ENERGY STAR® Program Requirements
Product Specification for Room Air Conditioners

Draft Final Test Method to Determine Room Air Conditioner Heating Mode Performance
April 2024

1 OVERVIEW

The following test method shall be used for determining heating mode performance for ENERGY STAR reverse cycle room air conditioners following cooling mode performance tests according to the U.S. Department of Energy (DOE) Test Procedure in Title 10 of the Code of Federal Regulations (CFR) Part 430, Appendix F to Subpart B (appendix F).

2 APPLICABILITY

This test method is applicable to products that meet the definition of room heat pumps below.

3 DEFINITIONS

Unless otherwise specified, all terms used in this document are consistent with the definitions in the ENERGY STAR Eligibility Criteria for Room Air Conditioners Version 5.0, appendix F, and DOE definitions in 10 CFR 430.2.

A) Active defrost: The removal of frost and ice on the outdoor coil by actively heating the outdoor coil, e.g., by operating the unit in cooling mode. Running the outdoor fan without additional outdoor coil heat input is not active defrost.

B) Coefficient of Performance (COP): The dimensionless ratio of heating capacity, converted from Btu/h to W, to the power consumed delivering heat, in W, at a given temperature of operation.

C) Heating capacity: The amount of heating, in British thermal units per hour (Btu/h), provided to a conditioned space, measured under the specified conditions and determined in section 6 of this test method.

D) Heating energy efficiency ratio (HEER): The energy efficiency of a room air conditioner in British thermal units per watt-hour (Btu/Wh) when in heating mode, as calculated in section 7 of this test method.

E) Room heat pump: A room air conditioner as defined at 10 CFR 430.2 that utilizes reverse cycle refrigeration as its prime source for heating the indoor space.

   1) Type 1 heat pump: A room heat pump that does not have active defrost or for which the specified compressor cut-in and cut-out temperatures are not both less than 40°F.

   2) Type 2 heat pump: A room heat pump that has active defrost and for which the specified compressor cut-in and cut-out temperatures are both less than 40°F but not both less than 17°F.

   3) Type 3 heat pump: A room heat pump that has active defrost and for which the specified compressor cut-in and cut-out temperatures are both less than 17°F but not both less than 5°F.

   4) Type 4 heat pump: A room heat pump that has active defrost and for which the specified compressor cut-in and cut-out temperatures are both less 5°F.

Note: In this draft final version, DOE and EPA have altered the definitions of room heat pump types from mild, cool, cold climate and other to Types 1-4, as shown above, and removed the capacity ratios and efficiency requirements originally proposed in the draft test method. These changes ensure the definitions are self-contained and don't require any initial testing to determine the type of room heat pump under test.

5) Single-speed heat pump: A heat pump that has a single, fixed compressor speed or capacity output.

6) Variable-speed heat pump: A room heat pump that has a compressor that uses either a variable speed driver or inverter to vary the compressor speed and controls the unit by monitoring unit operation and automatically modulates compressor output as required to maintain the indoor room temperature.

4 TEST REQUIREMENTS

4.1 Test Apparatus

4.1.1 Conduct tests using a calorimeter that meets the requirements of section 3 of appendix F or a psychrometric apparatus that meets the requirements of section 6.2 of ANSI/ASHRAE 16-2016 or a psychrometric chamber that meets the requirements of ASHRAE 37-2009. Tests involving air temperatures below 42 °F must be conducted using a psychrometric chamber. For heat pumps that must be installed in a psychrometric chamber, all heating tests shall be conducted in the same facility.

4.2 Test Tolerances

When determining allowable test tolerances, consult appendix F, if using a calorimeter or ANSI/ASHRAE 37-2009, if using a psychrometric chamber. For reference, the allowable tolerances are presented in Table 1.

Table 1: Test Tolerances for Non-Frost Heating Mode Tests

Reading	Calorimeter (Appendix F)		Psychrometer (ANSI/ASHRAE 37-2009)	
	Maximum Variation of Readings	Maximum Variation of Arithmetic Average	Maximum Variation of Readings	Maximum Variation of Arithmetic Average
Indoor entering dry-bulb temperature, °F	0.6	0.3	2.0	0.5
Indoor entering wet-bulb temperature, °F	0.6	0.3	1.0	0.3
Outdoor entering dry-bulb temperature, °F	0.6	0.3	2.0	0.5
Outdoor entering wet-bulb temperature, °F	0.6	0.3	1.0	0.3
Electrical voltage, % of reading	2.0	1.0	2.0	1.0
Calorimeter Coil Water Flow Rate, % of reading	2.0	1.0		

Calorimeter Coil Water Temp, °F	0.3			
External resistance to airflow, inches of water			0.05	0.02
Nozzle Pressure Drop, % of reading			2.0	1.5

Table 2: Test Tolerances for Frost Accumulation Tests

Reading	Maximum Variation of Readings		Maximum Variation of Arithmetic Average Sub-interval H[1]
	Sub-interval H[1]	Sub-interval D[2]	
Indoor entering dry-bulb temperature, °F	3.0	4.0[3]	0.5
Indoor entering wet-bulb temperature, °F	1.5		0.3
Outdoor entering dry-bulb temperature, °F	3.0	10.0	0.5
Outdoor entering wet-bulb temperature, °F	1.5		0.3
External resistance to airflow, inches of water	0.05		0.02
Electrical voltage, % of reading	2.0		1.5

[1]Applies when the heat pump is in the heating mode, except for the first 10 minutes after termination of a defrost cycle.
[2]Applies during a defrost cycle and during the first 10 minutes after the termination of a defrost cycle when the heat pump is operating in the heating mode.
[3]For heat pumps that turn off the indoor blower during the defrost cycle, the noted tolerance only applies during the 10-minute interval that follows defrost termination.

4.3 Supplemental Test Instructions

4.3.1 Manufacturers of units must submit the following information:

i. Room heat pump type (1-4)
ii. Compressor Cut-in and Cut-out temperatures
iii. Defrost settings (if adjustable and multiple options exist in the installation instructions)

4.3.2 Manufacturers of variable-speed units must submit supplemental test instructions in PDF format to EPA for each UUT that include additional testing and testing set up instructions (e.g., specific operational or control codes or settings) necessary to override the compressor speed and if necessary, operate at fan speeds representative of normal operation under the corresponding conditions of this test procedure (if the indoor and outdoor fans are not on the same shaft this applies only to the indoor fan).

Note: This draft final test method clarifies that supplemental test instructions may vary fan speed according to the test condition, based on feedback from commenters that the draft test method instructions were unclear on this point.

4.3.3 Manufacturers of units equipped with resistance heaters may submit supplemental test instructions in PDF format that detail additional testing and set-up instructions to disable resistance heat operation to allow accurate measurement of the test unit's heat pump-only operation and performance as specified in section 6.4 and 6.5 of this test method. If the resistance heaters were manually disabled for any test condition, the provisions of section 6.7 apply with respect to verifying the operation of resistance heaters.

5 PRE-TEST UUT CONFIGURATION

5.1 General Configuration

Heating mode tests conducted in a calorimeter may be conducted directly following appendix F cooling mode tests using the installation instructions provided in appendix F without removing the unit from the chamber. Otherwise, if testing in a psychrometer, the Unit Under Test (UUT) shall be installed according to the instructions provided by the manufacturer.

5.2 Through-the-wall installation.

As required in appendix F, install a non-louvered room air conditioner inside a compatible wall sleeve with the provided or manufacturer-required rear grille, and with only the included trim frame and other manufacturer-provided installation materials, per manufacturer instructions provided to consumers.

5.3 Control settings

If the room air conditioner has network capabilities, all network features must be disabled throughout testing.

6 HEATING MODE TEST

6.1 General

6.1.1 For each required test condition specified below, measure the heating capacity, Q, in Btu/h and the average unit power, E, in Watts (W).

6.1.2 Test measurements shall be made in accordance with appendix F for tests in a calorimeter or section 8 of ANSI/ASHRAE 37-2009 for tests in a psychrometer.

6.1.3 For units tested in accordance with ANSI/ASHRAE 37-2009, section 6.2 of ANSI/ASHRAE 16-2016 shall also apply. Additionally, for units that reject condensate to the indoor coil, apply the heating capacity calculations in section 9.4 of ANSI/ASHRAE 58-1986 instead of the heating capacity calculations in section 7.3.4.1 of ANSI/ASHRAE 37-2009.

6.1.4 A secondary capacity measurement is required for the $H_{1,Full}$ (for single-speed units) or $H_{1,Nom}$ (for variable-speed units) test condition. In order to fulfill the requirements of this specification, the method used to determine capacities shall agree as follows:

a. Indoor calorimetric and outdoor calorimetric measurement; within 4%, as specified in ANSI/ASHRAE 16-2016,

b. Indoor calorimetric and indoor psychrometric measurement; within 5%, as specified in ANSI/ASHRAE 16-2016,

c. Indoor psychrometric and outdoor calorimetric measurement; within 6%, as specified in ANSI/ASHRAE 16-2016,

d. Indoor psychrometric and outdoor psychrometric measurement; within 6%, as specified in ANSI/ASHRAE 37-2009, or

e. Indoor psychrometric and Indoor electric resistance heat apparatus; within 4%, as specified in the instructions in section 6.2.

6.2 Secondary Capacity Measurement – Electric Resistance Heat Apparatus

6.2.1 Use the instructions in this section to conduct the secondary capacity measurement described in section 6.1.3.e.

6.2.2 The electric resistance heat apparatus shall be constructed as shown in Figure 1. The apparatus shall be constructed and insulated so that radiant and conductive heat loss to the surrounding room is negligible. The electric resistance heat apparatus is attached to the air measuring apparatus in place of the air conditioner.

6.2.3 The electrical input to the resistance heater with the apparatus shall be adjusted to provide the equivalent test conditions. The airflow, the inlet temperature, and the outlet temperature shall agree with the values measured during the test of the air conditioner, within the tolerances of Table 1.

6.2.4 The heat input of the qualifying resistance heater shall be calculated as follows:

$$\dot{Q}_r = 3.41 * \dot{E}_r$$

Where:
$\dot{Q}_r$ = total heating capacity of the resistance heater, Btu/h (W)
$\dot{E}_r$ = power input to resistance heater, W

6.2.5 The net heating capacity output of the electric resistance heat apparatus shall be calculated as follows:

$$\dot{Q}_{th} = 60 * \dot{V}_m * C_{p,a} * \frac{T_{a2} - T_{a1}}{v_n' * (1 + W)} + \dot{Q}_l$$

Where:
$\dot{Q}_{th}$ = heating capacity of the resistance heat apparatus, Btu/h.
$\dot{V}_m$ = indoor airflow at point of measurement, cfm.
T_{a2} = temperature of air leaving indoor side, °F.
T_{a1} = temperature of air entering indoor side, °F.
v_n' = specific volume of air at point of measurement, ft^3/lb.
$C_{p,a}$= 0.24 + 0.44W, the constant pressure specific heat of the air-water vapor mixture expressed on a dry air basis, $Btu/lb_{dry\ air}$ °F.
W = specific humidity ratio of air.
$\dot{Q}_l$ = heat loss through measuring apparatus, Btu/h.

6.2.6 The test apparatus shall be considered to be calibrated if the heat input of the electric resistance heat apparatus agrees with the measured heat output within 4%.

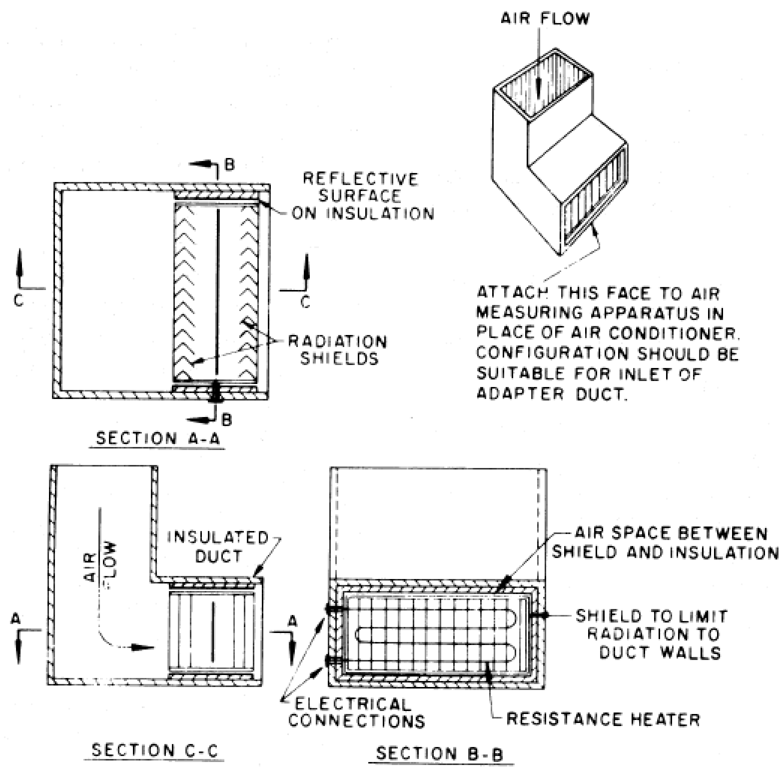

Figure 1: Electric Resistance Heat Apparatus (suggested)

6.2.7 The capacity and power measurements for the heating tests shall be determined using section 7, section 8, and section 11, of ANSI/ASHRAE 16–2016 and section 7 of ANSI/ASHRAE 37–2009 unless otherwise modified by this document.

6.3 Cut-out and Cut-in Temperatures

6.3.1 This section is not applicable to Type 1 room heat pumps. For Type 1 room heat pumps, the cut-out and cut-in temperatures shall be assumed to be 42 °F.

6.3.2 If the UUT is not a Type 1 room heat pump, follow these optional instructions to verify the cut-out and cut-in temperatures. If these tests are not conducted, T_L shall be equal to the average of the certified cut-out and cut-in temperatures. If these tests are conducted, T_L shall be equal to the average of the cut-out and cut-in temperatures determined by the test.

6.3.3 Capacity does not need to be measured. Measure a parameter that provides positive indication that the room heat pump is operating in heating mode (e.g., power or discharge pressure). Also monitor the temperature of the outdoor air entering the unit using one or more air samplers or parallel thermocouple grid(s). Collect measurements at a rate of once every 15 seconds or faster. The temperature of outdoor air entering the unit shall be used for determining outdoor temperature in the subsequent sections. Set the UUT to operate in heating mode with the thermostat set between 72 °F and 75 °F, to ensure the electric resistance heat will not be active with the conditioned space set at a lower temperature of 70 °F.

6.3.4 Determine the cut-out temperature, T_{off}. Reduce outdoor temperature to 5°F warmer than the specified cut-out temperature for dry-bulb temperature. When the outdoor temperature is above 17 °F, maintain a relative humidity below 60%. Pause outdoor chamber temperature reduction for at least three minutes to allow conditions to stabilize. Then continue to reduce outdoor chamber temperature in steps or continuously at an average rate of not more than 1 °F every 5 minutes. Compressor operation momentarily stopping for the purposes of a defrost cycle, not to exceed 30 seconds, is not considered a compressor cut-out. The test ends when one of the following conditions is met:

i. Test Facility has not reached the certified cut-out temperature, but the compressor stops running. Record the average outdoor coil air inlet temperature when the compressor operation stopped as the tested cut-out temperature T_{off}. Proceed to the Cut-In test.

ii. Test Facility reaches the certified cut-out temperature and compressor stops running at that temperature. Set Toff equal to the certified cut-out temperature. Proceed to the Cut-In test.

iii. Test Facility reaches the certified cut-out temperature, but the compressor continues to run. Set Toff equal to the certified cut-out temperature.

iv. If the outdoor chamber temperature reaches the colder of -5°F or the lowest temperature for which performance is specified, but no lower than -22°F, and the compressor continues to run proceed to the Simulated Cut-out in step 6.3.5.

6.3.5 Simulated Cut-out. For a unit where the compressor continues to run as described in 6.3.4, remove the heating demand when the outdoor temperature reaches the colder of -5°F or the lowest temperature for which performance is specified, but no lower than -22°F. Remove the heating demand by adjusting the controls to a setpoint at least 2°F lower than the room temperature measured by the unit's control. Allow the unit to remain off for not less than 30 seconds, then supply the heating demand by adjusting the controls to a setpoint at least 2°F lower than the room temperature measured by the unit's control. Use the indoor room dry-bulb sensor if the unit's control lacks indication of the measured room temperature. Proceed to the cut-in temperature test.

Note: Some room heat pumps may be able to operate the compressor at temperatures colder than can be achieved in typical psychrometric test chambers. The simulated cut-out provides a means for the test facility to complete the cut-out portion of the test for these types of units. The lowest temperature bin impacting the HEER is -5°F. For a unit that does not certify/report performance at a temperature lower than -5 °F, this would be the lowest outdoor temperature the test facility would need to achieve. For a unit that certifies/reports performance (e.g. $H_{x, full}$) the lowest outdoor temperature the test facility would have to achieve is the higher of the temperature designated at $H_{x, full}$ conditions or -22 °F.

6.3.6 Determine the cut-in temperature, T_{on}. Maintain the outdoor temperature within 2°F of T_{off} for 5 minutes following compressor cut-out—then increase outdoor chamber temperature by no more than 1 °F every 5 minutes. Continue temperature ramp until either the compressor operation restarts or the specified cut-in temperature is reached, whichever occurs first. The cut-in temperature is determined as follows:

i. If the compressor operation restarts before the specified cut-in temperature is reached, the test is complete. Set T_{on} equal to the specified cut-in temperature.

ii. If the compressor operation restarts within 2.5 minutes of the time that the specified cut-in temperature is reached, the test is complete. Set T_{on} equal to the specified cut-in temperature.

iii. If the compressor operation has not restarted more than 2.5 minutes after the certified cut-in temperature is reached, proceed as follows.

6.3.6.iii.1 Stabilize the outdoor temperature for at least five minutes until it remains within 0.5 ºF of the specified cut-in temperature. Wait a minimum of at least five minutes after stabilization of the outdoor temperature.

6.3.6.iii.2 Adjust the unit's thermostat setting to at least 2°F lower than the room temperature measured by the unit's control to stop the unit's heating demand. Wait 30 seconds, then increase the unit's thermostat setting to 2°F higher than the room temperature measured by the unit's control. Alternatively, use the indoor room dry-bulb sensor if the unit's control lacks indication of the measured room temperature.

6.3.6.iii.3 If the compressor operation restarts and the compressor continues running for five minutes, set T_{on} equal to the specified cut-in temperature—at this point, the test is complete. If the compressor operation does not restart, continue to step 6.3.6.iii.4.

6.3.6.iii.4 Increase the target outdoor temperature 1 ºF. Stabilize the outdoor temperature for at least five minutes until it remains within 0.5 ºF of this target. Wait a minimum of at least five minutes after stabilization of the outdoor temperature.

6.3.6.iii.5 Adjust the unit's thermostat setting to at least 2°F lower than the room temperature measured by the unit's control to stop the unit's heating demand. Wait 30 seconds, then increase the unit's thermostat setting to 2°F higher than the room temperature measured by the unit's control.

6.3.6.iii.6 If the compressor operation restarts and the compressor continues running for five minutes, set T_{on} equal to the current target outdoor temperature—at this point, the test is complete. Otherwise, go back to step 6.3.6.iii.4 and repeat until compressor operation restarts or until the current target outdoor temperature is 42 ºF.

6.4 Single-Speed Heat Pump Test

6.4.1 Set the fan speed to high, and where possible, ensure that the indoor fan is set to cycle on and off with the compressor.

6.4.2 Run tests from one of Tables 3-6 according to the type of UUT, as defined above.

6.4.3 The coefficient of performance (COP) of the UUT for temperatures at or below the cut-out temperature (or 42 °F, if the cut-out test is not conducted) will be assumed to be 1, representing resistance heat operation at these temperatures.

Table 3: Heating Mode Test Conditions for Type 1 Single-Speed Units

Test Name	Indoor side temperature (°F)		Outdoor side temperature (°F)	
	Dry bulb	Wet Bulb	Dry bulb	Wet Bulb
$H_{0, full}$ Test - optional	70	60 max	62	56.5
$H_{1, full}$ Test - required	70	60 max	47	43

Table 4: Heating Mode Temperature Test Conditions for Type 2 Single-Speed Units

Test Name	Indoor side temperature (°F)		Outdoor side temperature (°F)	
	Dry bulb	Wet Bulb	Dry bulb	Wet Bulb
$H_{0, full}$ Test – optional[1]	70	60 max	62	56.5
$H_{1, full}$ Test - required	70	60 max	47	43
$H_{2,full}$ Test—optional[2]	70	60 max	35	33
$H_{L, full}$ Test – required[1]	70	60 max	See note 2	See note 3

[1] If the $H_{L, full}$ test target dry-bulb outdoor temperature (see note 2) is greater than or equal to 37 °F, the $H_{0, full}$ test is required and the $H_{L, full}$ test would be optional. Otherwise, the $H_{0, full}$ test is optional and the $H_{L, full}$ test is required.
[2] Test at T_L as determined in section 6.3.
[3] Use a wet-bulb temperature corresponding to a maximum 60% RH level

Table 5: Heating Mode Temperature Test Conditions for Type 3 Single-Speed Units

Test Name	Indoor side temperature (°F)		Outdoor side temperature (°F)	
	Dry bulb	Wet Bulb	Dry bulb	Wet Bulb
$H_{1, full}$ Test - required	70	60 max	47	43
$H_{2,full}$ Test—optional[1]	70	60 max	35	33
$H_{3, full}$ Test - required	70	60 max	17	15

[1]Follow instructions in section 6.6

Table 6: Heating Mode Temperature Test Conditions for Type 4 Single-Speed Units

Test Name	Indoor side temperature (°F)		Outdoor side temperature (°F)	
	Dry bulb	Wet Bulb	Dry bulb	Wet Bulb
$H_{1, full}$ Test - required	70	60 max	47	43
$H_{2,full}$ Test—optional[1]	70	60 max	35	33
$H_{3, full}$ Test – required	70	60 max	17	15
$H_{4, full}$ Test - optional	70	60 max	5	4
$H_{x, full}$ Test – optional[2]	70	60 max	See note 3	See note 4

[1]Follow instructions in section 6.6
[2] See section 8.4
[3] Test at the average of the cut-out temperature and cut-in temperature determined in section 6.3.
[4] Use a wet-bulb temperature corresponding to a maximum 80% RH level

6.5 Variable-Speed Heat Pump Test

6.5.1 For each test, the fan setting shall be determined by the supplemental test instructions provided by the manufacturer as per section 4.3 of this test procedure.

6.5.2 Run tests from one of Tables 7-10 according to the type of UTT.

6.5.3 Set compressor speeds as follows. Use the values certified by the manufacturer for the low, intermediate, nominal and full compressor speeds.

i. Full and nominal compressor speed. The compressor shall operate at the maximum speed that the controls would operate the compressor in normal operation at 47 °F ambient temperature for the $H_{1,nom}$ test. This compressor speed is the full speed value used to determine the intermediate compressor speed for all Type 1 units and for Type 2 units for which the $H_{L,full}$ test is not conducted. The compressor shall operate for the $H_{0,full}$ test at the maximum speed that the controls would operate the compressor in normal operation at 62 °F ambient temperature. The compressor shall operate for the $H_{L,full}$ test at the maximum speed that the controls would operate the compressor in normal operation at the T_L ambient temperature. This compressor speed is the full speed value used to determine the intermediate compressor speed for Type 2 units for which the $H_{L,full}$ test is conducted. The compressor shall operate for the $H_{1,full}$ and $H_{3,full}$ tests at the maximum speed that the controls would operate the compressor in normal operation at 17 °F ambient temperature. This compressor speed is the full speed value used to determine the intermediate compressor speed for Type 3 and Type 4 units. The compressor shall operate for the $H_{4,max}$ test at the maximum speed that the controls would operate the compressor in normal operation at 5 °F ambient temperature. The compressor shall operate for the $H_{X,max}$ test at the maximum speed that the controls would operate the compressor in normal operation at an ambient temperature equal to T_L, the average of the cut-out and cut-in temperatures.

ii.

iii. Low compressor speed. The compressor shall operate at the same low speed for the $H_{0,low}$ and $H_{1,low}$ tests. Intermediate compressor speed. The intermediate compressor speed shall be determined using equation 6.5.3-1. A tolerance of plus 5 percent or the next higher inverter frequency step from that which was calculated is allowed

$$Intermediate\ speed = Minimum\ speed + \frac{Full\ speed - Minimum\ speed}{3}$$

Table 7: Heating Mode Test Conditions for Type 1 Variable-Speed Units

Test description	Air entering indoor unit temperature (°F)		Air entering outdoor unit temperature (°F)		Compressor Speed
	Dry bulb	Wet bulb	Dry bulb	Wet bulb	
$H_{0,low}$ Test—required	70	60 max	62	56.5	Low
$H_{1,nom}$ Test—required	70	60 max	47	43	Nominal[1]
$H_{1,int}$ Test—optional	70	60 max	47	43	Intermediate
$H_{1,low}$ Test—required	70	60 max	47	43	Low

[1] See description in section 6.5.3.

Table 8: Heating Mode Test Conditions for Type 2 Variable-Speed Units

Test description	Air entering indoor unit temperature (°F)		Air entering outdoor unit temperature (°F)		Compressor Speed
	Dry bulb	Wet bulb	Dry bulb	Wet bulb	
$H_{0\ full}$ Test—optional[1]	70	60 max	62	56.5	Full
$H_{0\ low}$ Test—required	70	60 max	62	56.5	Low
$H_{1,nom}$ Test—required	70	60 max	47	43	Nominal[2]
$H_{1,low}$ Test—required	70	60 max	47	43	Low
$H_{2,int}$ Test—optional[3]	70	60 max	35	33	Intermediate
$H_{L,\ full}$ Test—required[1]	70	60 max	See note 4	See note 5	Full

[1] If the $H_{L,\ full}$ test target dry-bulb outdoor temperature (see note 2) is greater than or equal to 37 °F, the $H_{0,\ full}$ test is required and the $H_{L,\ full}$ test is optional. Otherwise, the $H_{0,\ full}$ test is optional and the $H_{L,\ full}$ test is required.
[2] See description in section 6.5.3..
[3] Follow instructions in section 6.6
[4] Test at the average of the cut-in temperature and the cut-in temperature determined in section 6.3.
[5] Use a wet-bulb temperature corresponding to a maximum 60% RH level

Table 9: Heating Mode Test Conditions for Type 3 Variable-Speed Units

Test description	Air entering indoor unit temperature (°F)		Air entering outdoor unit temperature (°F)		Compressor Speed
	Dry bulb	Wet bulb	Dry bulb	Wet bulb	
$H_{0\ low}$ Test—required	70	60 max	62	56.5	Low
$H_{1,nom}$ Test—required	70	60 max	47	43	Nominal[1]
$H_{1,full}$ Test—optional	70	60 max	47	43	Full[2]
$H_{1,low}$ Test—required	70	60 max	47	43	Low
$H_{2,int}$ Test—optional[3]	70	60 max	35	33	Intermediate
$H_{3,\ full}$ Test—required	70	60 max	17	15	Full

[1] Maximum speed at which the unit controls would operate the compressor during normal operation in 47 °F ambient outdoor temperature.
[2] See description in section 6.5.3.[3] Follow instructions in section 6.6

Table 10: Heating Mode Test Conditions for Type 4 Variable-Speed Units

Test description	Air entering indoor unit temperature (°F)		Air entering outdoor unit temperature (°F)		Compressor Speed
	Dry bulb	Wet bulb	Dry bulb	Wet bulb	
$H_{0\ low}$ Test—required	70	60 max	62	56.5	Low
$H_{1,nom}$ Test—required	70	60 max	47	43	Nominal[1]
$H_{1,full}$ Test—optional	70	60 max	47	43	Full[2]
$H_{1,low}$ Test—required	70	60 max	47	43	Low
$H_{2,int}$ Test—optional[3]	70	60 max	35	33	Intermediate
$H_{3,\ full}$ Test—required	70	60 max	17	15	Full
$H_{4,\ max}$ Test—optional	70	60 max	5	4	Maxiumum[4]
$H_{x,\ max}$ Test – optional	70	60 max	See note 5	See note 6	Maxiumum[7]

[1] See description in section 6.5.3.
[2] See description in section 6.5.3.
[3] Follow instructions in section 6.6
[4] See description in section 6.5.3.
[5] Test at the average of the cut-in temperature and the cut-in temperature determined in section 6.3.
[6] Use a wet-bulb temperature corresponding to a maximum 80% RH level
[7] See description in section 6.5.3.

Note: In response to feedback from two stakeholders, DOE and EPA are adding test conditions for both single-speed and variable-speed units with active defrost but have cut-in and cut-out temperatures above 17 °F.

Additionally, in response to feedback from a stakeholder and recognizing developments in the packaged terminal heat pump (PTHP) test development process, the $H_{2,int}$ test is now optional for all units to reduce overall test burden. If a unit does not conduct an optional $H_{2,int}$ test, the HEER calculation will be conducted assuming that the unit alternates between high and low speeds to meet building load when intermediate speed would typically be used. Another commenter recommended that intermediate speed tests be required for all units to be consistent with the treatment of central heat pumps in appendix M1 to subpart B of 10 CFR 430 (appendix M1). While much of this room heat pump test method is similar to the appendix M1 test procedure, room heat pumps are smaller and more sensitive to increases in test burden than central heat pumps. Therefore, in this draft final test method, DOE and EPA are taking steps to minimize test burden for room heat pumps while maintaining test representativeness by making intermediate tests optional.

6.6 Frost Accumulation Tests

6.6.1 Use these instructions to conduct the optional $H_{2,int}$ (for variable-speed) or $H_{2,full}$ (for single-speed) tests specified above.

6.6.2 Ensure that frost meltwater is exiting the unit by a drain port, if possible.

Note: Room heat pumps may dispose of frost meltwater in a variety of ways, including by spraying the water outside, which is potentially desirable in situations where drain port plumbing is not possible. While useful in a real-world context, spraying water into the outdoor chamber during testing impacts test results, repeatability, reproducibility, and is a potential safety hazard. Therefore, DOE and EPA are requiring that meltwater be drained using an indoor or outdoor drain port, if possible, during tests.

6.6.3 Operate the test room reconditioning apparatus and the heat pump for at least 30 minutes at the specified test conditions as a stabilization period.

6.6.4 Defrost termination occurs when the controls of the heat pump actuate the first change in converting from defrost operation to normal heating operation. Defrost initiation occurs when the controls of the heat pump first alter its normal heating operation in order to eliminate possible accumulations of frost on the outdoor coil.

6.6.5 Following the stabilization period, use the following criteria to determine when to begin the preliminary test period:

i. For heat pumps containing defrost controls which are likely to cause defrosts at intervals less than one hour, the preliminary test period starts at the termination of an automatic defrost cycle and ends at the termination of the next occurring automatic defrost cycle.
ii. For heat pumps containing defrost controls which are likely to cause defrosts at intervals exceeding one hour, the preliminary test period must consist of a heating interval lasting at least one hour followed by a defrost cycle that is either manually or automatically initiated.

6.6.6 In all cases, the heat pump's own controls must govern when a defrost cycle terminates.

6.6.7 Begin the official test period immediately following the preliminary test period. The official test period ends at the termination of the next occurring automatic defrost cycle. If the heat pump has not undergone a defrost after 6 hours, immediately conclude the test and use the results from the full 6-hour period to calculate the average space heating capacity and average electrical power consumption.

6.6.8 To constitute a valid frost accumulation test, satisfy the test tolerances specified in Table 2 during both the preliminary and official test periods. As noted in Table 2, test operating tolerances are specified for two sub-intervals:

i. When heating, except for the first 10 minutes after the termination of a defrost cycle (sub-interval H) and
ii. When defrosting, plus these same first 10 minutes after defrost termination (sub-interval D).

Evaluate compliance with Table 2 test condition tolerances and the majority of the test operating tolerances using the averages from measurements recorded only during sub-interval H. Continuously record the dry bulb temperature of the air entering the indoor coil, and the dry bulb temperature and water vapor content of the air entering the outdoor coil. Sample the remaining parameters listed in Table 2 at equal intervals that span 5 minutes or less.

6.6.9 For the official test period, collect and use the following data to calculate average space heating capacity and electrical power. During heating and defrosting intervals when the controls of the heat pump have the indoor blower on, continuously record the dry-bulb temperature of the air entering (as noted above) and leaving the indoor coil. If using a thermopile, continuously record the difference between the leaving and entering dry-bulb temperatures during the interval(s) that air flows through the indoor coil. Determine the corresponding cumulative time (in hours) of indoor coil airflow, $\Delta\tau_a$. Sample measurements used in calculating the air volume rate (refer to sections 7.7.2.1 and 7.7.2.2 of ANSI/ASHRAE 37–2009) at equal intervals that span 10 minutes or less. Record the electrical energy consumed, expressed in watt-hours, from defrost termination to defrost termination, e(35), as well as the corresponding elapsed time in hours, $\Delta\tau_{FR}$.

6.7. Resistance Heat Controls Verification Procedure (RH_CVP).

6.7.1.1. For a unit where resistance heat was manually disabled for the tests specified in section 6.4 or 6.5, the operation of resistance heaters during unit operation must be accounted for in accordance with the provisions of this section. Manufacturers may choose to not conduct the RH_CVP for the purposes of certifying performance to EPA, as long as such certifications represent performance consistent with the requirements of this section. The RH_CVP, when applicable, must be conducted for verification testing.

6.7.1.2. The RH_CVP must be conducted after the official steady-state test at that outdoor test condition. The test setup shall not be modified in any way. The only modification shall be enabling the unit under test resistance heater.

6.7.1.3. To conduct the RH_CVP, begin by maintaining the indoor room and outdoor room ambient conditions from the respective test and selecting a setpoint (T_{ID}). T_{ID} shall be determined by accounting for offset plus 1°F. Temperature Offset (T_{Offset}) is the difference between the displayed ambient temperature on the test unit controls and the indoor room ambient temperature measured by the test facility during the official test.

Equation 6.7.1-1:

$$T_{ID} = 70°F + T_{Offset} + 1°F.$$

6.7.1.4. This shall result in the unit operating in heat pump only mode. Maintain equilibrium conditions for at least 10 minutes. At the conclusion of the 10 minute equilibrium period, evaluate if the resistance heat is engaged. If the resistance heat is engaged, the RH_CVP at the respective condition is complete. If the resistance heat is not engaged, begin reducing the indoor room ambient condition at a rate of no more than 1°F every 15 minutes until either the electric heat engages or the indoor room ambient temperature reaches 65°F.

6.7.1.5. Determine the RH_CVP cut-out factor, $\delta_{RH}(T_j)$. For the case where the electric resistance is engaged when the ambient room condition is ≥ 70°F, $\delta_{RH}(T_j) = 0$ for $T_j \geq T_{outdoor}$. For the case where the electric resistance is engaged when the ambient room condition is < 70°F and ≥ 69°F, $\delta_{RH}(T_j) = 1/2$ for $T_j \geq T_{outdoor}$. For the case where the electric resistance is engaged when the ambient room condition is < 69°F, $\delta_{RH}(T_j) = 1$, for $T_j \geq T_{outdoor}$.

6.7.2. If the resistance heat does not engage before the room reaches 65°F, evaluate for the following scenarios:

6.7.2.1. Determine if the resistance heat was properly enabled. If the resistance heat was not enabled, the RH_CVP shall be repeated once the resistance heat is properly enabled.

6.7.2.2. Determine if the unit has an ambient temperature electric heat lockout and what that temperature limit is. If the unit has this functionality and the outdoor conditions are above this limit, the test is complete and $\delta(RH) = 1$ for the evaluated outdoor condition.

Note: Three stakeholders observed during testing of several Packaged Terminal Heat Pumps (PTHPs) that resistance heat frequently switched on immediately to satisfy a new setpoint and that resistance heat and compressor operation never coincided. They recommended that DOE and EPA create design requirements governing the operation of supplemental heat, including limitations on when the resistance heater may operate in response to set point changes and when compressor operation is still possible.

Because this test method is performed under steady-state operating conditions, transient and short-term behavior (e.g., brief resistance heat that supplements or replaces heat pump operation to satisfy a new setpoint) is beyond the scope of this test. However, the RH_CVP procedure does address any resistance heat operation at representative outdoor temperatures and during steady-state operating conditions, which can represent significant hours of operation.

7 HEER CALCULATION

7.1 HEER Equation and Building Load Equation

Calculate HEER using equation 7.1.1:

$$HEER = \frac{\sum_{j=1}^{14} n_j * BL(T_j)}{\sum_{j=1}^{14} e_h(T_j) + \sum_{j=1}^{14} RH(T_j)} = \frac{\sum_{j=1}^{14} \frac{n_j}{N} * BL\left(T_j\right)}{\sum_{j=1}^{14} \frac{e_h(T_j)}{N} + \sum_{j=1}^{14} \frac{RH(T_j)}{N}}$$

Where:

$BL\left(T_j\right)$ = the value of the heating building load evaluated at the outdoor bin temperature, Btu/hr, as calculated in equation 7.1.2.

$\frac{e_h(T_j)}{N}$ = the ratio of the electrical energy consumed by the test unit when operating the heat pump during periods of the space heating season when the outdoor temperature fell within the range represented by the bin temperature T_j to the total number of hours in the heating season (N), W, as calculated in section 7.2 for single-speed units and section 7.3 for variable-speed units.

$\frac{RH(T_j)}{N}$ = the ratio of the electrical energy used for resistive space heating during periods when the outdoor temperature fell within the range represented by the bin temperature, T_j, to the total number of hours in the heating season (N), W, as calculated in section 7.2 for single-speed units and section 7.3 for variable-speed units. Resistive space heating is modeled as being used to meet that portion of the building load that the heat pump does not meet because of insufficient capacity or because the heat pump automatically turns off at the lowest outdoor temperatures.

$\frac{n_j}{N}$ = fractional bin hours for the heating season; the ratio of the number of hours during the heating season when the outdoor temperature fell within the range represented by bin temperature, T_j to the total number of hours in the heating season, dimensionless, as defined in Table 11.

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

Note: Five commenters recommended that HEER should account for standby power while in heating mode. While accounting for standby power usage is required for DOE test procedures, in this case, standby power for room heat pumps is already accounted for in the CEER metric, as that metric calculates the energy use of a full year’s worth of standby power operation (5,115 hours), not simply standby power during the cooling season. Therefore, simply adding standby power in the HEER metric would result in double counting of standby mode operation during the heating season.

Commenters also suggested that standby power in heating mode may be higher than the standby power measured in the cooling mode test due to the operation of crankcase heaters, drain pan heaters, and powered meltwater disposition systems. As many of these additional components may be activated at specific temperatures, each would need to be tested separately under multiple temperature-controlled conditions to ascertain when each component turned on and off. Such a testing regime would result in significant additional test burden and would not be guaranteed to be fully representative of all additional components that may affect a unit's standby power consumption. Additionally, while these additional components may consume more power than typical standby power for cooling mode, it is unlikely that the total power consumed is significant compared to energy use in heating mode. As it is unclear whether the potential benefits to test representativeness outweigh the potential increase in test burden, DOE and EPA opt to continue measuring standby mode power use using the appendix F method.

Evaluate the building heating load, $BL(T_j)$ using equation 7.1.2:

$$BL(T_j) = \frac{(T_{zl} - T_j)}{T_{zl} + 15} * Q_{C,full}$$

Where;
$Q_{C,full}$ = the rated cooling capacity of the unit, Btu/h.
T_{zl} = the zero-load temperature, °F, is equal to 63°F.
T_j = the representative outdoor bin temperature, °F, for each bin, j, as defined in Table 11.

Table 11: Distribution of Fractional Hours Within Heating Season Temperature Bins

Bin number, j	Bin temperature range °F	Representative temperature for bin °F	Fraction of total temperature bin hours, n_j/N
1	64-60	62	0.017
2	59-55	57	0.044
3	54-50	52	0.077
4	49-45	47	0.136
5	44-40	42	0.181
6	39-35	37	0.177
7	34-30	32	0.133
8	29-25	27	0.081
9	24-20	22	0.062
10	19-15	17	0.038
11	14-10	12	0.023
12	9-5	7	0.013
13	4-0	2	0.008
14	(-1) - (-5)	-3	0.01

7.2 Single-Speed Units

7.2.1 Evaluate $\frac{e_h(T_j)}{N}$ and $\frac{RH(T_j)}{N}$ using the following equations:

Equation 7.2.1-1:

$$\frac{e_h(T_j)}{N} = \frac{X(T_j) * \dot{E}_h(T_j) * \delta(T_j) * \delta_{RH}(T_j)}{PLF_j} * \frac{n_j}{N}$$

Equation 7.2.1-2:

$$\frac{RH(T_j)}{N} = \frac{BL(T_j) - [X(T_j) * \dot{Q}_h(T_j) * \delta(T_j) * \delta_{RH}(T_j)]}{3.413 \frac{Btu/h}{W}} * \frac{n_j}{N}$$

Where:

$X(T_j) = \begin{cases} \frac{BL(T_j)}{\dot{Q}_h(T_j)} \\ or \\ 1 \end{cases}$, whichever is less; the heating mode load factor for temperature bin j, dimensionless.

$\dot{Q}_h(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h, as calculated in equation 7.2.3-1, 7.2.4-1, 7.2.5-1, 7.2.6-1, 7.2.7-1, 7.2.8-1, or 7.2.9-1, depending on which tests are conducted.

$\dot{E}_h(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W, as calculated in equation 7.2.3-2, 7.2.4-2, 7.2.5-4, 7.2.6-3, 7.2.7-3, 7.2.8-3, or 7.2.9-2, depending on which tests are conducted.

$\delta_{RH}(T_j)$ = the resistance heat cut-in factor, dimensionless, as calculated in section 6.7.

$\delta(T_j)$ = the heat pump low temperature cut-out factor, dimensionless, as calculated in equation 7.2.2-1.

$PLF_j = 1 - \dot{C}_D^h * [1 - X(T_j)]$ the part load factor, dimensionless.

C_D^h = Heating degradation coefficient = 0.38.

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

> **Note:** The heating degradation coefficient accounts for performance losses due to the inefficiency of cycling the compressor on and off in response to decreased building loads. DOE and EPA have identified a heating degradation coefficient of 0.38 for single-speed units and of 0.44 for variable-speed units based on data collected for packaged terminal heat pumps. Packaged terminal heat pumps have similar construction to room air conditioners with heat pumps, and likely have similar behavior to room air conditioners when cycling.

Use Equation 7.1.2 to determine $BL(T_j)$. Obtain fractional bin hours for the heating season, $\frac{n_j}{N}$, from Table 11.

7.2.2 Determine the low temperature cut-out factor, $\delta(T_j)$, using the equation below:

Equation 7.2.2-1:

$$\delta(T_j) = \begin{cases} 0, & if\ T_j \le T_{off} \\ \frac{1}{2}, & if\ T_{off} < T_j \le T_{on} \\ 1, & if\ T_j > T_{on} \end{cases}$$

Where:

T_{off} = the outdoor temperature when the compressor is automatically shut off, °F, as determined in section 6.3. (If this temperature was not determined, T_{off} is equal to the lowest outdoor dry bulb temperature condition tested, or 42 °F for Type 1 heat pumps).

T_{on} = the outdoor temperature when the compressor is automatically turned back on, if applicable, following an automatic shut-off, °F, as determined in section 6.3. (If this temperature was not determined, T_{on} is equal to the lowest outdoor dry bulb temperature condition tested, or 42 °F for Type 1 heat pumps).
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

7.2.3 For Type 1 heat pumps, if only the $H_{1,Full}$ test is conducted, calculate $\dot{Q}_h(T_j)$ and $\dot{E}_h(T_j)$ as follows:

Equation 7.2.3-1:

$$\dot{Q}_h(T_j) = \dot{Q}_{h.full}(T_j) = \begin{cases} \dot{Q}_{H1,full} * \left[\dfrac{1 + (T_j - 17) * 0.0262}{1 + 30 * 0.0262}\right], if\ T_j \geq 42\ °F \\ 0, if\ T_j < 42\ °F \end{cases}$$

Where:
$\dot{Q}_h(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h
$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump as measured in the $H_{1,\ full}$ Test, Btu/h
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.
0.0262 = the standard capacity slope factor for full-load operation.

Equation 7.2.3-2:

$$\dot{E}_h(T_j) = \dot{E}_{h,full}(T_j) = \begin{cases} \dot{E}_{H1,full} * \left[\dfrac{1 + (T_j - 17) * 0.00455}{1 + 30 * 0.00455}\right], if\ T_j \geq 42\ °F \\ 0, if\ T_j < 42\ °F \end{cases}$$

Where:
$\dot{E}_h(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W
$\dot{E}_{H1,full}$= the electrical power consumption of the heat pump as measured in the $H_{1,\ full}$ Test, W
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.
0.00455 = the standard power slope factor for full-load operation.

7.2.4 For Type 1 heat pumps, if the optional $H_{0,\ full}$ test is conducted, calculate $\dot{Q}_h(T_j)$ and $\dot{E}_h(T_j)$ as follows:

Equation 7.2.4-1:

$$\dot{Q}_h(T_j) = \dot{Q}_{h.full}(T_j) = \begin{cases} \dot{Q}_{H1,full} + \dfrac{[\dot{Q}_{H0,full} - \dot{Q}_{H1,full}] * (T_j - 47)}{62 - 47}, if\ T_j \geq 42\ °F \\ 0, if\ T_j < 42\ °F \end{cases}$$

Where:
$\dot{Q}_h(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h
$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump as measured in the $H_{1,\,full}$ Test, Btu/h
$\dot{Q}_{H0,full}$ = = the space heating capacity of the heat pump when operating at the $H_{0,full}$ test condition, Btu/h
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

Equation 7.2.4-2:

$$\dot{E}_h(T_j) = \dot{E}_{h,full}(T_j) = \begin{cases} \dot{E}_{H1,full} + \dfrac{[\dot{E}_{H0,full} - \dot{E}_{H1,full}] * (T_j - 47)}{62 - 47}, if\ T_j \geq 42\ °F \\ 0, if\ T_j < 42\ °F \end{cases}$$

Where:
$\dot{E}_h(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W
$\dot{E}_{H1,full}$ = the electrical power consumption of the heat pump as measured in the $H_{1,\,full}$ Test, W
$\dot{E}_{H0,full}$ = the electrical power consumption of the heat pump as measured in the $H_{0,\,full}$ Test, W
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

7.2.5 For Type 2 heat pumps, if the $H_{0,full}$ test is not conducted and the T_L, determined as described in section 6.3 is less than or equal to 37 °F, calculate $\dot{Q}_h(T_j)$ and $\dot{E}_h(T_j)$ as follows:

Equation 7.2.5-1:

$$\dot{Q}_h(T_j) = \dot{Q}_{h.full}(T_j) = \begin{cases} \dot{Q}_{HL,full} + \dfrac{[\dot{Q}_{H1,full} - \dot{Q}_{HL,full}] * (T_j - T_L)}{47 - T_L}, \quad if\ \ T_j > 42°F \\ \dot{Q}_{H3,calc} + \dfrac{[\dot{Q}_{h,full}(35) - \dot{Q}_{H3,calc}] * (T_j - 17)}{35 - 17}, if\ \ T_{off} < T_j \leq 42°F \end{cases}$$

Where:
$\dot{Q}_h(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h
$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump as measured in the $H_{1,\,full}$ Test or the $H_{1,nom}$ test if the $H_{1,full}$ test was not conducted, as for variable-speed units, Btu/h
$\dot{Q}_{HL,full}$ = the space heating capacity of the heat pump as measured at the H_L test condition, Btu/h
$\dot{Q}_{h,full}(35)$= the space heating capacity of the heat pump when operating at 35 °F, accounting for frost accumulation, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.5-2, below, if the $H_{2,full}$ test is not conducted, Btu/h
$\dot{Q}_{H3,calc}$ = the theoretical space heating capacity of the heat pump when operating at 17 °F, as calculated in equation 7.2.5-3, below
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

T_L= the average of the cut-out temperature, T_{off}, and the cut-in temperature, T_{on}, as determined in section 6.3.
0.9 = the space heating capacity frost degradation factor

Equation 7.2.5-2:

$$\dot{Q}_{h,full}(35) = 0.9 * \{ \dot{Q}_{HL,full} + \frac{35 - T_L}{47 - T_L} * [\dot{Q}_{H1,full} - \dot{Q}_{HL,full}]\}$$

Equation 7.2.5-3:

$$\dot{Q}_{H3,calc} = \dot{Q}_{HL,full} + \frac{[\dot{Q}_{H1,full} - \dot{Q}_{HL,full}] * (17 - T_L)}{47 - T_L}$$

Equation 7.2.5-4:

$$\dot{E}_h(T_j) = \dot{E_{h,full}(T_j)} = \begin{cases} \dot{E}_{HL,full} + \frac{[\dot{E}_{H1,full} - \dot{E}_{HL,full}] * (T_j - T_L)}{47 - T_L}, if\ T_j > 42°\text{F} \\ \dot{E}_{H3,calc} + \frac{[\dot{E}_{h,full}(35) - \dot{E}_{H3,calc}] * (T_j - 17)}{35 - 17}, \quad if\ \ T_{off} < T_j \leq 42°\text{F} \end{cases}$$

Where:
$\dot{E}_h(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W
$\dot{E}_{H1,full}$ = the electrical power consumption of the heat pump as measured in the $H_{1,\ full}$ Test, or the $H_{1,nom}$ test if the $H_{1,full}$ test was not conducted, as for variable-speed units, W
$\dot{E}_{HL,full}$ = the electrical power consumption of the heat pump as measured in the $H_{L,\ full}$ Test, W
$\dot{E}_{h,full}(35)$ = the electrical power consumption of the heat pump when operating at 35 °F, accounting for frost accumulation, W, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.5-5, below, if the $H_{2,full}$ test is not conducted, Btu/h
$\dot{E}_{H3,calc}$ = the theoretical electrical power consumption of the heat pump when operating at 17 °F, as calculated in equation 7.2.5-6, below
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.
T_L= the average of the cut-out temperature, T_{off}, and the cut-in temperature, T_{on}, as determined in section 6.3.
0.985 = the electrical power frost degradation factor

Equation 7.2.5-5:

$$\dot{E}_{h,full}(35) = \ 0.985 * \{ \dot{E}_{HL,full} + \frac{35-T_L}{47-T_L} * [\dot{E}_{H1,full} - \dot{E}_{HL,full}]\}$$

Equation 7.2.7-6:

$$\dot{E}_{H3,calc} = \dot{E}_{HL,full} + \frac{\left[\dot{E}_{H1,full} - \dot{E}_{HL,full}\right] * (17 - T_L)}{47 - T_L}$$

7.2.6 For Type 2 heat pumps, if the $H_{L,full}$ test is not conducted or the T_L, determined as described in section 6.3, is greater than 37 °F,calculate $\dot{Q}_h(T_j)$ and $\dot{E}_h(T_j)$ as follows:

Equation 7.2.6-1:

$$\dot{Q}_h(T_j) = \dot{Q}_{h.full}(T_j) = \begin{cases} \dot{Q}_{H1,full} + \dfrac{\left[\dot{Q}_{H0,full} - \dot{Q}_{H1,full}\right] * (T_j - 47\ \ )}{62 - 47}, & if\ \ T_j > 42°\text{F} \\ \dot{Q}_{H3,calc} + \dfrac{\left[\dot{Q}_{h,full}(35) - \dot{Q}_{H3,calc}\right] * (T_j - 17\ \ )}{35 - 17}, & if\ \ T_{off} < T_j \le 42°\text{F} \end{cases}$$

Where:

$\dot{Q}_h(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h

$\dot{Q}_{H0,full}$ = the space heating capacity of the heat pump as measured in the $H_{0,\ full}$ Test, Btu/h

$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump as measured at the $H_{1,full}$ test condition, or the $H_{1,nom}$ test if the $H_{1,full}$ test was not conducted, as for variable-speed units, Btu/h

$\dot{Q}_{h,full}(35)$= the space heating capacity of the heat pump when operating at 35 °F, accounting for frost accumulation, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.6-2, below, if the $H_{2,full}$ test is not conducted, Btu/h

$\dot{Q}_{H3,calc}$ = the theoretical space heating capacity of the heat pump when operating at 17 °F, as calculated in equation 7.2.6-3, below

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

0.9 = the space heating capacity frost degradation factor

Equation 7.2.6-2:

$$\dot{Q}_{h,full}(35) = 0.9 * \{ \dot{Q}_{H3,calc} + \frac{35 - 17}{62 - 47} * [\dot{Q}_{H0,full} - \dot{Q}_{H1,full}]\}$$

Equation 7.2.6-3:

$$\dot{Q}_{H3,calc} = \dot{Q}_{H1,full} + \frac{\left[\dot{Q}_{H0,full} - \dot{Q}_{H1,full}\right] * (17 - 47)}{62 - 47}$$

Equation 7.2.6-4:

$$\dot{E}_h(T_j) = E_{h,full}(T_j) = \begin{cases} \dot{E}_{H1,full} + \dfrac{[\dot{E}_{H0,full} - \dot{E}_{H1,full}] * (T_j - 47)}{62 - 47}, if\ T_j > 42°F \\ \dot{E}_{H3,calc} + \dfrac{[\dot{E}_{h,full}(35) - \dot{E}_{H3,calc}] * (T_j - 17)}{35 - 17}, \quad if\ \ T_{off} < T_j \leq 42°F \end{cases}$$

Where:
$\dot{E}_h(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W
$\dot{E}_{H1,full}$ = the electrical power consumption of the heat pump as measured in the $H_{1,\ full}$ Test, or the $H_{1,nom}$ test if the $H_{1,full}$ test was not conducted, as for variable-speed units, W
$\dot{E}_{H0,full}$ = the electrical power consumption of the heat pump as measured in the $H_{0,\ full}$ Test, W
$\dot{E}_{h,full}(35)$ = the electrical power consumption of the heat pump when operating at 35 °F, accounting for frost accumulation, W, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.6-5, below, if the $H_{2,full}$ test is not conducted, Btu/h
$\dot{E}_{H3,calc}$ = the theoretical electrical power consumption of the heat pump when operating at 17 °F, as calculated in equation 7.2.6-6, below
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.
0.985 = the electrical power frost degradation factor

Equation 7.2.6-4:

$$\dot{E}_{h,full}(35) = \ \ 0.985 * \{\ \dot{E}_{H3,calc} + \tfrac{35-17}{62-47} * [\ \dot{E}_{H0,full} - \ \dot{E}_{H1,full}]\}$$

Equation 7.2.6-5:

$$\dot{E}_{H3,calc} = \dot{E}_{H1,full} + \frac{[\dot{E}_{H0,full} - \dot{E}_{H1,full}] * (17 - 47)}{62 - 47}$$

7.2.7 For Type 2 heat pumps, if the $H_{0,full}$ test was conducted and the T_L, as determined in section 6.3, is less than or equal to 37 °F, calculate $\dot{Q}_h(T_j)$ and $\dot{E}_h(T_j)$ as follows:

Equation 7.2.7-1:

$$\dot{Q}_h(T_j) = \dot{Q}_{h.full}(T_j) = \begin{cases} \dot{Q}_{H1,full} + \dfrac{[\dot{Q}_{H0,full} - \dot{Q}_{H1,full}] * (T_j - 47)}{62 - 47}, \quad if\ \ T_j > 47°F \\ \dot{Q}_{HL,full} + \dfrac{[\dot{Q}_{H1,full} - \dot{Q}_{HL,full}] * (T_j - T_L)}{47 - T_L}, if\ 42°F < T_j \leq 47°F \\ \dot{Q}_{H3,calc} + \dfrac{[\dot{Q}_{h,full}(35) - \dot{Q}_{H3,calc}] * (T_j - 17)}{35 - 17}, if\ \ T_{off} < T_j \leq 42°F \end{cases}$$

Where:
$\dot{Q}_h(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h
$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump as measured in the $H_{1,\ full}$ Test, or the $H_{1,nom}$ test if the $H_{1,full}$ test was not conducted, as for variable-speed units, Btu/h
$\dot{Q}_{H0,full}$ = the space heating capacity of the heat pump as measured in the $H_{0,\ full}$ Test, Btu/h
$\dot{Q}_{HL,full}$ = the space heating capacity of the heat pump as measured in the H_L test condition, Btu/h

$\dot{Q}_{h,full}(35)$= the space heating capacity of the heat pump when operating at 35 °F, accounting for frost accumulation, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.7-2, below, if the $H_{2,full}$ test is not conducted, Btu/h
$\dot{Q}_{H3,calc}$ = the theoretical space heating capacity of the heat pump when operating at 17 °F, as calculated in equation 7.2.7-3, below
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.
T_L= the average of the cut-out temperature, T_{off}, and the cut-in temperature, T_{on}, as determined in section 6.3.
0.9 = the space heating capacity frost degradation factor

Equation 7.2.7-2:

$$\dot{Q}_{h,full}(35) = 0.9 * \{\dot{Q}_{HL,full} + \frac{35 - T_L}{47 - T_L} * [\ \dot{Q}_{H1,full} - \ \dot{Q}_{HL,full}]\}$$

Equation 7.2.7-3:

$$\dot{Q}_{H3,calc} = \dot{Q}_{HL,full} + \frac{[\dot{Q}_{H1,full} - \dot{Q}_{HL,full}] * (17 - T_L)}{47 - T_L}$$

Equation 7.2.7-4:

$$\dot{E}_h(T_j) = E_{h,full}(T_j) = \begin{cases} \dot{E}_{H1full} + \frac{[\dot{E}_{H0,full} - \dot{E}_{H1,full}] * (T_j - 47)}{62 - 47}, if\ T_j > 42°F \\ \dot{E}_{HL,full} + \frac{[\dot{E}_{H1,full} - \dot{E}_{HL,full}] * (T_j - T_L)}{47 - T_L}, \quad if\ 42°F < T_j \leq 47°F \\ \dot{E}_{H3,calc} + \frac{[\dot{E}_{h,full}(35) - \dot{E}_{H3,calc}] * (T_j - 17)}{35 - 17}, \quad if\ T_{off} < T_j \leq 42°F \end{cases}$$

Where:
$\dot{E}_h(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W
$\dot{E}_{H1,full}$ = the electrical power consumption of the heat pump as measured in the $H_{1,\ full}$ Test, or the $H_{1,nom}$ test if the $H_{1,full}$ test was not conducted, as for variable-speed units, W
$\dot{E}_{H0,full}$ = the electrical power consumption of the heat pump as measured in the $H_{0,\ full}$ Test, W
$\dot{E}_{HL,full}$ = the electrical power consumption of the heat pump as measured in the $H_{L,\ full}$ Test, W
$\dot{E}_{h,full}(35)$ = the electrical power consumption of the heat pump when operating at 35 °F, accounting for frost accumulation, W, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.7-5, below, if the $H_{2,full}$ test is conducted, Btu/h
$\dot{E}_{H3,calc}$ = the theoretical electrical power consumption of the heat pump when operating at 17 °F, as calculated in equation 7.2.7-6, below
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.
T_L= the average of the cut-out temperature, T_{off}, and the cut-in temperature, T_{on}, as determined in section 6.3.
0.985 = the electrical power frost degradation factor

Equation 7.2.7-5:

$$\dot{E}_{h,full}(35) = \ 0.985 * \{ \dot{E}_{HL,full} + [\dot{E}_{H1,full} - \dot{E}_{HL,full}] * \frac{35-T_L}{47-T_L} \}$$

Equation 7.2.7-6:

$$\dot{E}_{H3,calc} = \dot{E}_{HL,full} + \frac{[\dot{E}_{H1,full} - \dot{E}_{HL,full}] * (17 - T_L)}{47 - T_L}$$

7.2.8 For Type 3 heat pumps, calculate $\dot{Q}_h(T_j)$ and $\dot{E}_h(T_j)$ as follows:

Equation 7.2.8-1:

$$\dot{Q}_h(T_j) = \dot{Q}_{h.full}(T_j) = \begin{cases} \dot{Q}_{H3,full} + \frac{[\dot{Q}_{H1,full} - \dot{Q}_{H3,full}] * (T_j - 17)}{47 - 17}, & if\ T_j < 17°\text{F or } T_j > 42°\text{F} \\ \dot{Q}_{H3,full} + \frac{[\dot{Q}_{h,full}(35) - \dot{Q}_{H3,full}] * (T_j - 17)}{35 - 17}, & if\ 17°\text{F} \le T_j \le 42°\text{F} \end{cases}$$

Where:

$\dot{Q}_h(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h

$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump as measured in the $H_{1,\ full}$ Test, Btu/h, or, if the $H_{1,\ full}$ Test was not conducted, as for variable-speed units, as calculated according to Equation 7.2.8-3.

$\dot{Q}_{H3,full}$ = = the space heating capacity of the heat pump when operating at the $H_{3,full}$ test condition, Btu/h

$\dot{Q}_{h,full}(35)$= the space heating capacity of the heat pump when operating at 35 °F, accounting for frost accumulation, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.5-2, below, if the $H_{2,full}$ test is not conducted, Btu/h

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

Equation 7.2.8-2

$$\dot{Q}_{h,full}(35) = \ 0.9 * \{ \dot{Q}_{H3,full} + 0.6 * [\dot{Q}_{H1,full} - \dot{Q}_{H3,full}]\}$$

Where:

$\dot{Q}_{h,full}(35)$= the space heating capacity of the heat pump when operating at 35 °F, accounting for frost accumulation, Btu/h

0.9 = the space heating capacity frost degradation factor

$\dot{Q}_{H3,full}$ = = the space heating capacity of the heat pump when operating at the $H_{3,full}$ test condition, Btu/h

$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump as measured in the $H_{1,\ full}$ Test, Btu/h, or, if the $H_{1,\ full}$ Test was not conducted, as for variable-speed units, as calculated according to Equation 7.2.7-3.

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

Equation 7.2.8-3:

$$\dot{Q}_{H1,full} = \ \dot{Q}_{H3,full} * (1 + 30 * 0.0262)$$

Where:
$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump when operating at full speed at 47 °F, Btu/h
$\dot{Q}_{H3,full}$ = = the space heating capacity of the heat pump when operating at the $H_{3,full}$ test condition, Btu/h
0.0262 = the standard capacity slope factor for full-load operation.

Equation 7.2.8-4:

$$\dot{E}_h(T_j) = \dot{E}_{h,full}(T_j) = \begin{cases} \dot{E}_{H3,full} + \dfrac{[\dot{E}_{H1,full} - \dot{E}_{H3,full}] * (T_j - 17)}{47 - 17}, & if \;\; T_j < 17\text{°F or } T_j > 42\text{°F} \\ \dot{E}_{H3,full} + \dfrac{[\dot{E}_{h,full}(35) - \dot{E}_{H3,full}] * (T_j - 17)}{35 - 17}, & if \; 17\text{°F} \le T_j \le 42\text{°F} \end{cases}$$

Where:
$\dot{E}_h(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W
$\dot{E}_{H1,full}$ = the electrical power consumption of the heat pump as measured in the $H_{1,\,full}$ Test, W or, if the $H_{1,\,full}$ Test was not conducted, as for variable-speed units, as calculated according to Equation 7.2.8-6.
$\dot{E}_{H3,full}$ = the electrical power consumption of the heat pump as measured in the $H_{3,\,full}$ Test, W
$\dot{E}_{h,full}(35)$ = the electrical power consumption of the heat pump when operating at 35 °F, accounting for frost accumulation, W, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.8-4, below, Btu/h
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

Equation 7.2.8-5

$$\dot{E}_{h,full}(35) = \;\; 0.985 * \{\, \dot{E}_{H3,full} + 0.6 * [\, \dot{E}_{H1,full} - \, \dot{E}_{H3,full}]\}$$

Where:
$\dot{E}_{h,full}(35)$= the electrical power consumption of the heat pump when operating at 35 °F, accounting for frost accumulation, W
0.985 = the electrical power frost degradation factor
$\dot{E}_{H1,full}$= the electrical power consumption of the heat pump as measured in the $H_{1,\,full}$ Test, W or, if the $H_{1,\,full}$ Test was not conducted, as for variable-speed units, as calculated according to Equation 7.2.8-6.
$\dot{E}_{H3,full}$ = the electrical power consumption of the heat pump as measured in the $H_{3,\,full}$ Test, W

Equation 7.2.8-6:

$$\dot{E}_{H1,full} = \dot{E}_{H3,full} * (1 + 18 * 0.00455)$$

Where:
$\dot{E}_{H1,full}$ = the electrical power consumption when operating at full speed at 47 °F, W
$\dot{E}_{H3,full}$ = the electrical power consumption of the heat pump as measured in the $H_{3,\,full}$ Test, W
0.00455 = the standard power slope factor for full-load operation.

7.2.9 For Type 4 Heat Pumps, calculate $\dot{Q}_h(T_j)$ and $\dot{E}_h(T_j)$ as follows:

Equation 7.2.9-1:

$$\dot{Q}_h(T_j) = \dot{Q}_{h.full}(T_j) = \begin{cases} \dot{Q}_{H4,full} + \frac{[\dot{Q}_{H3,full} - \dot{Q}_{H4,full}] * (T_j - 5)}{17 - 5}, if\ T_j < 17°\text{F}\ (if\ the\ H_{4,full}\ test\ was\ conducted) \\ \dot{Q}_{H3,full} + \frac{[\dot{Q}_{H1,full} - \dot{Q}_{H3,full}] * (T_j - 17)}{47 - 17}, if\ T_j < 17°\text{F}\ (if\ the\ H_{4,full}\ test\ was\ not\ conducted) \\ \dot{Q}_{H3,full} + \frac{[\dot{Q}_{h,full}(35) - \dot{Q}_{H3,full}] * (T_j - 17)}{35 - 17}, \quad if\ 17°\text{F} \leq T_j \leq 42°\text{F} \\ \dot{Q}_{H3,full} + \frac{[\dot{Q}_{H1,full} - \dot{Q}_{H3,full}] * (T_j - 17)}{47 - 17}, if\ T_j > 42°\text{F} \end{cases}$$

Where:

$\dot{Q}_h(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h

$\dot{Q}_{H1,full}$ = the space heating capacity of the heat pump as measured in the $H_{1,\,full}$ Test, Btu/h, or, if the $H_{1,\,full}$ Test was not conducted, as for variable-speed units, as calculated according to Equation 7.2.8-3.

$\dot{Q}_{H3,full}$ = the space heating capacity of the heat pump when operating at the $H_{3,full}$ test condition, Btu/h

$\dot{Q}_{H4,full}$ = the space heating capacity of the heat pump when operating at the $H_{4,full}$ test condition, Btu/h

$\dot{Q}_{h,full}(35)$ = the space heating capacity of the heat pump when operating at 35 °F, accounting for frost accumulation, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.8-2, above, Btu/h

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

Equation 7.2.9-2:

$$\dot{E}_h(T_j) = \dot{E}_{h,full}(T_j) = \begin{cases} \dot{E}_{H4,full} + \frac{[\dot{E}_{H3,full} - \dot{E}_{H4,full}] * (T_j - 5)}{17 - 5}, \quad if\ \ T_j < 17°\text{F}\ (if\ the\ H_{4,full}\ test\ was\ conducted) \\ \dot{E}_{H3,full} + \frac{[\dot{E}_{H1,full} - \dot{E}_{H3,full}] * (T_j - 17)}{47 - 17}, if\ T_j < 17°\text{F}\ (if\ the\ H_{4,full}\ test\ was\ not\ conducted) \\ \dot{E}_{H3,full} + \frac{[\dot{E}_{h,full}(35) - \dot{E}_{H3,full}] * (T_j - 17)}{35 - 17}, \quad if\ 17°\text{F} \leq T_j \leq 42°\text{F} \\ \dot{E}_{H3,full} + \frac{[\dot{E}_{H1,full} - \dot{E}_{H3,full}] * (T_j - 17)}{47 - 17}, \quad if\ \ T_j > 42°\text{F} \end{cases}$$

Where:

$\dot{E}_h(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W

$\dot{E}_{H1,full}$ = the electrical power consumption of the heat pump as measured in the $H_{1,\,full}$ Test, W, or, if the $H_{1,\,full}$ Test was not conducted, as for variable-speed units, as calculated according to Equation 7.2.8-6.

$\dot{E}_{H3,full}$ = the electrical power consumption of the heat pump as measured in the $H_{3,\,full}$ Test, W

$\dot{E}_{H4,full}$ = the electrical power consumption of the heat pump as measured in the $H_{4,\,full}$ Test, W

$\dot{E}_{h,full}(35)$ = the electrical power consumption of the heat pump when operating at 35 °F, accounting for frost accumulation, W, as calculated in section 7.4.1, if the $H_{2,full}$ test is conducted, or in equation 7.2.8-5, above

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

7.3 Variable-Speed Units

7.3.1 The calculation of $\frac{RH(T_j)}{N}$ and $\frac{e_h(T_j)}{N}$ in the HEER equation differs depending upon whether the heat pump would operate at low capacity (section 7.3.3 of this test method), cycle between low and high capacity (section 7.3.4 or 7.3.5 of this test method), or operate at high capacity (section 7.3.6 of this test method) in responding to the building load at a given temperature T_j. This determination is made by comparing $\dot{Q}_{h,full}(T_j)$ to the building load $\mathrm{BL}(\mathrm{T_j})$. Calculate $\dot{Q}_{h,full}(T_j)$ according to the single-speed equations 7.2.3-1, 7.2.4-1, 7.2.5-1, 7.2.6-1, 7.2.7-1, 7.2.8-1, or 7.2.9-1, depending on the type of heat pump.

7.3.2 If the optional $H_{2,int}$ test was conducted, calculate the space heating capacity, $\dot{Q}_{h,int}(T_j)$, and electrical power consumption, $\dot{E}_{h,int}(T_j)$, of the test unit when operating at outdoor temperature T_j and the intermediate compressor speed used during using the following equations:

i. For Type 1 heat pumps:

Equation 7.3.2i-1:

$$\dot{Q}_{h,int}(T_j) = \dot{Q}_{H1,int} * M_Q * (T_j - 47)$$

Equation 7.3.2i-2:

$$\dot{E}_{h,int}(T_j) = \dot{E}_{H1,int} * M_E * (T_j - 47)$$

Where:

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

M_Q, the intermediate-speed space heating slope is calculated using Equation 7.3.2i-3:

Equation 7.3.2i-3:

$$M_Q = \frac{\dot{Q}_{H0,low} - \dot{Q}_{H1,low}}{62 - 47} \cdot (1 - N_Q) + \frac{0.0262 * \dot{Q}_{H1,nom}}{1 + 30 * 0.0262} \cdot N_Q$$

N_Q is calculated using Equation 7.3.2i-4:

Equation 7.3.2i-4:

$$N_Q = \frac{\dot{Q}_{H1,Int} - \dot{Q}_{H1,low}}{\dot{Q}_{H1,nom} - Q_{H1,low}}$$

$\dot{Q}_{H0,low}$ = the space heating capacity of the heat pump when operating at low speed as measured in the $H_{0,\,low}$ test, Btu/h

$\dot{Q}_{H1,low}$ = the space heating capacity of the heat pump as measured in the $H_{1,\,low}$ test, Btu/h
$\dot{Q}_{H1,int}$ = the space heating capacity of the heat pump when operating at intermediate speed at 47 °F, as measured at the $H_{1,\,int}$ test condition, Btu/h,
$\dot{Q}_{H1,nom}$ = the space heating capacity of the heat pump as measured in the $H_{1,\,nom}$ test, Btu/h
0.0262 = the standard capacity slope factor for full-load operation.

M_E, the intermediate-speed electrical power slope, is calculated using Equation 7.3.2i-5.

Equation 7.3.2i-5:

$$M_E = \frac{\dot{E}_{H0,low} - \dot{E}_{H1,low}}{62 - 47} \cdot (1 - N_E) + \frac{0.00455 * \dot{E}_{H1,nom}}{1 + 30 * 0.00455} \cdot N_E$$

N_E is calculated using Equation 7.3.2i-3:

Equation 7.3.2i-6:

$$N_E = \frac{\dot{E}_{H1,int} - \dot{E}_{H1,low}}{\dot{E}_{H1,nom} - \dot{E}_{H1,low}}$$

$\dot{E}_{H0,low}$ = the electrical power consumption of the heat pump as measured in the $H_{0,\,low}$ test, W
$\dot{E}_{H1,low}$ = the electrical power consumption of the heat pump as measured in the H1, low test, W
$\dot{E}_{H1,int}$ = the electrical power consumption of the heat pump when operating at intermediate speed at 47 °F, as measured at the H1, int test condition, W
$\dot{E}_{H1,nom}$ = the electrical power consumption of the heat pump as measured in the H1, nom test, W
0.00455 = the standard power slope factor for full-load operation.

ii. For Type 2 heat pumps:

Equation 7.3.2ii-1:

$$\dot{Q}_{h,int}(T_j) = \dot{Q}_{H2,int} + M_Q * (T_j - 35)$$

Equation 7.3.2ii-2:

$$\dot{E}_{h,int}(T_j) = \dot{E}_{H2,int} + M_E * (T_j - 35)$$

Where:

T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.
$\dot{Q}_{H2,int}$ = the space heating capacity of the heat pump when operating at intermediate speed at 35 °F, as measured at the $H_{2,\,int}$ test condition, Btu/h, as calculated in section 7.4.1
$\dot{E}_{H2,int}$ = the electrical power consumption of the heat pump when operating at intermediate speed at 35 °F, as measured at the $H_{2,\,int}$ test condition, W, as calculated in section 7.4.2
M_Q = intermediate-speed space heating slope, calculated in Equation 7.3.2ii-3.
M_E = intermediate-speed electrical power slope, calculated in Equation 7.3.2ii-4.

Approximate the slopes of the intermediate speed heating capacity and electrical power input curves, M_Q and M_E, as follows:

Equation 7.3.2ii-3:

$$M_Q = \left[\frac{\dot{Q}_{H0,low} - \dot{Q}_{H1,low}}{62 - 47} * \left(1 - N_Q\right)\right] + \left[N_Q * \frac{\dot{Q}_{h,full}(35) - \dot{Q}_{H3,calc}}{35 - 17}\right]$$

Equation 7.3.2ii-4:

$$M_E = \left[\frac{\dot{E}_{H0,low} - \dot{E}_{H1,low}}{62 - 47} * (1 - N_E)\right] + \left[N_E * \frac{\dot{E}_{h,full}(35) - \dot{E}_{H3,calc}}{35 - 17}\right]$$

Where:
N_Q = the capacity differential ratio, as calculated in Equation 7.3.2ii-5.
N_E = the electrical power differential ratio, as calculated in Equation 7.3.2ii-6.
$\dot{Q}_{H0,low}$ = the space heating capacity of the heat pump when operating at low speed at 62 °F, as measured at the $H_{0,\,low}$ test condition, Btu/h
$\dot{Q}_{H1,low}$= the space heating capacity of the heat pump when operating at low speed at 47 °F, as measured at the $H_{1,\,low}$ test condition, Btu/h
$\dot{Q}_{H3,calc}$ = the theoretical space heating capacity of the heat pump when operating at 17 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, Btu/h
$\dot{Q}_{h,full}(35)$ = the space heating capacity of the heat pump when operating at full speed at 35 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, Btu/h.
$\dot{E}_{H0,low}$ = the electrical power consumption of the heat pump when operating at low speed at 62 °F, as measured at the $H_{0,\,low}$ test condition, W
$\dot{E}_{H1,low}$ = the electrical power consumption of the heat pump when operating at low speed at 47 °F, as measured at the $H_{1,\,low}$ test condition, W
$\dot{E}_{H3,calc}$ = the theoretical electrical power consumption of the heat pump when operating at full speed at 17 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, W
$\dot{E}_{h,full}(35)$ = the electrical power consumption of the heat pump when operating at full speed at 35 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, W

Equation 7.3.2ii-5:

$$N_Q = \frac{\dot{Q}_{H2,int} - \dot{Q}_{h,low,dry}(35)}{\dot{Q}_{h,full}(35) - \dot{Q}_{h,low,dry}(35)}$$

Where:
$\dot{Q}_{h,low,dry}(35) = \dot{Q}_{H1,low} - 0.8 * (\dot{Q}_{H0,low} - \dot{Q}_{H1,low})$, the space heating capacity of the heat pump when operating at low speed in dry conditions at 35 °F, Btu/h
$\dot{Q}_{h,full}(35)$ = the space heating capacity of the heat pump when operating at full speed at 35 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, Btu/h.
$\dot{Q}_{H2,int}$ = the space heating capacity of the heat pump when operating at intermediate speed at 35 °F, as measured at the $H_{2,\,int}$ test condition, Btu/h

Equation 7.3.2ii-6:

$$N_E = \frac{\dot{E}_{H2,int} - \dot{E}_{h,low}(35)}{\dot{E}_{h,full}(35) - \dot{E}_{h,low}(35)}$$

Where:

$\dot{E}_{h,low}(35) = \dot{E}_{H1,low} - 0.8 * (\dot{E}_{H0,low} - \dot{E}_{H1,low})$, the electrical power consumption of the heat pump when operating at low speed at 35 °F, W

$\dot{E}_{h,full}(35)$ = the electrical power consumption of the heat pump when operating at full speed at 35 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, W

$\dot{E}_{H2,int}$ = the electrical power consumption of the heat pump when operating at intermediate speed at 35 °F, as measured at the $H_{2,\,int}$ test condition, W

iii. For Type 3 and 4 heat pumps:

Equation 7.3.2iii-1:

$$\dot{Q}_{h,int}(T_j) = \dot{Q}_{H2,int} + M_Q * (T_j - 35)$$

Equation 7.3.2iii-2:

$$\dot{E}_{h,int}(T_j) = \dot{E}_{H2,int} + M_E * (T_j - 35)$$

Where:

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

$\dot{Q}_{H2,int}$ = the space heating capacity of the heat pump when operating at intermediate speed at 35 °F, as measured at the $H_{2,\,int}$ test condition, Btu/h, as calculated in section 7.4.1

$\dot{E}_{H2,int}$ = the electrical power consumption of the heat pump when operating at intermediate speed at 35 °F, as measured at the $H_{2,\,int}$ test condition, W, as calculated in section 7.4.2

M_Q = space heating slope factor, calculated in Equation 7.3.2iii-3.

M_E = electrical power slope factor, calculated in Equation 7.3.2iii-4.

Approximate the slopes of the intermediate speed heating capacity and electrical power input curves, M_Q and M_E, as follows:

Equation 7.3.2iii-3:

$$M_Q = \left[\frac{\dot{Q}_{H0,low} - \dot{Q}_{H1,low}}{62 - 47} * (1 - N_Q)\right] + \left[N_Q * \frac{\dot{Q}_{h,full}(35) - \dot{Q}_{H3,full}}{35 - 17}\right]$$

Equation 7.3.2iii-4:

$$M_E = \left[\frac{\dot{E}_{H0,low} - \dot{E}_{H1,low}}{62 - 47} * (1 - N_E)\right] + \left[N_E * \frac{\dot{E}_{h,full}(35) - \dot{E}_{H3,full}}{35 - 17}\right]$$

Where:

N_Q = the capacity differential ratio, as calculated in Equation 7.3.2iii-5.

N_E = the electrical power differential ratio, as calculated in Equation 7.3.2iii-6.

$\dot{Q}_{H0,low}$ = the space heating capacity of the heat pump when operating at low speed at 62 °F, as measured at the $H_{0,\,low}$ test condition, Btu/h

$\dot{Q}_{H1,low}$ = the space heating capacity of the heat pump when operating at low speed at 47 °F, as measured at the $H_{1,\,low}$ test condition, Btu/h

$\dot{Q}_{H3,full}$ = the space heating capacity of the heat pump when operating at full speed at 17 °F, as measured at the $H_{3,\,full}$ test condition, Btu/h

$\dot{Q}_{h,full}(35)$ = the space heating capacity of the heat pump when operating at full speed at 35 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, Btu/h.

$\dot{E}_{H0,low}$ = the electrical power consumption of the heat pump when operating at low speed at 62 °F, as measured at the $H_{0,\,low}$ test condition, W

$\dot{E}_{H1,low}$ = the electrical power consumption of the heat pump when operating at low speed at 47 °F, as measured at the $H_{1,\,low}$ test condition, W

$\dot{E}_{H3,full}$ = the electrical power consumption of the heat pump when operating at low speed at 17 °F, as measured at the $H_{3,\,full}$ test condition, W

$\dot{E}_{h,full}(35)$ =the electrical power consumption of the heat pump when operating at full speed at 35 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, W

Equation 7.3.2iii-5:

$$N_Q = \frac{\dot{Q}_{H2,int} - \dot{Q}_{h,low,dry}(35)}{\dot{Q}_{h,full}(35) - \dot{Q}_{h,low,dry}(35)}$$

Where:

$\dot{Q}_{h,low,dry}(35) = \dot{Q}_{H1,low} - 0.8 * (\dot{Q}_{H0,low} - \dot{Q}_{H1,low})$, the space heating capacity of the heat pump when operating at low speed in dry conditions at 35 °F, Btu/h

$\dot{Q}_{h,full}(35) =$ space heating capacity of the heat pump when operating at full speed at 35 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, Btu/h the space heating capacity of the heat pump when operating at full speed at 35 °F, Btu/h.

$\dot{Q}_{H2,int}$ = the space heating capacity of the heat pump when operating at intermediate speed at 35 °F, as measured at the $H_{2,\,int}$ test condition, Btu/h

Equation 7.3.2iii-6:

$$N_E = \frac{\dot{E}_{H2,int} - \dot{E}_{h,low}(35)}{\dot{E}_{h,full}(35) - \dot{E}_{h,low}(35)}$$

Where:

$\dot{E}_{h,low}(35) = \dot{E}_{H1,low} - 0.8 * (\dot{E}_{H0,low} - \dot{E}_{H1,low})$, the electrical power consumption of the heat pump when operating at low speed at 35 °F, W

$\dot{E}_{h,full}(35)$ =the electrical power consumption of the heat pump when operating at full speed at 35 °F, as calculated in section 7.2.5, 7.2.6, or 7.2.7, above, depending on which tests were conducted, W

$\dot{E}_{H2,int}$ = the electrical power consumption of the heat pump when operating at intermediate speed at 35 °F, as measured at the $H_{2,\,int}$ test condition, W

7.3.3 If the building load is less than low-stage capacity $(\mathrm{BL}(\mathrm{T_j}) < \dot{\mathrm{Q}}_{\mathrm{h,low}})$, calculate $\frac{RH(T_j)}{N}$ and $\frac{e_h(T_j)}{N}$ as follows:

Equation 7.3.3-1:

$$\frac{e_h(T_j)}{N} = \frac{X_{low}(T_j) * \dot{E}_{h,low}(T_j) * \delta(T_j) * \delta_{RH}(T_j)}{PLF_j} * \frac{n_j}{N}$$

Equation 7.3.3-2:

$$\frac{RH(T_j)}{N} = \frac{BL(T_j) * [1 - \delta(T_j) * \delta_{RH}(T_j)]}{3.413 \frac{Btu/h}{W}} * \frac{n_j}{N}$$

Where:

$BL(T_j)$ = the value of the heating building load evaluated at the outdoor bin temperature, Btu/hr, as calculated in equation 7.1.2.

$X_{low}(T_j) = \frac{BL(T_j)}{\dot{Q}_{h.low}(T_j)}$, the heating mode low-capacity load factor for temperature bin *j,* dimensionless.

$PLF_j = 1 - C_D^h * [1 - X_{low}(T_j)]$, the part load factor, dimensionless.

$\delta(T_j)$ = the low temperature cutoff factor, dimensionless, as calculated in section 7.3.3.i.

C_D^h = Heating degradation coefficient = 0.49

$\dot{Q}_{h,low}(T_j)$ = the space heating capacity of the heat pump when operating at outdoor temperature T_j, Btu/h, as calculated in equation 7.3.3.ii-1.

$\dot{E}_{h,low}(T_j)$ = the electrical power consumption of the heat pump when operating at outdoor temperature T_j, W, as calculated in equation 7.3.3.ii-2.

$\delta_{RH}(T_j)$ = the resistance heat cut-in factor, dimensionless, as calculated in section 6.7.

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

$\frac{n_j}{N}$ = fractional bin hours for the heating season; the ratio of the number of hours during the heating season when the outdoor temperature fell within the range represented by bin temperature, T_j to the total number of hours in the heating season, dimensionless, as defined in Table 11.

i. Determine the low temperature cut-out factor as follows:

Equation 7.3.3.i-1:

$$\delta(T_j) = \begin{cases} 0, & if\ T_j \leq T_{off} \\ \frac{1}{2}, & if\ T_{off} < T_j \leq T_{on} \\ 1, & if\ T_j > T_{on} \end{cases}$$

Where:

T_{off} = the outdoor temperature when the compressor is automatically shut off, °F. (If no such temperature exists, T_j is always greater than T_{off} and T_{on}).

T_{on} = the outdoor temperature when the compressor is automatically turned back on, if applicable, following an automatic shut-off, °F.

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

ii. Calculate $\dot{Q}_{h,low}(T_j)$ and $\dot{E}_{h,low}(T_j)$ as follows:

Equation 7.3.3.ii-1:

$$\dot{Q}_{h.low}(T_j) = \begin{cases} \dot{Q}_{H1,low} + \frac{[\dot{Q}_{H0,low} - \dot{Q}_{H1,low}] * (T_j - 47)}{62 - 47}, & if\ T_j \leq 17°F\ or\ T_j > 42°F \\ \dot{Q}_{H1,low} + \frac{[\dot{Q}_{H1,low} - \dot{Q}_{h,low}(35)] * (T_j - 47)}{47 - 35}, & if\ 17°F < T_j \leq 42°F \end{cases}$$

Where:
$\dot{Q}_{h,low}(T_j)$ = the space heating capacity of the heat pump when operating at low speed at outdoor temperature T_j, Btu/h
$\dot{Q}_{H1,low}$= the space heating capacity of the heat pump when operating at low speed at 47 °F, as measured at the $H_{1,\,low}$ test condition, Btu/h
$\dot{Q}_{H0,low}$ = the space heating capacity of the heat pump when operating at low speed at 62 °F, as measured at the $H_{0,\,low}$ test condition, Btu/h
$\dot{Q}_{h,low}(35) = 0.9 * \{ \dot{Q}_{H1,low} - 0.8 * [\dot{Q}_{H0,low} - \dot{Q}_{H1,low}]\}$, the space heating capacity of the heat pump when operating at low speed at 35 °F, accounting for frost accumulation, Btu/h
0.9 = the space heating capacity frost degradation factor
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

Equation 7.3.3.ii-2:

$$\dot{E}_{h,low}(T_j) = \begin{cases} \dot{E}_{H1,low} + \dfrac{\left[\dot{E}_{H0,low} - \dot{E}_{H1,low}\right] * (T_j - 47)}{62 - 47}, & if\ \ T_j \leq 17°\text{F}\ or\ T_j < 42°\text{F} \\ \dot{E}_{H1,low} + \dfrac{\left[\dot{E}_{H1,low} - \dot{E}_{h,low}(35)\right] * (T_j - 47)}{47 - 35}, & if\ 17°\text{F} < T_j \leq 42°\text{F} \end{cases}$$

Where:
$\dot{E}_{h,low}(T_j)$ = the electrical power consumption of the heat pump when operating at low speed at outdoor temperature T_j, W
$\dot{E}_{H0,low}$ = the electrical power consumption of the heat pump when operating at low speed at 62 °F, as measured at the $H_{0,\,low}$ test condition, W
$\dot{E}_{H1,low}$ = the electrical power consumption of the heat pump when operating at low speed at 47 °F, as measured at the $H_{1,\,low}$ test condition, W
$\dot{E}_{h,low}(35) = 0.985 * \{ \dot{E}_{H1,low} - 0.8 * [\dot{E}_{H0,low} - \dot{E}_{H1,low}]\}$, electrical power consumption of the heat pump when operating at low speed at 35 °F, accounting for frost accumulation, W
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

7.3.4 If the building load is higher than the low-stage capacity and less than the full-stage capacity ($\dot{Q}_{h,low} < BL(T_j) < \dot{Q}_{h,full}$), if the $H_{2,int}$ test was conducted and the compressor operates at an intermediate speed in order to match the building heating load at a temperature T_j, calculate $\frac{RH(T_j)}{N}$ and $\frac{e_h(T_j)}{N}$ as follows:

Equation 7.3.4-1

$$\frac{e_h(T_j)}{N} = \dot{E}_{h,int-bin}(T_j) * \delta(T_j) * \delta_{RH}(T_j) * \frac{n_j}{N}$$

Equation 7.3.4-2:

$$\frac{RH(T_j)}{N} = \frac{BL(T_j) * [1 - \delta(T_j) * \delta_{RH}(T_j)]}{3.413 \frac{Btu/h}{W}} * \frac{n_j}{N}$$

Equation 7.3.4-3

$$\dot{E}_{h,int-bin}(T_j) = \frac{\dot{Q}_{h,int-bin}(T_j)}{3.413\frac{Btu/h}{W} * COP_{int-bin}(T_j)}$$

Where:

$BL(T_j)$ = the value of the heating building load evaluated at the outdoor bin temperature, Btu/hr, as calculated in equation 7.1.2.

$\delta(T_j)$ = the low temperature cutoff factor, evaluated using Equation 7.3.3.i-1

$\dot{E}_{h,int-bin}(T_j)$ = the electrical power consumption of the heat pump when operating at intermediate speed, W, as calculated in Equation 7.3.4-3.

$\dot{Q}_{h,int-bin}(T_j) = BL(T_j)$, the space heating capacity delivered by the unit in matching the building load at temperature (T_j), Btu/h. The matching occurs with the heat pump operating at an intermediate compressor speed.

$COP_{int-bin}(T_j)$ = the steady-state coefficient of performance of the heat pump when operating at an intermediate compressor speed and temperature T_j, dimensionless, calculated in sections 7.3.4.i and 7.3.4.ii.

$\delta_{RH}(T_j)$ = the resistance heat cut-in factor, dimensionless, as calculated in section 6.7.

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

$\frac{n_j}{N}$ = fractional bin hours for the heating season; the ratio of the number of hours during the heating season when the outdoor temperature fell within the range represented by bin temperature, T_j to the total number of hours in the heating season, dimensionless, as defined in Table 11.

i. For each temperature bin where $\dot{Q}_{h,low}(T_j) < BL(T_j) < \dot{Q}_{h,int}(T_j)$, calculate $COP_{int-bin}(T_j)$ using:

Equation 7.3.4.i-1:

$$COP_{int-bin}(T_j) = COP_{low}(T_j) + \frac{COP_{int}(T_j) - COP_{low}(T_j)}{\dot{Q}_{h,int}(T_j) - \dot{Q}_{h,low}(T_j)} * (BL(T_j) - \dot{Q}_{h,low}(T_j))$$

Where:

$COP_{low}(T_j) = \frac{\dot{Q}_{h,low}(T_j)}{\dot{E}_{h,low}(T_j)*3.413\frac{Btu/h}{W}}$, the steady-state coefficient of performance of the heat pump when operating at minimum compressor speed and temperature T_j, dimensionless, calculated using capacity $\dot{Q}_{h,low}(T_j)$ calculated using Equation 7.3.3.ii-1 and electrical power consumption $\dot{E}_{h,low}(T_j)$ calculated using Equation 7.3.3.ii-2;

$COP_{int}(T_j) = \frac{\dot{Q}_{h,int}(T_j)}{\dot{E}_{h,int}(T_j)*3.413\frac{Btu/h}{W}}$, the steady-state coefficient of performance of the heat pump when operating at intermediate compressor speed and temperature T_j, dimensionless, calculated using capacity $\dot{Q}_{h,int}(T_j)$ calculated using Equation 7.3.2-1 for Type 1 units or 7.3.2-3 for Type 3 and Type 4 units and electrical power consumption $\dot{E}_{h,int}(T_j)$ calculated using Equation 7.3.2-2 for Type 1 units or 7.3.2-4 for Type 3 and Type 4 units;

$BL(T_j)$ is the building heating load at temperature T_j, Btu/h.

T_j = the representative outdoor bin temperature, °F, as found in Table 11.

j = the bin number, as found in Table 11.

ii. For each temperature bin where $\dot{Q}_{h,int}(T_j \le BL(T_j) < \dot{Q}_{h,full}(T_j)$, calculate $COP_{int-bin}(T_j)$ using:

Equation 7.3.4.ii-1:

$$COP_{int-bin}(T_j) = COP_{int}(T_j) + \frac{COP_{full}(T_j) - COP_{int}(T_j)}{\dot{Q}_{h,full}(T_j) - \dot{Q}_{h,int}(T_j)} * (BL(T_j) - \dot{Q}_{h,int}(T_j))$$

Where:

$COP_{int}(T_j) = \frac{\dot{Q}_{h,int}(T_j)}{\dot{E}_{h,int}(T_j)*3.413\frac{Btu/h}{W}}$, the steady-state coefficient of performance of the heat pump when operating at intermediate compressor speed and temperature T_j, dimensionless, calculated using capacity $\dot{Q}_{h,int}(T_j)$ calculated using Equation 7.3.2-1 for Type 1 units or 7.3.2-3 for Type 3 and Type 4 units and electrical power consumption $\dot{E}_{h,int}(T_j)$ calculated using Equation 7.3.2-2 for Type 1 units or 7.3.2-4 for Type 3 and Type 4 units;

$COP_{full}(T_j) = \frac{\dot{Q}_{h,full}(T_j)}{\dot{E}_{h,full}(T_j)*3.413\frac{Btu/h}{W}}$, the steady-state coefficient of performance of the heat pump when operating at full compressor speed and temperature T_j, dimensionless, calculated using capacity $\dot{Q}_{h,full}(T_j)$, and electrical power consumption $\dot{E}_{h,full}(T_j)$, both calculated as described in section 7.2.3 for Type 1 units, using data from the $H_{1,nom}$ test when data from the $H_{1,full}$ test is called for, in section 7.2.6 for Type 3 units, and in section 7.2.7 for Type 4 units;

$BL(T_j)$ is the building heating load at temperature T_j, Btu/h;

T_j = the representative outdoor bin temperature, °F, as found in Table 11; and

j = the bin number, as found in Table 11.

7.3.5 If the building load is higher than the low-stage capacity and less than the full-stage capacity ($\dot{Q}_{h,low} < BL(T_j) < \dot{Q}_{h,full}$), if the $H_{2,int}$ test was not conducted calculate $\frac{RH(T_j)}{N}$ and $\frac{e_h(T_j)}{N}$ as follows:

Equation 7.3.5-1

$$\frac{e_h(T_j)}{N} = [X_{low} * \dot{E}_{h,low}(T_j) + X_{full} * \dot{E}_{h,full}(T_j)] * \delta(T_j) * \delta_{RH}(T_j) * \frac{n_j}{N}$$

Equation 7.3.5-2

$$\frac{RH(T_j)}{N} = \frac{BL(T_j) * [1 - \delta(T_j) * \delta_{RH}(T_j)]}{3.413\frac{Btu/h}{W}} * \frac{n_j}{N}$$

Where:

$X_{low} = \frac{\dot{Q}_{h,full}(T_j) - BL(T_j)}{\dot{Q}_{h,full}(T_j) - \dot{Q}_{h,low}(T_j)}$, the low-capacity load factor, dimensionless

$X_{high} = 1 - X_{low}$, the high-capacity load factor, dimensionless

$BL(T_j)$ = the value of the heating building load evaluated at the outdoor bin temperature, Btu/hr, as calculated in equation 7.1.2.

$\dot{Q}_{h,full}(T_j)$, and electrical power consumption $\dot{E}_{h,full}(T_j)$, both calculated as described in section 7.2.3 for Type 1 units, using data from the $H_{1,nom}$ test when data from the $H_{1,full}$ test is called for, in section 7.2.5 or 7.2.6 for Type 2 units, in section 7.2.7 for Type 3 units, and in section 7.2.8 for Type 4 units.

$$\delta(T_j) = \begin{cases} 0, \ if\ T_j \le T_{off} \\ \frac{1}{2}, \ if\ T_{off} < T_j \le T_{on} \\ 1, \ if\ T_j > T_{on} \end{cases};$$

$\delta_{RH}(T_j)$ = the resistance heat cut-in factor, dimensionless, as calculated in section 6.7.

T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

7.3.6 If the building load is higher than the full-stage capacity a ($\mathrm{BL}(\mathrm{T_j}) > \dot{\mathrm{Q}}_{\mathrm{h,full}}$), calculate $\frac{RH(T_j)}{N}$ and $\frac{e_h(T_j)}{N}$ as follows:

Equation 7.3.5-1:

$$\frac{e_h(T_j)}{N} = \dot{E}_{h,full}(T_j) * \delta(T_j) * \delta_{RH}(T_j) * \frac{n_j}{N}$$

Equation 7.3.5-2:

$$\frac{RH(T_j)}{N} = \frac{BL(T_j) - [\dot{Q}_{h,full}(T_j) * \delta(T_j) * \delta_{RH}(T_j)]}{3.413\frac{Btu/h}{W}} * \frac{n_j}{N}$$

Where:

$$\delta(T_j) = \begin{cases} 0, \ if\ T_j \le T_{off} \\ \frac{1}{2}, \ if\ T_{off} < T_j \le T_{on} \\ 1, \ if\ T_j > T_{on} \end{cases};$$

$\dot{Q}_{h,full}(T_j)$, and electrical power consumption $\dot{E}_{h,full}(T_j)$, both calculated as described in section 7.2.3 for Type 1 units, using data from the $H_{1,nom}$ test when data from the $H_{1,full}$ test is called for, in section 7.2.5, 7.2.6, or 7.2.7 for Type 2 units, in section 7.2.8 for Type 3 units, and in section 7.2.9 for Type 4 units.
$BL(T_j)$ = the value of the heating building load evaluated at the outdoor bin temperature, Btu/hr, as calculated in equation 7.1.2.
$\delta_{RH}(T_j)$ = the resistance heat cut-in factor, dimensionless, as calculated in section 6.7.
T_j = the representative outdoor bin temperature, °F, as found in Table 11.
j = the bin number, as found in Table 11.

7.4 Defrost Performance Calculations

7.4.1 If the $H_{2,int}$ or $H_{2,fulll}$ test is conducted, calculate the heating capacity at 35 °F in the equations above using equation 7.4.1-1:

Equation 7.4.1-1:

$$\dot{Q}_{h,full/int}(35) = \frac{60 * \bar{\dot{V}} * C_{p,a} * \Gamma}{\Delta\tau_{FR}[v_n' * (1 + W_n)]}$$

Where:

$\dot{Q}_{h,full/int}(35)$ = the heating capacity of a unit when defrosting at 35 °F, $\dot{Q}_{h,full}(35)$ for single-speed units, and $\dot{Q}_{h,int}(35)$ for variable-speed units, in Btu/h
$\bar{\dot{V}}$ = the average indoor air volume rate measured during sub-interval H, cfm.
$C_{p,a}$ = 0.24 + 0.444 · W_n, the constant pressure specific heat of the air-water vapor mixture that flows through the indoor coil and is expressed on a dry air basis, Btu/lb_{mda} · °F.
v_n' = specific volume of the air-water vapor mixture at the nozzle, ft^3/lb_{mmx}.
W_n = humidity ratio of the air-water vapor mixture at the nozzle, lb_m of water vapor per lb_m of dry air.
$\Delta\tau_{FR}$ = τ2 − τ1, the elapsed time from defrost termination to defrost termination, hr.
Γ = the result of equation 7.4.1-2

Equation 7.4.1-2:

$$\Gamma = \int_{\tau 1}^{\tau_2} [T_{a2}(\tau) - T_{a1}(\tau)] d\tau$$

Where:

$T_{a1}(\tau)$ = dry bulb temperature of the air entering the indoor coil at elapsed time τ, °F; only recorded when indoor coil airflow occurs; assigned the value of zero during periods (if any) where the indoor blower cycles off.

$T_{a2}(\tau)$ = dry bulb temperature of the air leaving the indoor coil at elapsed time τ, °F; only recorded when indoor coil airflow occurs; assigned the value of zero during periods (if any) where the indoor blower cycles off.

τ_1 = the elapsed time when the defrost termination occurs that begins the official test period, hr.

τ_2 = the elapsed time when the next automatically occurring defrost termination occurs, thus ending the official test period, hr.

7.4.2 Calculate the energy use at 35 °F in the equations above using equation 7.4.2-2:

Equation 7.4.2-2:

$$\dot{E}_{h,full/int}(35) = \frac{e(35)}{\Delta\tau_{FR}}$$

Where:

$\dot{E}_{h,full/int}(35)$= the average electrical power of a unit when defrosting at 35 °F, $\dot{E}_{h,full}(35)$for single-speed units, and $\dot{E}_{h,int}(35)$ for variable-speed units, W.

$e(35)$ = the electrical energy consumed from defrost termination to defrost termination, watt-hours.

$\Delta\tau_{FR}$ = τ2 − τ1, the elapsed time from defrost termination to defrost termination, hr.

8 OTHER REPORTED VALUES

8.1 Heating Capacity

The heating capacity of the UUT shall be reported as the measured capacity in the $H_{1,nom}$ (for variable-speed) or the $H_{1,full}$ test (for single-speed).

8.2 Type 3 Capacity and Efficiency

8.2.1 Calculate and report the full-speed heating capacity at 17 °F, $\dot{Q}_{H3,full}$, for Type 3 and Type 4 room heat pumps, as follows:

$$Capacity_{17} = \dot{Q}_{H3,full}$$

8.2.2 Calculate and report the full-speed efficiency at 17 °F for Type 3 and Type 4 room heat pumps, as follows:

$$COP_{17} = \frac{\dot{Q}_{H3,full}}{\dot{E}_{H3,full}}$$

8.3 Type 4 Capacity and Efficiency

8.3.1 Calculate and report the full-speed heating capacity at 5 °F for Type 4 room heat pumps if the $H_{4,full}$ test is conducted, as follows:

$$Capacity_5 = \dot{Q}_{H4,full}$$

8.3.2 Calculate and report the full-speed efficiency at 5 °F for Type 4 room heat pumps, if the $H_{4,full}$ test is conducted, as follows:

$$COP_5 = \frac{\dot{Q}_{H4,full}}{\dot{E}_{H4,full}}$$

8.4 Coldest Temperature Capacity and Efficiency

8.4.1 Calculate and report the full-speed coldest temperature capacity for Type 4 room heat pumps, which is the unit performance at the average of the low cut-in and cut-out temperatures, if the $H_{x,full}$ test is conducted, as follows:

$$Capacity_x = \dot{Q}_{Hx,full}$$

8.4.2 Calculate and report the full-speed coldest temperature efficiency for Type 4 room heat pumps, which is the unit performance at the average of the low cut-in and cut-out temperatures, if the $H_{x,full}$ test is conducted, as follows:

$$COP_x = \frac{\dot{Q}_{Hx,full}}{\dot{E}_{Hx,full}}$$

8.5 Meltwater Disposition

Report the method(s) used by the room heat pump to dispose of meltwater generated from defrosting the outdoor coil, including which method is enabled by default. The meltwater disposition report should specify whether meltwater is disposed of outside or inside, whether the meltwater is atomized before leaving the unit, whether meltwater is sprayed onto the indoor coil during heating operation, whether a pump is used, and whether a water storage tank is used.

9 REFERENCES

A) 10 CFR Part 430, Subpart B, Appendix F. Uniform Test Method for Measuring the Energy Consumption of Room Air Conditioners.

B) ENERGY STAR Program Requirements for Room Air Conditioners - Eligibility Criteria - Version 4.0.

C) ANSI/ASHRAE Standard 16-2016, Method of Testing for Rating Room Air Conditioners, Packaged Terminal Air Conditioners, and Packaged Terminal Heat Pumps for Cooling and Heating Capacity.

D) ANSI/ASHRAE Standard 37-2009, Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment.

E) ANSI/ASHRAE Standard 58-1986, Method Of Testing For Rating Room Air Conditioner And Packaged Terminal Air Conditioner Heating Capacity.