ENERGY STAR® Commercial Water Heaters

Draft 1 Test Method for Central Heat Pump Water Heater Systems July 2024

1 OVERVIEW

The following test method shall be used for qualifying the performance for central heat pump water heater ("central HPWH") systems. For the purpose of this proposed test method, the Environmental Protection Agency (EPA) is focusing on the performance of the heat-pump water heater(s), the storage tank(s) (electric or unfired), and the circulator pump(s), which altogether make up a central HPWH system. The system components as well as the number of each component in a system may vary between installations and can be sold individually or as a package.

This test method separately tests each component of the system to determine its efficiency. In a later version of this test procedure, the Department of Energy (DOE) and EPA may combine the metric of performance of each system component into an overall system performance metric to better account for the system effects and interactions between different components.

Note: In this Draft 1, the DOE and EPA propose which components of the central heat pump water heater system must be tested and the test metrics and methods that would be associated with each component. The DOE and EPA request comment on the scope of system components included in this test method. The DOE and EPA request comment on whether combining the performance of each system component into an overall system performance metric could be representative of the overall efficiency of the system using only the information required for and gathered in this test procedure and manufacturer literature. The DOE and EPA also request comment on how this test procedure should gather other information that may be required to produce a representative system efficiency.

The DOE and EPA request comment on an appropriate method to calculate the overall system performance given the system configuration and the efficiency of each component as tested according to the test procedures set out in this test method. Additionally, the DOE and EPA request comment on appropriate values that can be used to weight the expected operating time of each system component in its active mode or other modes, as applicable.

2 APPLICABILITY

This test method is applicable to central HPWH system components, including the heat pump unit, auxiliary water storage tanks (including unfired hot water storage tanks and electric storage water heaters), and recirculating pumps. Specifically, this method is applicable to heat pump units that are supplied without a matching storage tank (Type IV equipment is as defined in section 4.4 of ANSI/ASHRAE 118.1-2022) and heat pump units that are supplied with a matching storage tank (Type V equipment, as defined in section 4.5 of ANSI/ASHRAE 118.1-2022) that is not integrated (*i.e.*, the matching storage tank is supplied as a separate assembly).

Note: The test method applies to individual components of central HPWH systems, including the heat pump unit, auxiliary water storage tanks (including unfired hot water storage tanks and electric storage water heaters), and recirculating water pumps and thus can be applied to central HPWH systems supplied by individual or multiple manufacturers. The DOE and EPA request comment on whether there are any heat pumps, storage tanks, or recirculating water pumps that cannot be tested according to the methods in this Draft.

The DOE and EPA request comment on whether any other components of central HPWH systems not included in this test procedure would have significant impacts on the energy efficiency of the system. The DOE and EPA also request comment regarding the energy consumption and/or savings effects of such components.

3 DEFINITIONS

A) Air-source commercial heat-pump water heater: A commercial heat pump water heater that utilizes indoor or outdoor air as the heat source.
B) Circulator Energy Rating: The weighted average electric input power to the driver or control of a circulator pump, over a specific load profile for each control type (expressed in HP).
C) Commercial heat pump water heater: A water heater (including all necessary ancillary equipment such as fans, blowers, pumps, storage tanks, piping, and controls, as applicable) that uses a refrigeration cycle, such as vapor compression, to transfer heat from a low-temperature source to a higher-temperature sink for the purpose of heating potable water, and operates with a current rating greater than 24 amperes or a voltage greater than 250 volts. Such equipment includes, but is not limited to, air-source heat pump water heaters, water-source heat pump water heaters, and direct geo-exchange heat pump water heaters.
    1) Central heat pump water heater system: A commercial heat pump water heater in which the heat pump unit is not contained within the same casing as the storage tank(s) and thus is not an integrated heat pump water heater. A central heat pump water heater system can include products that come pre-mounted on a skid or pallet with multiple components and may require infield plumbing between components.
    2) Integrated heat pump water heater: A heat pump water heater that has a built-in storage tank contained within the same casing.
D) Direct geo-exchange commercial heat-pump water heater: A commercial heat pump water heater that utilizes the earth as a heat source and allows for direct exchange of heat between the earth and the refrigerant in the evaporator coils.
E) Heat Pump Water Heater Coefficient of Performance: The dimensionless ratio of the rate of useful heat transfer gained by the water (expressed in Btu/h), to the rate of electric power consumed during operation (expressed in Btu/h).
F) Multi-pass central HPWH: A central HPWH that cannot meet the requirements of a Single Pass central HPWH.
G) Single-pass central HPWH: A central HPWH which has equipment that can modulate the flow rate through the heat pump to achieve the outlet water temperature at each of the specified inlet temperatures.
H) Standby Loss: The energy required to maintain the stored water temperature.
I) Thermal Efficiency: The ratio of the heat transferred to the water flowing through the electric storage water heater to the amount of energy consumed by the electric storage water heater.
J) Water-source commercial heat pump water heater: A commercial heat pump water heater that utilizes water or a brine solution as the heat source. For the purposes of this test procedure, it refers to ground-source closed-loop commercial heat pump water heaters, ground water-source commercial heat pump water heaters, and indoor water-source commercial heat pump water heaters.
    1) Ground-source closed-loop commercial heat pump water heater: A commercial heat pump water heater that utilizes a fluid circulated through a closed piping loop as a medium to transfer heat from the ground to the refrigerant in the evaporator. The piping loop may be buried inside the ground in horizontal trenches or vertical bores or submerged in a surface water body.
    2) Ground water-source commercial heat pump water heater: A commercial heat pump water heater that utilizes ground water as the heat source.
    3) Indoor water-source commercial heat pump water heater: A commercial heat pump water heater that utilizes indoor water as the heat source.

K) Acronyms:
    1) ANSI: American National Standards Institute
    2) AS: Air-Source
    3) AS-central HPWH: Air-Source Central Heat Pump Water Heater

4) ASHRAE: American Society of Heating Refrigerating and Air-Conditioning Engineers
5) BTU: British Thermal Unit
6) CER: Circulator Energy Rating
7) CFR: Code of Federal Register
8) Central HPWH: Central Heat Pump Water Heater
9) COP_H: Coefficient of Performance of the Central Heat Pump Water Heater as measured in section 4.1
10) DG-central HPWH: Direct Geo-exchange Central Heat Pump Water Heater
11) DOE: United States Department of Energy
12) DR: Decay Rate
13) EPA: United States Environmental Protection Agency
14) F: Fahrenheit
15) FR: Flow Rate
16) GPM: Gallons Per Minute
17) hp: horsepower
18) in WC: Inches of water column
19) lb: Pound
20) kW: kilowatt
21) OH: Operating Hours
22) psi: pound per square inch
23) Q: Quantity of Energy
    a) Q_h: heat-pump water heater water-heating capacity; average of test results from the heat-pump water heater water-heating output test
    b) Q_{he}: heat-pump water heater power input from heat-pump water heater water-heating output test
    c) Q_{res}: the rate of energy input to the electric resistance element during the electric storage water heater test
    d) Q_{tank}: the rate of change in energy stored by the water in the tank during the electric storage water heater test
24) SL: Standby Loss
25) T: Temperature
26) t: Time
27) V: Volume
28) W: Watt
29) WS-central HPWH: Water-Source Central Heat Pump Water Heater

4 TEST METHODS

4.1 Heat Pump Unit Test Method

A) General.

Determine the average water-heating capacity, Q_h, the average rate of energy input, Q_{he}, and coefficient of performance COP_H at each test condition for the heat pump unit in accordance with the procedures in the sections that follow. The following test procedure references certain sections of ANSI/ASHRAE 118.1-2022 for set-up, testing instructions, and data collection. Where the instructions contained in this section differ from ANSI/ASHRAE 118.1-2022, this document controls.

B) Definitions and Symbols.

The definitions and symbols used in this test procedure are as listed in section 3 of ANSI/ASHRAE 118.1-2022.

C) Instrumentation.

The instruments required for the test are as described in section 6 of ANSI/ASHRAE 118.1-2022 (except sections 6.3, 6.4, and 6.6).

D) Test Set-Up, Apparatus, and Conditions

Set-up and install the heat pump unit as per the provisions described in ANSI/ASHRAE 118.1-2022 and in the subsections that follow for either "Type IV" or "Type V" equipment, as appropriate. If a Type V AS-HPWH and matching storage tank are unable to meet the plumbing configuration shown in ANSI/ASHRAE 118.1-2022, test the AS-HPWH as Type IV equipment.

1) Test set-up and installation instructions.

   a) For AS-central HPWHs, follow the instructions in sections 7.1 and 7.7.1 of ANSI/ASHRAE 118.1-2022, except for heat pump units that can be installed in either ducted or nonducted configurations, test in the ducted configuration. Test in the ducted configuration as per section 7.7.5 of ANSI/ASHRAE 118.1-2022. Except for the test operating tolerance for external static pressure which shall be ±0.05 in WC and for the airflow (nozzle pressure drop) tolerance which shall be ±5%.

   b) For DG-central HPWHs, set up the unit for testing as per section 7.1 and section 7.7.2 of ANSI/ASHRAE 118.1-2022.

   c) For WS-central HPWHs, set up the unit for testing as per section 7.1 and section 7.7.3 of ANSI/ASHRAE 118.1-2022.

2) Use the water piping instructions described in section 7.2 of ANSI/ASHRAE 118.1-2022 and, if applicable, section 7.7.6 of ANSI/ASHRAE 118.1-2022.

3) Install the thermocouples, including the room thermocouples, as per the instructions in sections 7.3.1, 7.3.2, and 7.3.3 (as applicable) of ANSI/ASHRAE 118.1-2022. The outlet heat exchanger water temperature (T_{ohx}) does not need to be measured for heat pump units.

4) Install the temperature sensors at the locations specified in Figures 6-14 of ANSI/ASHRAE 118.1-2022, as applicable. Follow the instructions provided in section 7.7.7.1 of ANSI/ASHRAE 118.1-2022 to install the temperature and flow-sensing instruments.

5) For AS- central HPWHs, use the evaporator-side rating conditions in Table 4.1. If the manufacturer specified compressor cutout temperature is higher than the evaporator-side rating conditions listed in Table 4.1, test all the conditions above the manufacturer specified compressor cutout temperature. For example, if the manufacturer specified compressor cutout temperature is 40°F, only tests 1, 2 and 3 would be conducted. Conduct a separate test for each condition specified in Table 4.1. Maintain the specified conditions throughout the conduct of the test.

6) For other types of central HPWHs, use the evaporator-side rating conditions in Table 4.2. Maintain the specified conditions throughout the conduct of the test.

Table 4.1 AS-central HPWHs Evaporator Test Conditions

Test Number	Evaporator Entering Air Temperature °F (± 1 °F)	
	Dry-bulb temperature	Wet-bulb temperature
1	95.0	75
2	80.6	71.2
3	50.0	44.3
4	17.0	15.0
5	5.0	4.0

Table 4.2 Other central HPWHs Evaporator Test Conditions

Central HPWH Type	Test Condition
DG-central HPWHs	Maintain the evaporator refrigerant temperature at 32.0 °F ± 1 °F.
Indoor WS-central HPWHs	Maintain the evaporator entering water temperature at 68.0 °F ± 1 °F.
Ground WS-central HPWHs	Maintain the evaporator entering water temperature at 50.0 °F ± 1 °F.
Ground-Source Closed-Loop central HPWHs*	Maintain the evaporator entering water temperature at 32.0 °F ± 1 °F.

* For ground-source closed-loop central HPWHs, the evaporator water must be mixed with 15-percent methanol by-weight to allow the solution to achieve the required rating conditions.

7) Follow the directions in section 7.7.4 of ANSI/ASHRAE 118.1-2022 for heat pump unit mounting and installation instructions, as applicable. Do not make any alterations to the equipment except as specified in this document for installation, testing, and the attachment of required test apparatus and instruments.

8) Use Table 1 of ANSI/ASHRAE 118.1-2022 for operating and condition tolerances of measured parameters.

9) If the heat pump unit is equipped with a thermostat that is used to control the throttling valve of the equipment, then use the provisions in section 7.7.7.2 of ANSI/ASHRAE 118.1-2022 to set up the thermostat.

10) Supplemental heat inputs such as electric resistance elements must be disabled when testing the heat pump.

11) Install instruments to measure the electricity supply to the equipment as specified in section 7.5 of ANSI/ASHRAE 118.1-2022.

12) Install the water pump as specified in section 7.6 of ANSI/ASHRAE 118.1-2022.

Note: This test procedure references several sections of ANSI/ASHRAE 118.1-2022 except that certain sections of ANSI/ASHRAE 118.1-2022 are modified in this test procedure for clarity and/or to be more directly applicable to the goals of this test procedure. For example, 4.1E)3) and 4.1E)4) of this document are based on sections 9.1.1 and 10.3.1 of ANSI/ASHRAE 118.1-2022, respectively. However, these sections are modified in this test procedure to eliminate variables that are not necessary for this test method, harmonize nomenclature, and make measuring instructions more explicit.

The DOE and EPA request comment on whether referencing ANSI/ASHRAE 118.1-2022 (as opposed to ANSI/ASHRAE 118.1-2012, or any other existing test method) is appropriate for this test procedure and if any additional modifications to its reference in this test procedure are necessary.

This test procedure references figures in ANSI/ASHRAE 118.1-2022 that show the test setup for various types of central HPWH. The DOE is aware of certain HPWH models that have plumbing connections to connect to a separate tank (or tanks) that are oriented in a way that does not match the figures in ASHRAE 118.1-2022. This procedure proposes to test such models without a tank connected, i.e., as a Type IV model to provide an alternative approach that would still meet ASHRAE 118.1-2022 that would still be repeatable and provide a representative result. The DOE and EPA request comment on whether this approach is sufficiently representative, and on how manufacturers test according to ANSI/ASHRAE 118.1-2022 if their equipment is incompatible with the plumbing configurations in ANSI/ASHRAE 118.1-2022.

The DOE and EPA request comment on its proposal to test units that can be set up in either ducted or nonducted configurations in only the ducted configuration. The DOE and EPA expect the performance of a particular unit in its nonducted configuration to be better than the same unit in a ducted configuration. Therefore, to calculate the most conservative ratings, the DOE and EPA have proposed to test central HPWHs that can operate in either nonducted or ducted configurations in their ducted configuration. The DOE and EPA request comment on whether the ducted configuration is representative of typical performance of such units, or if separate tests should be conducted in both configurations. The DOE and EPA also specifically request comment on whether the ESP requirements in 4.1D)1) are appropriate for all ducted AS-central HPWHs with ducted discharge air.

E) Test Procedure

Test all heat pump units as per the provisions described in ANSI/ASHRAE 118.1-2022 for either "Type IV" equipment as defined in section 4.4 of ANSI/ASHRAE 118.1-2022 or "Type V" equipment as defined in section 4.5 of ANSI/ASHRAE 118.1-2022, as appropriate. Tests for all heat pump units must follow the steps described below.

1) Supply the heat pump unit with electricity at the voltage specified by the manufacturer. Follow the provisions in section 8.2.1 of ANSI/ASHRAE 118.1-2022 to maintain the electricity supply at the required level. For models with multiple voltages specified by the manufacturer, use the minimum voltage specified by the manufacturer to conduct the test. Maintain the voltage as per the limits specified in section 8.2.1 of ANSI/ASHRAE 118.1-2022.

2) Set the condenser entering water temperature and outlet water temperature for each test per the following provisions. For single-pass heat pump units test each of the evaporator test conditions from Table 4.1 or Table 4.2 (as applicable) with both the Single-Pass and Multi-Pass test conditions, if possible, in Table 4.3. For multi-pass heat pump units test each of the evaporator test conditions from Table 4.1 or Table 4.2 (as applicable) with just the multi-pass test condition in Table 4.3.

   a) Use the applicable provisions in sections 8.7.2 of ANSI/ASHRAE 118.1-2022 with the conditions specified in Table 4.3 of this document to adjust water flow rate and the mean condenser entering water temperature for each test. Equilibrium at a given target outlet water temperature is achieved when the target water temperature is maintained with no variation in excess of 2 °F over a three-minute period.

Table 4.3 Condenser Entering Water Temperature and Temperature Rise Conditions for Central HPWHs

Single-Pass Test	Multi-Pass Test
Adjust the target mean outlet water temperature to 70°F ± 2°F above the mean condenser entering water temperature of 70°F ± 1°F. If the tested model is unable to achieve the required mean outlet water temperature condition, omit this test.	Adjust the target mean outlet water temperature to 15°F ± 2°F above the mean condenser entering water temperature of 125°F ± 1°F.

Note: This proposed test procedure prescribes up to ten different tests with up to five different sets of test evaporator conditions and two sets of entering water temperature conditions for each type of heat pump water

heater. The DOE and EPA request comment on the standardized temperatures shown in Table 4.1 and Table 4.2 for each type of central HPWH. Those temperatures were chosen based on a review of available product literature. However, the DOE and EPA specifically request comment on the readiness of market-available products to meet the temperatures shown in Table 4.1 and Table 4.2. The DOE and EPA request comment on the proposed condenser entering water temperature and rise in Table 4.3 and specifically whether the proposed condenser entering water temperatures will be difficult to meet while using the proposed ambient test conditions in Table 4.1 and Table 4.2.

The DOE and EPA also request comment on whether additional evaporator or entering water temperature conditions should be included as required test conditions.

Finally, the DOE and EPA request comment on whether any other modifications are necessary to this proposed test procedure to improve its repeatability or representativeness in determining the performance of central heat pump water heaters.

3) The flow rate, FR, is the flow rate of water through the heat pump unit expressed in gallons per minute obtained after following the steps in section 4.1E)2) of this document. Use the evaporator side rating conditions specified in section 4.1D)5) and 4.1D)6) (as applicable).The water-heating equipment shall be operated at this flow rate for 30 minutes. Record the initial electric meter reading ($Z_{h0,k,y}$) and the test start time, $t_{0h,k}$. Record the outlet water temperature ($T_{o,k,y}$), the supply water temperature ($T_{s,k,y}$), the water flow readings ($FR_{h.k}$), and, if a pump is required to circulate water between the tank and heat pump unit, and is provided with the central HPWH, the electrical power input to the heat pump unit circulator pump, $Z_{pc,k,y}$, at equal intervals no greater than one minute. At the end of the 30-minute period, record the final electric meter reading ($Z_{hf,k,y}$) and the time, $t_{fh,k,y}$. If the central HPWH requires a heat pump unit circulator pump but none is provided, record the pressure differential between the heat pump unit entering and leaving water flow, P_{wd}, at equal intervals no greater than one minute and use section 7.6 of ANSI/ASHRAE 118.1-2022 to calculate $Z_{pc,k,y}$. In this test procedure, the subscript *k* can be 1, 2, 3, 4, or 5 for AS-central HPWHs which represent the test conditions used from Table 4.1. For other types of central HPWHs subscript k is not utilized as only a single evaporator test condition is used. Additionally, the subscript *y* can be "SP" or "MP" to represent either the Single-Pass Test or the Multi-Pass Test from Table 4.3.

4) In addition to the above, record the following at equal intervals of one minute over the 30-minute test period for the heat-pump water heaters, as applicable:

- AS-central HPWH: Heat-pump water-heater evaporator air dry-bulb, $T_{adb,k,y}$, and wet-bulb, $T_{awb,k,y}$, temperatures.
- DG-central HPWH: Heat-pump water-heater evaporator entering refrigerant vapor temperature, $T_{r,k,y}$; heat exchanger test water supply temperature, $T_{tw.k,y}$; and test water flow rate, $FR_{tw,k,y}$.
- WS-central HPWH: Heat-pump water-heater evaporator test water supply temperature, $T_{tw,k,y}$; and test water flow rate, $FR_{tw,k,y}$.

Determine the following quantities:

- P_{wd} = average of pressure differential between the central HPWH entering and leaving water flow over the 30-minute period (this value is used to calculate $Z_{pc,k}$ in section 7.6 of ANSI/ASHRAE 118.1-2022), kPa.
- $Z_{h,k,y}$ is the electrical energy used by heat-pump water-heater in full-input water heating mode, measure from initial to final meter reading and is calculated as $Z_{hf,k,y}$-$Z_{h0,k,y}$, in kWh
- $Z_{pc,k,y}$ is the average electrical power input to the heat-pump water-heater water pump water pump at full input as measured during the 30-minute test period, in kW, or as calculated according to section 7.6 of ANSI/ASHRAE 118.1-2022.

5) Calculate the $Q_{h,k,y}$, $Q_{he,k,y}$, and $COP_{H,k,y}$ of the heat pump unit according to the procedure in this section. For all calculations, time differences must be expressed in minutes.

Use the data recorded in 4.1E)3) and 4.1E)4). Water heating capacity, $Q_{h,k,y}$, in Btu/h shall be calculated as follows. For each of the 31 readings made during the 30-minute test period, calculate $Q_{h,k,y,n}$ for reading n=0 to n=30 as:

$$Q_{h,k,y,n} = FR_{h,k,y,n} \times 60 \times \left(T_{o,k,y,n} - T_{s,k,y,n}\right) \times \left[C_p/\left(C_{fg} \times v\right)\right]$$

Where,

C_p = specific heat of water = 1.004 Btu/lb ·°F
C_{fg} = volume conversion factor = 7.48055 gal/ft^3
v = specific volume of water, temperature compensated, ft^3/lb

Determine $Q_{h,k,y}$ by calculating the average of these 31 values, as follows:

$$Q_{h,k,y} = \sum_{n=0}^{30} \frac{Q_{h,k,y,n}}{31}$$

Calculate the average rate of energy input, $Q_{he,k}$, in Btu/h during the test as follows:

$$Q_{he,k,y} = \left(C_{ge} \times Z_{pc,k,y}\right) + \left\{\left(C_{ge} \times Z_{h,k,y}\right)/\left(t_{fh,k,y} - t_{oh,k,y}\right)\right\}$$

Where,

C_{ge} = conversion factor from kWh to Btu = 3412 Btu/kWh

6) Calculate the average coefficient of performance at each test condition, $COP_{H,k}$, a dimensionless quantity, as follows:

$$COP_{H,k,y} = Q_{h,k,y}/Q_{he,k,y}$$

7) For AS- central HPWHs this results in up to two unique COPs at each evaporator test condition where the unit is able to operate: $COP_{H,1,SP}$, $COP_{H,1,MP}$, $COP_{H,2,SP}$, $COP_{H,2,MP}$, $COP_{H,3,SP}$, $COP_{H,3,MP}$, $COP_{H,4,SP}$, $COP_{H,4,MP}$, $COP_{H,5,SP}$, $COP_{H,5,MP}$.

8) For non-AS central HPWHs this results in two unique COPs for each entering water temperature test condition that the unit is able to meet: $COP_{H,SP}$ and $COP_{H,MP}$.

Note: The DOE and EPA are considering developing an integrated heating metric for the heat pump unit that would use the results of the testing conducted according to this test method to represent the seasonal efficiency of this equipment. A seasonal metric might entail:
- Using bins across the range of outdoor air operating temperatures, with weighting to represent climate conditions (e.g., national average and/or cold climate)
- Comparing unit capacity and water heating load within each bin and applying an electric resistance performance factor to make up the difference for bins with load greater than the highest stage unit capacity.
- Interpolating capacity between compressor stages for bins where the highest stage capacity is greater than the bin load, but the load is less than the lowest stage capacity.
- Applying cyclic degradation for bins where the lowest stage capacity is greater than the load.
- Multiple outdoor air temperatures and part-load testing for units with multiple compressor stages being used to determine capacity, power, and water heating load at each bin temperature.
- Using different provisions depending on the intended operating conditions for heat pumps (e.g., whether models have defrost mode)
- Varying the water heating load with outdoor air temperature to reflect variation in ground water temp

The DOE and EPA request comment and information on using a seasonal metric for heat pump units, especially feedback on the considerations listed above.

4.2 Test Method for the Measurement of Storage Tank Standby Losses

In a central heat pump water heating system, the heat pump may be connected to an unfired tank or an external electric storage water heater. The standby losses of these tanks shall be measured according to the applicable test procedure in this section. Unfired storage tanks shall be tested according to the instructions in section 4.2.1 and electric storage water heaters shall be tested according to the instructions in section 4.2.2.

4.2.1 Unfired Storage Tanks

A) General

Determine standby loss in accordance with the following sections. Certain sections reference sections of GAMA Testing Standard IWH-TS-1 (March 2003 Edition). Where the instructions contained in the sections below conflict with instructions in GAMA IWH-TS-1, the instructions contained herein control.

B) Test Set up

Set up the tank for testing in accordance with sections 4, 5, (except for section 5.5), 6.0, and 6.1 of GAMA IWH-TS-1.

1) Piping Insulation

Insulate all water piping external to the water heater jacket including heat traps and piping that are installed by the manufacturer or shipped with the unit, for at least 4 ft of piping length from the connection at the appliance with material having an R-value not less than 8 °F·ft ^{2}·h/Btu. Ensure that the insulation does not contact any appliance surface except at the location where the pipe connections penetrate the appliance jacket.

C) Test Conditions

1) Water Supply.

Follow the following provisions regarding the water supply to the water heater:

a) The pressure of the water supply must be maintained between 40 psi and the maximum pressure specified by the manufacturer of the unit being tested. The accuracy of the pressure-measuring devices must be ± 1.0 pounds per square inch (psi).

2) Ambient Room Temperature.

During the soak-in period and standby loss test, maintain the ambient room temperature at 75 °F ± 10 °F at all times. Measure the ambient room temperature at 30-second intervals during these periods. Measure the average ambient room temperature separately for the soak-in period and standby loss test. During the soak-in period and standby loss test, the measured room temperature must not vary more than ±5.0 °F at any reading from the average ambient room temperature.

3) Maximum Air Draft.

During the soak-in period and standby loss test, the storage tank must be located in an area protected from drafts of more than 50 ft/min from room ventilation registers, windows, or other external sources of air movement. Prior to beginning the soak-in period and standby loss test, measure the air draft within three feet of the jacket of the water heater to ensure this condition is met. Ensure that no other changes that would increase the air draft are made to the test set up or conditions during conduct of the test.

4) Data Collection

Follow the data recording intervals specified in the following sections.

a) Soak-In period

Measure the air draft, in ft/min, before beginning the soak-in period. Measure the ambient room temperature, in °F, every minute during the soak-in period.

b) Standby Loss Test

Follow the data recording intervals specified in Table B.1 of this section.

Table 4.4 Data to be Recorded Before and During the Standby Loss Test

Item recorded	Before test	Every minute[1]
Air draft, ft/min	X	
Time, minutes/seconds		X
Mean tank temperature, °F		X
Ambient room temperature, °F		X

D) Determination of Storage Volume

Determine the storage volume by subtracting the tare weight—measured while the system is dry and empty—from the weight of the system when filled with water and dividing the resulting net weight of water by the density of water at the measured water temperature.

E) Soak-In Period

Prior to conducting a standby loss test, a soak-in period must occur, in which the tank must sit without any draws taking place for at least 12 hours. Begin the soak-in period after filling the tank with water such that the initial mean tank temperature of 145 °F ± 5 °F is achieved.

F) Standby Loss Test

1) After conducting the soak-in period but prior to the start of the standby loss test, fill the storage tank with water that is heated sufficiently to achieve a mean tank temperature of at least 145°F.

2) When the mean tank temperature falls to 142°F, start recording mean tank temperature and ambient room temperature at regular minute intervals as the tank temperature decays.

3) When the mean tank temperature falls below 138°F, stop the test and record the final mean tank temperature reading.

4) Calculate the standby loss in Btu per hour as follows:

a) Select the data points starting when the mean tank temperature first falls to 142°F and ending when the mean tank temperature first falls below 138°F. Calculate the uncorrected decay rate, DR_u in °F/h, by a least squares method as given by:

$$DR_u = \frac{n\sum x_i T_i - (\sum x_i)(\sum T_i)}{n\sum(x_i^2) - (\sum x_i)^2}$$

Where:

n = 31 (the number of data points collected);

x_i = Elapsed time of each data point from the start of the decay period when the tank first achieves a mean temperature of 142°F (hours);

T_i = Mean tank temperature in °F measured at each 30-second interval during the decay period between the time when the mean tank temperature first falls to 142°F and when the mean tank temperature drops below 138°F.

[1] These measurements are to be recorded at the start and end of the test, as well as at intervals of exactly one minute during the test.

b) Calculate the mean tank water temperature decay rate ("DR"), in °F/h, as follows:

$$DR = DR_u \times \frac{140°\text{F} - 75°\text{F}}{140°\text{F} - T_a}$$

Where T_a is the average ambient room temperature during the test, °F.

c) The standby loss, SL, in Btu per hour, for unfired hot water storage tanks is determined as:

$$SL_U = DR \times V \times \rho \times C_p$$

Where:

V = tank volume expressed in gallons, measured in accordance with section 4.2.1D of this appendix

ρ = 8.205 pounds per gallon, density of water at 140°F

C_p = 0.999 Btu per pound-mass· °F, specific heat of water at 140°F

Note: This test procedure is based largely on a test procedure that was proposed on May 9, 2016, in the test procedure Notice of Proposed Rulemaking ("NOPR") for Commercial Water Heating Equipment. 81 FR 28587. However, that proposal was never finalized. The DOE and EPA request comment on the representativeness of this method for measuring standby loss of unfired hot water storage tanks, as well as any alternative metrics and/or test methods it should consider. The DOE and EPA also request comment on how unfired hot water storage tank standby losses are impacted by using a stratified tank and interactions with central HPWH.

4.2.2 Electric Storage Water Heaters

A) General

Use appendix B to subpart G of 10 CFR 431 ("appendix B"), except for section 5.7 of appendix B and instead as specified in section 4.2.2B of this section, to set-up, test, and collect data to determine the rate of energy input to the electric resistance element in Btu/h (Q_{res}), the rate of change in energy stored by the water in the tank in Btu/h (Q_{tank}), and the standby loss of the electric storage water heater in Btu/h (SL_E).

B) Standby Loss Calculations

1) Calculate the rate of energy input to the electric resistance element (Qres), in Btu/h, using the following equation:

$$Q_{res} = \frac{E_c}{t}$$

Where,

E_C = Electrical energy consumed by the water heater during the duration of the test in Btu
t = Total duration of the test in hours

a) Calculate the rate of change in energy stored by the water in the tank (Q_{tank}), in Btu/h, using the following equation:

$$Q_{tank} = \frac{k(V_a)(\Delta T_4)}{t(E_t/100)}$$

Where,

ΔT_4= Final mean tank temperature measured at the end of the test minus the initial mean tank temperature measured at the start of the test, expressed in °F
k = 8.25 Btu/gallon·°F, the nominal specific heat of water multiplied by the density of water
V_a = Volume of water contained in the water heater in gallons measured in accordance with section 4.2.1D
E_t = Thermal efficiency = 98 percent for electric water heaters with immersed heating elements
t = as defined in section 2.1.1.1
100 = conversion from percent to decimal

2) The standby loss of the electric storage water heater (SL_E), expressed in Btu/h, and determined as the average hourly energy required to maintain the stored water temperature, must be calculated using the following equation:

$$SL_E = Q_{res} - Q_{tank}$$

4.3 Test Method for the Measurement of Energy Consumption of Circulator Pumps

To measure the energy consumption of any additional circulator pumps in the central HPWH system other than the heat pump unit circulator pump, use sections 0-5 of appendix D to subpart Y of 10 CFR 431 to set-up, test, and collect data to determine the circulator energy rating (CER), in hp, determined in accordance with Table 1 of appendix D.

5 REFERENCES

A) 10 CFR Part 431, Subpart G, Appendix E. Uniform Test Method for the Measurement of Energy Efficiency of Commercial Heat Pump Water Heaters (as of November 6, 2017).
B) "Uniform Test Method for the Measurement of Energy Efficiency of Unfired Hot Water Storage Tanks (as proposed in the May 2016 NOPR for Commercial Water Heating Equipment Test Procedure)" 81 FR 28587, 28654-28655. Energy Conservation Program for Certain Commercial and Industrial Equipment: Test Procedure for Commercial Water Heating Equipment; Notice of Proposed Rulemaking. May 9, 2016.
C) 10 CFR Part 431. Subpart G, Appendix B. Uniform Test Method for the Measurement of Standby Loss of Electric Storage Water Heaters and Storage-Type Instantaneous Water Heaters.
D) 10 CFR Part 431, Subpart Y, Appendix D. Uniform Test Method for the Measurement of Energy Consumption of Circulator Pumps (as of March 20, 2023).
E) ANSI/AHRI Standard 1300-2013, ("ANSI/AHRI 1300-2013"), Performance Rating for Commercial Heat Pump Water Heaters, approved by ANSI on October 1, 2013
F) ANSI/ASHRAE Standard 37-2009, ("ANSI/ASHRAE 37-2009"), Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment, approved by ANSI on June 25, 2009
G) ANSI/ASHRAE Standard 118.1-2022, "Method of Testing for Rating Commercial Gas, Electric, and Oil Service Water Heating Equipment," approved by ASHRAE and ANSI on August 31, 2022