-state test is achieved in the flue pipe. Flue temperatures are then measured in the 5 ft (1.52 m) flue pipe during the cool-down and heat-up tests. Use a five-thermocouple grid to obtain the steady-state stack gas temperature. See Figure 7-8a for an integral (insulated) stack.

9.2.1.3 Thermostat Setting. To avoid shutdown of the burner during the test, the normal thermostat setting shall be bypassed and the burner operated manually.

9.2.1.4 Cool-Down Test. Begin the cool-down test by setting the control of the unit to pilot position or turning the burner to the OFF position if there is no pilot position and closing off the supply water valves.

9.2.1.5 Water Circulation. Water shall be circulated through the appliance using the space-heating supply and return connections specified by the manufacturer. If not specified, the supply connection for the space-heating test shall be the hot water supply connection, and the return connection shall be the water main connection.

9.2.2 Water Heating. Water-heating tests shall be conducted in accordance with *ASHRAE Standard 118.2-1993, Method of Testing for Rating Residential Water Heaters*[2] or *ANSI/ASHRAE Standard 118.1-2003, Methods of Testing for Rating Commercial Gas, Electric, and Oil Service Water Heating Equipment.*[3]

10. DATA TO BE RECORDED

All readings specified in Section 9, except those during draw periods, shall be recorded on an appropriate log sheet. The five-second readings during draw periods may be reduced to average values before recording.

11. CALCULATIONS

11.1 Space-Heating Function

11.1.1 Space-heating parameters shall be calculated in accordance with the procedures as specified in Section 11 of *ASHRAE Standard 103-1993, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces*

and Boilers[1] for the installation options prescribed by the jurisdiction.

For electric appliances, $Effy_{SS} = Effy_{hS} = 100$

11.1.2 For gas-fired, storage-type residential water heaters equipped with power burner, electronic ignition, and vent damper, parameters are calculated as follows:

$$Effy_{hS} = E_r \text{ (Calculated in Section 11.2.2.1)}$$

11.2 Water-Heating Function

11.2.1 Water-heating parameters for Type I appliances shall be calculated as follows.

11.2.1.1 First-Hour Rating for Integrated Heaters. Calculate the first-hour rating, *F*, expressed in gallons (liters), for the case in which the final draw is initiated at or prior to an elapsed time of one hour, as follows:

$$F = \sum_{i=1}^{n} V_i^*$$

where

n = number of draws that are completed during the first-hour rating test

V_i^* = volume of water removed during the *i*th draw of the first-hour rating test, gal (L)

Or, if the mass of water is being measured:

$$V_i^* = W_i^*(7.48055 v_t) ,$$

where

W_i^* = mass of water removed during the *i*th draw of the first-hour rating test, lb (kg)

v_t = specific volume of water at a temperature of T_t, ft^3/lb (L/kg)

7.48055 = a constant to convert ft^3 to gallons

For the case in which a draw is not in progress at the elapsed time of one hour and a final draw is imposed at the elapsed time of one hour, the following equation applies:

$$F = \sum_{i=1}^{n-1} V_i^* + V_n^* \left(\frac{\bar{T}_{del,n}^* T_{min,n-1}^*}{\bar{T}_{del,n-1}^* T_{min,n-1}^*} \right)$$

where n and V_i^* are the same quantities as defined above, and

V_n^* = volume of water drawn during the *n*th (final) draw of the first-hour rating test, gal (L)

$\bar{T}_{del,n-1}^*$ = average water outlet temperature measured during the *(n*-1*)*th draw of the first-hour rating test, °F (°C)

$\bar{T}_{del,n}^*$ = average water outlet temperature measured during the *n*th (final) draw of the first-hour rating test, °F (°C)

$T_{min,n-1}^*$ = minimum water outlet temperature measured during the *(n*-1*)*th draw of the first-hour rating test, °F (°C)

11.2.1.2 Maximum GPM (L/s) Rating for Tankless Heaters. Compute the maximum gpm (L/s) rating as follows:

$$F_{max} = \frac{W_{10m}(\bar{T}_{del} - \bar{T}_{in})}{10(1/7.48055 vt)(135°F - 58°F)}$$

or

$$F_{max} = \frac{W_{10m}(\bar{T}_{del} - \bar{T}_{in})}{10(1/vt)(57.2°C - 14.4°C)}$$

which may be expressed as:

$$F_{max} = \frac{W_{10m}(\bar{T}_{del} - \bar{T}_{in})}{10(1/7.48055 vt)(77°F)}$$

or

$$F_{max} = \frac{W_{10m}(\bar{T}_{del} - \bar{T}_{in})}{10(1/vt)(42.8°C)}$$

where

W_{10m} = mass of water collected during the 10-minute test, lb (kg)

$\bar{T}_{del}$ = average delivery temperature, °F (°C)

$\bar{T}_{in}$ = average inlet temperature, °F (°C)

v_t = specific volume of water at a temperature of T_t, ft^3/lb (L/kg)

7.48055 = a constant to convert ft^3 to gallons

If a water meter is used, the maximum gpm (L/s) rating is computed as

$$F_{max} = \frac{V_{10m}(\bar{T}_{del} - \bar{T}_{in})}{10(77°F)}$$

or

$$F_{max} = \frac{V_{10m}(\bar{T}_{del} - \bar{T}_{in})}{10(42.8°C)} ,$$

where

V_{10m} = total volume of water measured during the 10-minute test, gal (L);

$\bar{T}_{del}$ = as defined in this section; and

$\bar{T}_{in}$ = as defined in this section.

11.2.1.3 Standby Energy Input for Integrated Heaters with Storage. The standby energy shall be corrected for the variation of the test mean tank temperature and room air temperature from the nominal values. The corrected standby energy, Q_1, is defined as follows:

$$Q_1 = (Q_{sb} + Q_{r1})\,(T_t - T_r)\,(24 - t_{run})/[18\,(T_s - T_a)] \quad (11\text{-}1)$$

where

$(T_t - T_r)$ = nominal temperature difference between mean tank and air, °F (°C)

$(T_s - T_a)$ = test temperature difference between mean tank and air, °F (°C)

Q_{sb} = standby period measured energy consumption during the 18-h standby period, Btu (kJ)

Q_{r1} = energy consumption at end of 18-hr standby period, Btu (kJ)

t_{run} = burner operating time recorded during the draw period

11.2.1.4 Draw Period Energy Input. The draw period energy due to the six draws shall be corrected for the variation of the average test inlet and outlet temperatures from the nominal values. The corrected draw period energy, Q_2, is defined as in Equation 11-2.

$$Q_2 = [(Q_d + Q_{r2})(T_t - T_c)/(T_o - T_i)] - [Q_1(6 - t_{run})/(24 - t_{run})] \quad (11\text{-}2)$$

where

$(T_t - T_c)$ = nominal temperature difference between the mean tank and inlet water temperatures, °F (°C)

$(T_o - T_i)$ = test temperature difference between average outlet and average inlet water temperatures during draws, °F (°C)

Q_1 = corrected standby energy consumption, Btu (kJ).

Q_d = $[Q_{rs} - (Q_{sb} + Q_{r1} + Q_{r2})]$, draw period energy consumption, Btu (kJ)

Q_{r2} = energy consumption at end of draw period, Btu (kJ)

11.2.1.5 Energy Factor for Integrated Heaters with Storage. The energy factor, *EF*, is calculated by dividing the nominal energy delivered in the hot water draws during the 6-hour draw period by the corrected energy consumption in the total 24-hour test period and is defined as follows:

$$EF = 1 \times 1/(7.48055 \times v_t) \times U_s \times (T_t - T_c) / [Q_1 + Q_2 + (3413 \times C_{aux})] \quad \text{(I-P)(11-3a)}$$

$$EF = c_p \times v_t \times U_s \times (T_t - T_c) / [1000\,(Q_1 + Q_2 + (C_{aux} \times 1000))] \quad \text{(SI) (11-3b)}$$

where

1 = specific heat of water, Btu/lb °F

c_p = specific heat of water, kJ/(kg °C)

v_t = specific volume of water at a temperature of T_t, ft^3/lb (L/kg)

7.48055 = a constant to convert ft^3 to gallons

Q_1 = corrected standby energy consumption for 24 hr, Btu (kJ)

Q_2 = corrected draw period energy consumption for water drawn, Btu (kJ)

U_s = amount of water drawn during simulated use test, gal (L)

C_{aux} = auxiliary electrical input for entire test, kWh (MJ)

11.2.1.6 Energy Factor for Tankless Heaters. The energy factor, *EF*, is the energy delivered in the hot water draws divided by the energy consumption for the 24 hours and is defined as follows:

$$EF = 1 \times 1/(7.48055 \times v_t) \times U_s \times (T_o - T_i) / [Q_{rs} + (3413 \times C_{aux})] \quad \text{(I-P) (11-4a)}$$

$$EF = c_p \times 1/v_t \times U_s \times (T_o - T_i) / [1000\,(Q_{rs} + (C_{aux} \times 1000))] \quad \text{(SI) (11-4b)}$$

where

$(T_o - T_i)$ = test temperature difference between average outlet and average inlet water, °F (°C)

Q_{rs} = total energy input, Btu (kJ)

C_{aux} = total auxiliary electrical input, kWh (MJ)

11.2.1.7 Recovery Efficiency for Integrated Heaters with Storage. Calculate the recovery efficiency, E_r, defined as follows:

$$E_r = 1 \times 1/(7.48055 \times v_t) \times U_s \times (T_t - T_c) / [Q_2 + 3413(C_{aux\text{-}d}) + 3413(C_{aux\text{-}r2})] \quad \text{(I-P)(11-5a)}$$

$$E_r = c_p \times 1/v_t \times U_s \times (T_t - T_c) / [1000\,(Q_2 + 1000(C_{aux\text{-}d} + C_{aux\text{-}r2}))] \quad \text{(SI)(11-5b)}$$

where

$(T_t - T_c)$ = nominal temperature difference between mean tank and inlet water, °F (°C)

$C_{aux\text{-}d}$ = auxiliary energy during draw period, kWh (MJ)

$C_{aux\text{-}r2}$ = auxiliary energy at recovery following draw period, kWh (MJ)

11.2.1.8 Standby Loss for Integrated Heaters with Storage. For appliances with storage tanks, the corrected standby loss, *S*, in $hour^{-1}$, is defined as:

$$S = Q_1/[(24 - t_{run}) \times 1/(7.48055 \times v_t) \times V \times (T_t - T_r)] \quad \text{(I-P)} \quad (11\text{-}6a)$$

$$S = 1000\,Q_1/[c_p\,(24 - t_{run}) \times 1/v_t \times V\,(T_t - T_r) \quad \text{(SI)} \quad (11\text{-}6b)$$

where

$(T_t - T_r)$ = nominal difference between the mean stored water temperature and the ambient air temperature during the standby portion of the simulated-use test, °F (°C)

V = measured storage volume, gal (L)

11.2.2 Water-Heating Parameters for Type II Appliances. Water-heating parameters for Type II appliances shall be calculated as follows.

11.2.2.1 For Type II appliances tested in accordance with ASHRAE Standard 118.2-1993,[2] the first-hour rating, energy factor, and recovery efficiency shall be determined in accordance with the calculations of that procedure.

11.2.2.2 The thermal efficiency and standby loss for Type II appliances tested in accordance with ANSI/ASHRAE Standard 118.1- 2003[3] shall be determined in accordance with the calculations of that procedure. The energy factor shall be calculated using the following:

$$EF = \frac{H}{\left(\frac{H}{E_t}\right) + \left(\begin{array}{c} S \times V \times c_p (1/(7.48055 \times v_t))(T_t - T_r) \times \\ \left(24 - \frac{H}{E_t \times Q_{in}}\right) \end{array}\right)} \quad (11\text{-}7a)$$

$$EF = \frac{H}{\frac{H}{E_t} + \left(S \times V \times c_p \times \frac{1}{v_t}(T_r - T_t)\right) \times \left(24 - \left(\frac{H}{E_t \times Q_{in}}\right)\right)} \quad (11\text{-}7b)$$

where

H = heat content of water = $c_p\,(1/(7.48055 \cdot v_t))(U)(T_o - T_i)$ (I-P units)

H = heat content of water = $c_p\,(1/v_t)\,(U)(T_o - T_i)$ (SI units)

E_t = thermal efficiency measured in ANSI/ASHRAE 118.1-2003

S = standby loss measured in ANSI/ASHRAE 118.1 2003 (Note: for ≥140 gallon (530L) storage tank water heaters with tank surface thermally insulated to R-12.5 ft^2 h· °f /Btu [2.2 m^2·K/W], with electronic ignition and with power combustion or flue damper, the value of S in the equation of 11.2.2.2 may either be measured in accordance with ANSI/ASHRAE Standard 118.1-2003 or taken to be equal to 0.018.)

11.3 Space-Heating and Water-Heating Factors

11.3.1 Heating Season Space-Heating Factor (SHF) The SHF shall be obtained from Equation 11-8.

$$SHF = 0.225 \times Effy_{ss} / Effy_{hs} \quad (11\text{-}8)$$

where

0.225 = a constant based on the temperature base for degree-days (65°F), the national average outdoor temperature during the heating season (42°F), the national average outdoor heating design temperature (5°F), and the oversize fraction (0.7) (see Annex B)

$Effy_{ss}$ = steady-state, space-heating efficiency, %

$Effy_{hs}$ = space-heating seasonal efficiency, %

11.3.2 Heating Season Water-Heating Factor (WHF) The WHF shall be obtained from Equation 11-9.

$$WHF = U \times (T_t - T_c) \times 1/(7.48055 \times v_t) \times 1.0 / [q_{in} \times (Effy_{ss}/100) \times 24] \quad \text{(I-P)(11-9a)}$$

$$WHF = U \times (T_t - T_c) \times 1/v_t \times c_p / [3600 \times q_{in} \times (Effy_{ss}/100) \times 24] \quad \text{(SI)(11-9b)}$$

where

$T_t - T_c$ = temperature rise of water, °F (°C)

24 = hours per day

Q_{in} = input rate, Btu/h; for modulating units, this is maximum input

11.3.3 Non-Heating-Season Water-Heating Factor (NHF) The NHF shall be obtained from Equation 11-10.

$$NHF = U \times (T_t - T_c) \times 1/(7.48055 \times v_t) \times 1.0/ (q_{in} \times EF \times 24) \quad \text{(I-P)(11-10a)}$$

$$NHF = U \times (T_t - T_c) \times 1/v_t \times C_p/(3600 \times q_{in} \times EF \times 24) \quad \text{(SI)(11-10b)}$$

where

EF = water-heating energy factor as determined in Section 11.2

11.4 Calculation of Combined Annual Efficiency, CAE.

CAE shall be determined from Equation 11-11.

$$CAE = [(SHF \times Effy_{hs}/100) + (WHF \times Effy_{ss}/100) + (R \times NHF \times EF)] / [(SHF) + (WHF) + (R \times NHF)] \quad (11\text{-}11)$$

where

SHF = as defined in Section 11.3.1

WHF = as defined in Section 11.3.2

NHF = as defined in Section 11.3.3

EF = as defined in Section 11.2

R = ratio of non-heating-season days to heating-season days (see Annex D for major US cities)

$$R = D_n / D_h \quad (11\text{-}12)$$

11.5 Season Efficiencies

11.5.1 Combined Heating-Season Efficiency. The combined heating-season efficiency for both space heating and water heating is obtained from Equation 11-13.

$$CE_{HS} = [(SHF \times Effy_{hs}/100) + (WHF \times Effy_{ss}/100)] / (SHF + WHF) \quad (11\text{-}13)$$

11.5.2 Non-Heating-Season Efficiency. The non-heating-season efficiency is obtained from Equation 11.14.

$$CE_{NS} = R \times NHF \times EF/(R \times NHF) = EF \quad (11\text{-}14)$$

12. REFERENCES

1. *ASHRAE Standard 103-1993, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.
2. *ASHRAE Standard 118.2-1993, Method of Testing for Rating Residential Water Heaters.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.
3. *ANSI/ASHRAE Standard 118.1-2003, Method of Testing for Rating Commercial Gas, Electric, and Oil Service Water Heating Equipment*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.
4. *ANSI/ASHRAE Standard 41.1-1986 (RA 2006), Standard Method for Temperature Measurement*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.
5. *ANSI/ASTM-D-2156-94 (2003), Standard Test Method for Smoke Density in the Flue Gases from Burning Distillate Fuels*. American Society for Testing and Materials, Philadelphia.
6. *2005 ASHRAE Handbook—Fundamentals*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

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INFORMATIVE ANNEX A
DETERMINATION OF COMBINED ANNUAL EFFICIENCY (CAE) FOR INSTALLATIONS WITH SINGLE-FUNCTION APPLIANCES

The combined annual efficiency (CAE) of an installation consisting of a single-function appliance providing the space heating plus a single-function appliance providing water heating can be determined from the following expression:

$$CAE = \text{Annual Output/Annual Input} = (ASHL + AWHL) / (ASHL / AFUE + AWHL / EF) \quad \text{(A-1)}$$

where

$ASHL$ = annual space-heating load in Btu

$AWHL$ = annual water-heating load in Btu

$AFUE$ = annual fuel utilization efficiency of the space-heating appliance as determined from *ASHRAE Standard 103-1993, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*[A1]

EF = energy factor of the water-heating appliance as determined from DOE procedures outlined in Federal Reulations,10 CFR 430[A2]

The annual space-heating load (ASHL), consistent with the DOE calculation for furnaces and boilers, is the following:

$$ASHL = 24 \times D_h \times 0.225 \times Q_{out}$$

$$ASHL = 24 \times 214 \times 0.225 \times Q_{out}$$

$$ASHL = 1155.6 \times Q_{out} \quad \text{(A-2a)}$$

where

24 = hours per day

D_h = 214 = days in national average heating season

Q_{out} = heating capacity of the space-heating appliance, Btu/h

0.225 = part-load factor = [(65 - 42)/(65 - 5)][1/(1 + 0.7)]

The annual space-heating load can also be expressed as follows:

$$ASHL = DLH \times DHR \quad \text{(A-2b)}$$

where

DLH = design load hours = 1969 national average

DHR = design heating requirement for space heating, Btu/h

$DHR = Q_{out} / (1 + a)$

a = oversize fraction = 0.7 DOE national average

The annual water-heating load consistent with the DOE energy factor of the water-heating appliance is shown in the following equation:

$$AWHL = (U)\ (\text{days})\ (\text{average temperature rise})\ (1/\text{specific volume}) = (64.3)\ (365)\ (77)\ (1/(7.48055 \times 0.01626)) = 14{,}855{,}000 \quad \text{(A-3)}$$

REFERENCES

A1. *ASHRAE Standard 103-1993, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

A2. US Government Printing Office. Federal Regulations, 10 CFR 430, Subpart B, Appendix E. Washington, DC.

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INFORMATIVE ANNEX B
US NATIONAL AND REGIONAL AVERAGE CONDITIONS

1. US National Average SHF:

$$SHF = 0.225 \times Effy_{ss} / Effy_{hs}$$

2. National Average R:

R = 151/214 (From Annex C for Pittsburgh, PA)

$$R = 0.71$$

3. Example:
Assume an appliance with the following:

$$Q_{in} = 64{,}000 \text{ Btu/h}$$

Heating capacity = 51,000 Btu/h

$$Effy_{ss} = 80\%$$

$$Effy_{hs} = 73\%$$

$$EF = 0.55$$

$$SHF = 0.225 \times (0.80/0.73) = 0.247$$

$$WHF = 64.3 \times 77 \times (1/(7.48055 \times 0.01626)) \times 1.0/(64{,}000 \times 0.80 \times 24) = 0.0331$$

$$NHF = 64.3 \times 77 \times (1/(7.48055 \times 0.01626)) \times 1.0/(64{,}000 \times 0.55 \times 24) = 0.0482$$

$$CAE = (0.247 \times 0.73) + (0.0331 \times 0.80) + 0.71(0.0482 \times 0.55) / 0.247 + 0.0331 + 0.71(0.0482)$$

CAE = 0.718 or 71.8% for national average conditions.

US REGIONAL VALUES

DOE Heating Region	D_H (days/year)	D_N (days/year)	R
I	76	289	3.80
II	131	234	1.79
III	186	179	0.96
IV	235	130	0.55
V	290	75	0.26
VI	261	104	0.40

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INFORMATIVE ANNEX C
LENGTH OF HEATING SEASON

The information in this table was compiled from *Climatography of the United States No.84,* published by the National Climatic Data Center, Asheville, NC. The length of the heating season for each city was determined by noting the first date in the fall when the daily normal temperature (a thirty-year average of lowest temperatures recorded for the date and the highest temperatures recorded for the date) drops below 57°F and the first date in the spring when the daily normal temperature is 57°F or greater.

State/City	Heating Season Days, D_H	Nonheating Season Days, D_N
ALABAMA		
Birmingham	147	218
Huntsville	155	210
Mobile	99	266
Montgomery	127	238
ALASKA		
Anchorage	346	19
Fairbanks	322	43
Juneau	365	
Kodiak	365	
Nome	365	
ARIZONA		
Flagstaff	261	104
Phoenix	81	284
Prescott	217	148
Tucson	108	257
Winslow	194	171
Yuma	73	292
ARKANSAS		
Fort Smith	155	210
Little Rock	148	217
CALIFORNIA		
Bakersfield	119	246
Bishop	192	173
Eureka	309	56
Fresno	145	220
Long Beach	92	273
Los Angeles	71	294
Oakland	164	201
Sacramento	153	212
San Diego	44	321
San Francisco	180	185
COLORADO		
Colorado Springs	232	133
Denver	223	142
Grand Junction	200	165
Pueblo	205	160
CONNECTICUT		
Bridgeport	209	156
Hartford	216	149
DELAWARE		
Wilmington	196	169
FLORIDA		
Daytona Beach		365
Fort Meyers		365
Jacksonville	110	255
Key West		365
Lakeland		365
Miami		365
Orlando		365
Pensacola	92	273
Tallahassee	98	267
Tampa		365
West Palm Beach		365
GEORGIA		
Athens	149	216
Atlanta	150	215
Augusta	138	227
Columbus	129	236
Macon	127	238
Savannah	111	254
HAWAII		
Honolulu		365
IDAHO		
Boise	222	143
Idaho Falls	266	99
Lewiston	218	147
Pocatello	246	119

State/City	Heating Season Days, D_H	Nonheating Season Days, D_N
ILLINOIS		
Cairo	162	203
Chicago O'Hare	213	152
Moline	206	159
Peoria	202	163
Quincy	193	172
Rockford	217	148
Springfield	191	174
INDIANA		
Evansville	180	185
Fort Wayne	213	152
Indianapolis	197	168
South Bend	215	150
IOWA		
Des Moines	201	164
Dubuque	223	142
Mason City	226	139
Sioux City	208	157
Waterloo	222	143
KANSAS		
Concordia	180	185
Dodge City	184	181
Goodland	216	149
Russell	189	176
Topeka	185	180
Wichita	177	188
KENTUCKY		
Bowling Green	176	189
Jackson	196	169
Lexington	186	179
Louisville	179	186
LOUISIANA		
Alexandria	111	254
Baton Rouge	97	268
Lake Charles	91	274
New Orleans	95	270
Shreveport	123	242
MAINE		
Bangor	249	116
Caribou	268	97
Portland	249	116
MARYLAND		
Baltimore	172	193
Salisbury	188	177
MASSACHUSETTS		
Boston	213	152
Chatham	237	128
Nantucket	236	129
Worcester	235	130
MICHIGAN		
Alpena	259	106
Detroit	221	144
Grand Rapids	226	139
Lansing	227	138
Marquette	260	105
Muskegon	231	134
Saginaw	229	136
Sault Ste. Marie	272	93
Traverse City	244	121
MINNESOTA		
Alexandria	244	121
Duluth	271	94
International Falls	270	95
Minneapolis/St. Paul	227	138
Rochester	235	130
MISSISSIPPI		
Greenwood	138	227
Jackson	129	236
Meridian	133	232
MISSOURI		
Columbia	185	180
Kansas City	184	181
Saint Joseph	135	180
Saint Louis	179	186
Springfield	178	187
MONTANA		
Billings	242	123
Butte	294	71
Great Falls	254	111
Havre	251	114
Helena	268	97
Kalispell	274	91

State/City	Heating Season Days, D_H	Nonheating Season Days, D_N
Lewistown	277	88
Miles City	234	131
Missoula	265	100
NEBRASKA		
Grand Island	208	157
Lincoln	193	172
Norfolk	213	152
North Platte	225	140
Omaha	196	169
Scottsbluff	227	138
Valentine	228	137
NEVADA		
Las Vegas	136	229
Reno	238	127
Tonopah	222	143
Winnemucca	241	124
NEW HAMPSHIRE		
Concord	240	125
Mt. Washington	365	
NEW JERSEY		
Atlantic City	204	161
Newark	194	171
Trenton	196	169
NEW MEXICO		
Albuquerque	185	180
Clayton	206	159
Clovis	178	187
Roswell	152	213
Truth or Consequences	163	202
Tucumcari	173	192
NEW YORK		
Albany	227	138
Binghamton	238	127
Buffalo	229	136
Massena	241	124
New York	191	174
Rochester	226	139
Syracuse	227	138
NORTH CAROLINA		
Asheville	186	179
Cape Hatteras	143	222
Charlotte	159	206
Greensboro	172	193
New Bern	142	223
Raleigh-Durham	164	201
Wilmington	134	231
NORTH DAKOTA		
Bismarck	248	117
Fargo	244	121
Grand Forks	251	114
Minot	254	111
Williston	251	114
OHIO		
Akron-Canton	217	148
Cincinnati	187	178
Cleveland	217	148
Columbus	205	160
Dayton	201	164
Mansfield	216	149
Toledo	223	142
Youngstown	225	140
OKLAHOMA		
Oklahoma City	158	207
Tulsa	157	208
OREGON		
Astoria	259	106
Bums	252	113
Eugene	232	133
Medford	215	150
North Bend	267	98
Pendleton	216	149
Portland	220	145
Redmond	262	103
Salem	234	131
PENNSYLVANIA		
Allentown	212	153
Bradford	254	111
Erie	232	133
Harrisburg	200	165
Philadelphia	193	172
Pittsburgh	214	151
Wilkes Barre/Scranton	220	145
Williamsport	215	150

State/City	Heating Season Days, D_H	Nonheating Season Days, D_N
RHODE ISLAND		
Block Island	227	138
Providence	221	144
SOUTH CAROLINA		
Charleston	110	255
Columbia	137	228
Florence	134	231
Greenville/Spartanburg	158	207
SOUTH DAKOTA		
Aberdeen	236	129
Huron	230	135
Pierre	225	140
Rapid City	234	131
Sioux Falls	227	138
TENNESSEE		
Bristol	182	183
Chattanooga	163	202
Knoxville	165	200
Memphis	150	215
Nashville	164	201
Oak Ridge	172	193
TEXAS		
Amarillo	175	190
Austin	100	265
Brownsville		365
Corpus Christi		365
Dallas/Fort Worth	126	239
Del Rio	87	278
El Paso	141	224
Galveston	95	270
Houston	88	277
Lubbock	160	205
Lufkin	109	256
Midland	139	226
Port Arthur	110	255
San Angelo	125	240
San Antonio	91	274
Wichita Falls	143	222

State/City	Heating Season Days, D_H	Nonheating Season Days, D_N
UTAH		
Blanding	225	140
Cedar City	225	140
Salt Lake City	215	150
Wendover	209	156
VERMONT		
Burlington	241	124
VIRGINIA		
Norfolk	162	203
Richmond	172	193
Roanoke	182	183
Washington DC/Dulles	196	169
Washington National	174	191
WASHINGTON		
Seattle/Tacoma	236	129
Spokane	246	119
Walla Walla	205	160
Yakima	228	137
WEST VIRGINIA		
Bluefield	203	162
Charleston	188	177
Elkins	222	143
Huntington	185	180
Parkersburg	192	173
WISCONSIN		
Eau Claire	238	127
Green Bay	242	123
La Crosse	220	145
Madison	232	133
Milwaukee	233	132
Wausau	244	121
WYOMING		
Casper	251	114
Cheyenne	254	111
Lander	252	113
Rock Springs	264	101
Sheridan	254	111

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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