

STANDARD

ANSI/ASHRAE/AHRI Standard 155-2024

Method of Testing for Rating Commercial Space Heating Boiler Systems

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NOTE

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FOREWORD

This standard provides a method of test for rating commercial space heating boiler systems. The ultimate objective is to provide a means to determine the seasonal efficiency of individual, modular, and multiple boiler systems having various means of staging boilers to meet the building load, various boiler outlet (supply) or boiler inlet (return) water control strategies, and various pumping strategies, when applied, to meet the load of a particular building or prototype building in a particular climate. This standard provides test procedures and calculation procedures that allow a full performance map to be created for an individual boiler from the test results.

Development of this standard was initiated in 1993–94 by ASHRAE Technical Committee 6.1, Hydronic and Steam Equipment and Systems. At that time, ASHRAE Standing Standard Project Committee 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, was independently pushing for a more meaningful standard for rating of commercial boilers. Among the needs identified by these committees were procedures that would result in ratings based on thermal efficiency rather than combustion efficiency for all boilers; test boilers at entering and leaving temperatures typical of space heating applications; allow performance to be determined at part-load, idling, and full-load conditions; and include energy used by integral electrical equipment. To date, no other standard available has addressed these needs.

In developing this standard, the project committee gave substantial consideration to the testing burden, because many commercial boiler models are sold in small quantities. The resulting standard requires only steady-state tests and idling tests; no part-load tests under cyclic operation (i.e., while cycling on and off below the lowest steady state meet a load below the lowest steady-state output) are required. At the same time, the project committee sought to avoid the single-load profile and oversizing ratio implicit in the Standard 103 test for residential boilers. To provide a flexible procedure that would allow users to determine energy use for any boiler system configuration, load profile, and oversizing ratio while minimizing the testing burden required the use of numerous computational procedures. Many of the procedures developed to enable generation of a full-performance map from a small number of test results are elucidated in Informative Appendix C. A particular concern was the determination of cyclic performance. Cyclic tests are expensive and require accurate measurement of output under continuously varying conditions, yet are critical to seasonal efficiency. To address this, the project committee designed and oversaw the completion of tests that validated a linear input-output model for this operating regime (also described in Informative Appendix C).

Where the standard allows a datum to be determined through tests or through computations, the guiding principle used was that the calculated datum should be conservative, that is, should result in no lower estimate of energy use than that resulting from an accurate test.

The control volume for this standard is the boiler system. The building distribution loop is external to this control volume, so for complete accounting of energy use, heat losses from the building loop must be included in the building load.

A related ASHRAE Research Project, RP-1196, developed software that automates the application of the results of this test method to specific buildings.

1. PURPOSE

This standard provides procedures for determining the steady-state thermal efficiency, part-load efficiency, and idling energy input rate of space heating boilers.

2. SCOPE

2.1 This standard applies to steam and hot-water boiler systems (individual, modular, or multiple boilers) for use in space heating applications and having individual boilers or modules with gas, oil, electric, or multiple fuel inputs of at least 300,000 Btu/h (87.92 kW) but no more than 12,500,000 Btu/h (3664 kW).

Exception to 2.1: Custom-designed, field-assembled boilers are not covered by this standard.

2.2 This standard provides methods to compare energy consumption measures of various boiler systems. It is not intended to provide an absolute measure of performance in any specific installation configuration.

2.3 This standard includes

- a. test methods for determining full-load and part-load steady-state thermal efficiency, idling energy input rate, and throughflow loss rate of individual boilers;
- b. methods for interpolating and extrapolating test data; and
- c. rating conditions to be used in executing tests and calculations for a range of classes of space heating applications.

2.4 This standard applies to the space heating performance of boiler systems used for multiple functions, including space heating.

2.5 This standard does not cover methods of testing boiler systems used only in service water heating applications.

3. DEFINITIONS AND NOMENCLATURE

3.1 Definitions

barometric draft regulator: a balanced damper device attached to the vent connector to control draft (negative pressure).

boiler

atmospheric: a low-pressure packaged boiler that incorporates a gas atmospheric burner that operates with a nonpositive vent static pressure.

condensing: a low-pressure packaged boiler that will, during at least one of the thermal efficiency tests in this standard, condense part of the water vapor in the flue gases and is equipped with a means of collecting and draining this condensate from the heat exchange section.

counterflow: a low-pressure packaged boiler in which all of the heat transfer surface contacted by the water as it enters the heat exchanger is within the last 25% of the flue gas flow path.

cross-flow: a low-pressure packaged boiler that is neither a parallel-flow boiler nor a counterflow boiler.

custom-designed, field-assembled: a boiler that is designed for a specific installation and is constructed at the installation site.

low-pressure: a boiler designed to supply low-pressure steam or hot water. A low-pressure steam boiler operates with a steam pressure at or below 15 psig (103.4 kPa); a low-pressure hot-water boiler operates with a water pressure at or below 160 psig (1103. kPa) and temperatures at or below 250°F (121°C), respectively.

modular: a steam or hot-water heating assembly consisting of a grouping of individual low-pressure packaged boilers, commonly referred to as modules, intended to be installed as a unit. Modules may be under one jacket or may be individually jacketed.

modulating: a low-pressure packaged boiler equipped with one of the modulating control arrangements defined herein such that the minimum input rate is equal to or less than 75% of the maximum input rating.

multiple: an assembly consisting of a grouping of individual low-pressure packaged boilers.

noncondensing: a low-pressure packaged boiler that is not a condensing boiler.

outdoor: a low-pressure packaged boiler with integral venting means that is factory assembled, weather-proofed, and wired for use outdoors.

packaged: a boiler that is shipped in one or more assemblies complete with burner and controls authorized by the boiler manufacturer. If the boiler is shipped in more than one assembly, the assemblies may originate from suppliers other than the manufacturer.

parallel-flow: a low-pressure packaged boiler in which all of the heat transfer surface contacted by the water as it enters the heat exchanger is within the first 25% of the flue gas flow path.

steam and hot water: a low-pressure packaged boiler that can be sold as a steam or hot-water boiler simply by changing the controls.

boiler loop: pipes and devices connected to the boiler and through which water flows during conduction of the idling tests, not including attached piping and devices through which water does not flow during the test, such as dead legs and expansion tanks.

burner: a device for the introduction of fuel and air into a firebox at the desired velocities, turbulence, and concentration to establish and maintain proper ignition and combustion of the fuel.

atmospheric: a burner for the final conveyance of a mixture of gas and air at atmospheric pressure to the combustion zone. Air at atmospheric pressure is injected into the burner by a jet of gas.

nonatmospheric: a burner that supplies air for combustion at a pressure exceeding atmospheric pressure (forced draft), a burner that depends on the draft induced by a fan incorporated in the boiler (induced draft), a fan-powered burner that depends on the natural draft developed by a chimney for proper operation, or a pulse combustion burner.

burner modulation signal: the burner control input signal used by the boiler control system to automatically modulate input rate in response to changes in heat load. The burner modulation signal may be a software variable.

combustion chamber: that portion of the firebox, which may be lined with heat-resisting material, in which the initial combustion of fuel takes place.

combustion efficiency: 100% less the losses due to dry flue gas, incomplete combustion, and moisture formed by combustion of hydrogen.

condensate, flue: liquid formed by the condensation of moisture in the flue gases.

control

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

single-stage, manually adjustable: a control that is adjusted by the installer to a single selected input rate and then operates as a single-stage burner.

modulating: a device that controls burner operation at the maximum input rating and at one or more reduced inputs, either continuously or in a series of one or more steps.

draft hood: a nonadjustable device, either built into or external to the boiler, that is designed to provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft hood; prevent a back draft from entering the firebox; and neutralize the effect of thermally induced draft of the chimney or gas vent upon the operation of the boiler.

draft regulator: see *barometric draft regulator*.

electrical equipment: electricity-using components that are required for the normal operation of an individual boiler, such as burners, blowers, controls, recirculating pumps, and heavy oil heaters.

excess air: air that passes through the combustion chamber and the boiler flues in excess of that which is theoretically required for complete combustion.

firebox: the space provided within the boiler for combustion of the fuel.

flue collar: that portion of a boiler designed for attachment of a draft hood, vent connector, or continuous open passageway to the outdoors for the purpose of removing flue or vent gases.

flue gas: products of combustion plus excess air in the boiler flue or heat exchanger.

flue losses: the sum of sensible and latent heat losses above room temperature of the flue gases leaving the boiler.

flue temperature: the temperature of the flue gases before dilution.

heating value

gas: amount of heat produced by the complete combustion of a unit quantity of fuel. This standard only uses the higher heating value (HHV), which is obtained when all the products of combustion are cooled to the temperature existing before combustion, water vapor formed during combustion is condensed, and all necessary corrections to standard conditions have been made in accordance with Normative Appendix A. The gas heating value is expressed in Btu/ft³ (MJ/m³) at standard conditions or water vapor saturation at a temperature of 60°F (15.6°C) and a pressure of 30 in. of mercury absolute (101.6 kPa).

oil: the higher heating value (HHV) determined per ASTM D240¹ or ASTM D4809.²

input rating

maximum: the maximum energy Btu/h (kW) or fuel flow gph (L/hour) input located on the boiler rating plate.

minimum: the minimum continuous energy Btu/h (kW) or fuel flow gph (L/hour) input specified by the manufacturer on the boiler rating plate or in the manufacturer's instructions shipped with the boiler.

inlet air temperature: the temperature of the air for combustion being supplied to the burner inlet.

inlet water temperature: the temperature of the water entering the boiler.

IR camera: infrared thermographic camera and its associated software that detects infrared energy (heat) from a surface, converts it into a thermal image, and performs temperature calculations.

jacket: outer enclosure of the boiler. This includes all components shipped with and physically connected to the boiler, including supply and return piping to the point of connection with field piping.

jacket loss: rate of energy loss, in terms of Btu/h [kW], from the boiler through the jacket to the surrounding space. In the case of a vented jacket, where the jacket vent openings cannot be sealed, also includes energy loss due to jacket airflow.

louver field: a set of adjacent, identical, ventilation openings in a jacket panel meeting both of the following requirements:

- The area of each opening is not greater than 4.5 in.² (29 cm²).
- The sum of the area of all openings in the field is at least 25% of the total area of the field (see Figure 13).

oil: “light oil” refers to No. 2 oil. “Heavy oil” refers to No. 4, No. 5, and No. 6 oils. All fuel oil shall comply with ASTM D396, *Standard Specification for Fuel Oils*³, but all fuels shall not contain greater than 5% bio-diesel or other oxygenated fuels.

outlet water temperature: the temperature of the water exiting the boiler.

rating

high temperature: a rating at a boiler outlet (supply) water temperature of 180°F (82.2°C) in accordance with Table 5.

intermediate temperature: a rating for use in applications with a boiler outlet (supply) water temperature greater than 120°F (48.9°C) and less than 180°F (82.2°C) at design conditions.

low temperature: a rating at a boiler outlet (supply) water temperature of 120°F (48.9°C) in accordance with Table 5.

recirculation loop: a bypass pipe system used to divert water leaving the boiler outlet back into the boiler inlet in order to maintain the required boiler water flow rate and/or the boiler inlet water temperature.

resistance heating element: the electrical conducting medium that is intended to be heated by an electric current and that also dissipates this heat into the air or a fluid.

room air temperature: ambient temperature measured within 6 ft (1.83 m) in front of the unit at midheight of the unit.

shall: is/are required to; must.

stabilization cycle: a boiler operating cycle from one closure of controller call-for-heat contact to the next, under a no-load condition, which occurs prior to the start of an idling test.

temperature rise, boiler: the difference between the boiler inlet (return) and the boiler outlet (supply) water temperature.

test efficiency: the heat absorbed by the water or the water and steam divided by the heat value in the fuel burned.

thermal efficiency: the heat absorbed by the water or the water and steam divided by the sum of the heat value in the fuel burned and the heat equivalent of the electrical input to electrical equipment such as burners, blowers, controls, recirculating pumps, and heavy oil heaters.

vent: a passageway used to convey flue gases from boilers or their vent connectors to the outdoors.

vent connector: the pipe or duct that connects a fuel-burning boiler to a vent or chimney.

3.2 Nomenclature

A	air required for complete combustion of gas, ft ³ /1000 Btu (m ³ /MJ) at standard conditions
c_p	specific heat of air, water, or steam (vapor), Btu/lb·°F (kJ/kg·°C)
$c_{p,air}$	specific heat of air, Btu/lb·°F (kJ/kg·°C); for calculations in the standard, $c_{p,air} = 0.24$ Btu/lb·°F (1.005 kJ/kg·°C)
$c_{p,fluegas,nom}$	effective (nominal) flue gas specific heat, Btu/lb·°F (kJ/kg·°C)
$c_{p,water}$	specific heat of water Btu/lb·°F (kJ/kg·°C); for calculations in this standard, $c_{p,water} = 1.0$ Btu/lb·°F (4.1868 kJ/kg·°C)
C	carbon content of fuel oil, percent by weight ($0 \leq C \leq 100$)
CO	percent by volume of carbon monoxide in dry flue gas ($0 \leq CO \leq 100$)
CO_2	percent by volume of carbon dioxide in dry flue gas ($0 \leq CO_2 \leq 100$)
$C_{r,rated}$	ratio of water and flue gas heat capacity rates in hot-water mode at tested conditions, dimensionless
$C_{r,newflow}$	ratio of water and flue gas heat capacity rates in hot-water mode under a new flow condition in extrapolation, dimensionless
C_s	correction factor from Normative Appendix A to be applied to the higher heating

	value (HHV) if the gaseous fuel, as metered, is not at standard temperature and pressure, dimensionless
$C_{thermal}$	heat capacity of boiler, Btu/°F (kJ/°C)
E_{burner}	electrical energy consumed by fuel-fired burner during the applicable test, kWh
$E_{controls}$	electrical energy consumed by controls during the applicable test, kWh
E_{fan}	electrical energy consumed by mechanical draft fan during the applicable test, kWh
E_{htr}	electrical energy consumed by heavy oil heater during the applicable test, kWh
E_{in}	electrical energy consumed by resistance heating elements during the applicable test, kWh
E_{pump}	electrical energy consumed during the applicable test by the pump(s) used to maintain the required flow rate through the boiler, kWh
E_{WH}	electrical energy consumed by water heater during throughflow loss test, kWh
f_{xs}	fraction of excess air in flue gas, dimensionless
$G_{l,ss}$	latent heat gain due to condensation in flue, percent
h_{fg}	latent heat of vaporization of steam at test saturated steam pressure, Btu/lb (kJ/kg)
H	hydrogen content of fuel oil, percent by weight ($0 \leq H \leq 100$)
hA	overall rate of heat transfer from boiler to environment, Btu/h·°F (kW/°C)
HHV	higher heating value of the fuel. For oil: Btu/lb (kJ/kg); for gas: Btu/ft ³ (MJ/m ³)
IWT	temperature of the water entering the boiler
$L_{cond,ss}$	steady-state heat loss due to flue condensate going down drain, percent
L_f	flue loss, percent of heat input at relevant input rate ($0 \leq L_f \leq 100$)
L_l	steady-state latent heat loss in flue gas, percent ($0 \leq L_l \leq 100$)
L_s	steady-state sensible heat loss in dry flue gases, percent ($0 \leq L_s \leq 100$)
L_u	radiation and unaccounted-for loss, percent of total thermal input ($0 \leq L_u \leq 100$)
m_B	dry mass of boiler without the fuel train, lb (kg)
$\dot{m}_{blr,min}$	manufacturer's minimum water flow rate, as specified in the manufacturer's instructions supplied with the boiler, converted to mass flow rate, lb/h, (kg/h). If not provided, the minimum mass flow rate shall be $\dot{m}_{rating}$.
m_c	mass of flue condensate per cycle, lb (kg)
$m_{cond,ss}$	mass of flue condensate collected during condensate collection test, lb (kg)
$\dot{m}_{cond,ss}$	mass flow rate of flue condensate collected during condensate collection test period, lb/h (kg/h)
$\dot{m}_{fluegas}$	flue gas mass flow rate, lb/h (kg/h)
m_{oil}	mass of oil burned, lb (kg)
$\dot{m}_{rating}$	mass flow rate at the conditions established by Section 7.7.1, lb/h (kg/h), as calculated using the following formula:
	$\dot{m}_{rating} = \frac{\dot{q}_{out,ss,rated}}{c_{p,water}(T_{out,rating} - T_{in,rating})}$
M_r	ratio of flue gas mass flow to burner input, lb/1000 Btu (kg/MJ)
NTU	heat exchanger number of transfer units, dimensionless
NTU _{steam}	heat exchanger number of transfer units in steam mode, dimensionless
NTU _{water,nom}	nominal heat exchanger number of transfer units in water mode, dimensionless
O ₂	percent by volume of oxygen in dry flue gas ($0 \leq O_2 \leq 100$)
P	dry constituents in flue gases from stoichiometric combustion, ft ³ /1000 Btu (m ³ /MJ) of gas burned at standard conditions
P_{baro}	barometric pressure, in. of mercury (kPa)
$P_{sat,abs}$	test saturated steam pressure, in. of mercury absolute (kPa absolute)
P_{std}	standard pressure to measure natural gas and propane heat value, = 14.696 psi or 30 in. of mercury
P_{steam}	test steam pressure, in. of mercury gage (kPa gage)
P_{ws}	saturation pressure of liquid water, psia (kPa absolute)
$\dot{q}_{in,aux}$	auxiliary electrical power input to electrical equipment including burners, controls, mechanical draft fans, and pumps, kW
$\dot{q}_{in,aux,ss}$	auxiliary electrical power input to electrical equipment including burners, controls, mechanical draft fans, and pumps during steady-state operation, kW

$\dot{q}_{in,cond,ss}$	fuel energy input during steady-state condensate collection test, Btu (kJ)
$\dot{q}_{in,cyc} \langle T_{out} \rangle$	calculated energy input of boiler when cycling between the minimum input rating and idle
$\dot{q}_{in,idle,corr}$	energy input rate in idling mode, corrected to the water temperature specified in Section 7.9 and 75°F (23.9°C) room air temperature, Btu/h (kW)
$\dot{q}_{in,idle,rated}$	rated idling energy input rate including auxiliary power, Btu/h (kW); auxiliary power includes electric power supplied to the boiler, burner, boiler controls, blower, and pump
$\dot{q}_{in,idle,rated,avg}$	rated average idling energy input rate for all the idling cycles during one idling test, Btu/h (kW)
$\dot{q}_{in,idle,test}$	test fuel energy input rate in idling mode, Btu/h (kW)
$\dot{q}_{in,idle,180} (\dot{q}_{in,idle,82.2})$	rated idling energy input rate at 180°F (82.2°C), including auxiliary power based on high-temperature hot-water idling test or steam idling test and calculation of energy input in hot-water mode from steam test
$\dot{q}_{in,idle,120} (\dot{q}_{in,idle,48.9})$	rated idling energy input rate at 120°F (48.9°C), including auxiliary power, based on low-temperature hot-water idling test
$\dot{q}_{in,ss}$	primary (fuel or electric) energy input rate at steady-state operation (including any pilot burner input), Btu/h (kW)
$\dot{q}_{jacket,ss}$	nominal jacket loss rate, Btu/h (kW)
$\dot{q}_{jacket,avg}$	average jacket loss while idling Btu/h (kW)
$\dot{q}_{latent}$	latent heat output rate, Btu/h (kW)
$\dot{q}_{out,ss}$	steady-state output rate, Btu/h (kW)
$\dot{q}_{out,ss} \langle T_{out} \rangle$	steady-state output at outlet water temperature of T_{out} , Btu/h (kW)
$\dot{q}_{out,ss} \langle T_{low,rating} \rangle$	steady-state output at the low-temperature rating established by Section 7.7.1, Btu/h (kW)
$\dot{q}_{out,ss} \langle T_{out,test} \rangle$	steady-state output at an intermediate temperature rating established by Section 7.7.1, Btu/h (kW)
$\dot{q}_{out,ss,higher} \langle T \rangle$	steady-state output at the higher of two tested input rates used for interpolation for the temperature (boiler outlet or inlet) defined in the relevant section of the standard and adjusted for flow rate as required in the relevant section of the standard, Btu/h (kW)
$\dot{q}_{out,ss,lower} \langle T \rangle$	steady-state output at the lower of two tested input rates used for interpolation for the temperature (boiler outlet or inlet) defined in the relevant section of the standard and adjusted for flow rate as required in the relevant section of the standard, Btu/h (kW)
$\dot{q}_{out,nom,water}$	rated steady-state output of steam and water boiler in water mode, determined from steam test results, Btu/h (kW)
$\dot{q}_{pilot}$	fuel energy input rate to pilot burner, Btu/h (kW)
$\dot{q}_{sensible}$	sensible heat output rate, Btu/h (kW)
$\dot{q}_{thru,test}$	test throughflow loss rate, Btu/h (kW)
$\dot{q}_{thru,rated}$	rated throughflow loss rate, Btu/h (kW)
RH	relative humidity of the inlet air supplied for combustion, percent
t_{on}	total burner on time during idling test, h
t_{test}	duration of the relevant test, hours
T	total constituents in flue gases from stoichiometric combustion, ft ³ /1000 Btu (m ³ /MJ), of gas burned at standard conditions
T_a	absolute inlet air temperature °R (K)
T_{air}	inlet air temperature, °F (°C)
T_{blr}	temperature of water in steam boiler during idling test, °F (°C)
T_f	absolute flue gas temperature, °R (K)
$T_{flame,nom}$	nominal adiabatic flame temperature, °F (°C)
$T_{flue,nom,ss,water}$	nominal flue gas temperature in water mode, computed from steam test data, °F (°C)
$T_{flue,ss}$	flue gas temperature at steady state, °F (°C)
$T_{flue,ss,newflow}$	flue gas temperature at steady state under a new flow condition in extrapolation, °F (°C)
T_g	gas temperature at the gas meter, °F (°C)
T_{idle}	midpoint of the highest and lowest outlet water temperatures observed over a cycle while idling, °F (°C)
$T_{idle, rated, hi}$	target outlet temperature during the idling test under high-temperature rating conditions, as specified in Section 7.9.2.2, °F (°C)

$T_{idle, rated, low}$	target outlet temperature during the idling test under low-temperature rating conditions, as specified in Section 7.9.2.2, °F (°C)
T_{in}	temperature of the water entering the boiler, °F (°C) (see Figures 9 through 11)
$T_{in,min}$	manufacturer's minimum entering (return) water temperature, as specified in the manufacturer's instructions shipped with the boiler, °F (°C)
$T_{in,rated,high}$	boiler entering (return) water temperature at high-temperature rating condition, °F (°C)
$T_{in,rated,low}$	boiler entering (return) water temperature at low-temperature rating condition, °F (°C)
$T_{in, rating}$	boiler entering (return) water temperature at rating conditions, °F (°C)
$T_{in,trans,nom}$	nominal inlet (return) water temperature at which boiler transitions between noncondensing and condensing operation, °F (°C)
T_{out}	boiler outlet (supply) water temperature, °F (°C)
$T_{out, rating}$	boiler outlet (supply) water temperature specified in section 7.7.1.1, °F (°C)
$T_{out,trans,nom}$	nominal outlet (supply) water temperature at which boiler transitions between noncondensing and condensing operation, °F (°C)
T_r	absolute test room temperature, °R (K)
T_{rise}	rise in water temperature from boiler inlet to boiler outlet, °F (°C)
T_{room}	test room temperature, °F (°C)
$T_{room, rated}$	rated condition room temperature, 75°F (23.9°C)
T_{sat}	saturated steam temperature corresponding to test steam pressure, °F (°C)
T_{std}	standard temperature to measure natural gas or propane heat value, = 60°F (16°C)
T_{thru}	boiler inlet (return) water temperature while undergoing throughflow
$T_{thru,rated, hi}$	rating temperature for high-temperature throughflow loss, = 180°F (82.2°C)
$T_{thru, rated, lo}$	rating temperature for low-temperature throughflow loss, = 120°F (48.9°C)
U	maximum percentage of carbon dioxide obtainable in stoichiometric combustion in flue gas, percent ($0 \leq U \leq 100$)
UA_{steam}	heat exchanger conductance in steam mode, Btu/h·°F (W/°C)
$UA_{water,nom}$	nominal heat exchanger conductance in water mode, Btu/h·°F (W/°C)
V_{gas}	metered volume of gaseous fuel burned, ft ³ (m ³)
V_W	boiler water volume when operating, gallons (litres)
$\epsilon_{newflow}$	heat exchanger effectiveness under a new flow condition in extrapolation, dimensionless
ϵ_{steam}	heat exchanger effectiveness in steam mode, dimensionless
$\epsilon_{ratedflow}$	heat exchanger effectiveness in water mode, dimensionless
$\epsilon_{counterflow}$	heat exchanger effectiveness in water mode for counterflow boiler, dimensionless
$\epsilon_{counterflow,newflow}$	heat exchanger effectiveness in water mode for counterflow boiler under a new flow condition in extrapolation, dimensionless
$\epsilon_{crossflow}$	heat exchanger effectiveness in water mode for cross-flow boiler, dimensionless
$\epsilon_{crossflow,newflow}$	heat exchanger effectiveness in water mode for cross-flow boiler under a new flow condition in extrapolation, dimensionless
$\epsilon_{parallel}$	heat exchanger effectiveness in water mode for parallel-flow boiler, dimensionless
$\epsilon_{parallel,newflow}$	heat exchanger effectiveness in water mode for parallel-flow boiler under a new flow condition in extrapolation, dimensionless
η_0	test efficiency, percent
$\eta_{0,nom,120}$ ($\eta_{0,nom,48.9}$)	nominal combustion efficiency while idling at 120°F (48.9°C). For single-stage boilers, the steady state η_0 at the maximum input rating is used. For boilers with modulating control, the steady state η_0 at the minimum input rating is used, percent.
$\eta_{ss,comb}$	steady-state combustion efficiency, percent
$\eta_{SS,R}$	steady-state efficiency at reduced fuel input rate, percent
$\eta_{ss,thermal}$	rated steady-state thermal efficiency, including auxiliary power input, percent
$\eta_{STK,SS}$	combustion efficiency while idling, steady state, percent
τ	boiler time constant, hours

4. REQUIREMENTS

4.1 Types of Tests

4.1.1 Required and Optional Tests. The required tests specified in Table 1 shall be conducted. The optional tests shown in Table 1 shall be conducted when the requirements specified for each optional test are met.

4.1.1.1 Steady-State Tests

- Steady-state tests shall be conducted at the high-temperature rating conditions specified in Section 7, unless the manufacturer's instructions shipped with the boiler state the boiler outlet (supply) water temperature must not exceed 120°F (48.9 °C).
- Steady-state and idle tests shall be conducted at the low-temperature rating conditions as specified in Section 7 if both of the following conditions are present:
 - The manufacturer's instructions shipped with the boiler do not advise against operation with boiler inlet (return) water temperature of 80°F (26.7°C) or lower.
 - The manufacturer's instructions shipped with the boiler state that the boiler is a condensing boiler.
- Each steady-state test conducted shall include a jacket loss determination and a combustion efficiency test.
- When requested and specified by the boiler manufacturer, steady-state tests shall be conducted at up to four alternate boiler outlet (supply) water temperature rating points.

4.1.1.2 Idling and Throughflow Tests

- Idling tests for water boilers shall be conducted at the idle test target outlet (supply) temperature for boilers with a high-temperature rating (as specified in Section 7.9.2.2, Table 7), unless the manufacturer's instructions shipped with the boiler state the boiler outlet (supply) water temperature must not exceed 120°F (48.9°C), in which case the idling tests shall be conducted at the idle test target temperature for boilers with low-temperature rating (as specified in Section 7.9.2.2, Table 7).
- Idling tests for water boilers shall be conducted at the idle test target temperature for boilers with a low-temperature rating (as specified in Section 7.9.2.2, Table 7), if requested and specified by the boiler manufacturer and if either or both of the following conditions are present:
 - The manufacturer's instructions shipped with the boiler state that boiler outlet (supply) water temperatures of 120°F (48.9°C) or lower are allowed.
 - The boiler is a condensing boiler.
- Throughflow loss tests for a hot-water boiler shall be conducted at the high throughflow test inlet water temperature shown in Table 6, if requested and specified by the boiler manufacturer.

Table 1 Required (R) and Optional (O) Tests (see Section 4.1.1)

Boiler Type	Rating Condition	Steady-State Tests				Other Tests	
		Single-Stage Burner	Modulating Burner			All	
		Maximum Input Rating	Maximum Input Rating	Intermediate Input Rating ^b	Minimum Input Rating	Idling	Throughflow
Steam	Steam	R	R	O	R	R	O
Hot water	High-temperature rating	R ^d	R ^d	O	R ^d	R ^d	O
	Intermediate-temperature rating ^c	O	O	O	O	—	—
	Low-temperature rating	R ^a	R ^a	O	R ^a	R ^a	O

a. Required for boilers compliant with Section 4.1.1.1, requirement b, and optional for all other boilers.

b. Tests are allowed to be conducted for up to three intermediate firing rates. The same intermediate input rates shall be used for all outlet (supply) water temperatures tested at intermediate input rates.

c. Optional steady-state tests at any outlet (supply) water temperatures between 120°F (48.9°C) and 180°F (82.2°C) are allowed for boilers on which both low and high inlet water temperature tests are conducted. The optional steady-state tests shall include operation at both the maximum input rating and the minimum input rating and are allowed to include up to three intermediate firing rates that are also tested at the high-temperature rating.

d. High-temperature rating tests are not required when the manufacturer's instructions shipped with the boiler states the outlet (supply) water temperature must be equal to or lower than 120°F (48.9°C).

- d. Throughflow loss tests for a hot-water boiler shall be conducted at the low throughflow test inlet water temperature shown in Table 6, if requested and specified by the boiler manufacturer and where either or both of the following conditions are present:
- The manufacturer's instructions shipped with the boiler state that boiler outlet (supply) water temperatures of 120°F (48.9°C) or lower are allowed.
 - The boiler is a condensing boiler.

Informative Note: The throughflow loss test quantifies jacket and flue losses as a result of water flow through boilers or boiler modules that are not firing.

4.1.1.3 Steady-State Test Firing Rates

- a. Steady-state input rating tests shall be conducted at 100% $\pm$ 2% of the boiler manufacturer's maximum input rate specified on the rating plate.
- b. For modulating boilers, steady-state, low fire tests shall be conducted at 100% $\pm$ 2% of the boiler manufacturer's minimum input specified on the rating plate or the input obtained with the minimum burner modulation signal, whichever is higher. The minimum burner modulation signal shall be that with which the boiler was shipped, unless the manufacturer's instructions shipped with the boiler provide complete instructions, including any required access codes, to allow the minimum burner modulation signal to be further reduced.
- c. For modulating boilers, steady-state, intermediate fire tests shall be conducted at up to three intermediate inputs when requested and specified by the boiler manufacturer.

4.2 Calculated Results

4.2.1 Calculation of Rated Performance from Test Results. Rated thermal efficiency, combustion efficiency, idling energy input rate, and throughflow loss rate shall be calculated from test results using the procedures in Section 10.

4.2.2 Calculation of Hot-Water Ratings from Steam Test Results. If a steam and hot-water boiler is tested only as a steam boiler, the steady-state, idling, and throughflow performance in hot-water mode shall be calculated from the steam ratings using the procedures in Section 11.

4.2.3 Interpolation and Extrapolation of Test Results

4.2.3.1 Steady-state output as a function of water flow rate for a fixed input rate and boiler inlet (return) water temperature shall be calculated using the procedures in Section 12.1.

4.2.3.2 Steady-state output as a function of boiler inlet (return) water temperature for a fixed input rate and water flow rate shall be calculated using the procedures in Section 12.2.

4.2.3.3 Idling energy input as a function of water flow rate for a fixed water temperature shall be calculated using the procedures in Section 12.3.

4.2.3.4 Idling energy input as a function of water temperature for a fixed water flow rate shall be calculated using the procedures in Section 12.4.

4.2.3.5 Throughflow loss rate as a function of water temperature shall be calculated using the procedures in Section 12.5. If the optional throughflow loss tests are not conducted, the throughflow loss rate at any water temperature shall be calculated from the idling energy input rate and combustion efficiency using the procedures in Section 12.5.

4.2.3.6 Part-load performance when cycling between minimum steady-state input rate and idling energy input rate at a fixed flow rate and constant outlet or boiler inlet (return) water temperature shall be calculated using the procedures in Section 12.6.

4.2.3.7 Part-load performance when modulating between tested steady-state input rates at fixed boiler outlet (supply) or boiler inlet (return) water temperature and with fixed water flow rate or fixed temperature rise shall be calculated using the procedures in Section 12.7.

4.2.3.8 The boiler time constant for use in computing transient losses of a boiler isolated from water flow shall be calculated using the procedures in Section 12.8.

5. INSTRUMENTS

Instruments shall have the resolution and accuracy listed in Table 2 at the measurement condition and shall be used within the range of their calibration. Instruments shall be calibrated at least once per year, and a record shall be kept containing, at least, the date of calibration, method of calibration, and traceability to National Institute of Standards and Technology standards or equivalent national standards.

Table 2 (I-P) Instrumentation Resolution and Accuracy

Property Measured	Item Measured	Minimum Resolution	Minimum Accuracy	Example of Instrument Type	Approximate Range of Readings
Temperature	Room air	0.2°F	±1°F	Thermometer, thermocouple, RTD	60° to 100°F
	Inlet water	1°F	±1°F	Thermocouple or RTD	75° to 140°F
	Outlet water	1°F	±1°F	Thermocouple or RTD	130° to 190°F
	Surface	0.1°F	±2°F	Thermocouple or RTD	65° to 800°F
	Flue gas	1°F	±2°F	Thermocouple grid	350° to 650°F
	Fuel gas	1°F	±1°F	Thermometer or RTD	30° to 100°F
Pressure	Atmospheric	0.05 in. of mercury	±0.05 in. of mercury	Barometer	28 to 31 in. of mercury
	Steam	Greater of 0.1 in. of water or 10% of observed value	Greater of ±0.1 in. of water or ±10% of observed value	Manometer, bourdon tube gage	0 to 5 psi
	Fuel oil	5 psi	±5 psi	Bourdon tube gage	80 to 250 psi
	Fuel gas	≤14 in. of water: 0.1 in. of water >14 in. of water: 0.01 psi	≤14 in. of water: ±0.1 in. of water >14 in. of water: ±0.05 psi	Manometer	0 to 14 in. of water 0.5 to 15 psi
	Firebox	Greater of 0.02 in. of water or 10% of observed value	Greater of ±0.02 in. of water or ±10% of observed value	Draft gage	As needed
	Vent	0.01 in. of water	±0.01 in. of water	Draft gage	0 to 0.5 in. of water
	Flue/vent connector	0.01 in. of water	±0.01 in. of water	Draft gage	0 to 0.5 in. of water
Mass or volume	Oil	0.25% of hourly mass flow rate	±0.25% of hourly mass flow rate	Scale	Size for rated flow
	Gas	Greater of 1 ft ³ or 0.25% of hourly rate	±1% of hourly rate	Volume meter	Size for rated flow
	Flue condensate	Greater of 0.5 lb or 0.5% of measured weight	Greater of ±0.5 lb. or ±0.5% of measured weight	Scale	As needed
	Steady-state water flow	0.5% of hourly rate	±5% of hourly rate	Flow meter	As needed
	Idling and throughflow test water flow	0.5% of hourly rate	±5% of steady-state flow rate	Flow meter	As needed
Time	Test period	1 second/h	±1 second/h	Stopwatch	0 to 3 h
Gas chemistry	Carbon dioxide	0.1% CO ₂	±0.1% CO ₂	CO ₂ analyzer	0 to 15% CO ₂
	Carbon monoxide	1 ppm	Greater of ±10 ppm or ±5% of reading	CO analyzer	0 to 500 ppm CO
	Oxygen	0.1% O ₂	±0.1% O ₂	O ₂ analyzer	0% to 20% O ₂
Gas optics (for oil)	Smoke	1 smoke spot	±1/2 smoke spot	Smoke spot ^a	0 to 7

a. Smoke measurement shall be consistent with ASTM Standard D2156.⁵

Table 2 (I-P) Instrumentation Resolution and Accuracy (Continued)

Property Measured	Item Measured	Minimum Resolution	Minimum Accuracy	Example of Instrument Type	Approximate Range of Readings
Heating value	Natural gas or propane	2 Btu/ft ³	±1% of reading	Calorimeter or gas chromatograph	970 to 1100 Btu/ft ³
	Fuel oil	1 Btu/lb	±1% of reading	See Section 7.3.1	18,500 to 20,500 Btu/lb
Humidity	Relative humidity	5.0%	±5% of full scale	Psychrometer	10% to 90%
Electrical power	Watts	1 W	±1% of reading	—	—
Electrical energy	kWh	Greater of 0.01 kWh or 0.5% of the reading	±1% of reading	—	—
Room air velocity	ft/min	1 ft/min	±5 ft/min at 50 ft/min	Vane anemometer	10 to 50 ft/min

a. Smoke measurement shall be consistent with ASTM Standard D2156.⁵

Table 2 (SI) Instrumentation Resolution and Accuracy

Property Measured	Item Measured	Minimum Resolution	Minimum Accuracy	Example of Instrument Type	Approximate Range of Readings
Temperature	Room air	0.1°C	±0.5°C	Thermometer, thermocouple, RTD	16° to 38°C
	Inlet water	0.5°C	±0.5°C	Thermocouple or RTD	24° to 60°C
	Outlet water	0.5°C	±0.5°C	Thermocouple or RTD	54° to 88°C
	Surface	0.05°C	±1°C	Thermocouple or RTD	18° to 425°C
	Flue gas	0.5°C	±1°C	Thermocouple grid	175° to 340°C
	Fuel gas	0.5°C	±0.5°C	Thermometer or RTD	0° to 38°C
Pressure	Atmospheric	170 Pa	±170 Pa	Barometer	95 to 105 kPa
	Steam	Greater of 25 Pa or 10% of observed value	Greater of ±25 Pa or ±10% of observed value	Manometer, bourdon tube gage	0 to 34 kPa
	Fuel oil	34 kPa	±34 kPa	Bourdon tube gage	550 to 1700 kPa
	Fuel gas	≤3.5 kPa: 25 Pa >3.5 kPa: 69 Pa	≤3.5 kPa: ±25 Pa >3.5 kPa: ±69 Pa	Manometer	0 to 3.5 kPa 3.5 to 103 kPa
	Firebox	Greater of 5 Pa or 10% of observed value	Greater of ±5 Pa or ±10% of observed value	Draft gage	As needed
	Vent	2.5 Pa	±2.5 Pa	Draft gage	0 to 125 Pa
	Flue/vent connector	2.5 Pa	±2.5 Pa	Draft gage	0 to 125 Pa
Mass or volume	Oil	0.25% of hourly mass flow rate	±0.25% of hourly mass flow rate	Scale	Size for rated flow
	Gas	Greater of 0.028 m ³ or 0.25% of hourly rate	±1% of hourly rate	Volume meter	Size for rated flow
	Flue condensate	Greater of 0.23 kg or 0.5% of measured weight	Greater of ±0.23 kg or ±0.5% of measured weight	Scale	As needed
	Steady-state water flow	0.5% of hourly rate	0.5% of hourly rate	Flow meter	As needed
	Idling and throughflow test water flow	0.5% of hourly rate	±5% of steady-state flow rate	Flow meter	As needed

a. Smoke measurement shall be consistent with ASTM Standard D2156.⁵

Table 2 (SI) Instrumentation Resolution and Accuracy (Continued)

Property Measured	Item Measured	Minimum Resolution	Minimum Accuracy	Example of Instrument Type	Approximate Range of Readings
Time	Test period	1 second/h	±1 second/h	Stopwatch	0 to 3 h
Gas chemistry	Carbon dioxide	0.1% CO ₂	±0.1% CO ₂	CO ₂ analyzer	0% to 15% CO ₂
	Carbon monoxide	1 ppm	Greater of ±10 ppm or ±5% of reading	CO analyzer	0 to 500 ppm CO
	Oxygen	0.1% O ₂	±0.1% O ₂	O ₂ analyzer	0% to 20% O ₂
Gas optics (for oil)	Smoke	1 smoke spot	±1/2 smoke spot	Smoke spot ^a	0 to 7
Heating value	Natural gas or propane	74.5 kJ/m ³	±1% of reading	Calorimeter or gas chromatograph	36.1 to 41.0 MJ/m ³
	Fuel oil	3 kJ/kg	±1% of reading	See Section 7.3.1	43000 to 47700 kJ/kg
Humidity	Relative humidity	5.0%	±5% of full scale	Psychrometer	10% to 90%
Electrical power	Watts	1 W	±1% of reading	—	—
Electrical energy	kWh	Greater of 0.01 kWh or 0.5% of the reading	±1% of reading	—	—
Room air velocity	m/s	0.005 m/s	0.025 m/s at 0.25 m/s	Vane anemometer	0.5 to 0.25 ft/min

a. Smoke measurement shall be consistent with ASTM Standard D2156.⁵

6. APPARATUS

6.1 Test Room or Area. The test location must be a size that permits access to all parts of the test unit and instrumentation and that maintains stable ambient conditions. Provisions for removing the products of combustion from the test area and for supplying air for combustion are required.

6.2 Vent Connection. Boilers for installation with either positive or negative pressure venting shall be tested with positive pressure venting following the requirements of Section 6.2.3.

6.2.1 Test Vent for Atmospheric Boilers. When the same atmospheric boiler has the option to have either a horizontal vent or a vertical vent when installed and configured according to the manufacturer's instructions shipped with the boiler, the performance testing specified in this standard shall be conducted with the boiler configured with a vertical vent. The vertical vent test results shall apply to the boiler configured with a horizontal vent without additional testing.

The boiler vent connector or draft hood flue collar shall be connected to an uninsulated sheet metal vent sized to fit the vent connector or flue collar or, if a sizing adapter is specified by the manufacturer's instructions shipped with the boiler, the vent shall be sized to fit the adapter. If elbows are used, the elbows shall be of the 90° (1.57 rad) and four-piece sheet metal type. The vent pipe shall have a reasonably smooth inner contour.

When the vent gases discharge horizontally, an elbow and the greater of 5 ft (1.5 m) or five pipe diameters of vertical vent pipe measured from the end of the elbow shall be attached to the draft hood or external draft diverter outlet or, in the absence of an external draft control device, to the flue collar. When vent gases discharge vertically, the greater of 5 ft (1.5 m) or five pipe diameters measured from point of attachment shall be connected vertically to the draft hood or external draft diverter outlet or, in the absence of an external draft control device, to the flue collar (see Figure 1).

If additional vent height or a mechanical draft inducer are needed to obtain the minimum draft in the vent specified in the manufacturer's installation instructions shipped with the boiler, the additional vent or mechanical draft inducer shall be attached to the end of the vertical test vent and the draft obtained must be within 0.02 in. of water (5 Pa) of that specified minimum draft. If needed, a draft regulator shall be installed according to the instructions included with the draft regulator and shall be located immediately before the additional vent height or mechanical draft inducer.

6.2.2 Test Vent for Noncondensing Boilers with Nonatmospheric Gas or Oil Burners and with Negative Vent Pressure. The following applies to both horizontal and vertical discharge boilers:

When the same noncondensing boiler has the option to have either a horizontal vent or a vertical vent when installed and configured according to the manufacturer's instructions shipped with the boiler, the per-

formance testing specified in this standard shall be conducted with the boiler configured with a vertical vent. The vertical vent test results shall apply to the boiler configured with a horizontal vent without additional testing.

When the same noncondensing boiler with nonatmospheric burners has the option to have either a negative pressure vent or a positive pressure vent when installed and configured according to the manufacturer's instructions shipped with the boiler, the performance testing specified in this standard shall be conducted with the boiler configured with a positive pressure vent. If the boiler installed and configured with a positive pressure vent has the option to be installed with either a vertical or horizontal vent, the boiler shall be configured and installed with a vertical vent. The positive pressure vent test results, whether installed vertically or horizontally, shall apply to the boiler configured with a negative pressure, both vertical and horizontal, without additional testing.

If installed with negative pressure, the elbows shall be of the 90° (1.57 rad) and four-piece sheet metal type. The vent pipe shall have a reasonably smooth inner contour. All vent pipe connections shall be sealed before the insulation is applied. A minimum of R-7 foil-faced insulation shall be applied from the boiler to a point three pipe diameters downstream of the first elbow, as shown in Figure 2. The plane of the thermocouple grid is one pipe diameter downstream of the first elbow, and the flue gas sampling point is two pipe diameters downstream of the first elbow, as shown in Figure 2. If dilution air is introduced into the flue gases before the plane of the thermocouple and flue gas sampling points in the vent, utilize an alternate plane of thermocouple grid and flue gas sampling point located downstream from the heat exchanger and upstream from the point of dilution air introduction (see Figure 2).

If additional vent height or a mechanical draft inducer are needed to obtain the minimum vent draft specified in the manufacturer's installation instructions shipped with the boiler, the additional vent or mechanical draft inducer shall be attached to the end of the vertical test vent, and the draft obtained must be within 0.02 in. of water (5 Pa) of that specified minimum draft. If needed, the draft regulator shall be installed according to the instructions included with the draft regulator and shall be located immediately before the additional vent height or mechanical draft inducer.

6.2.2.1 Horizontal Discharge. When the vent gases discharge horizontally, attach an elbow, sized to fit, directly to the flue collar, or if a sizing adapter is specified by the manufacturer's instructions shipped with the boiler, the elbow shall be sized to fit the adapter. Adding pipe between the flue collar and the elbow is allowed, if necessary for the test vent to clear obstructing boiler parts. To the elbow, attach a vertical length of vent that is the greater of five times the vent pipe diameter or 5 ft (1.5 m), as shown in Figure 2.

6.2.2.2 Vertical Discharge. When the vent gases discharge vertically, attach an elbow, sized to fit, directly to the flue collar or, if a sizing adapter is specified by the manufacturer's instructions shipped with the boiler, the elbow shall be sized to fit the adapter. Adding pipe between the flue collar and the first elbow is allowed, if necessary for the test vent to clear obstructing boiler parts. Attach a horizontal section of vent to the elbow that is three times the vent pipe diameter. Attach a second elbow, oriented up, to the end of this horizontal length of vent pipe. To the second elbow, attach a vertical length of vent that is the greater of five times the vent pipe diameter or 5 ft (1.5 m), as shown in Figure 2.

6.2.3 Test Vent for Condensing and Noncondensing Boilers with Gas or Oil Nonatmospheric Burners and with Positive Vent Pressure. When the same boiler with positive vent pressure and without combustion air preheat has the option to have either a horizontal vent or a vertical vent when installed and configured according to the manufacturer's instructions shipped with the boiler, the performance testing specified in this standard shall be conducted with the boiler configured with a horizontal vent. The horizontal vent test results shall apply to the boiler without combustion air preheat configured with a vertical vent, without additional testing.

When the same boiler with positive vent pressure and with combustion air preheat has the option to have either a horizontal vent or a vertical vent when installed and configured according to the manufacturer's instructions shipped with the boiler, the performance testing specified in this standard shall be conducted with the boiler configured with a horizontal vent. The horizontal vent test results shall apply to the boiler with combustion air preheat configured with a vertical vent, without additional testing.

6.2.3.1 Horizontal Discharge. When the vent gases discharge horizontally, attach a length of straight vent pipe that is the greater of two times the vent diameter or the additional length necessary for this horizontal vent length to comply with the minimum vent length specified in the manufacturer's instructions shipped with the boiler. All venting, prior to the final vertical section and the connecting tee or elbow, shall be the smallest diameter allowed by the manufacturer's instructions shipped with the boiler, except the vent diameter shall not be smaller than the flue collar on the boiler. Attach an elbow or tee to the horizontal vent pipe. Adding pipe between the flue collar and the elbow or tee is allowed, if necessary for the test vent to clear

obstructing boiler parts. To the elbow or tee, attach a vertical length of vent that is the greater of five times the vent pipe diameter or 5 ft (1.5 m), as shown in Figures 4 and 6. If needed, apply a concentric orifice at the flue connection to obtain the minimum vent pressure specified in the manufacturer's installation instructions. The vent must freely discharge to the atmosphere. Additional vent piping shall not be connected.

The plane of the thermocouple grid shall be three pipe diameters from the vent termination, and the flue gas sampling point shall be two diameters from the vent termination, as shown in Figures 4 and 6.

For condensing boilers, a condensate trap shall be applied to the tee attached below the final vertical section of vent pipe. Flue gas condensate from this trap shall be combined with condensate from the boiler in one or more smooth, nonporous collection containers. The collection containers shall have a vent opening to the atmosphere.

For condensing boilers in which flue gas velocity is too high to collect all liquid condensate entrained in the flue gas, the final vertical section and connecting tee or elbow pipe diameter shall be increased to the diameter no greater than the industry diameter that prevents the vent velocity from falling below 400 ft/min (2.54 m/s) when operating at the maximum input rating. For a specific fuel, input rate, excess air level, flue gas temperature, flue pipe diameter, and barometric pressure, the flue gas velocity shall be calculated using methods provided in *ASHRAE Handbook—HVAC Systems and Equipment*, Chapter 35.⁴ Measurement of flue gas velocity for the purpose of selecting flue diameter is not required. This same flue diameter shall be used during testing at lower input rates.

All vent pipe connections shall be sealed before the insulation is applied. For boilers without combustion air preheat, a minimum of R-7 foil-faced insulation shall be applied from the boiler to the vent termination, as shown in Figure 4. For boilers with combustion air preheat, a minimum of R-7 foil-faced insulation shall be applied to all venting between the combustion air entrance for preheat and vent termination, as shown in Figure 6. Do not insulate the combustion air preheat venting.

If dilution air is introduced into the flue gases before the plane of the thermocouple and flue gas sampling points in the vent, utilize an alternate plane of thermocouple grid and flue gas sampling point located downstream from the heat exchanger and upstream from the point of dilution air. Attach a length of vent that is the greater of five times the vent pipe diameter or 5 ft (1.5 m), or the minimum vent length specified in the manufacturer's instructions shipped with the boiler, as shown in Figure 3. The vent shall be the smallest diameter allowed by the manufacturer's instructions shipped with the boiler, except it shall not be smaller than the flue collar on the boiler. Vent insulation is not required if the plane of the thermocouple grid and flue gas sampling are located at a point before the flue gases enter the vent.

6.2.3.2 Vertical Discharge. When the vent gases discharge vertically, attach an elbow directly to the flue collar. The elbow shall be sized to fit directly to the flue collar, or if a sizing adapter is specified by the manufacturer's instructions shipped with the boiler, the elbow shall be sized to fit the adapter. Adding pipe between the flue collar and the elbow or tee is allowed, if it is necessary for the test vent to clear obstructing boiler parts. To the elbow, attach a length of horizontal vent pipe that is the greater of two times the standard diameter of the vent elbow or the additional length necessary for this horizontal vent length to comply with the minimum vent length specified in the manufacturer's instructions shipped with the boiler. Attach an elbow or tee to the horizontal length of vent pipe. To the elbow or tee, attach a vertical length of vent that is the greater of five times the vent pipe diameter or 5 ft (1.5 m), as shown in Figures 5 and 7. If needed, apply a concentric orifice at the flue connection to obtain the minimum vent pressure specified in the manufacturer's installation instructions shipped with the boiler. The vent must freely discharge to the atmosphere. Additional vent piping shall not be connected.

The plane of the thermocouple grid shall be two pipe diameters from the vent termination, and the flue gas sampling point is two pipe diameters from the vent termination, as shown in Figures 5 and 7.

For condensing boilers, a pipe and trap shall be applied to the tee attached below the final vertical section of vent pipe. Flue gas condensate from this pipe and trap shall be combined with condensate from the boiler in one or more smooth, nonporous collection containers. The collection containers shall have a vent opening to the atmosphere.

For condensing boilers in which flue gas velocity is too high to collect all liquid condensate entrained in the flue gas, the final vertical section and its connecting tee or elbow pipe diameter shall be increased to the diameter no larger than the industry diameter that prevents the vent velocity from falling below 400 ft/min (2.54 m/s) when operating at the maximum input rating. For a specific fuel, input rate, excess air level, flue gas temperature, flue pipe diameter, and barometric pressure, the flue gas velocity shall be calculated using methods provided in *ASHRAE Handbook—HVAC Systems and Equipment*, Chapter 35.⁴ Measurement of flue gas velocity for the purpose of selecting flue diameter is not required. This same flue diameter shall be used during testing at lower input rates.

All vent pipe connections shall be sealed before the insulation is applied. For boilers without combustion air preheat, a minimum of R-7 foil-faced insulation shall be applied from the boiler to the vent termination, as shown in Figure 5. For boilers with combustion air preheat, a minimum of R-7 foil-faced insulation shall be applied to all venting between the combustion air entrance for preheat and the vent termination, as shown in Figure 7. Do not insulate the combustion air preheat venting.

If dilution air is introduced into the flue gases before the plane of the thermocouple and flue gas sampling points in the vent, utilize an alternate plane of thermocouple grid and flue gas sampling point located downstream from the heat exchanger and upstream from the point of dilution air. Attach a length of vent that is the greater of five times the vent pipe diameter or 5 ft (1.5 m), or the minimum vent length specified in the manufacturer's instructions shipped with the boiler, as shown in Figure 3. The vent shall be the smallest diameter allowed by the manufacturer's instructions shipped with the boiler, except the vent diameter shall not be smaller than the flue collar on the boiler. Vent insulation is not required if the plane of the thermocouple grid and flue gas sampling are located at a point before the flue gases enter the vent.

6.2.4 Additional Requirements for Outdoor Boilers. If the manufacturer provides more than one outdoor venting arrangement, the boiler shall be tested with the arrangement having the least draft loss and results applied to all outdoor venting arrangements.

6.3 Steam Piping. Figure 8 shows a diagram of a boiler setup. Size and install riser, header, and equalizer piping as specified in the manufacturer's instructions shipped with the boiler. If risers and headers are required but are not specified in the manufacturer's instructions shipped with the boiler, the risers shall be the same size as the steam outlet connections, and the internal cross section of the headers shall be the sum of the internal cross-section area of the risers, rounded up to the next standard pipe size.

6.4 Water Piping

6.4.1 Steady-State Test. The water outlet shall be connected to the boiler outlet (supply). Piping and attached devices between the boiler and at least ten pipe diameters upstream of the boiler inlet temperature measurement location (T_{in}) shall be insulated to a minimum of R-7. Piping and attached devices between the boiler and at least ten pipe diameters downstream of the boiler outlet temperature measurement location (T_{out}) shall be insulated to a minimum of R-7. The water inlet shall be connected to the boiler inlet (return). Provision shall be made for heat rejection and control of the inlet (return) water temperature. A recirculation loop, shown diagrammatically in Figure 9, is allowed to be used to obtain the required temperature rise or boiler water flow rate specified in Section 7.7.1. If a recirculation loop is used, the recirculation loop pump used shall have a close-coupled design such that the impeller is on the same shaft as the electric motor that drives the pump and the motor has a face on one end that matches the face on the pump casing that is mounted against the motor case, and all recirculation loop devices and piping to and from the boiler shall be insulated to a minimum of R-7.

6.4.2 Idling Test. The pumped boiler loop piping and devices between the boiler inlet and outlet shall be insulated to a minimum of R-7. A flowmeter shall be installed in the boiler loop piping to confirm the requirements of Section 7.9.2.1. See Figure 10 for a boiler idling test configuration. The boiler loop pump used shall have a close-coupled design such that the impeller is on the same shaft as the electric motor that drives the pump and the motor has a face on one end that matches the face on the pump casing that is mounted against the motor case. The volume of water in the boiler loop piping shall not exceed 10 gallons (37.9 L) plus 1 gallon (3.8 L) per 100,000 Btu/h (29.3 kW) of maximum input rating over 1,000,000 Btu/h (293.1 kW). The volume of pipes, valves, fittings, flowmeters, and pumps shall be calculated based on their standard pipe size internal diameter and measured length. If the boiler loop includes a storage tank, the storage tank volume shall be based on the nameplate capacity or, in the absence of nameplate capacity, shall be based on the tare tank water weight, the measured volume of water required to fill the tank, or tank dimensions.

Exception to 6.4.2: If the idling test cannot be conducted because the manufacturer's maximum water temperature limit control setting, as specified in the manufacturer's instructions shipped with the boiler, is exceeded, the amount of water in the boiler loop shall be increased as necessary to enable the test to be conducted.

6.4.3 Throughflow Loss Test. The boiler loop described in Section 6.4.2 or 6.4.4 shall be used and provided with a means to offset the throughflow loss of the boiler by adding heat to maintain the required inlet water temperature. All piping and components between the means to maintain the required inlet water temperature and the boiler loop shall be insulated to a minimum of R7. The energy consumed to maintain the required inlet water temperature shall be measurable in kilowatt-hours.

Informative Note: A well-insulated, small electric water heater without storage volume or an electric immersion element with continuously variable output located in the boiler loop is recommended.

6.4.4 Optional Combined Setup for Steady-State, Idling, and Throughflow Tests. The piping shown in Figures 9 and 10 or the setup shown in Figure 11 is allowed to be used for steady-state, idling, and through-flow tests. During the steady-state test, control of the boiler outlet water temperature is accomplished by adjusting the rate of heat dissipation from the heat rejection device. During conduction of the idling test, the heat rejection system shall be isolated from the boiler loop by closing the isolation valves shown in Figure 11. The boiler loop and boiler loop pump shall meet the requirements specified in Sections 6.4.2. and 6.4.3. With this combined setup, a flowmeter shall be installed in the boiler loop, if required by Section 7.7.2.

6.5 Application of Instruments (Steam and Water)

6.5.1 Flue Gas Temperature Measurement. The average temperature of boiler flue gases shall be taken downstream from the boiler heat exchanger and before any dilution air is introduced. The flue gas temperature shall be taken using a thermocouple grid, constructed as shown in Figure 12, installed in a plane perpendicular to the flow of flue gas as shown in Figure 1 or Figure 3, as appropriate. Thermocouples in the grid shall be made from thermocouple wire not larger than 22 gage and shall be connected in parallel. Where the thermocouples are exposed to direct radiation from the burner flame, thermocouple radiation shields must be applied.

6.5.1.1 Round Pipe. A nine (9) thermocouple grid, constructed as shown in Figure 12, shall be used in round pipe up to and including 24 in. (0.61 m) in diameter. A seventeen (17) thermocouple grid, constructed as shown in Figure 12, shall be used in round pipe over 24 in. (0.61 m) in diameter.

6.5.1.2 Rectangular Measurement Plane. A 3×3, nine (9) thermocouple grid constructed with uniform spacing, as shown in the example in Figure 12, shall be used in rectangular openings up to and including 24 in. (0.61 m) in width. For rectangular openings over 24 in. (0.61 m) in width, use a 3×6, eighteen (18) thermocouple grid constructed with uniform spacing based on the example in Figure 12. For the purpose of this requirement, width is the longest side dimension in the flue cross section.

6.5.2 Flue Gas Sampling. All instruments inserted to sample flue gas shall be sealed. Flue gas sampling shall be conducted downstream from the flue gas thermocouple grid and at a location prior to the ingress of any dilution air.

When taking flue gas samples from a round pipe, the samples shall be collected using an open-end tube projecting into the pipe one-fourth to one-half of the pipe diameter, or an alternate sampling tube shall be used to obtain an average flue gas sample. When taking flue gas samples from a rectangular plane, the samples shall be collected using a sampling tube located so as to obtain an average flue gas sample.

6.5.3 Draft Measurement. A draft measurement instrument shall be connected to a tube located in the vent downstream of the thermocouple grid and downstream from the entry of any dilution air into the flue gas. The tube shall project into the vent up to the diameter of the pipe and be positioned perpendicular to the flow. When the manufacturer specifies a firebox draft, it shall be measured in accordance with the manufacturer's instructions shipped with the boiler.

6.5.4 Smoke Measurement, Oil. The smoke measuring device shall be connected to an open-end tube located as shown in Figure 1. The tube shall project into the flue one-fourth to one-half of the pipe diameter and shall be installed in the opening provided for the draft gage sampling tube for the time required to obtain the smoke sample.

The smoke spot reading shall be evaluated in accordance with ASTM D2156.⁵

6.5.5 Boiler Jackets

6.5.5.1 With the boiler operating under steady-state conditions, as described in Section 7.6, use a source of smoke to identify all jacket openings into which ambient air is drawn. Other jacket openings having an area greater than 0.5 in.² (3.2 cm²), which are not known to be needed for combustion air, ventilation, or draft control, shall be sealed with tape. For atmospheric boilers, record a flue CO₂ reading before and after sealing these openings. If the difference between these two readings is greater than 0.3%, identify and remove the tape that is causing this difference.

6.5.5.2 Install a thermocouple in the center of each opening having a cross-sectional area greater than 0.5 in.² (3.2 cm²), which was not sealed and which did not have air flowing into the opening during conduction of the smoke test. If the smoke test was inconclusive, install a thermocouple in the opening. When an opening is greater than 9 in.² (58 cm²), subdivide the opening into smaller, equal-sized areas in accordance with Section 6.5.5. Place one thermocouple at the center of each area. Louver fields shall be divided into smaller, equal-sized areas in accordance with Section 6.5.5 based on the area encompassed by the outermost louvers (see Figure 13). A thermocouple shall then be placed in the louver closest to the center of each area. Thermocouple(s) shall not be located outside of the outer jacket surface nor more than 0.125 in. (3.2 mm) inside the opening (see Figure 14). Record the area of each opening (A_{OX}) and the vertical distance from the

Table 3 Method of Dividing Opening and Louver Fields

Opening or Louver Field Area, in. ² (cm ²)	Number of Equal Size Subareas
≤9 (58)	1
>9 (58), ≤18 (116)	2
>18 (116), ≤27 (174)	3
>27 (174)	4

bottom of the boiler to the center of the opening (H_{OX}). For noncircular openings, record the perimeter of the opening (P_{OX}).

6.5.5.3 For boilers having draft diverters or other openings that draw dilution air from within the jacket, install thermocouples to measure the temperature of this dilution air on the plane of the opening ± 0.125 in. (3.18 mm). When an opening is greater than 9 in.² (58 cm²), subdivide the opening into equal-sized areas, as shown in Table 3. Place one thermocouple at the center of each area. Record the cross-sectional area of the dilution opening at this plane(s) (AD) and the height from the bottom of the boiler to the center of this opening(s) (HD).

6.5.6 Energy Consumed

6.5.6.1 Oil. The fuel oil shall be fed to the burner using a measuring means meeting the requirements of Section 5. If oil is fed to the burner from a tank resting on a scale, a siphon connection from the oil supply to the burner shall be used to permit free play of the scale (see Figure 15).

6.5.6.2 Gas. Gas shall be fed to the burner through a wet or dry gas meter. If T_g cannot be measured inside the gas meter, then T_g shall be measured upstream and within 6 in. (15.3 cm) of the gas meter and the gas piping shall be insulated with R-6 from the temperature sensor to the meter.

Informative Note: Many common gas flowmeters are not accurate below 10% of their maximum rate.

6.5.6.3 Electricity. A watt-hour meter shall be connected as necessary to record the input to all electrical equipment. For an electric boiler, a separate wattmeter shall measure the input to the steam or water. A watt-hour meter shall be used to record the input to the electric water heater in the throughflow loss test. One or more watt-hour meters shall be used to measure electrical energy consumption of all components that draw electric power.

6.5.7 Air Temperature and Humidity. All air temperature sensors shall be shielded from thermal radiation.

6.5.7.1 Combustion Air. The combustion air temperature and relative humidity shall be measured not greater than 12 in. (30 cm) from the point at which the air enters

- the boiler, where the burner or burners are located within the boiler and where (c) does not apply;
- the burner, where the burner or burners are located external to the boiler and where (c) does not apply; or
- the combustion air entrance at the minimum intake duct length specified in the manufacturer's instructions supplied with the boiler or the coaxial combustion air entrance specified in Figures 6 and 7, as applicable.

The temperature sensor shall be shielded from thermal radiation. No means to increase the humidity shall be applied.

6.5.7.2 Room Ambient Air. The room ambient temperature shall be measured within 6 ft (1.83 m) in front of the unit at midheight of the unit.

6.5.8 Additional Instruments, Steam

6.5.8.1 Steam Pressure. A pressure measuring instrument shall be connected to the steam space of the boiler.

6.5.8.2 Feedwater Temperature. A temperature measuring instrument shall be located the closer of 12 in. (30.5 cm) $\pm$ 6 in. (15.3 cm) upstream of the feedwater supply valve (see Figure 8) or the minimum distance upstream of the feedwater supply valve required to prevent the impact of conduction or convection on feedwater temperature measurement.

6.5.8.3 Boiler Water Temperature. For the idling test, a direct immersion thermocouple shall be located in the highest connection below the water line.

6.5.8.4 Water Temperature Control. For the idling test, a water temperature controller shall be located in the standard connection below the water line specified by the manufacturer in the manufacturer's instruc-

tions shipped with the boiler. The controller differential shall have a minimum accuracy of $\pm 1.0^{\circ}\text{F}$ (0.5°C), and the setpoint shall have a minimum repeatability of $\pm 0.5^{\circ}\text{F}$ (0.25°C).

6.5.9 Additional Instruments, Water

6.5.9.1 Water Temperatures. The inlet (return) water temperature (T_{in}) shall be measured with a single sensor located as shown in Figure 9 and the greater of 12 in. (30.5 cm) or four pipe diameters $\pm$ one pipe diameter upstream of the boiler inlet and downstream of all heat rejection devices, pumps, recirculation loop connections, and other mixing locations. When a recirculation loop is used, water exiting the recirculation loop must flow through the branch of four tees, as shown in Figure 9. Water exiting the boiler outlet must flow through a branch of four tees, as shown in Figure 9, and the outlet water temperature (T_{out}) shall be measured with a single sensor located as shown in Figure 9.

6.5.9.2 Water Temperature Control. For the idling test, a water temperature control shall be located in the standard connection specified in the manufacturer's instructions shipped with the boiler.

7. TEST CONDITIONS

7.1 General

7.1.1 The boiler shall be installed as described in Section 6, and the instrumentation shall be installed as described in Section 5. Refer to Figures 1 through 16 when equipping the boiler with the apparatus and instrumentation. The equipment shall be adjusted to the test requirements or conditions described in this section.

7.1.2 For modulating boilers, all test conditions and test procedures in Sections 7 and 8 shall be met at both the maximum input rating and the minimum input rating.

7.1.3 When installing the test boiler, route and place pipes and other components to minimize the impact on viewing boiler surfaces with an IR camera. Boiler components that impact viewing shall be removed or relocated if the components do not otherwise impact test results.

7.2 Test Unit

7.2.1 Boiler. The boiler shall be assembled in accordance with the manufacturer's directions. All openings shall be sealed as specified by the manufacturer's instructions shipped with the boiler to prevent the leakage of air.

7.2.2 Insulated Jacket. The insulated flush jacket cataloged or furnished with the boiler shall be in place during the test. The insulation thickness and spacing as specified shall be maintained.

7.2.3 Cleaning of Boiler. The internal wet surfaces of the boiler and the heating surface of the boiler (exposed to combustion products) shall be clean.

7.2.4 Tests for Determining Output and Efficiency

7.2.4.1 Steam-only boilers shall be tested as steam boilers.

7.2.4.2 Hot-water-only boilers shall be tested as hot-water boilers.

7.2.4.3 Steam and hot-water boilers claiming the same efficiency as a steam boiler and as a hot-water boiler shall be tested as a steam boiler.

7.2.4.4 Steam and hot-water boilers claiming a different efficiency than a steam boiler or hot-water boiler shall be tested both as a steam boiler and as a hot-water boiler.

7.3 Energy Source

7.3.1 Oil. Boilers with a maximum input rating up to and including 5 gph (18.9 L/h) shall use No. 2 (light) fuel oil not more than 5% biodiesel content. Boilers with a maximum input rating in excess of 5 gph (18.9 L/h) shall use No. 2 (light) fuel oil or No. 4, No. 5, or No. 6 (heavy) fuel oil when their oil supply temperatures are specified in the manufacturer's instructions shipped with the boiler. All fuel oil shall comply with ASTM D396, *Standard Specification for Fuel Oil*³, but all fuels shall not contain greater than 5% biodiesel. No. 2 fuel oil shall be supplied at room temperature. A certificate of analysis from the fuel supplier documenting that the fuel does not contain greater than 5% biodiesel or a test of the biodiesel content is required. Heating value shall be measured to an accuracy of $\pm 1\%$ following ASTM D2401 or ASTM D4809.²

7.3.2 Gas. The test gas shall be natural gas or propane, as applicable. The actual higher heating value (HHV) shall be determined to an accuracy defined in Table 2 by use of a calorimeter or gas chromatography, or by using bottled gas of a known calorific value.

7.3.3 Electricity. The voltage supplied to resistance heating elements and electrical equipment shall be controlled to within $\pm 1\%$ of the nameplate voltage.

7.4 Installation of Burners. The burner shall be installed in accordance with the manufacturer's instructions shipped with the boiler.

7.5 Input Rate. See Section 4.1.1.

Table 4 Allowable Variation in Flue Gas Temperature

Temperature at Start of Test		Allowable Variation in Temperature			
		Light Oil, Natural Gas, or Propane		Heavy Oil	
°F	°C	°F	°C	°F	°C
$T \leq 300$	$T \leq 148.9$	5.0	2.8	7.5	4.2
$300 < T \leq 400$	$148.9 < T \leq 204.4$	7.0	3.9	11.0	6.1
$400 < T \leq 500$	$204.4 < T \leq 260$	9.0	5.0	13.5	7.5

7.6 Steady-State Test Conditions, Steam and Water

7.6.1 Vent and Firebox Pressure. The draft shall be as established by the vent system specified in Section 6.2. If the manufacturer provides a dedicated venting arrangement, the boiler shall be tested with the arrangement having the least draft loss. If a firebox pressure is specified in the manufacturer's instructions shipped with the boiler, make the adjustment in accordance with those instructions.

7.6.1.1 Natural or Negative Vent Pressure (Draft). The draft shall be as established by the vent system specified in Section 6.2. If the manufacturer provides a dedicated venting arrangement, the boiler shall be tested with the arrangement having the least draft loss. If a firebox pressure is specified in the manufacturer's instructions shipped with the boiler, make the adjustment in accordance with those instructions.

7.6.1.2 Vent Pressure for Boilers with Positive Vent Pressure and Nonatmospheric Burner. If a minimum positive vent pressure is specified in the manufacturer's instructions shipped with the boiler, that pressure, within the greater of ± 0.02 in. of water (5 Pa) or 10% of the specified vent pressure shall be established before testing and data collection begins.

7.6.1.3 Outdoor Boiler (Water Only). Outdoor boilers shall be installed as specified in the manufacturer's instructions shipped with the boiler. If the manufacturer prescribes more than one dedicated venting arrangement, the boiler shall be tested with the arrangement having the least draft loss.

7.6.2 Flue Gas Temperature. The flue gas temperature during the test shall not vary from the initial test reading by more than the values shown in Table 4 at any time during the test.

7.6.3 Air Temperatures. The room air temperature and inlet air temperature shall be between 65°F (18.3°C) and 100°F (37.8°C) at all times during the test and during burner adjustments.

Exception to 7.6.3: For low boiler inlet water temperature tests, the air temperatures shall not exceed 85°F (29.4°C).

7.6.4 Combustion Air Humidity. The relative humidity of the combustion air, as measured at the location specified in Section 6.5.7.1, for condensing boilers shall not exceed 80% when recorded at the specified interval.

7.6.5 CO₂ or O₂ in Flue Gas

7.6.5.1 Oil and Nonatmospheric Gas Burners

7.6.5.1.1 Specified CO₂ or O₂ Level. Follow the instructions shipped with the boiler for tuning combustion setup to the specified level(s) at the specified firing rate(s). If the CO₂ or O₂ level(s) is specified in the manufacturer's instructions shipped with the boiler as a single number (rather than a range), the burner system shall be adjusted to within $\pm 0.1\%$ of the specified level. The burner system shall not be adjusted at firing rates not specified in the instructions (e.g., if the instructions only specify CO₂ at high fire, do not adjust CO₂ at low fire). The setup shall meet the requirements of Sections 7.6.6 and 7.6.7 and input rate as required to comply with Section 8.2.1.1.6.

7.6.5.1.2 Specified CO₂ Range. If a CO₂ range is specified in the manufacturer's instructions shipped with the boiler, the burner system shall be adjusted to within 0.2% of, but no greater than, the maximum CO₂ level that is within the specified range and that, at the maximum input rating and minimum input rating, meets the requirements of Sections 7.6.6 and 7.6.7 and input rate as required to comply with Section 8.2.1.1.6.

7.6.5.1.3 Specified O₂ Range. If an O₂ range is specified in the manufacturer's instructions shipped with the boiler, the burner system shall be adjusted to within 0.2% of, but not less than, the minimum O₂ level that is within the specified range and that, at the maximum input rating and minimum input rating, meets the requirements of Sections 7.6.6 and 7.6.7 and input rate as required to comply with Section 8.2.1.1.6.

7.6.5.1.4 No Specified CO₂ or O₂ Level or Range. If a burner CO₂ or O₂ level or range is not specified in the manufacturer's instructions shipped with the boiler, the burner system shall be adjusted at the maximum input rating and the minimum input rating to within $\pm 0.2\%$ of the CO₂ level closest to 8% for nat-

ural gas firing, 9% for propane firing, and 11% for oil firing that meets the requirements of Sections 7.6.6 and 7.6.7 and input rate as required to comply with Section 8.2.1.1.6.

7.6.5.2 Atmospheric Burners. Adjust the input rate as required to meet the requirements of Section 4.1.1.

7.6.5.3 Inputs Other than High Fire, All Burners

7.6.5.3.1 No Low or Intermediate Rate Burner Adjustments Specified by Manufacturer. When no low or intermediate rate burner adjustments are specified by the manufacturer, make high-fire burner adjustments in accordance with Section 7.6.5.1 or 7.6.5.2, as appropriate, before performing any tests at low or intermediate firing rates. After making high-fire burner adjustments, adjust the input rate to the low or intermediate firing rate solely by adjustment of the burner modulation signal.

7.6.5.3.2 Low or Intermediate Rate Burner Adjustments Specified by Manufacturer. No tests shall be performed at any input until all adjustments specified in this section have been made.

Make permitted burner adjustments in the order specified in the manufacturer's instructions shipped with the boiler. If no order is specified, make high-fire burner adjustments first. Make any adjustments to CO₂ and O₂ specified at low or intermediate firing rates in accordance with Section 7.6.5.1.1, 7.6.5.1.2, or 7.6.5.1.3, as appropriate.

After adjustments at all input rates are complete, adjust the burner modulation signal to return to the first input rate at which adjustments were made and confirm that those adjustments remain in compliance with this section. If they do not, repeat the entire adjustment process until compliant burner adjustments are achieved at the maximum and minimum input rating and at any intermediate input ratings specified by the manufacturer as part of the adjustment process using only the burner modulation signal to change the input rate.

Once burner adjustments are complete, adjust the input rate solely by adjustment of the burner modulation signal.

7.6.5.4 Burner Adjustments Between Tests. If burner adjustments are required between tests to compensate for barometric pressure, HHV, or other changing conditions, the laboratory shall confirm that the all-burner adjustment requirements in Section 7.6.5 are still met.

Exception to 7.6.5.4: Input rate may be adjusted on modulating boilers using just the burner modulation signal without repeating the entire burner adjustment process.

7.6.6 Smoke. The smoke readings shall not exceed No. 1 for light oil or No. 4 for heavy oil during any test. These values are based on the ASTM D2156⁵ measurement method.

7.6.7 Carbon Monoxide in Flue Gas. A gas burner shall not produce carbon monoxide exceeding 400 ppm (air-free basis).

7.7 Additional Test Requirements for Water, Steady State

7.7.1 Water Temperatures. The boiler temperature rise ($T_{out} - T_{in}$) and the outlet temperature shall be within the temperature tolerances specified in Table 5 at all times during each test.

Exception to 7.7.1: If the boiler manufacturer's instructions shipped with the boiler or the boiler's controls system prohibit operation at the boiler water flow rate, at the calculated inlet temperature, or at both (see Table 5), increase the boiler water flow rate not higher than required to meet the manufacturer's minimum specified flow rate requirements, while maintaining the outlet temperature at the value shown in Table 5 (boiler rise will be less than that shown in Table 5). This shall be accomplished by means of a recirculation loop, as shown in Figure 9, or by otherwise increasing the water flow rate through the boiler.

7.7.2 Verification of Manufacturer's Minimum Specified Flow Rate. If the boiler manufacturer's instructions shipped with the boiler specify a minimum flow rate through the boiler, the flowmeter shown in Figures 9 through 11 shall be used to verify that this flow rate is met or exceeded during the conduction of all tests.

7.8 Additional Test Requirements for Steam, Steady State

7.8.1 Steam Pressure. Tests shall be made at atmospheric pressure or at a pressure not exceeding 15 psi gage (103.4 kPa). If necessary, pressure shall be developed by throttling the discharge with a valve.

7.8.2 Inlet Water. The inlet (return) water temperature shall be between 35°F (1.7°C) and 80°F (26.7°C).

7.9 Idling Test Conditions, Steam or Hot Water

7.9.1 Steam

7.9.1.1 Steam Pressure. Tests shall be made at atmospheric pressure at the threshold of steaming.

7.9.1.2 Boiler Temperature. Boiler water temperature shall be measured at the highest connection below the water line.

7.9.1.3 Output. Output is not measured and shall be assumed to be zero.

Table 5 (I-P) Outlet (Supply) Water Temperature and Boiler Temperature Rise

Test/Rating Condition	Outlet Temp	Outlet Temp Tolerance	Boiler Rise ($T_{out} - T_{in}$) ^a	Boiler Rise Tolerance
Maximum input rating/high-temperature rating	180°F	±2.5°F	40°F	±2°F
Maximum input rating/low-temperature rating	120°F	±2.5°F	40°F	±2°F
Maximum input rating/intermediate-temperature rating, optional test	Between 120°F and 180°F	±2.5°F	40°F	±2°F
Minimum and intermediate input/high-temperature rating	180°F	±2.5°F	40°F	±2°F
Minimum and intermediate input/low-temperature rating	120°F	±2.5°F	40°F	±2°F
Minimum and intermediate input/intermediate-temperature rating, optional test	Between 120°F and 180°F	±2.5°F	40°F	±2°F

a. Boiler rise is allowed to be lower, if required to meet manufacturer's minimum flow rate specified in the manufacturer's instructions supplied with the boiler (see Section 7.7.1).

Table 5 (SI) Outlet (Supply) Water Temperature and Boiler Temperature Rise

Test/Rating Condition	Outlet Temp	Outlet Temp Tolerance	Boiler Rise ($T_{out} - T_{in}$) ^a	Boiler Rise Tolerance
Maximum input rating/high-temperature rating	82.2°C	±1.4°C	22.2°C	± 1.1°C
Maximum input rating/high-temperature rating	48.9°C	±1.4°C	22.2°C	± 1.1°C
Maximum input rating/low-temperature rating	Between 48.9°C and 82.2°C	±1.4°C	22.2°C	± 1.1°C
Maximum input rating/intermediate-temperature rating, optional test	82.2°C	±1.4°C	22.2°C	± 1.1°C
Minimum and intermediate input/high-temperature rating	48.9°C	±1.4°C	22.2°C	± 1.1°C
Minimum and intermediate input/intermediate-temperature rating, optional test	Between 48.9°C and 82.2°C	±1.4°C	22.2°C	± 1.1°C

a. Boiler rise is allowed to be lower, if required to meet manufacturer's minimum flow rate specified in the manufacturer's instructions supplied with the boiler (see Section 7.7.1).

7.9.2 Water

7.9.2.1 Water Flow Rate. The water flow rate during the entire idle test period shall be the lowest flow rate as measured during the steady-state testing, or as calculated in Section 10.8, ±15%. When the piping shown in Figures 9 and 10 is used, this shall be confirmed using a flowmeter. When the piping setup shown in Figure 11 is used, this requirement shall be deemed met when adjustments to boiler loop valves or boiler loop pump speed are not made between the minimum input steady-state and idling tests.

7.9.2.2 Water Temperature Control. A burner ON sequence shall be initiated when the boiler water outlet (supply) temperature falls 5°F (2.8°C) ±1°F (±0.6°C) below the target temperature described in Table 7, and a burner OFF sequence shall be initiated when the boiler outlet (supply) water temperature rises 5°F (2.8°C) ±1°F (±0.6°C) above the same target temperature.

All other installation and operational requirements shall be as specified in the manufacturer's installation instructions shipped with the boiler. The boiler controls integral to the boiler shall not be altered and shall be allowed to operate.

7.9.3 CO₂ or O₂ in Flue Gas. Burner setup shall be established per Section 7.6.5.

7.9.4 Air Temperatures. The room air temperature and inlet air temperature shall be between 65°F (18.3°C) and 100°F (37.8°C) at all times during the idling test. The room air temperature and inlet air temperature shall not differ from each other by more than 5°F (2.8°C) at any time during any given test when the burner is firing.

Exception to 7.9.4: For low boiler inlet (return) water temperature idling tests, the temperatures shall not exceed 85°F (29.4°C).

7.10 Throughflow Loss Test Conditions, Water

7.10.1 Water Flow Rate. The water flow rate shall be the full-fire steady-state test flow rate, ±15%. When the piping shown in Figures 9 and 10 is used, this shall be confirmed using a flowmeter. When the

Table 6 Throughflow Test Inlet (Return) Water Temperatures

Room Temperature	Boilers with High-Temperature Rating	Boilers with Low-Temperature Rating
≤75°F (≤23.9°C)	180°F ±5°F (82.2°C ±2.8°C)	120°F ±5°F (48.9°C ±2.8°C)
>75°F (>23.9°C)	105°F ±5°F (58.3°C ±2.8°C) above room temperature	45°F ±5°F (25.0°C ±2.8°C) above room temperature

Table 7 Idle Test Target Outlet (Supply) Temperatures

Room Temperature	Boilers with High-Temperature Rating	Boilers with Low-Temperature Rating
≤75 0176°F (≤23.9°C)	180°F (82.2°C)	120°F (48.9°C)
>75°F (>23.9°C)	105°F (58.3°C) above room temperature	45°F (25.0°C) above room temperature

pipng setup shown in Figure 11 is used, this requirement shall be deemed met when adjustments to boiler loop valves or boiler loop pump speed are not made between the steady-state and throughflow tests.

7.10.2 Water Temperature. The boiler inlet (return) water temperature shall be maintained as shown in Table 6 for the duration of the test.

8. TEST PROCEDURES

8.1 Steady-State Tests for Determining Efficiency and Output

8.1.1 Steam-only boilers shall be tested as steam boilers.

8.1.2 Water-only boilers shall be tested as water boilers.

8.1.3 If the manufacturer's instructions shipped with the boiler specifies that a boiler model has the option to be used either as a steam boiler or a water boiler, the boiler shall be tested as a steam boiler, and the procedures in Section 11 shall be used to calculate performance in hot-water mode. The jacket loss rate shall be tested in steam mode, and the jacket loss in hot-water mode shall be taken as equal to the jacket loss rate in steam mode.

8.1.4 If a boiler is to have more than one input or output rating, whether due to fixed burner adjustments or modulating control, separate tests are required.

8.2 Steady-State Combustion Efficiency Test

8.2.1 Steam

8.2.1.1 Warm-Up Period

8.2.1.1.1 With all required testing apparatus connected, and with boiler water at the operating level, the burner shall be started and the system warmed up until steaming occurs.

8.2.1.1.2 The burner shall be adjusted to the required input rate as specified in Section 4.1.1.3. Oil or nonatmospheric gas shall be adjusted to produce the required vent or firebox pressure as specified in Section 7.6.1 and CO₂ or O₂ as specified in Section 7.6.5. After the warm-up period has started, if further burner adjustment is necessary, the warm-up period shall be restarted.

8.2.1.1.3 Tests shall be conducted at atmospheric pressure or at a steam pressure not exceeding 15 psig (103.4 kPa). If necessary, pressure shall be developed by throttling with a valve located downstream of the separator. This valve shall be set before the test is started and shall not be changed during the test.

8.2.1.1.4 Readings shall not begin until steaming occurs. Once started, readings shall continue uninterrupted at intervals of not less than 15 minutes.

8.2.1.1.5 Prior to collecting data, any fuel shall be balanced, and if totalizing flowmeters, wattmeters, or both are used, the starting readings shall be recorded at the beginning of data collection. The water level shall be maintained within the range specified in the manufacturer's instructions shipped with the boiler. If a water level is not specified in the instructions shipped with the boiler, the water level shall be maintained within ±1 in. (25.4 mm) of the water level indicated on the boiler, or if a water level is not indicated on the boiler, the water level shall be maintained at 3 in. (76.2 mm) ±1 in. (25.4 mm) above the highest fired surface.

8.2.1.1.6 Steady state shall have been reached when three consecutive readings have been recorded at 15 minute intervals that confirm input is within 2% of the maximum input rating and steam pressure does not vary more than 5%.

8.2.1.2 Test Period

8.2.1.2.1 The test period shall start when a steady state has been reached, and the last reading of the warm-up period shall be the first reading of the test period. For nonatmospheric burners, the average of all

Table 8 Flue Gas Measurement Tolerance

Flue Gas Measurement Tolerance		
Fuel	If % CO ₂ is Measured	If % O ₂ is Measured
Gas	±0.3%	±0.5%
Fuel oil	±0.3%	±0.4%

CO₂ or O₂ readings during the test period shall not differ from the first reading by greater than the tolerance specified in Table 8.

8.2.1.2.2 Test conditions shall be maintained throughout the test period and shall be recorded at each 15 minute interval, as specified in Section 9.1.

8.2.1.2.3 The test period shall be 30 minutes. The average energy input rate measured during the test period shall be within ±2% of the boiler maximum input rating.

8.2.2 Water

8.2.2.1 Warm-Up Period

8.2.2.1.1 With all required test apparatus connected, and with the boiler and piping filled and with water flowing through the system, the burner shall be started and the system warmed up until the outlet (supply) water temperature approaches the outlet temperature specified in Section 7.7. After the warm-up period has started, if further burner adjustment is necessary, the warm-up period shall be restarted.

8.2.2.1.2 The burner shall be adjusted to the required input rate as specified in Section 4.1.1.3. Oil or nonatmospheric gas burners shall be adjusted to produce the required vent or firebox pressure as specified in Section 7.6.1 and CO₂ or O₂ as specified in Section 7.6.5.

8.2.2.1.3 The water flow rate shall be adjusted to the conditions specified in Section 7.7.

8.2.2.1.4 Readings shall not begin until the water temperature conditions are met. Once started, readings shall continue uninterrupted at 15 minute intervals.

8.2.2.1.5 Prior to collecting data, the fuel scales shall be balanced; the gas meter, oil meter, or wattmeter shall be read; and measurement of flows shall be started.

8.2.2.1.6 Steady state shall have been reached when three consecutive readings at 15 minute intervals confirm that input is in compliance with Section 4.1.1.3 and water temperatures are within the limits described in Section 7.7.

8.2.2.2 Test Period

8.2.2.2.1 The test period shall start when steady state has been reached, and the last reading of the warm-up period shall be the first reading of the test period. For nonatmospheric burners, the average of all CO₂ or O₂ readings during the test period shall not differ from the first reading by greater than the tolerance specified in Section 8.2.1.2.1.

8.2.2.2.2 Test conditions shall be maintained throughout the test period and shall be recorded at each 15 minute interval, as specified in Section 9.1.

8.2.2.2.3 The test period shall be 30 minutes for condensing and noncondensing boilers and shall end with a regularly scheduled 15 minute reading. The average energy input rate measured during the test period shall be in compliance with Section 4.1.1.3.

8.2.3 Condensing Boilers, Measurement of Flue Condensate. Flue condensate shall be collected at 30 minute intervals during the combustion efficiency test. Flue condensate mass shall be measured immediately at the end of each collection period to prevent evaporation loss from the sample. Determine the mass of flue condensate for the steady-state period by subtracting the tare container mass from the total container and flue condensate mass measured at the end of each test period.

8.2.4 Jacket Loss Test

8.2.4.1 Outer Surface Convective and Radiative Loss. The following test procedure shall be performed at all inputs and water temperatures at which steady-state efficiencies are measured. All measurements described in this section shall be recorded following the conclusion of the final steady-state test described in Section 8.2.1 or 8.2.2.

Exceptions to 8.2.4.1:

1. The boiler manufacturer is allowed to apply the jacket loss rates (as energy per unit time) identified at higher input rates as the jacket loss rates at lower input rates for the same boiler inlet water tempera-

ture. The absolute jacket loss rate identified at higher boiler inlet water temperatures is allowed to be used as the absolute jacket loss rate at lower boiler inlet water temperatures for the same input rate.

2. The boiler manufacturer is allowed to apply the following default jacket loss values for condensing boilers meeting the following identified conditions:
 - a. The boiler manufacturer is allowed to apply a default jacket loss rate of 1.0% of the maximum input rating for condensing boilers that produce condensate throughout the steady-state, low inlet water temperature efficiency test and for which 90% of the exterior-facing surface area of the secondary heat exchanger section and >75% of the exterior-facing surface area of the combustion chamber section are constructed such that heat flows to the surrounding room through passages filled with boiler water, the jacket is insulated to a minimum of R5, and, for condensing boilers, where the combustion chamber, heat exchanger, and flue collector are fully enclosed in the space through which combustion air passes.
 - b. A default jacket loss rate of 3% of the maximum input rating is allowed to apply for all condensing boilers.

8.2.4.1.1 Air contacting boiler surfaces shall have a velocity of less than 50 ft/min (0.25 m/s). Average room ambient temperature, T_{RA} , shall be determined by the average of readings taken every 15 minutes during the test.

8.2.4.1.2 Temperature measurements shall be recorded for all horizontal and vertical boiler surfaces during steady-state operation. Vertical surfaces are those within 45 degrees of vertical, and horizontal surfaces are those 45 degrees or less from horizontal. Horizontal and vertical surfaces must be separately measured.

8.2.4.1.3 Unless otherwise noted, boiler surface temperatures shall be determined by infrared thermography, using an IR camera with minimum thermal resolution of 160×120 pixels. The IR camera shall be adjusted for the surface emissivity to be measured. Surfaces that are reflective shall be made nonreflective by painting or coating with a nonreflective material. Surfaces with areas having more than one emissivity shall either be painted or coated to have a single emissivity or shall have the average temperature of areas with differing emissivity determined separately. Before testing the first surface, the IR camera shall be calibrated so the temperature of a heated surface measured by the IR camera is the same as that surface verified at the center point by a direct-contact temperature sensor. Input this measured temperature offset into IR cameras with temperature offset capability. For IR cameras without temperature offset capability, this shall be accomplished by adjusting the IR camera emissivity so the surface temperature measured by the IR camera is the same as the surface temperature measured by the direct-contact temperature sensor.

When taking IR images of flat or curved surfaces, the angle between a line drawn between the camera lens and any point on the face subsection and the tangent to the surface at that same point must be equal to or greater than 15 degrees. This is illustrated in Figure 16.

For each area being measured, the entire area must be within the field of view of the IR camera.

8.2.4.1.4 Each jacket surface shall be divided into one or more areas, and the average temperature of each area determined in accordance with the following requirements:

- a. The average temperature of a given area shall be determined using the IR image alone if all of the following conditions are met:
 - The area has a uniform emissivity (see Section 8.2.4.1.3)
 - The difference between the minimum and maximum temperatures in the area does not exceed 30°F (16.7°C)
 - The portion of the thermal image used to calculate the average temperature of the surface area includes that entire area and nothing else
 - The field of view and camera angular requirements in Section 8.2.4.1.3 are met
- b. In cases where a given area fails to meet all the requirements in specified in (a), but where the requirements are met by further dividing the area, break the area into two or more sections meeting all of the requirements in (a). Measure the average temperature for each area using the IR image.
- c. For areas having dimensions of 6×6 in. (15.2×15.2 cm) or smaller, the temperature at the center of the area shall be taken as the average temperature. The temperature at this point shall be measured using direct-contact temperature sensor or an IR camera. The field of view and camera angular requirements in Section 8.2.4.1.3 must be met to use the IR camera.
- d. If the IR camera is unable to view or determine the temperature of any area or areas of the boiler and the total of all these areas is equal to or less than 5% of the overall surface area of the boiler, excluding the boiler bottom, then the temperature of the unmeasured portion of the surface shall be the average tem-

perature of the surfaces, as defined in Section 8.2.4.1.2 and determined by Sections 8.2.4.1.3 and 8.2.4.1.4, that contact the unmeasured portion of the surfaces.

8.2.4.1.5 The temperature of the bottom surface of the boiler, if not previously determined, shall be assumed to be the sum of the area-weighted average temperature of all the area or subdivided areas within 6 in. (15.2 cm) of the boiler bottom measured using the method described in Sections 8.2.4.1.3 and 8.2.4.1.4.

Exception to 8.2.4.1.5: The bottom of the boiler shall be excluded from jacket loss calculation if the bottom jacket perimeter is less than or equal to 3 in. (7.6 cm) above the floor or if the convective losses from the bottom have a path to be drawn into the combustion chamber or jacket interior.

8.2.4.2 Determination of the Loss Rate. The loss rate shall be determined for each area, then the loss rates of all areas shall be summed to obtain the total loss rate for each jacket surface. The loss rates for all of the jacket surfaces are then summed to determine the total jacket surface loss rate for the boiler.

8.2.4.3 Jacket Internal Convection Flow Loss

8.2.4.3.1 Record the temperature of the air exiting each jacket opening (T_{OX}) using the thermocouples installed in Section 6.5.5.2.

8.2.4.3.2 Record the mean temperature of the dilution air (T_D) using the thermocouples installed in Section 6.5.5.

8.2.4.3.3 Record the relative humidity of the inlet air (RH).

8.2.4.3.4 Record the barometric pressure (P_{baro}).

8.3 Idling Test

8.3.1 Steam or Water

8.3.1.1 Burner adjustment shall be made prior to the idling test. Further adjustments shall not be made during the test.

8.3.1.2 The burner or heating elements shall be actuated by a water temperature controller meeting the requirements in Section 7.9 for the duration of the test.

The test shall be immediately preceded by a minimum of one cycle for stabilization if the cycle time exceeds 10 minutes. If the average cycle time is equal to or less than 10 minutes, the test shall be immediately preceded by a minimum of three cycles for stabilization.

Cycles for stabilization are only required immediately preceding the first test cycle and are not required to be conducted in between test cycles. Recording data during the stabilization cycles is not required.

When determining the required number of test cycles for calculating average idling energy input rate, all of the following criteria must be met:

- Total duration of all test cycles must be at least 90 minutes
- At least two test cycles
- If the idling energy input rates of consecutive cycles are not within 5% of each other, at least six cycles are required.

Test cycles must be consecutive and immediately follow the stabilization cycle(s). Total energy input and total time for the test cycles shall be measured for the calculations in Section 10.6. A test cycle is the period between an action of the controller to initiate a call for heat until the next action of the controller to initiate a call for heat. For boilers that do not cycle in a 32 hour period, the last 24 hours shall be the test period.

8.3.1.3 If, over a period of 48 hours, the burner does not fire and the rate of decrease of the boiler outlet temperature for 12 hours is not measurable, the idle energy input shall be assumed to be equal to the auxiliary energy input, as determined in Section 10.3.

8.3.2 Steam

8.3.2.1 The steam valve shall be closed.

8.3.2.2 Prior to the stabilization cycles, the controller shall be set to close at 190°F (87.8°C) boiler water temperature and to open at the highest temperature that does not cause steaming, including steaming that occurs after the burner shuts off. Adjustments shall not be made to the controller setpoint or differential during the stabilization cycles or test cycles.

8.3.3 Water. Water temperature control shall comply with the requirements in Section 7.9.2.2.

8.4 Throughflow Loss Test

8.4.1 The throughflow loss test shall be performed immediately after conducting the idling test (to maintain temperature stabilization).

8.4.2 The boiler shall be turned off, valve positions shall be adjusted to direct the boiler water flow through the electric water heater, and the heater shall be turned on. The heater output shall be adjusted until the heater

is able to maintain the outlet water temperature within $\pm 2^{\circ}\text{F}$ (1°C) of the setpoint (see Section 7.10.2 for setpoint) for a stabilization period of at least one hour. The throughflow test shall then be continued for a test period of two hours to determine the average input rate from the electric heater required to offset the throughflow loss rate of the boiler.

9. DATA TO BE RECORDED

9.1 Combustion Efficiency Test

9.1.1 Steam or Water. The following data shall be recorded before the start of the test on the same day as the test:

- Date of test
- Manufacturer
- Boiler model number
- Burner model number and manufacturer
- Oil analysis—H, C, API gravity, and higher heating value (HHV), Btu/lb (kJ/kg)
- Gas HHV, Btu/ ft³ (MJ/m³)
- Gas manifold pressure, in. of water (Pa)
- Gas line pressure, in. of water (Pa), and temperature, $^{\circ}\text{F}$ ($^{\circ}\text{C}$), at meter
- Barometric pressure (not required for oil-fired water boilers, Pa)
- Burner type (single stage, two stage, step modulating)
- Boiler dry mass, lb (kg)
- Boiler water volume when operating, gallons (litres)
- Heat exchanger type—parallel flow, counterflow, cross flow
- Product application (steam, hot water, steam and hot water)
- Voltage to electric resistance heating elements
- Voltage to electrical equipment
- Manufacturer-specified pressure at flue connection, in. of water (Pa)

9.1.2 Steam or Water. The following data shall be recorded at 15 minute intervals:

- Time, minutes
- Thermal energy fed—lb (kg) oil, ft³ (m³) gas, or kWh (electric)
- Boiler inlet water temperature, $^{\circ}\text{F}$ ($^{\circ}\text{C}$)
- Boiler outlet water temperature, $^{\circ}\text{F}$ ($^{\circ}\text{C}$), or steam pressure, in. of mercury (kPa)
- Room air temperature, $^{\circ}\text{F}$ ($^{\circ}\text{C}$)
- Inlet air temperature, $^{\circ}\text{F}$ ($^{\circ}\text{C}$)
- Flue gas temperature, $^{\circ}\text{F}$ ($^{\circ}\text{C}$)
- Draft in vent, in. of water (Pa) (oil and nonatmospheric gas)
- Draft in firebox, in. of water (Pa) (if required per Section 6.5.3)
- Flue gas smoke spot reading (oil)
- Flue gas CO₂ or O₂, percent
- Flue gas CO, ppm
- Room relative humidity, percent
- Recirculating loop temperature (if used), $^{\circ}\text{F}$ ($^{\circ}\text{C}$)
- Flue condensate weight, lb (kg), condensing, every 30 minutes
- Auxiliary electrical energy used, kWh (excludes all water pumps)
- Electrical energy used, kWh, for water pumps that are downstream of T_{in} and upstream of T_{out} measurement points

9.2 Idling Test

9.2.1 Steam or Water. For steam or water idling tests, the following items shall be recorded before the start of the test:

- Date of test
- Manufacturer
- Boiler model number
- Name of person conducting test
- Burner model number
- Oil analysis—H, C, API gravity, and Btu/lb (kJ/kg)
- Gas HHV, Btu/ ft³ (MJ/m³)