



**BSR/ASHRAE Standard 118.2-2006R**

**Public Review Draft**

# **Method of Testing for Rating Residential Water Heaters and Residential-Duty Commercial Water Heaters**

**Third Public Review (April 2021)  
(This draft shows only proposed Independent Substantive  
Changes to Previous Public Review Draft)**

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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

**draw time limit**: the maximum duration of pre-conditioning draws before the First-Hour Rating and the 24-Hour Simulated Use Test for water heaters with Rated Storage Volumes greater than or equal to 2 gallons(7.6 L).

**7.3.3.1 General.** During hot water draws for water heaters with rated storage volumes greater than or equal to 20 gallons, remove water at a rate of  $3.0 \pm 0.25$  gallons per minute ( $11.4 \pm 0.95$  liters per minute). During hot water draws for ~~storage type~~non-flow activated water heaters with rated storage volumes below 20 gallons, remove water at a rate of  ~~$1.0 \pm 0.25$~~   $1.5 \pm 0.25$  gallon per minute ( ~~$3.85.7 \pm 0.95$~~   $\pm 0.95$  liters per minute).

.....Remaining Text Unchanged.....

**7.3.3.3 First-Hour Rating Test Preparation.** Draw time limit determination is the time at which the main heating source is turned off. For draws conducted at 1.5 gpm (5.7 lpm) or at 3gpm (11.36 lpm) the draw time limit shall be the nominal capacity times 1.2 divided by the flow rate. (i.e. for a 75-gallon (284 liters) tank the draw time would be 30 minutes,  $((75\text{gall} * 1.2) / 3\text{gpm})$  for SI units  $(284\text{L} * 1.2) / 11.35\text{lpm}$ )

If the water heater is not presently heating, initiate a draw. The draw shall be terminated when the outlet temperature drops 15°F (8.33°C) below the maximum recorded outlet temperature. If the draw time limit has been reached, turn off the main heat source and continue the draw until the outlet temperature has dropped 15°F (8.33°C) from the maximum outlet temperature. Turn the main heating source back on after termination of draw and allow the water heater to fully recover test such that the main burner, heating elements, or heat pump compressor of the water heater are no longer raising the temperature of the stored water(cut-out).

If the water heater is heating, wait for the maximum mean tank temperature after cut-out, then initiate a draw. Terminate the draw when the outlet temperature drops 15°F (8.33°C) below the maximum recorded outlet temperature. If the draw time limit has been reached, turn off the main heat source and continue the draw until the outlet temperature has dropped 15°F (8.33°C) from the maximum outlet temperature, turn the main heating source back on after termination of draw and allow the water heater to fully recover test such that the main burner, heating elements, or heat pump compressor of the water heater are no longer raising the temperature of the stored water (cut-out).

If the water heater is recovering from previously run First Hour Rating test allow the water heater

to fully recover test such that the main burner, heating elements, or heat pump compressor of the water heater are no longer raising the temperature of the stored water(cut-out).

**7.3.3.34 Test Sequence.** ~~Establish normal water heater operation, if necessary. If the water heater is not presently heating, initiate a draw. The draw shall be terminated when the outlet temperature drops 15°F below the maximum recorded outlet temperature or when cut in occurs, whichever is longer. If the water heater is heating, wait for the maximum mean tank temperature after cut out, then initiate a draw. Terminate the draw when the outlet temperature drops 15°F below the maximum recorded outlet temperature or when cut in occurs, whichever is longer.~~ After cut-out occurs (i.e., all temperature controllers are satisfied), record the internal storage tank temperature at each sensor described in Section 6.5 every one minute, and determine the mean tank temperature by averaging the values from these sensors. Initiate a draw after a maximum mean tank temperature (the maximum of the mean temperatures of the individual sensors) has been observed following a cut-out. Record the time when the draw is initiated and designate it as an elapsed time of zero ( $\tau^* = 0$ ). (The superscript \* is used to denote variables pertaining to the first-hour rating test). Record the outlet and inlet water temperature beginning 15 seconds after the draw is initiated and at 5-second intervals thereafter until the draw is terminated. Determine the maximum outlet temperature that occurs during this first draw and record it as  $T_{\max,1}^*$ . For the duration of this first draw and all successive draws, in addition, monitor the inlet temperature to the water heater to ensure that the required nominal inlet temperature  $\pm 2^\circ\text{F}$  ( $\pm 1.1^\circ\text{C}$ ) test condition is met. Terminate the hot water draw when the outlet temperature decreases to  $T_{\max,1}^* - (T_{\text{del,nom}} - 110)^\circ\text{F}$  [ $T_{\max,1}^* - (T_{\text{del,nom}} - 43.3)^\circ\text{C}$ ]. (Note, if the outlet temperature does not decrease to  $T_{\max,1}^* - (T_{\text{del,nom}} - 110)^\circ\text{F}$  [ $T_{\max,1}^* - (T_{\text{del,nom}} - 43.3)^\circ\text{C}$ ] during the draw, then hot water would be drawn continuously for the duration of the test. In this instance, the test would end when the temperature decreases to  $T_{\max,1}^* - (T_{\text{del,nom}} - 110)^\circ\text{F}$  [ $T_{\max,1}^* - (T_{\text{del,nom}} - 43.3)^\circ\text{C}$ ] after the electrical power and/or fuel supplied to the water heater is shut off, as described in the following paragraphs.) Record this temperature as  $T_{\min,1}^*$ . Following draw termination, determine the average outlet water temperature and the mass or volume removed during this first draw and record them as  $T_{\text{del},1}^*$  and  $M_{\text{del},1}^*$  or  $V_{\text{del},1}^*$ , respectively.

Initiate a second and, if applicable, successive draw(s) each time the applicable draw initiation criteria described in Section 7.3.3.2 are satisfied. As required for the first draw, record the outlet water temperature 15 seconds after initiating each draw and at 5-second intervals thereafter until the draw is terminated. Determine the maximum outlet temperature that occurs during each draw and record it as  $T_{\max,i}^*$ , where the subscript i refers to the draw number. Terminate each hot water draw when the outlet temperature decreases to  $T_{\max,i}^* - (T_{\text{del,nom}} - 110)^\circ\text{F}$  [ $T_{\max,i}^* - (T_{\text{del,nom}} - 43.3)^\circ\text{C}$ ] or 105°F (40.6°C), whichever is higher. Record this temperature as  $T_{\min,i}^*$ . Calculate and record the average outlet temperature and the mass or volume removed during each draw ( $T_{\text{del},i}^*$  and  $M_{\text{del},i}^*$  or  $V_{\text{del},i}^*$ , respectively). Continue this sequence of draw and recovery until one hour after the start of the test, then shut off the electrical power and/or fuel supplied to the water heater.

If a draw is occurring at one hour from the start of the test, continue this draw until the outlet temperature decreases to  $T_{\max,n}^* - (T_{\text{del,nom}} - 110)^\circ\text{F}$  [ $T_{\max,n}^* - (T_{\text{del,nom}} - 43.3)^\circ\text{C}$ ], at which time the draw shall be immediately terminated. (The subscript n shall be used to denote measurements associated with the final draw.) If a draw is not occurring one hour after the start of the test, initiate a final draw at one hour, regardless of whether the criteria described in Section 7.3.3.2 are satisfied.

This draw shall proceed for a minimum of 30 seconds and shall terminate when the outlet temperature first indicates a value less than or equal to the cut-off temperature used for the previous draw ( $T_{\min,n-1}$ ) or 105°F (40.6°C), whichever is higher. If an outlet temperature greater than  $T_{\min,n-1}$  is not measured within 30 seconds of initiation of the draw, zero additional credit shall be given towards first-hour rating (i.e.,  $M_n = 0$  or  $V_n = 0$ ) based on the final draw. After the final draw is terminated, calculate and record the average outlet temperature and the mass or volume removed during the final draw ( $T_{\text{del},n}$  and  $M_n$  or  $V_n$ , respectively).

## 7.4 24-Hour Simulated Use-Test

**7.4.1 Selection of Draw Pattern.** If the entity requesting the test has specified multiple draw patterns, the water heater shall ~~will~~ be tested under a draw profile that depends upon the first-hour rating obtained following the test prescribed in Section 7.3.3 of this test procedure, or the maximum GPM rating obtained following the test prescribed in Section 7.3.2 of this test procedure, whichever is applicable.

**7.4.2 24-Hour Simulated Use Test Preparation.** If the water heater is not presently heating, initiate a draw. The draw shall be terminated when the outlet temperature drops 15°F (8.33°C) below the maximum recorded outlet temperature. If the draw time limit has been reached, turn off the main heat source and continue the draw until the outlet temperature has dropped 15°F (8.33°C) from the maximum outlet temperature. Turn the main heating source back on after termination of draw and wait for cut-out

If the water heater is heating, wait for the maximum mean tank temperature after cut-out, then initiate a draw. Terminate the draw when the outlet temperature drops 15°F (8.33°C) below the maximum recorded outlet temperature. If the draw time limit has been reached, turn off the main heat source and continue the draw until the outlet temperature has dropped 15°F (8.33°C) from the maximum outlet temperature. Turn the main heating source back on after termination of draw and allow the water heater to fully recover test such that the main burner, heating elements, or heat pump compressor of the water heater are no longer raising the temperature of the stored water (cut-out).

If the water heater has undergone a first-hour rating test or maximum GPM (LPM) test prior to conduct of the simulated-use test, allow the water heater to fully recover after completion of that test such that the main burner, heating elements, or heat pump compressor of the water heater are no longer raising the temperature of the stored water (cut-out).

In all cases, the water heater shall sit idle for 1 hour after cut-out prior to the start of the 24-hour test; during which time no water is drawn from the unit and there is no energy input to the main heating elements, heat pump compressor, and/or burners. At the end of this period, the 24-hour simulated-use test will begin.

**7.4.23 Test Sequence for Water Heaters with Rated Storage Volumes Greater Than or Equal to 2 gallons (7.6 L).** ~~If the water heater is turned off, fill the water heater with supply water and maintain supply water pressure as described in Section 4.6. Turn on the water heater and~~

~~associated heat pump unit, if present. If turned on in this fashion, the soak-in period described in Section 7.2.4 shall be implemented. If the water heater has undergone a first-hour rating test or maximum GPM test prior to conduct of the simulated use test, allow the water heater to fully recover after completion of that test such that the main burner, heating elements, or heat pump compressor of the water heater are no longer raising the temperature of the stored water. In all cases, the water heater shall sit idle for 1 hour prior to the start of the 24-hour simulated use test; during which time no water is drawn from the unit and there is no energy input to the main heating elements, heat pump compressor, and/or burners. At the end of this period, the 24-hour simulated-use test will begin.~~

At the start of the 24-hour simulated-use test, record the mean tank temperature ( $\bar{T}_0$ ), and the electrical and/or fuel measurement readings, as appropriate. Begin the 24-hour simulated-use test by withdrawing the volume specified in the applicable draw pattern table for the first draw at the flow rate specified in the applicable draw pattern table. Record the time when this first draw is initiated and assign it as the test elapsed time ( $\tau$ ) of zero (0). Record the average storage tank and ambient temperature every minute throughout the 24-hour simulated-use test. At the elapsed times specified in the applicable draw pattern table initiate additional draws pursuant to the applicable draw pattern, removing the volume of hot water at the prescribed flow rate specified by the applicable draw pattern table. The maximum allowable deviation from the specified volume of water removed for any single draw taken at a nominal flow rate less than or equal to 2 GPM (7.6 liters per minute) is  $\pm 0.1$  gallon ( $\pm 0.4$  liters). The maximum allowable deviation from the specified volume of water removed for any single draw taken at a nominal flow rate greater than or equal to 2.0 GPM (7.6 liters per minute) is  $\pm 0.25$  gallons ( $\pm 0.9$  liters). The quantity of water withdrawn during the last draw shall be increased or decreased as necessary such that the total volume of water withdrawn equals the prescribed daily amount for that draw pattern  $\pm 1.0$  gallons ( $\pm 3.8$  liters). If this adjustment to the volume drawn during the last draw results in no draw taking place, the test is considered invalid.

All draws during the 24-hour simulated-use test shall be made at the flow rates specified in the applicable draw pattern table, within a tolerance of  $\pm 0.25$  gallons per minute ( $\pm 0.9$  liters per minute). Measurements of the inlet and outlet temperatures shall be made 5 seconds after the draw is initiated and at every subsequent 3-second interval throughout the duration of each draw. Calculate and record the mean of the hot water outlet temperature and the cold water inlet temperature for each draw ( $\bar{T}_{del,i}$  and  $\bar{T}_{in,i}$ ). Determine and record the net mass or volume removed ( $M_i$  or  $V_i$ ), as appropriate, after each draw.

At the end of the first recovery period following the initiation of the first draw, which may extend beyond subsequent draws, record the maximum mean tank temperature observed after cut-out,  $\bar{T}_{max,1}$ , and the energy consumed by an electric resistance, gas, or oil-fired water heater (including electrical energy), from the beginning of the test,  $Q_r$ . For heat pump water heaters, the total energy consumed during the first recovery by the heat pump (including compressor, fan, controls, pump, etc.), and, if applicable, by the resistive element(s) shall be recorded as  $Q_r$ .

The start of the portion of the test during which the standby loss coefficient is determined depends upon whether the unit has fully recovered from the first draw cluster. If a recovery is occurring at or within five minutes of the end of the final draw in the first draw cluster, as identified in the

applicable draw pattern table in Section 7.5 of this test procedure, then the standby period starts when a maximum average tank temperature is observed starting five minutes after the end of the recovery period that follows that draw. If a recovery does not occur at or within five minutes of the end of the final draw in the first draw cluster, as identified in the applicable draw pattern table in Section 7.5 of this appendix, then the standby period starts five minutes after the end of that draw. In these cases, proceed to Section 7.4.2.1 to complete the test. In the event that the recovery period continues from the end of the last draw of the first draw cluster until the subsequent draw, or the time from the observed maximum mean tank temperature after cut-out to the start of the next draw following the first draw cluster is less than 6 hrs, or there is only one draw cluster, the standby period shall start after the end of the first recovery period after the last draw of the simulated-use test. For this case, proceed to Section 7.4.3.2 to complete the test.

#### **7.4.23.1 Completion of Test when Standby Period Occurs Between Draw Cluster 1 and Draw Cluster 2**

In preparation for determining the energy consumed during standby, record the reading given on the electrical energy (watt-hour) meter, the gas meter, and/or the scale used to determine oil consumption, as appropriate. Determine and record the total electrical energy and/or fossil fuel consumed from the beginning of the test to the start of the standby period,  $Q_{su,0}$ . Record the mean tank temperature at the start of the standby period as  $\bar{T}_{su,0}$ . At 1-minute intervals, record the mean tank temperature and the electric and/or fuel instrument readings until the next draw is initiated. Just prior to initiation of the next draw, record the mean tank temperature as  $\bar{T}_{su,f}$ . If the water heater is undergoing recovery when the next draw is initiated, record the mean tank temperature  $\bar{T}_{su,f}$  at the minute prior to the start of the recovery. The time at which this value occurs is the end of the standby period. Determine the total electrical energy and/or fossil fuel energy consumption from the beginning of the test to this time and record as  $Q_{su,f}$ . Record the time interval between the start of the standby period and the end of the standby period as  $\tau_{stby,1}$ . Record the time during which water is not being withdrawn from the water heater during the entire 24-hour period as  $\tau_{stby,2}$ . Following the final draw of the prescribed draw pattern and first recovery period following the subsequent recovery, allow the water heater to remain in the standby mode until exactly 24 hours have elapsed since the start of the simulated-use test (i.e., since  $\tau = 0$ ). During the last hour of the simulated-use test, power to the main burner, heating element, or compressor shall be disabled. At 24 hours, record the reading given by the gas meter, oil meter, and/or the electrical energy meter as appropriate. Determine the fossil fuel and/or electrical energy consumed during the entire 24-hour simulated-use test and designate the quantity as  $Q$ . ~~Record the time during which water is not being withdrawn from the water heater during the entire 24-hour period as  $\tau_{stby,2}$ .~~

#### **7.4.23.2 Completion of Test when Standby Period Occurs after All Draws.**

In the event that the recovery period continues from the end of the last draw of the first draw cluster until the subsequent draw, or the time from the observed maximum mean tank temperature after cut-out to the start of the next draw following the first draw cluster is less than 6 hrs, or there is only one draw cluster, the standby period will start after the last draw of the simulated-use test. If a recovery is occurring at or within five minutes of the end of the final draw, as identified in the applicable draw pattern table in Section 7.5 of this test procedure, then the standby period starts when a maximum average tank temperature is observed starting five minutes after the end of the recovery period that follows that draw. If a recovery does not occur at or within five minutes of the end of the final draw, as identified in the applicable draw pattern table in Section 7.5 of this

appendix, then the standby period starts five minutes after the end of that draw. The standby period shall last at least eight hours or until hour 24 of the simulated use test, whichever is longer. ~~so~~ ~~Testing may will~~ extend beyond the 24-hour duration of the simulated-use test.

Determine and record the total electrical energy and/or fossil fuel consumed from the beginning of the simulated-use test to the start of the ~~8-hour~~ standby period,  $Q_{su,0}$ . In preparation for determining the energy consumed during standby, record the reading(s) given on the electrical energy (watt-hour) meter, the gas meter, and/or the scale used to determine oil consumption, as appropriate. Record the mean tank temperature at the start of the standby period as  $\bar{T}_{su,0}$ . Record the mean tank temperature, the ambient temperature, and the electric and/or fuel instrument readings until the end of the ~~8-hour~~ standby period. Record the mean tank temperature at the end of the ~~8-hour~~ standby period as  $\bar{T}_{su,f}$ . If the water heater is undergoing recovery at the end of the standby period, record the mean tank temperature  $\bar{T}_{su,f}$  at the minute prior to the start of the recovery, which will mark the end of the standby period. Determine the total electrical energy and/or fossil fuel energy consumption from the beginning of the test to the end of the standby period and record this value as  $Q_{su,f}$ . Record the time interval between the start of the standby period and the end of the standby period as  $\tau_{stby,1}$ . Record the time during which water is not being withdrawn from the water heater during the 24-hour period as  $\tau_{stby,2}$ .

Following the final draw of the prescribed draw pattern and subsequent recovery, allow the water heater to remain in the standby mode until exactly 24 hours have elapsed since the start of the simulated-use test (i.e., since  $\tau = 0$ ). If no recovery has taken place between hour 23 and 24, record the reading given by the gas meter, oil meter, and/or the electrical energy meter, as appropriate, at hour 24. Determine the fossil fuel and/or electrical energy consumed during the entire 24-hour simulated-use test and designate the quantity as  $Q$ . Determine the mean tank temperature at hour 24,  $T_{24}$ .

If the water heater undergoes a recovery between elapsed times of 23 hrs and 24 hrs since the start of the test, record the total energy used,  $Q_{24*}$ , and the mean tank temperature  $\bar{T}_{24*}$  at 1 minute prior to the start of the recovery. Record the elapsed time in hours since the start of the test until 1 minute prior to the start of the recovery,  $t_{24*}$ . Determine the average ambient temperature,  $\bar{T}_{amb,24*}$ , during the period from the minute prior to the recovery until an elapsed time of 24 h.

### 8.1 First Hour Rating

$\rho_i$  = the water density ~~corresponding to where the flow rate is measured~~ at the outlet during the  $i$ th draw, lb/gal (kg/L).

### 8.2 Maximum GPM (L/min) Rating:

$\rho$  = the water density ~~corresponding to where the flow rate is measured~~ at the outlet, lb/gal (kg/L).

### 8.3.3 Hourly Standby Losses.

$Q_{su,0}$  = cumulative energy consumption of the water heater from the start of the 24-hour simulated-use test to the start of the standby period as determined in Section 7.4.2~~time at which the maximum mean tank temperature is attained starting five minutes after the recovery following the end of the first draw cluster,~~ Btu (kJ).

$Q_{su,f}$  = cumulative energy consumption of the water heater from the start of the 24-hour simulated-use test to the end of the standby period as determined in Section 7.4.2~~minute prior to the start of the draw following the end of the first draw cluster or the minute prior to a recovery occurring at the start of the draw following the end of the first draw cluster,~~ Btu (kJ).

$\bar{T}_{su,f}$  = the mean tank temperature observed at the end of the standby period as determined in Section 7.4.2~~minute prior to the start of the draw following the first draw cluster or the minute prior to a recovery occurring at the start of the draw following the end of the first draw cluster,~~ °F (°C).

$\bar{T}_{su,0}$  = the maximum mean tank temperature observed at the start of the standby period as determined in Section 7.4.2~~starting five minutes after the first recovery following the final draw of the first draw cluster,~~ °F (°C).

$\tau_{stby,1}$  = elapsed time between the start and end of the standby period as determined in Section 7.4.2~~between the time at which the maximum mean tank temperature is observed starting five minutes after recovery from the first draw cluster and the minute prior to the start of the first draw following the end of the first draw cluster of the 24-hour simulated-use test or the minute prior to a recovery occurring at the start of the draw following the end of the first draw cluster,~~ h.

$\bar{T}_{t,stby,1}$  = overall average storage tank temperature between the start and end of the standby period as determined in Section 7.4.2~~the time when the maximum mean tank temperature is observed starting five minutes after cut-out following the first draw cluster and the minute prior to commencement of the next draw following the first draw cluster of the 24-hour simulated-use test or the minute prior to a recovery occurring at the start of the draw following the end of the first draw cluster,~~ °F (°C).

$\bar{T}_{a,stby,1}$  = overall average ambient temperature between the start and end of the standby period as determined in Section 7.4.2~~the time when the maximum mean tank temperature is observed starting five minutes after cut-out following the first draw cluster and the minute prior to commencement of the next draw following the first draw cluster of the 24-hour simulated-use test or the minute prior to a recovery occurring at the start of the draw following the end of the first draw cluster,~~ °F (°C).

## 8.4 Water Heaters With Rated Storage Volume Less Than 2 Gallons.

### 8.4.1 Recovery Efficiency.

$\rho$  = the water density ~~corresponding to where the flow rate is measured,~~ at the outlet, lb/gal (kg/L).

#### **8.4.2 Daily Water Heating Energy Consumption.**

$\rho_i$  = the water density at the outlet during the  $i$ th draw, lb/gal (kg/L).