BSR/ASHRAE/AHRI Standard 155P

Public Review Draft

# Method of Testing for Rating Commercial Space Heating Boiler Systems

**Public Review (December 2020)**
**(Draft Shows Proposed Independent Substantive Changes to Previous Public Review Draft)**

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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**This is a review of Independent Substantive Changes** that were made since the last Public Review of Independent Substantive Changes. Text that was removed from the Public Review Draft is provided for reference but is shown in ~~strikeout~~, and text that has been added is shown with underlines.

Only these changes are open to comment at this time. All other material is provided for context only and is not open for Public Review comment except as it relates to the proposed changes.

## 3. DEFINITIONS AND NOMENCLATURE

***IWT*:** the temperature of the water entering the boiler

~~***rating, high inlet water temperature***: the calculation used when a boiler rated for use in applications with inlet water temperatures above 120°F (48.9°C) at design conditions.~~

***rating, high temperature***: A rating use in applications with a boiler outlet (supply) water temperature of 180°F (82.2°C) at design conditions.

~~***rating, low inlet water temperature:*** the calculation used when a boiler rated for use in applications with inlet return water temperatures of 120°F (48.9°C) or lower at design conditions.~~

***rating, low temperature:*** A rating for use in applications with a boiler outlet (supply) water temperature of 120°F (48.9°C) at design conditions.

***rating, 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.

### 3.2 Nomenclature

~~$\dot{m}_{rating}$ mass flow rate at rating conditions, lbm/h (kg/h)~~

~~$$\dot{m}_{rating} = \frac{\dot{q}_{in,ss,rated}}{c_{p,water}\left(T_{out,rating} - T_{in,rating}\right)}$$~~

$\dot{m}_{rating}$ mass flow rate at the conditions established by Section 7.7.1.1, as calculated using the following formula, lb/h (kg/h)

$$\dot{m}_{rating} = \frac{\dot{q}_{out,ss,rated}}{c_{p,water}\left(T_{out,rating} - T_{in,rating}\right)}$$

~~$T_{idle,\ rated,\ hi}$ rating temperature for high temperature idling test, = 180°F (82.2ºC)~~

$T_{idle,\ rated,\ hi}$ The target outlet temperature during the idling test under high temperature rating conditions, as specified in Section 4.1.1.2, °F (°C)

~~$T_{idle, rated, low}$ rating temperature for low temperature idling test, = 120°F (48.9ºC)~~

$T_{idle, rated, low}$ The target outlet temperature during the idling test under low temperature rating conditions, as specified in Section 4.1.1.2, °F (°C)

## 4. REQUIREMENTS

4.1 Types of Tests

**~~Table 1. Required (R) and Optional (O) Tests~~**

| ~~Boiler Type~~ | | ~~Steady State Tests~~ | | | | | | | | ~~Other tests~~ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ~~Single stage burner~~ | ~~Two-stage burner~~ | | ~~Step-modulating burner~~ | | | | | ~~All~~ | |
| | | ~~High fire~~ | ~~High fire~~ | ~~Low fire~~ | ~~High fire~~ | ~~Int fire 1**~~ | ~~Int fire 2**~~ | ~~Int fire 3**~~ | ~~Low fire~~ | ~~Idling~~ | ~~Throughflow~~ |
| ~~Steam~~ | ~~Steam~~ | ~~R~~ | ~~R~~ | ~~R~~ | ~~R~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~R~~ | ~~R~~ | ~~O~~ |
| ~~Hot Water~~ | ~~High boiler inlet water temperature (IWT)~~ | ~~R~~ | ~~R~~ | ~~R~~ | ~~R~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~R~~ | ~~R~~ | ~~O~~ |
| | ~~Other IWT 1***~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | | |
| | ~~Other IWT 2***~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | | |
| | ~~Other IWT 3***~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | | |
| | ~~Other IWT 4***~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~O~~ | | |
| | ~~Low IWT~~ | ~~R*~~ | ~~R*~~ | ~~R*~~ | ~~R*~~ | ~~O~~ | ~~O~~ | ~~O~~ | ~~R*~~ | ~~O~~ | ~~O~~ |

~~*Required for low inlet water temperature and condensing boilers only.~~

~~**Tests may be conducted for up to three intermediate firing rates. The same intermediate firing rates shall be used for all inlet water temperatures tested at intermediate firing rates.~~

~~***When steady-state tests are conducted at inlet water temperatures other than the required high and low temperatures, such tests shall include, at a minimum, tests at high and low fire, and may include tests at up to three intermediate firing rates.~~

**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 | Two-stage burner | | Step-modulating burner | | | All | |
| | | High fire | High fire | Low fire | High fire | Int fire [2] | Low fire | Idling | Throughflow |
| Steam | Steam | R | R | R | R | O | R | R | O |
| Hot Water | *High Temperature Rating* | R[4] | R[4] | R[4] | R[4] | O | R[4] | R[4] | O |
| | *Intermediate Temperature Rating*[3] | O | O | O | O | O | O | | |
| | *Low Temperature Rating* | R[1] | R[1] | R[1] | R[1] | O | R[1] | R[1] | O |

[1]Required for boilers compliant with 4.1.1.1 b and optional for all other boilers.
[2]Tests are allowed to be conducted for up to three intermediate firing rates. The same intermediate firing rates shall be used for all outlet (supply) water temperatures tested at intermediate firing rates.
[3]Optional steady-state tests at any outlet (supply) water temperature 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 both high and low firing rates and are allowed to include up to three intermediate firing rates that are also tested at the H*igh Temperature Rating*.
[4] *High Temperature Rating* tests are not required when the manufacturer's instructions shipped with the boiler state~~s~~ the outlet (supply) water temperature must be equal to or lower than 120°F (48.9°C).

### 4.1.1.2 Idling and Throughflow Tests

~~a. Idling tests shall be conducted at high boiler inlet water temperature, unless the manufacturer's instructions shipped with the boiler state the return water temperature must not exceed 120°F (48.9 °C), in which case the idling tests shall be conducted at low boiler inlet water temperature. Also,~~

~~b. Idling tests shall be conducted at low return water temperature, if requested by the manufacturer and if either or both of the following conditions are present:~~

- ~~the manufacturer's instructions shipped with the boiler state that boiler inlet water temperatures of 120°F (48.9°C) or lower are allowed.~~
- ~~the boiler is a condensing boiler.~~

~~c. Throughflow loss tests at high boiler inlet water temperature shall be conducted on a hot water boiler, if requested by the manufacturer.~~

~~d. Throughflow loss tests at low boiler inlet water temperature shall be conducted on hot water boilers, if requested by the manufacturer and where either or both of the following conditions are present:~~

- ~~the manufacturer's instructions shipped with the boiler state that boiler inlet water temperatures of 120°F (48.9 °C) or lower are allowed.~~
- ~~the boiler is a condensing boiler.~~

a. Idling tests for water boilers shall be conducted at the idle test target outlet (supply) temperature for boilers with a *High Temperature Rating* shown in Table 4 as specified in 7.9.2.2, 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* shown in Table 4 as specified in 7.9.2.2 .

b. Idling tests for water boilers shall be conducted at the idle test target temperature for boilers with a *Low Temperature Rating* shown in Table 4 as specified in 7.9.2.2, 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,

c. Throughflow loss tests for a hot water boiler shall be conducted at the high throughflow test inlet water temperature shown in Table 5, if requested and specified by the boiler manufacturer, and

d. Throughflow loss tests for a hot water boiler shall be conducted at the low throughflow test inlet water temperature shown in Table 5, 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.

## 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, the method of calibration, and the traceability to National Institute of Standards and Technology standards or equivalent national standards.

**Table 2. (IP)**

…..Other Properties Measured in Table are Unchanged…..

| Property Measured | Item Measured | Minimum Resolution | Minimum Accuracy | ***Informative Note:*** Example of Instrument Type | ***Informative Note:*** Approximate Range of Readings |
|---|---|---|---|---|---|
| Mass or Volume | Oil | 0.25% of hourly mass flow rate | ± 0.25% of hourly mass flow rate | Scale~~, Burette or Flow Meter~~ | Size for Rated Flow |

**Table 2. (SI)**

…..Other Properties Measured in Table are Unchanged…..

| Property Measured | Item Measured | Minimum Resolution | Minimum Accuracy | ***Informative Note:*** Example of Instrument Type | ***Informative Note:*** Approximate Range of Readings |
|---|---|---|---|---|---|
| Mass or Volume | Oil | 0.25% of hourly mass flow rate | ± 0.25% of hourly mass flow rate | Scale~~, Burette or Flow Meter~~ | Size for Rated Flow |

### 6.1 Test Room or Area

~~The test location should be of sufficient size to permit access to all parts of the test unit and instrumentation, as well as to maintain relatively stable ambient conditions. Provisions for removing the products of combustion from the test area and for supplying sufficient air for combustion are required.~~

The test location must be a size that permits access to all parts of the test unit and instrumentation, as well as to maintain stable ambient conditions. Provisions for removing the products of combustion from the test area and for supplying air for combustion are required.

**6.2.3.2 Vertical Discharge**.

…..Preceding Text Unchanged…..

When needed to collect liquid condensate entrained in the flue gas, the final vertical section and its connecting tee or elbow pipe diameter shall be increased to the largest industry diameter that does not cause the vent velocity to fall below 400 ft/min (2.54 m/s) when operating at maximum input. For a specific fuel, firing rate, excess air level, flue gas temperature, flue pipe diameter, and barometric pressure, the flue gas velocity ~~can~~ shall be calculated using methods provided in the ASHRAE Handbook [Chimney, Vent, and Fireplace Systems Chapter, HVAC Systems and Equipment Handbook]. Measurement of flue gas velocity for the purpose of selecting flue diameter is not required. This same flue diameter ~~can~~ shall be used during testing at lower input rates.

…..Remaining Text Unchanged…..

**6.3 Steam Piping**

A ~~typical~~ boiler set-up is shown diagrammatically in Figure 5. ~~Connect to the boiler risers and other near boiler piping~~ 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 nominal pipe size.

**6.4.1 Steady State Test**

~~The water outlet shall be connected to the boiler outlet (supply) connection of the boiler. Piping and attached devices between the boiler and at least ten pipe diameters upstream of Tin and between the boiler and at least ten pipe diameters downstream of Tout shall be insulated to a minimum of R7. The water inlet shall be connected to the boiler inlet ("return") connection of the boiler. Provision shall be made for heat rejection and control of the inlet water temperature. A recirculation loop, shown diagrammatically in Figure 6A, may be used to obtain the required temperature rise, or boiler water flow rate, specified by 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 which 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 R7.~~

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 (Tin) shall be insulated to a minimum of R7. Piping and attached devices between the boiler and at least ten pipe diameters downstream of the boiler outlet temperature

measurement location (Tout) shall be insulated to a minimum of R7. The water inlet shall be connected to the boiler inlet (return). Provisions shall be made for heat rejection and control of the inlet (return) water temperature. A recirculation loop, shown diagrammatically in Figure 6A, is allowed to be used to obtain the required temperature rise, or boiler water flow rate, specified by 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 which 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 R7.

**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 7 installed in a plane perpendicular to the flow of flue gas as shown in Figures 1 or 3, as appropriate. Thermocouples in the grid shall be made from thermocouple wire not larger than 22 gauge and shall be connected in parallel. Where ~~there is a possibility~~ thermocouples ~~could receive~~ are exposed to direct radiation from the burner flame, thermocouple radiation shields must be applied.

**6.5.5.1** With the boiler operating under steady state conditions described in 7.6, use a source of smoke to identify all jacket openings into which ambient air is ~~clearly~~ drawn. Other jacket openings having an area greater than 0.5in$^2$ (3.2 cm$^2$), which are not known to be needed for combustion air, ventilation, or draft control ~~may~~ shall be sealed with tape. For atmospheric boilers, record a flue $CO_2$ reading before and after sealing these openings. If the difference between these two readings is greater than 0.3%, identify and remove the tape which is causing this difference.

**6.5.6.2 Gas.** Gas shall be fed to the burner through a wet or dry gas meter. ~~Gas meter flow rate may not be below 10% of the maximum reading for the meter.~~ If $T_g$ cannot be measured inside the gas meter then ~~it~~ $T_g$ shall be measured upstream and within 6 inches of the gas meter and the gas piping shall be insulated with R-6 from the temperature sensor to the meter.

**6.5.7 Air Temperature and Humidity.** The inlet air temperature and relative humidity shall be measured ~~at the burner inlet~~ not greater than 12 inches (30 cm) from the point at which combustion air enters:

a. the boiler, where the burner or burners are located within the boiler, or
b. the burner, where the burner or burners are located external to the boiler, or
c. the coaxial combustion air entrance specified in Figures 4C and 4D, or
d. the combustion air entrance at the minimum intake duct length specified in the manufacturer's instructions supplied with the boiler.

The temperature sensor shall be shielded ~~where~~from thermal radiation ~~can it will change the measured temperature~~. ~~No a~~Artificial means of increasing the relative humidity or temperature shall not be applied between the point of measurement and the burner. The room ambient temperature and humidity shall be measured within 6 ft (1.83 m) in front of the unit at mid height of the unit.

**6.5.8.3 Boiler Water Temperature.** For the idling test, a direct immersion thermocouple shall be located in the highest ~~available~~ 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 ~~recommended~~ specified by the manufacturer in the manufacturer's instructions shipped with the boiler. The controller differential shall have a minimum accuracy of ± 1.0°F (0.5°C) and the setpoint shall have a minimum repeatability of ± 0.5°F (0.25°C).

**6.5.9.1 Water Temperatures.** The inlet (return) water temperature (Tin) shall be measured with a single sensor located as shown in Figure 6A and the greater of 12 inches (30.5 cm) or 4 pipe diameters ±1 pipe diameter upstream of the boiler inlet and downstream of all heat rejection devices, pumps, ~~and mixing locations, such as~~ recirculation loop connections, and other mixing locations. When a recirculation loop is used, water exiting the recirculation loop must flow through the branch of 4 tee's as shown in Figure 6A. Water exiting the boiler outlet must flow through a branch of 4 tees as shown in Figure 6A and the outlet water temperature (Tout) shall be measured with a single sensor located as shown in Figure 6A.

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

**7.1.2** For modulating boilers, all requirements in this section shall be met at both high fire and low fire as follows:

a. Where the manufacturer's instructions shipped with the boiler does not specify ~~no~~ burner adjustments at low fire, first obtain the high fire conditions as described in this section. Then adjust the firing rate to the required low or intermediate firing rate by controlling the boiler modulation system. ~~using the direct control variable that modulates input.~~
b. Where the manufacturer's instructions shipped with the boiler specify burner adjustments at both high and low fire, first obtain the required high fire and low fire conditions as described in this section. Then, if tests at intermediate firing rates are being performed, adjust the firing rate to the required intermediate firing rate by controlling the boiler modulation system. ~~using the direct control variable that modulates input.~~
c. If burner adjustments are required between tests to compensate for ~~changing conditions (such as~~ barometric pressure, higher heating value, or other changing conditions~~)~~, the laboratory shall confirm that the requirements in (a) and (b) above are met at both high and low fire before proceeding with the next test.

**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 ~~may~~ impact viewing ~~may~~ shall be removed or relocated, if ~~they~~ the components do not otherwise impact test results.

**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. ~~The heating surface of the boiler may be cleaned before each test.~~

**7.3.1 Oil.** Boilers with an Input Rating up to and including 5 gph shall use No. 2 (light) fuel oil not more than 5% biodiesel content. Boilers with an Input Rating in excess of 5 gph (18.9 L/hr) shall use No. 2 (light) fuel oil, or No. 4, 5, or 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 D396-15b Standard Specification for fuel oil but all fuels shall not contain greater than 5% biodiesel. #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 ~~adequate~~ required**.** Heating value shall be measured to an accuracy of ±1% following ASTM D240 or ASTM D4809. ~~to meet the specified biodiesel limit. A test of the biodiesel content is not required.~~

~~**7.3.2.1 Fuel Oil Analysis.** A representative sample of the fuel oil of approximately one quart shall be taken and analyzed to an accuracy of ±1% for the following values:~~

~~**7.3.2.1.1** Heating Value, per ASTM D240-14 or ASTM D4809-13;~~

~~**7.3.2.1.2** Hydrogen and carbon content, per ASTM D5291-10, and;~~

~~**7.3.2.1.3** Density in pounds per gallon and API gravity, according to the methods specified by ASTM D396-15b.~~

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

**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 below at any time during the test:

| **Temperature at start of test** | | **Allowable variation in temperature** | | | |
|---|---|---|---|---|---|
| | | **Light oil, ~~&~~ natural gas, or propane** | | **Heavy oil** | |
| °F | °C | °F | °C | °F | °C |
| T ≤300 | T ≤148.9 | 5.0 | 2.8 | 7.5 | 4.2 |
| 300< T ≤400 | 148.9< T ≤204.4 | 7.0 | 3.9 | 11.0 | 6.1 |

| | | | | | |
|---|---|---|---|---|---|
| 400< T ≤500 | 204.4< T ≤260 | 9.0 | 5.0 | 13.5 | 7.5 |

**7.6.4 ~~Ambient~~ Inlet Humidity.** The inlet relative humidity of the room for condensing boilers shall not exceed 80 percent when recorded at the specified interval. ~~For condensing boiler, the relative humidity of the combustion air shall not differ by more than 5% from the room air relative humidity.~~

**7.6.5.1.4 No Specified $CO_2$ or $O_2$ Level or Range.** If ~~there is no~~ a burner $CO_2$ or $O_2$ level or range is not specified in the manufacturer's instructions shipped with the boiler, the burner system shall be adjusted to within ±0.2% of the $CO_2$ level closest to 8% for natural gas firing, 9% for propane firing, and 11% for oil firing that ~~also~~ 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.

**7.7.1.1 Water Temperatures**. The boiler temperature rise ($T_{out}$-$T_{in}$) and the outlet temperature shall be within the temperature tolerances in Table 3 at all times during each test. Exception: If the boiler manufacturer's instructions shipped with the boiler prohibit operation at the boiler water flow rate, at the calculated ~~and/or inferred~~ inlet temperature, or at both shown in Table 3, increase the boiler water flow rate not higher than required to ~~a point just sufficient to meet~~ the manufacturer's requirements, while maintaining the outlet temperature at the value shown in Table 3 (boiler rise will be less than that shown in Table 3). This ~~can~~ shall be accomplished by means of a recirculation loop as shown in Figure 6A, or by otherwise increasing the water flow rate through the boiler.

**~~Table 3. Outlet Water Temperature and Boiler Temperature Rise (IP Version)~~**

| ~~Test~~ | ~~Outlet Temp~~ | ~~Outlet Temp Tolerance~~ | ~~Boiler Rise (Tout-Tin) (NOTE 1)~~ | ~~Boiler Rise Tolerance~~ |
|---|---|---|---|---|
| ~~High Fire / High Temp~~ | ~~180°F~~ | ~~± 2.5°F~~ | ~~40°F~~ | ~~± 2°F~~ |
| ~~High Fire / Low Temp~~ | ~~120°F~~ | ~~±2. 5°F~~ | ~~40°F~~ | ~~± 2°F~~ |
| ~~High Fire / Optional Temp~~ | ~~Between 120°F and 180°F~~ | ~~± 2.5°F~~ | ~~40°F~~ | ~~± 2°F~~ |
| ~~Low and Intermediate Fire / High Temp~~ | ~~180°F~~ | ~~± 2.5°F~~ | ~~40°F~~ | ~~± 2°F~~ |
| ~~Low and Intermediate Fire / Low Temp~~ | ~~120°F~~ | ~~± 2.5°F~~ | ~~40°F~~ | ~~± 2°F~~ |
| ~~Low and Intermediate Fire / Optional Temp~~ | ~~Between 120°F and 180°F~~ | ~~± 2.5°F~~ | ~~40°F~~ | |

~~NOTE 1: Boiler rise may be lower in order to meet manufacturers recommended minimum flow rate based on manufacturer's instructions shipped with the boiler.~~

**~~Table 3. Outlet Water Temperature and Boiler Temperature Rise (SI Version)~~**

| ~~Test~~ | ~~Outlet Temp~~ | ~~Outlet Temp Tolerance~~ | ~~Boiler Rise (Tout-Tin) (NOTE 1)~~ | ~~Boiler Rise Tolerance~~ |
|---|---|---|---|---|
| ~~High Fire / High Temp~~ | ~~82.2°C~~ | ~~± 1.4°C~~ | ~~22.2°C~~ | ~~± 1.1°C~~ |
| ~~High Fire / Low Temp~~ | ~~48.9°C~~ | ~~±1.4°C~~ | ~~22.2°C~~ | ~~± 1.1°C~~ |
| ~~High Fire / Optional Temp~~ | ~~Between 48.9°C and 82.2°C~~ | ~~± 1.4°C~~ | ~~22.2°C~~ | ~~± 1.1°C~~ |
| ~~Low and Intermediate Fire / High Temp~~ | ~~82.2°C~~ | ~~± 1.4°C~~ | ~~22.2°C~~ | ~~± 1.1°C~~ |
| ~~Low and Intermediate Fire / Low Temp~~ | ~~48.9°C~~ | ~~± 1.4°C~~ | ~~22.2°C~~ | ~~± 1.1°C~~ |
| ~~Low and Intermediate Fire / Optional Temp~~ | ~~Between 48.9°C and 82.2°C~~ | ~~± 1.4°C~~ | ~~22.2°C~~ | |

~~NOTE 1: Test rig rise may be lower in order to meet manufacturers recommended minimum flow rate. Based on manufacturer's instructions shipped with the boiler.~~

**Table 3. Outlet (Supply) Water Temperature and Boiler Temperature Rise (IP Version)**

| Test / Rating Condition | Outlet Temp | Outlet Temp Tolerance | Boiler Rise (Tout-Tin) (NOTE 1) | Boiler Rise Tolerance |
|---|---|---|---|---|
| High Fire / *High Temperature Rating* | 180ºF | ± 2.5°F | 40ºF | ± 2°F |
| High Fire / *Low Temperature Rating* | 120ºF | ±2.5°F | 40ºF | ± 2°F |
| High Fire / *Intermediate Temperature Rating*, Optional Test | Between 120ºF and 180ºF | ± 2.5°F | 40ºF | ± 2°F |
| Low and Intermediate Fire / *High Temperature Rating* | 180ºF | ± 2.5°F | 40ºF | ± 2°F |

| | | | | |
|---|---|---|---|---|
| Low and Intermediate Fire / *Low Temperature Rating* | 120ºF | ± 2.5°F | 40ºF | ± 2°F |
| Low and Intermediate Fire / *Intermediate Temperature Rating*, Optional Test | Between 120ºF and 180ºF | ± 2.5°F | 40ºF | |

NOTE 1: Test rig rise is allowed to be lower, if required to meet manufacturer's specified minimum flow rate. ~~–~~ specified in the manufacturer's instructions supplied with the boiler (see 7.3.1.1).

**Table 3. Outlet (Supply) Water Temperature and Boiler Temperature Rise (SI Version)**

| **Test / Rating Condition** | **Outlet Temp** | **Outlet Temp Tolerance** | **Boiler Rise (Tout-Tin) (NOTE 1)** | **Boiler Rise Tolerance** |
|---|---|---|---|---|
| High Fire / *High Temperature Rating* | 82.2ºC | ± 1.4°C | 22.2ºC | ± 1.1°C |
| High Fire / *High Temperature Rating* | 48.9ºC | ±1.4°C | 22.2ºC | ± 1.1°C |
| High Fire / *Low Temperature Rating* | Between 48.9ºC and 82.2ºC | ± 1.4°C | 22.2ºC | ± 1.1°C |
| High Fire / *Intermediate Temperature Rating*, Optional Test | 82.2ºC | ± 1.4°C | 22.2ºC | ± 1.1°C |
| Low and Intermediate Fire / *High Temperature Rating* | 48.9ºC | ± 1.4°C | 22.2ºC | ± 1.1°C |
| Low and Intermediate Fire / *Intermediate Temperature Rating*, Optional Test | Between 48.9ºC and 82.2ºC | ± 1.4°C | 22.2ºC | |

NOTE 1: Test rig rise is allowed to be lower, if required to meet manufacturer's specified minimum flow rate. ~~–~~ specified in the manufacturer's instructions supplied with the boiler (see 7.3.1.1).

**7.7.1.2 Verification of Manufacturer's minimum ~~recommended~~ specified flow rate.** If the boiler manufacturer's instructions shipped with the boiler specify a minimum flow rate through the boiler, the flow meter shown in Figure 6 shall be used to verify that this flow rate is met or exceeded during the conduct of all tests.

**7.9.2.1 Water Flow Rate**. The water flow rate during the entire idle test period shall be the high fire flow rate as measured during the high fire test or as calculated in 10.8 ± 15%. When the piping shown in Figures 6A and 6B is used, this shall be confirmed using a flow meter. When the piping setup shown in Figure 6C 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 Idling Tests.

~~**7.9.2.2 Water Temperature Control.** A burner on sequence shall be initiated when the boiler water outlet temperature falls 5°F ±1°F (2.8°C ± 0.6 °C) below the midpoint temperature described in the table below and a burner off sequence shall be initiated when the boiler outlet water temperature rises 5°F ±1°F (2.8°C ± 0.6 °C) above the same midpoint temperature.~~

| ~~**Room temperature**~~ | ~~**High temperature idle test midpoint temperature**~~ | ~~**Low temperature idle test midpoint temperature**~~ |
|---|---|---|
| ~~≤ 75°F (≤ 23.9ºC)~~ | ~~180°F (82.2°C)~~ | ~~120°F (48.9°C)~~ |
| ~~> 75°F (> 23.9ºC)~~ | ~~105°F (58.3°C) above room temperature~~ | ~~45°F (25.0°C) above room temperature~~ |

**7.9.2.2 Water Temperature Control.** A burner on sequence shall be initiated when the boiler water outlet (supply) temperature falls 5°F ±1°F (2.8°C ± 0.6 °C) below the target temperature described in Table 4, and a burner off sequence shall be initiated when the boiler outlet (supply) water temperature rises 5°F ±1°F (2.8°C ± 0.6°C) above the same target temperature.

Table 4: Idle Test Target Outlet (Supply) Temperatures

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

~~**7.10.2 Water Temperature.** The boiler inlet water temperature shall be maintained as follows for the duration of the test.~~

| ~~**Room temperature**~~ | ~~**High temperature throughflow test**~~ | ~~**Low temperature throughflow test**~~ |
|---|---|---|

| | | |
|---|---|---|
| ~~≤ 75°F (≤ 23.9ºC)~~ | ~~180°F ± 5°F (82.2°C ±2.8°C)~~ | ~~120°F ± 5°F (48.9°C ±2.8°C)~~ |
| ~~> 75°F (> 23.9ºC)~~ | ~~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~~ |

**7.10.2 Water Temperature.** The boiler inlet (return) water temperature shall be maintained as shown in Table 5 for the duration of the test.

Table 5: Throughflow Test Inlet (Return) Water Temperatures

| **Room temperature** | **Boilers with *High Temperature Rating*** | **Boilers with *Low Temperature Rating*** |
|---|---|---|
| ≤ 75°F (≤ 23.9ºC) | 180°F ± 5°F (82.2°C ±2.8°C) | 120°F ± 5°F (48.9°C ±2.8°C) |
| > 75°F (> 23.9ºC) | 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 |

**8.2.1.1.3** Tests ~~may be made~~ 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 ~~may be started as soon as~~ 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 flow meters, ~~and/or~~ 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 ~~no~~ a water level is not specified in the instructions shipped with the boiler, the water level shall be maintained within ± 1 inch (±25.4 mm) of the water level indicated on the boiler or, if ~~no~~ a water level is not indicated on the boiler, the water level shall be maintained at 3 inches ± 1 inch (76.2 ±25.4 mm) above the highest fired surface.

**8.2.2.1.1** With all required test apparatus ~~properly~~ connected, and with the boiler and piping filled and with water ~~such that~~ flowing~~s~~ 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.

**8.2.2.1.4** Readings ~~may be started as soon as~~ 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, ~~or~~ the gas meter, oil meter, or ~~read, and/or the~~ wattmeter shall be read, and measurement of flows shall be started.

### 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. ~~The humidity of the room shall at no time exceed 80%.~~ 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.

**8.2.4.1** Outer Surface Convective and Radiative Loss – The following test procedure shall be performed at all inputs and ~~boiler inlet~~ water temperatures ~~(IWT)~~ 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:**
1. The boiler manufacturer is allowed to apply the jacket loss rates (as energy per unit time) identified at higher input rates ~~are allowed to apply~~ as the jacket loss rates at lower input rates for the same boiler inlet water temperature. The absolute jacket loss rate identified at higher boiler inlet water temperatures is allowed to be used as the absolute jacket loss rate ~~apply~~ at lower boiler inlet water temperatures for the same input rate, and

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 ~~A~~ default jacket loss rate of 1.0% of the full load input rate ~~is allowed to apply, in lieu of test determination,~~ 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 and ~~have R-5 ($ft^2 \cdot °F \cdot hr/Btu$) or greater~~ the jacket ~~insulation~~ 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 full load input rate is allowed to apply~~, in lieu of test determination,~~ for all condensing boilers.

**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 six inches of the boiler bottom measured using the method described in 8.2.4.1.3 and 8.2.4.1.4. Exception: The bottom of the boiler ~~may~~ shall be excluded from jacket loss calculation if the bottom jacket perimeter is less than or equal to 3 inches (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.

**8.2.4.3.4** Record the relative humidity of the ~~ambient~~ inlet air ($R_h$).

**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 1 cycle for stabilization if the cycle time exceeds 10 minutes. If the average cycle time is equal to or less than 10 minutes, then the test shall be immediately preceded by a minimum of 3 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.

Two test cycles, following the initial cycle(s) for stabilization, are permitted if the idling energy input rates, measured in total energy consumed during a cycle divided by the cycle period, for two consecutive cycles are within 5% of each other. If this condition is not met, then 6 test cycles, following the initial cycles for stabilization are required.

Test cycles must be consecutive with each other and immediately follow ~~with~~ the stabilization cycle(s). Total energy input and total time for the test cycles shall be measured for the calculations in Section 10.6. Closure of the controller call for heat contact shall indicate the end of one cycle and the start of the next. For electric boilers that do not cycle in a 32 hour period, the last 24 hours shall be the test period.

**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 ~~possible without~~ that does not cause steaming, including steaming ~~taking into account any carry-over rise in temperature~~ that occurs after the burner shuts off. ~~No a~~Adjustments shall not be made to the controller setpoint or differential during the stabilization cycles or test cycles.

**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 ~~it~~ the heater is able to maintain the outlet water temperature within ± 2°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.

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

…..Preceding Text Unchanged…..

Barometric pressure (not required for oil-fired water boilers, Pa) ~~steam or natural gas only)~~

…..Remaining Text Unchanged…..

**10.1.1.1 Measurements to be Averaged (Mean) Over the Test Period**. For the following parameters (if recorded), the average (mean) of the values recorded during the test period shall be used for the calculations in this section:

…..Other Parameters Unchanged…..

Inlet (return) water temperature, $T_{in}$
Steam ~~Boiler~~ temperature, $T_{blr}$ (only for steam boilers)
Outlet (supply) water temperature, $T_{out}$
Inlet relative humidity, $R_h$

**10.1.3.1** Sensible Heat Loss in Dry Flue Gases, $L_S$, Percent

…..Preceding Text Unchanged…..

C = Default value of carbon content of fuel, % which is:
=85.04% for No. 2 fuel oil
=87.85% for No. 4 fuel oil
=88.0% for No. 5 fuel oil
=88.19% for No. 6 fuel oil

H = Default value of hydrogen content of fuel, % which is:
=12.97% for No. 2 fuel oil
=12.15% for No. 4 fuel oil
=12.0% for No. 5 fuel oil
=10.81% for No. 6 fuel oil

…..Remaining Text Unchanged…..

**10.1.4 Steady State Flue Loss for Natural Gas and Propane Fired Boilers, $L_f$, Percent**

IP:

$$L_f = \frac{1}{379}\left(C_1 + C_2 + C_3 + C_4\right) + 5.04\left(T - P\right)$$

where:

$$C_1 = \left(\frac{PU}{1000}\right)\left[16.2\left(T_f - T_a\right) + 6.53*10^3 \ln\frac{T_a}{T_f} + 1.41*10^6\left(T_a^{-1} - T_f^{-1}\right)\right]$$

$$C_2 = \left(\frac{P}{10}\right)\left[1 - \frac{U}{100}\right]\left[9.47\left(T_f - T_a\right) + 3.47*10^3 \ln\frac{T_a}{T_f} + 1.16*10^6\left(T_a^{-1} - T_f^{-1}\right)\right]$$

$$C_3 = \left(\frac{P}{10}\right)\left[\frac{U - CO_2}{CO_2}\right]\left[9.46\left(T_f - T_a\right) + 3.29*10^3 \ln\frac{T_a}{T_f} + 1.07*10^6\left(T_a^{-1} - T_f^{-1}\right)\right]$$

$$C_4 = \left[\frac{T - P}{10} + 0.0017\frac{R_h}{100}A\right]\left[1 + \frac{P}{A}\left(\frac{U - CO_2}{CO_2}\right)\right]\left[19.86\left(T_f - T_a\right) + 7.5*10^3 \ln\frac{T_f}{T_a} + 1194\left(T_a^{1/2} - T_f^{1/2}\right)\right]$$

where:

~~A= 9.4 SCF per 1,000 Btu of gas burned~~

$CO_2$ = $CO_2$ in flue gases, percent of total dry constituents in the flue gas, shall be measured, or calculated per:

$$CO_2 = U \cdot \frac{\left(20.9 - O_{2,meas}\right)}{20.9}$$

~~P = 8.47 SCF per 1,000 Btu of gas burned~~
~~T= 10.42 SCF per 1,000 Btu of gas burned~~
~~$U_{gas}$ = Ultimate $CO_2$ of the flue gas = 11.9%~~

For all equations in this section, the following constants shall be used for natural gas:
A=9.44
P=8.47
T=10.42
U=11.9

For all equations in this section, the following constants shall be used for propane:
A=9.44
P=8.65
T=10.23
U=13.75

**10.2.1.1.2** When calculating, ignore the bottom convective losses if:

a) the boiler is close to the floor~~, such that~~ and heat from the bottom does not convectively escape into the room, or
b) the bottom freely communicates with the combustion air~~, such that~~ and all convective losses from the bottom are drawn into the combustion chamber.

**10.2.2 Jacket Internal Convective Flow Loss.** The jacket loss rate due to cooling air flow out of the top of the jacket ~~may~~ shall be assumed to be at a default value of 300 Btu/ft$^2$ hr or a loss rate measurement ~~may~~ shall be performed as per the following sections.

**10.2.2.1** Density of ambient air, $\rho_{amb}$, lb~~m~~/ft$^3$

$\rho_{amb} = 1.325 \times (P_{baro}/(T_{room} + 459.67\text{~~60~~}))$

where:
$P_{baro}$ = Barometric pressure, inches Hg
$T_{room}$ = Room temperature, F

**10.2.2.2** Density of air exiting jacket opening "x," $\rho_{OX}$, lb/ft$^3$

$\rho_{OX} = 1.325 \times (P_{baro}/(T_{OX} + 459.67\text{~~60~~}))$

where:
$P_{baro}$ = Barometric pressure, inches Hg
$T_{OX}$ = Temperature of air exiting jacket opening "x," F

**10.2.2.6** For boilers which draw dilution air from within the jacket, calculate the density of dilution air at draft diverter entrance, $\rho_{OD}$, lb/ft$^3$

$$\rho_{OD} = 1.325 \times (P_{baro}/(T_D + 459.67\text{~~60~~}))$$

where:
$P_{baro}$ = Barometric pressure, inches Hg
$T_D$ = Temperature of dilution air at draft diverter entrance, F

**10.2.2.9** Saturation Pressure of Liquid Water, $P_{ws}$, psia

$$P_{ws} = e^{\left[C_1/T_r + C_2 + C_3 \bullet T_r + C_4 \bullet T_r^2 + C_5 \bullet T_r^3 + C_6(\ln(T_r))\right]}$$

where:
Tra = $T_{room}$ + 459.67~~60~~
$C_1$ = -1.0440397E+04
$C_2$ = -1.1294650E+01
$C_3$ = -2.7022355E-02
$C_4$ = 1.2890360E-05
$C_5$ = -2.4780681E-09
$C_6$ = 6.5459673

[Source: 2013 Handbook of Fundamentals, Chapter 1, eq. 6]

**10.2.2.10** Absolute humidity of ambient air, $W_{room}$, lb~~m~~ water / lb~~m~~ dry air

$W_{room} = 0.6219[(P_{ws})(R_h/100) / [(P_{baro})(0.4911) – (P_{ws})(R_h/100)]]$ where:

$R_h$ = inlet ~~R~~relative humidity, %
0.4911 = Factor to convert inHg to psia
0.6219 = Factor to convert mole fraction to mass fraction

[Source: 2013 Handbook of Fundamentals, Chapter 1, eq. 22]

### 10.2.3 Total Jacket Loss, $\dot{q}_{jacket,ss}$ ~~qdot jacket,total~~, Btu/h (kW)

$$\dot{q}_{jacket,ss} = \sum H_s + Q_{CX}$$

**10.6.2.1** Steam
IP:

$$\dot{q}_{in,idle,corr} = \dot{q}_{in,idle,test} \frac{(200 - 75)}{(T_{blr} - T_{room})}$$

where:

200 = ~~standard~~ rating condition for steam boiler water temperature during idling test, °F

75 = ~~standard~~ rating condition for room air temperature during idling test, °F

SI:

$$\dot{q}_{in,idle,corr} = \dot{q}_{in,idle,test} \frac{(93.3 - 23.9)}{(T_{blr} - T_{room})}$$

where:

93.3 = ~~standard~~ rating condition for steam boiler water temperature during idling test, °C

23.9 = ~~standard~~ rating condition for room air temperature during idling test, °C

**10.6.2.2** High Water Temperature Hot Water

IP:

$$\dot{q}_{in,idle,corr} = \dot{q}_{in,idle,test} \frac{(180-75)}{(T_{out}-T_{room})}$$

where:

~~180 = rating condition for outlet water temperature during high temperature idling test, °F~~
180 = nominal outlet water temperature, °F
~~75 = rating condition for room air temperature during idling test, °F~~
75 = nominal room air temperature, °F

SI:

$$\dot{q}_{in,idle,corr} = \dot{q}_{in,idle,test} \frac{(82.2-23.9)}{(T_{out}-T_{room})}$$

where:
82.2 = ~~rating condition for outlet water temperature during high temperature idling test, °C~~
82.2 = nominal outlet water temperature, °C
23.9 = ~~rating condition for room air temperature during idling test, °C~~
23.9 = nominal room air temperature, °C

**10.6.2.3** Low Water Temperature Hot Water
IP:

$$\dot{q}_{in,idle,corr} = \dot{q}_{in,idle,test} \frac{(120-75)}{(T_{out}-T_{room})}$$

where:
~~120 = rating condition for outlet water temperature during low temperature idling test, °F~~
120 = nominal outlet water temperature, °F
~~75 = rating condition for room air temperature during idling test, °F~~
75 = nominal room air temperature, °F

SI:

$$\dot{q}_{in,idle,corr} = \dot{q}_{in,idle,test} \frac{(48.9-23.9)}{(T_{out}-T_{room})}$$

where:
~~48.9 = rating condition for outlet water temperature during low temperature idling test, °C~~
48.9 = nominal outlet water temperature, °C
~~23.9 = rating condition for room air temperature during idling test, °C~~
23.9 = nominal room air temperature, °C

10.7.2.1 High Water Temperature Hot Water
IP:

$$\dot{q}_{thru,rated} = \dot{q}_{thru,test} \frac{(180 - 75)}{(T_{inlet} - T_{room})}$$

where:
~~180 = rating condition for outlet water temperature during high temperature throughflow loss test, °F~~
180 = nominal inlet water temperature, °F
~~75 = rating condition for room air temperature during high temperature throughflow loss test, °F~~
75 = nominal room air temperature, °F

SI:

$$\dot{q}_{thru,rated} = \dot{q}_{thru,test} \frac{(82.2 - 23.9)}{(T_{inlet} - T_{room})}$$

where:
~~82.2 = rating condition for outlet water temperature during high temperature throughflow loss test, °C~~
82.2 = nominal inlet water temperature, °C
~~23.9 = rating condition for room air temperature during high temperature throughflow loss test, °C~~
23.9 = nominal room air temperature, °C

**10.7.2.2** Low Water Temperature Hot Water

IP:

$$\dot{q}_{thru,rated} = \dot{q}_{thru,test} \frac{(120 - 75)}{(T_{inlet} - T_{room})}$$

where:
~~120 = rating condition for outlet water temperature during low temperature throughflow loss test, °F~~
120 = nominal inlet water temperature, °F
~~75 = rating condition for room air temperature during low temperature throughflow loss test, °F~~
75 = nominal room air temperature, °F

SI:

$$\dot{q}_{thru,rated} = \dot{q}_{thru,test} \frac{(48.9 - 23.9)}{(T_{inlet} - T_{room})}$$

where:
~~48.9 = rating condition for outlet water temperature during low temperature throughflow loss test, °C~~
48.9 = nominal inlet water temperature, °C
~~23.9 = rating condition for room air temperature during low temperature throughflow loss test, °C~~
23.9 = nominal room air temperature, °C

**10.8 Calculation of boiler water mass flow rate during steady state test, $\dot{m}_{rating}$ , by heat balance, lb~~m~~/hr(kg/hr)**

$$\dot{m}_{rating} = \frac{\dot{q}_{out,ss,rated}}{c_{p,water}\left(T_{out,rating} - T_{in,rating}\right)}$$

**11.1.1.1** Using measured flue gas oxygen content:

$$f_{xs} = \frac{(C_1 O_2)}{100(C_2 - C_3 O_2)}$$

where $C_1$, $C_2$, and $C_3$ are taken from the table below:

| | **$C_1$** | **$C_2$** | **$C_3$** |
|---|---|---|---|
| natural gas | 5228 | 1223 | 58.21 |
| propane | 5234 | 1209 | 58.09 |
| No. 2 fuel oil | 4580 | 1030 | 49.02 |
| No. 4 fuel oil | 4631 | 1037 | 49.37 |
| No. 5 fuel oil | 4608 | 1031 | 49.06 |
| No. 6 fuel oil | 4514 | 1005 | 47.86 |

***Informative Note:*** Table based on same fuel composition as for Section 12.~~1~~.2.3.2.1.

**11.1.1.2** Using measured flue gas carbon dioxide content:

$$f_{xs} = \frac{(C_4 - C_5 CO_2)}{100(C_6 CO_2)}$$

where $C_4$, $C_5$, $C_6$ are taken from the table below:

| | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|
| natural gas | 629.8 | 52.82 | .582 |
| propane | 730.0 | 53.04 | .581 |
| No. 2 fuel oil | 708.0 | 45.80 | .490 |
| No. 4 fuel oil | 731.4 | 46.31 | .494 |
| No. 5 fuel oil | 732.7 | 46.08 | .491 |
| No. 6 fuel oil | 734.3 | 45.15 | .479 |

***Informative Note:*** Table based on same fuel composition as for Section 12.~~1~~.2.3.2.1.

### 11.2.1 Idling Heat Input Rate, $\dot{q}_{in,idle,corr,water}$, Btu/h (kW)

IP:

$$\dot{q}_{in,idle,corr,water} = \dot{q}_{in,idle,corr,steam}\left(\frac{180-75}{200-75}\right)$$

where:

200 = ~~standard~~ rating condition for steam boiler water temperature during idling test, °F

180 = ~~standard~~ rating condition for water boiler outlet water temperature during idling test, °F

75 = standard rating condition for room air temperature during idling test, °F

SI:

$$\dot{q}_{in,idle,corr,water} = \dot{q}_{in,idle,corr,steam}\left(\frac{82.2-23.9}{93.3-23.9}\right)$$

where:

93.3 = ~~standard~~ rating condition for steam boiler water temperature during idling test, °C

82.2 = ~~standard~~ rating condition for water boiler outlet water temperature during idling test, °C

23.9 = ~~standard~~ rating condition room air temperature during idling test, °C

### 12.1.1 Nominal adiabatic flame temperature, ~~T~~$_{flame}$ °F (°C)

IP:

$$T_{flame,nom}(^{o}F) = 845.75\,f_{xs}^{2} - 2333.1\,f_{xs} + 3643.9$$

SI:

$$T_{flame,nom}(^{o}C) = 469.9\, f_{xs}^{2} - 1296.2\, f_{xs} + 2006.6$$

~~Where: $f_{xs}$ = fraction of excess air in flue gas (dimensionless), Section 11.1.1.~~

**12.2.3.1** Performance shall not be extrapolated to boiler inlet (return) water temperatures below 80°F (26.7°C) or the minimum entering (return) water temperature ~~recommended~~ specified by the ~~manufacturer in the~~ manufacturer's instructions shipped with the boiler, whichever is higher, nor above 180°F (82.2°C) or the maximum entering (return) water temperature ~~recommended~~ specified by the manufacturer's instructions shipped with the boiler, whichever is lower. Performance shall not be extrapolated to outlet water temperatures above the maximum leaving water temperature ~~recommended~~ specified by the ~~manufacturer~~ the manufacturer's instructions shipped with the boiler.

**12.2.3.2.1** Nominal boiler inlet (return) water temperature at which condensation begins, $T_{inlet,trans,nom}$, °F (°C).

The boiler ~~return~~ inlet (return) water temperature at which condensation begins shall be interpolated from Table 6. Percent excess air shall be calculated according to Section 11.1.1.

**Table 46-IP. Nominal inlet (return) water temperature at which condensation begins, $T_{inlet,trans,nom}$, °F**

| Excess Air (%) | Natural gas | Propane | #2 oil | #4 oil | #5 oil | #6 oil |
|---|---|---|---|---|---|---|
| 0 | 133.8 | 133.8 | 118.5 | 116.8 | 116.5 | 114.0 |
| 10 | 130.6 | 130.8 | 115.4 | 113.7 | 113.4 | 111.0 |
| 20 | 127.7 | 128.1 | 112.6 | 110.9 | 110.7 | 108.2 |
| 30 | 125.0 | 125.6 | 110.1 | 108.4 | 108.1 | 105.7 |
| 40 | 122.5 | 123.3 | 107.8 | 106.1 | 105.8 | 103.5 |
| 50 | 120.2 | 121.3 | 105.6 | 104.0 | 103.7 | 101.4 |
| 70 | 116.2 | 117.6 | 101.8 | 100.2 | 99.9 | 97.6 |
| 100 | 111.0 | 112.9 | 97.0 | 95.4 | 95.1 | 92.9 |
| 150 | 104.0 | 106.8 | 90.5 | 89.0 | 88.8 | 86.7 |
| 200 | 98.5 | 102.1 | 85.5 | 84.0 | 83.8 | 81.8 |

**Table 6-SI. Nominal inlet (return) water temperature at which condensation begins, $T_{inlet,trans,nom}$, °C**

| Excess Air (%) | Natural gas | Propane | #2 oil | #4 oil | #5 oil | #6 oil |
|---|---|---|---|---|---|---|
| 0 | 56.6 | 56.6 | 48.1 | 47.1 | 46.9 | 45.6 |
| 10 | 54.8 | 54.9 | 46.3 | 45.4 | 45.2 | 43.9 |
| 20 | 53.1 | 53.4 | 44.8 | 43.8 | 43.7 | 42.4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 30 | 51.7 | 52.0 | 43.4 | 42.4 | 42.3 | 41.0 |
| 40 | 50.3 | 50.7 | 42.1 | 41.2 | 41.0 | 39.7 |
| 50 | 49.0 | 49.6 | 40.9 | 40.0 | 39.8 | 38.5 |
| 70 | 46.8 | 47.5 | 38.8 | 37.9 | 37.7 | 36.5 |
| 100 | 43.9 | 45.0 | 36.1 | 35.2 | 35.1 | 33.8 |
| 150 | 40.0 | 41.6 | 32.5 | 31.7 | 31.5 | 30.4 |
| 200 | 37.0 | 39.0 | 29.7 | 28.9 | 28.8 | 27.6 |

***Informative note:*** These tables assume that the ambient air humidity is 0.004 lb/lb dry air and that condensation begins when the inlet water temperature is 5°F below the dew point of the flue gases. ~~They~~ The tables are based on the following fuel compositions:

Natural gas: 93.4% methane, 3.0% ethane, 0.7% propane, 1.2% $CO_2$, 1.3% nitrogen, 0.4% $C_4H_{10}$.
Propane: 97.3% propane, 2.2% ethane, 0.5% butane

Liquid fuels:

| **% by weight** | **# 2 oil** | **#4 oil** | **#5 oil** | **#6 oil** |
|---|---|---|---|---|
| C | 85.04 | 87.85 | 88.0 | 88.19 |
| H | 12.97 | 12.15 | 12.0 | 10.81 |
| O | 0 | 0 | 0 | 0.05 |

**12.2.3.3** Steady state output as a function of inlet (return) water temperature between the *high temperature rating* ~~point~~ and the temperature of transition to condensing operation as identified in Table 4, for fixed input rate and water flow rate.

**12.2.3.3.1** Boilers for which the only steady state test conducted is ~~the high temperature rating test~~ at the *high temperature rating*.

For a non-condensing boiler or for a condensing boiler at ~~leaving~~ boiler inlet (return) water temperatures down to and including the transition to condensing operation, output as a function of inlet water temperature shall be calculated as:

$$\dot{q}_{out,ss}\left\langle T_{in}\right\rangle = \dot{q}_{in,ss}\left(\frac{100-L_f}{100}\right)\left(\frac{T_{flame,nom}-T_{in}}{T_{flame,nom}-T_{in,rated,high}}\right)-\dot{q}_{jacket,ss}$$

where:

$T_{flame}$ is calculated according to Section 12.1.1.

$L_f$ and $\dot{q}_{jacket,nom}$ are calculated according to equations in Section 10.2.

**12.2.3.4** Steady state output as a function of ~~leaving~~ boiler inlet (return) water temperature between the transition to condensing operation and the *low temperature rating* ~~point~~.

**12.4.3 Boilers for which both high and low temperature idling tests are conducted.**

The idling energy input at water temperature $T_{idle}$ shall be calculated as a quadratic function of boiler idling water temperature minus room air temperature, passing through the energy input at the *low temperature rating*, energy input at the *high temperature rating*, ~~two rating points~~ and zero idling energy input at zero temperature difference:

$$\dot{q}_{in,idle}\left\langle T_{idle}\right\rangle = a*(T_{idle}-T_{room,rated})^2 + b*(T_{idle}-T_{room,rated})$$

where:

$$a = \frac{\dot{q}_{in,idle,rated,hi}\left(T_{idle,rated,lo}-T_{room,rated}\right)-\dot{q}_{in,idle,rated,lo}\left(T_{idle,rated,hi}-T_{room,rated}\right)}{\left(T_{idle,rated,hi}-T_{room,rated}\right)^2\left(T_{idle,rated,lo}-T_{room,rated}\right)-\left(T_{idle,rated,lo}-T_{room,rated}\right)^2\left(T_{idle,rated,hi}-T_{room,rated}\right)}$$

$$b = \frac{\dot{q}_{in,idle,rated,hi}\left(T_{idle,rated,lo}-T_{room,rated}\right)^2-\dot{q}_{in,idle,rated,lo}\left(T_{idle,rated,hi}-T_{room,rated}\right)^2}{\left(T_{idle,rated,hi}-T_{room,rated}\right)\left(T_{idle,rated,lo}-T_{room,rated}\right)^2-\left(T_{idle,rated,lo}-T_{room,rated}\right)\left(T_{idle,rated,hi}-T_{room,rated}\right)^2}$$

**12.5.1 Boilers for which both high and low temperature throughflow loss tests are conducted.**

The throughflow loss at water temperature $T_{thru}$ and rated room temperature $T_{room,rated}$ shall be calculated as a quadratic function of boiler idling water temperature minus room air temperature, passing through the energy input at the *low temperature rating*, energy input at *high temperature rating*, ~~two rating points~~ and zero throughflow loss at zero temperature difference:

$$\dot{q}_{in,thru}\left\langle T_{thru}\right\rangle = a*(T_{thru}-T_{room,rated})^2 + b*(T_{thru}-T_{room,rated})$$

where:

$$a = \frac{\dot{q}_{thru,rated,hi}\left(T_{thru,rated,lo}-T_{room,rated}\right)-\dot{q}_{thru,rated,lo}\left(T_{thru,rated,hi}-T_{room,rated}\right)}{\left(T_{thru,rated,hi}-T_{room,rated}\right)^2\left(T_{thru,rated,lo}-T_{room,rated}\right)-\left(T_{thru,rated,lo}-T_{room,rated}\right)^2\left(T_{thru,rated,hi}-T_{room,rated}\right)}$$

$$b = \frac{\dot{q}_{thru,rated,hi}\left(T_{thru,rated,lo}-T_{room,rated}\right)^2-\dot{q}_{thru,rated,lo}\left(T_{thru,rated,hi}-T_{room,rated}\right)^2}{\left(T_{thru,rated,hi}-T_{room,rated}\right)\left(T_{thru,rated,lo}-T_{room,rated}\right)^2-\left(T_{thru,rated,lo}-T_{room,rated}\right)\left(T_{thru,rated,hi}-T_{room,rated}\right)^2}$$

**12.5.3 Boilers for which ~~no~~ a throughflow loss test is not conducted.**

**12.5.3.1** When ~~both high and low temperature~~ the idling test ~~are~~ is conducted at both the *high temperature rating* and *low temperature rating* the throughflow loss rate at the *high ~~water~~ temperature rating* and a room temperature shall be calculated from the idling test results at the *high temperature rating* using the following equation:

IP:

$$\dot{q}_{thru}\langle 180\rangle = \eta_{0,nom,180} * \dot{q}_{in,idle,C}\langle 180\rangle$$

SI:

$$\dot{q}_{thru}\langle 82.2\rangle = \eta_{0,nom,82.2} * \dot{q}_{in,idle,C}\langle 82.2\rangle$$

The throughflow loss rate at low temperature rating point shall be calculated using the equations in 12.5.2.1. Using the equations in ~~Section~~ 12.5.1, the througflow loss rate shall be calculated as a function of boiler outlet (supply) water temperature at the measured room temperature.

~~**12.5.3.2** When only a high temperature idling test is conducted~~
~~The throughflow loss rate at the high water temperature rating point (180°F or 82.2°C) and room temperature (75°F or 23.9°C) shall be calculated from the idling test results at high water temperature using the equations in Section 12.5.3.1.~~
~~The througflow loss rate shall be calculated as a linear function of boiler water temperature minus room air temperature using the equations in Section 12.5.2.2.~~

**12.5.3.2**-When the idling test is conducted only at the high temperature rating point, the equations in 12.5.3.1 shall be used to calculate the throughflow loss rate at the high temperature rating point from the idling test results.

The throughflow loss rate shall be calculated as a linear function of boiler outlet (supply) water temperature minus room air temperature using the equations in 12.5.2.2.

**12.8 Boiler Time Constant**

IP:

$$\tau = C_{thermal} / hA$$

SI:

$$\tau = C_{thermal} / 3600 * hA$$

where

$C_{thermal}$ =

0.12 Btu/lb°F * $W_B$ + 8.154~~7.482~~ Btu/gal°F * $V_W$ (IP)

0.50 kJ/kg°C * $W_B$ + ~~4.1868 kJ/kg°C * 1 kg/l~~ 4.091 kJ/L°C* $V_W$ (SI)

$$hA = \frac{\dot{q}_{in,idle,corr}\langle T_{out}\rangle * \dot{q}_{out,ss}\langle T_{out}\rangle}{(\dot{q}_{in,ss}\langle T_{out}\rangle - \dot{q}_{in,idle,corr}\langle T_{out}\rangle) * (T_{out} - T_{room,rated})}$$

where:

$\dot{q}_{out,ss}$ = rated steady state output rate at full fire for burners with single stage control, low fire for burners with modulating control and at 180°F (82.2°C) for hot water and steaming conditions for steam

$\dot{q}_{in,ss}$ = rated steady state input rate at full fire for burners with single stage control, low fire for burners with modulating control and at 180°F (82.2°C) for hot water and steaming conditions for steam

$T_{idle}$ = boiler idling water temperature at rating conditions = 180°F (82.2°C) for hot water, 200°F (93.3°C) for steam