A Specification for
Residential Water Heaters
Advanced Water Heater Specification

Formally known as the Northern Climate Specification

Version 6.0

Prepared by the Northwest Energy Efficiency Alliance (NEEA)
in collaboration with Northwest utilities and Ecotope

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Background

In the early 1980s, electric utilities in colder portions of North America introduced heat pump technology into the residential water heating market. Heat pump water heater (HPWH) programs have subsequently spanned three generations of technology and produced detailed measurements of technical performance and consumer acceptance. The experience gained from these programs yields definitive direction about key consumer needs as well as important technical and reliability criteria for proper application of this technology throughout a range of climates.

The ENERGY STAR® program released its first specification for residential water heaters in 2008, which included qualifying criteria for heat pump water heaters. ENERGY STAR included requirements for efficiency (EF 2.0 or better), capacity (first-hour rating 50 gallons per hour), longevity (warranty ≥ 6 years), and electrical safety (UL 174 and UL 1995). While these requirements are important, the ENERGY STAR program did not address critical performance and comfort issues which have inhibited widespread adoption of HPWHs in colder climates. In 2009, several major manufacturers launched integrated HPWH units in North American markets which were ENERGY STAR qualified but failed to address key performance issues in colder climates.

While this specification initially focused on “Northern” climates (generally considered to be any location in the International Energy Conservation Code Climate Zones 4 or colder), it provides a framework that extends to other climates. Prioritizing heat pump use over resistance elements, additional performance-related functionality and consumer satisfaction, ensures this specification and testing methodology produces high-efficiency water heating in all climates.

1.0 Purpose

This specification provides guidance to manufacturers and other market actors who are interested in developing products that not only meet ENERGY STAR criteria but are able to provide high levels of consumer satisfaction and energy performance in a range of climates. The end goal of this effort is to ensure that the North American introduction of new generations of HPWH products will be successful in paving the way for HPWHs to become the standard product for the electric water heating market. The expansion of additional tiers in this version of the specification is not meant to be a requirement that manufacturers provide product, but rather a guideline of where the specification will trend towards over the next two to ten years. For example, tiers outlined in this specification could be attained by split systems (units which separate the storage tank and the pump); however, that test procedure is not defined in this document.

Utilities and other entities that invest in market transformation programs and/or incentives require reliable energy savings. Accordingly, this specification is also intended as a foundational document for utility program efforts that work in partnership with manufacturers to accelerate market adoption of HPWH for any American and Canadian climate. Using this specification will help improve market acceptance, reduce the number of geographic targeted SKUs for manufacturers and ensure the expected savings materialize and are persistent on the grid.

This specification addresses key topics that fall in four main categories:

- Comfort/satisfaction – exhaust air, noise, ease of installation, serviceability and sufficient hot water for customer needs
- Performance – energy efficiency and savings, condensate management, freeze protection, user controls, reliability
- Consideration of challenging installations – central locations with limited access to heat sources
- Integration of Demand Response (DR) enabling technologies as optional for tier levels (1-3) and required for tiers 4 & 5

2.0 Scope

2.1 Equipment Type. This specification covers integrated (with tank) electric heat pump water heaters.[1] Heat pump water heaters configured to “add-on” to existing storage tanks are not covered by this specification. “Split-system” units which separate the storage tank and the pump, as well as combination space + water systems, are not currently covered by this specification. A future version of this specification (or a related specification) will address these systems.

[1]Electric heat pump water heater means a water heater that uses electricity as the energy source to power the compressor and all auxiliary equipment such as fans, pumps, controls, and any resistive elements; is designed to transfer thermal energy from one temperature level to another for the purpose of heating water; and is designed to heat and store water at a thermostatically controlled temperature.

2.2 Applications. The focus of this specification is on replacements for existing electric resistance storage water heaters and alternatives to new electric resistance water heaters. As such, storage tanks shall be configured to meet the space installation and code requirements for typical electric resistance storage water heaters. Units meeting Tier 1 of this specification are expected to provide configuration options for semi-conditioned spaces such as unheated basements and unconditioned spaces such as garages or crawl spaces. Units meeting Tiers 2 and above are expected to provide configuration options for semi-conditioned, unconditioned, AND conditioned spaces such as heated utility rooms. Split system applications are not covered by this specification.

2.3 Climate. This specification is intended to ensure high performance in climates with 4,000 heating degree days or higher and average ambient temperatures below 60 degrees Fahrenheit. This equates roughly to locations in North America within the International Energy Conservation Code climate zones 4 or higher herein referred to as "Northern climates"[2]. Meeting performance standards in these climates ensures additional savings in all other climates in North America.

[2] Includes International Energy Conservation Code 2012 Climate Zones 4, 5, 6, 8 and the following states Alaska, Colorado, Connecticut, California, Idaho, Illinois, Indiana, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Nevada, Ohio, Oregon, Pennsylvania, Rhode Island, South Dakota, Utah, Vermont, Washington, West Virginia, Wisconsin, and Wyoming (as listed in proposed 10 CFR Part 430.32(e)(1)(iii), as published in FR 76, No. 123, June 27, 2011, p. 37548.)

3.0 Product Tiers

3.1 Overview. Tiers are incorporated into this specification recognizing variations in product performance and supported applications. Table 1 summarizes each Tier:

Table 1. Product Tier Overview

	Minimum Northern Climate UEF*	**Minimum Features**	**Minimum supported installation locations**	**Sound levels** Appendix B**	**Demand Response Enabled**
Tier 1.0	2.0	• ENERGY STAR compliance • Freeze protection	• Semi-conditioned[3] • Unconditioned[4]	dBA < 65	Optional
Tier 2.0	2.3	Tier 1 plus: • Minimal use of resistance heating elements (see section 5.1) • Compressor shut-down/notification • 10 year warranty • Condensate management	• Conditioned[5] • Semi-conditioned • Unconditioned	dBA < 60	Optional
Tier 3.0	2.6	Tier 2 plus: • Simultaneous intake and exhaust ducting capable • Air filter management • Unit to be tested in factory-default mode. • Override and default mode behavior as per section 6.1	• Conditioned • Semi-conditioned • Unconditioned	dBA < 55	Optional but preferred
Tier 4.0	3.0	Tier 3 plus: • Physical design or default controls which limits resistance element heating to less than upper 50% of tank	• Tier 3	dBA < 50	Yes
Tier 5.0	3.5	Tier 4 plus: • No resistance element usage in default mode unless outside ambient air temperature below -5°F	• Tier 4	dBA < 50	Yes

* see Appendix A for details on definition and calculation method
** see Appendix D for details on measurement method

[3] Semi-conditioned: Unconditioned spaces that are thermally linked to a conditioned space, for example, unheated basements or utility rooms.
[4] Unconditioned: No space conditioning/no thermostatic control.
[5] Conditioned: A space under thermostatic control for space conditioning.

4.0 Requirements for All Units (Tiers 1.0, 2.0, 3.0, 4.0 and 5.0)

4.1 UL or Equivalent Approved. The unit shall be UL, ETL or equivalent approval and have the ability to be installed in the US and/or Canada.

4.2 ENERGY STAR Compliance. The unit shall meet ENERGY STAR criteria effective at time of manufacture.

4.3 Northern Climate Energy Factor. The unit shall meet minimum Northern Climate Energy Factor values under default operating mode settings according to Table 1. See **Appendix A** for the Northern Climate Performance EF Test Procedure and corresponding Northern Climate EF Calculation Method.

4.4 Northern Climate Delivery Rating. To aid in proper sizing, the unit shall be rated on its ability to deliver hot water in cool ambient conditions while maintaining high efficiency operation. Reported in "number of showers" rounded to the nearest ½ shower. See **Appendix B** for Northern Climate Delivery Rating Method.

4.5 Sound Levels. The unit shall not exceed maximum sound levels according to Table 1. See **Appendix D** for Sound Measurement Test Method.

4.6 Freeze Protection Test. For units circulating water outside the hot water tank for purposes other than delivery to the house (i.e. to a heat exchanger for heating), the unit shall pass 24-hour power-off freeze protection test as specified in **Appendix C**. The key reason for this test is to ensure that water heaters do not freeze during power outages. Manufacturers should clearly state in installation manuals how to install units to prevent freezing.

4.7 Remote Heat Pump Application. If unit employs remote heat pump, unit shall be tested with a 25' standard length line set. All supporting equipment including fans, pumps, line set insulation and required heaters will be measured in total energy consumption for calculations.

4.8 Installation Guidance. Installation guidance shall be provided so unit is installed with adequate clearance for all airflow to and from the evaporator. Installation manual shall provide several possible configuration and/or installation scenarios to assist the installer.

5.0 Additional and Optional Requirements for Tiers 2.0 and Above

5.1 Minimal Use of Electric Resistance Heating Elements. In default operating mode, units shall make minimal or no use of electric resistance heating elements in order to maximize energy-savings potential. During the first draw of the standard DOE First Hour Rating Test[6], the electric resistance heating element shall not be turned on until at least 66% of the tank's measured water volume has been withdrawn. Measured water volume is defined as the amount of water the unit actually stores under test, and not the nominal rated tank volume.

5.2 Compressor Shut-down, Notification. The unit shall provide notification to the consumer that the heat-pump operation of the product has been disabled due to normal events, user selected override or product failure.

5.2.1 Normal, Temporary Event. The unit shall display that the heat pump is not currently operating if the compressor is temporarily disabled due to specific operational controls (e.g. low intake temperature or defrosting). The controls shall automatically restore compressor operation as soon as conditions return to allowable control parameters (e.g. return to minimum intake temperature or completion of the defrost cycle).

5.2.2 User Selected Override and/or Power Failure. If the unit has a temporary, user-selectable heat pump override option, the unit shall provide a default override period of up to 72 hours before returning to the previously selected operating mode (preferably to the as-shipped or better settings) except 100% electric resistance.

5.2.3 Product Failure Alarm. The unit shall provide to the consumer an audible and visible alarm on the interior unit when the unit's heat pump has a failure and requires service. The unit shall provide a consumer acknowledgement feature which turns off the audible alarm. Audible alarm shall be at least 50 dBA at specified location in Appendix D for measuring noise level on the HPWH. The visual alarm shall be visible without removal of panels and/or covers with clear nomenclature and enunciation to the homeowner to take needed action to solve the problem.

5.3 Warranty and Service. The unit shall carry a warranty of a minimum of 10 years for all system parts and a minimum of 1 year for labor from date of installation.

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[6] http://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9

5.3.1 Contact Information. The unit shall include information on how to obtain warranty service, replacement filters or other maintenance items, and technical support via a toll-free phone number clearly marked on the exterior of the unit.

5.4 Condensate Management. Condensate shall be drained away according to local plumbing codes and industry best practices.

5.4.1 Acceptable Condensate Piping. The unit shall include a minimum standard piping connection for condensate drainage of proper size to function for the life of the product under normal use (field installation materials to be acquired by the installer for the connection). The manufacturer shall supply appropriate condensate piping specifications including piping diameter, length, allowable turns, and acceptable termination for gravity drains and for condensate pumping in locations, such as basements, where gravity drainage is not possible. Instructions for the installer shall highlight importance of correct condensate line installation practices and adherence to local plumbing code.

5.4.2 Condensate Overflow Shut-off and Alarm. The unit shall include a safety switch to shut off compressor operation in the event of a blockage of the condensate removal system for any units installed in interior applications. An audible and visible alarm shall be activated to signal the need for service in the event of a compressor shut-off due to condensate drain failure (see alarm section in 5.2.3).

5.4.3 Condensate Collection Pan and Drain Service. The condensate collection pan and drain shall be designed to not require regular maintenance or interaction by the consumer for the life of the product. In the event of a blockage, the pan and drain shall be designed to allow the consumer to be able to clear the drain with normal household tools and restore normal operation of the condensate line. Collection-pan equipment and installation shall meet local code.

5.5 OPTIONAL: Exhaust Ducting. The unit may have a manufacturer-supplied optional ducting kit to provide for exhaust air ducting (“ducting kit”), available from same distribution/retail channels as the unit. For installations within conditioned spaces with exhaust ducting installed (and no intake ducting), manufacturers shall provide installation guidance to achieve exhaust airflow of no more than 250 CFM.[7] Exhaust ducting capabilities shall comply with the same requirements for both inlet and exhaust ducting as specified in section 6.2.

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[7] Any amount of exhaust airflow will increase the infiltration rate and energy use of the building. Lower airflow is better and 250 CFM is set as an acceptable threshold.

5.6 Demand Response Features. Units shall be configured and shipped with the capability of responding appropriately to DR and grid emergency and efficiency messages over a standard communication protocol and hardware interface. Units to have communication port that operates in compliance with CTA 2045 (or equivalent open modular interface standard) with specific DR signals such as shed, end shed, etc. If product is DR-qualified it must revert to user's previously selected mode (or factory settings) after DR event.

6.0 Additional Requirements Tiers 3.0, 4.0, and 5.0

6.1 Default Settings. The unit shall be shipped in the default operational mode used in demonstrating compliance to Federal energy efficiency standards. Enhanced efficiency operational modes may be selected by the consumer during installation. Should a user initiate an override to a mode less energy efficient than the default condition, such selection will expire in no more than a 72-hour period. Upon expiration, the appliance shall then automatically return to the mode previously selected by the user unless that mode was less efficient than the default, in which case it shall return to the default. The customer, technician, and/or installer shall have the ability to override the default setting. In the event of total power loss to the unit, it shall revert to the last settings selected as long as it is not electric only.

6.2 Intake and Exhaust Ducting. The unit may have a manufacturer-supplied optional ducting kit to provide for simultaneous intake and exhaust air ducting ("ducting kit"), available from same distribution/retail channels as the unit.

> **6.2.1 Ducting Hardware.** The unit shall include all necessary flanges, collars, or other connections that are capable of directly connecting to common ducting products. Alternatively, manufacturer-supplied add-on ducting modifications may be used if they provide the same capabilities.
>
> **6.2.2 Minimum Flow Rate/Pressure Drop***.* The unit shall maintain 80% of the necessary airflow to achieve the rated performance (UEFnc) when the fan is subject to an external static pressure of up to 0.2 inches water column.
>
> **6.2.3 Application Options.** The unit shall be capable of operating with or without ducting installed. Manufacturers shall clearly identify which models are configured for which ducting option along with a clear description (e.g., parts list and drawings) of the appropriate layout/configurations and accessory parts necessary to meet the requirements for specific applications.

6.3 Air Filters: Routine Maintenance and Homeowner Notification. If any air filters are present, they shall be either 1) permanent, washable media or 2) replaceable, standard filters in shape and form that are obtainable at a typical hardware store. The unit shall provide visible notification to the homeowner of appropriate need to change or service the filter in order to prevent compromise of performance of the heat pump from reduced air flow. Recommendations to be defined by the manufacturer.

Appendix A: Northern Climate Uniform Energy Factor

Overview: Measure and calculate a Northern Climate Uniform Energy Factor (UEF_{NC}) representative of water heater performance for equipment installed in semi-conditioned (e.g basements, unheated utility rooms) and unconditioned (e.g garages, crawl spaces) locations in northern climates.

Determining the UEF_{NC} consists of lab measurement of Uniform Energy Factors at 67°F and 50°F (UEF_{67} and UEF_{50}), compressor cut-off temperature, and a temperature bin-based calculation procedure.

Definitions:

UEF_{67} – Uniform Energy Factor from the standard DOE 24-hour test, at 67.5°F.
UEF_{50} – Uniform Energy Factor based on the standard DOE 24-hour test, at 50°F.
UEF_{R} – Uniform Energy Factor for the HPWH operating in resistance-only heat mode
C_{cutoff} is the compressor cut-off temperature. See Appendix E.

1.0 Test Setup and Procedure:

UEF_{67}: Follow standard DOE 24-hour test procedure (Section 6 of 10 CFR Pt. 430, Subpart B, App. E as published in Federal Register Vol. 79 No. 122, July 11, 2014).

UEF_{50}: Follow standard DOE 24-hour test procedure with the following adjustments:

- Ambient conditions shall be 50°F dry bulb, 43.5°F wet bulb (58% R.H).
- Inlet water temperature: 50°F

2.0 Calculation Methodology:

The UEF_{NC} utilizes a temperature bin weighted calculation.[8] Figure 1 at the end of Appendix A provides several graphical examples of the end result of the calculation. The temperature bins for use in the UEF weightings are given in Table 2.

[8] The method is based on the Heating Seasonal Performance Factor (HSPF) method for space conditioning heat pumps.

Table 2. Temperature Bins[9].

j	T_j (°F)	f_j
1	77	0.021
2	72	0.121
3	67	0.124
4	62	0.131
5	57	0.132
6	52	0.141
7	47	0.121
8	42	0.096
9	37	0.071
10	32	0.040

The Northern Climate Uniform Energy Factor is calculated as:

$$UEF_{NC} = \sum_{j=1}^{10} UEF_j * f_j \qquad (1)$$

where:

j is the bin number from Table 2

f_j is the fraction of hours for that bin

<u>UEF_j is determined in the following way:</u>

If *no* resistance heat is used in either the UEF_{67} or UEF_{50} test:

$$UEF_j = (T_j - 50)*m_{UEF} + UEF_{50} \qquad (2)$$

where:

T_j is the bin temperature

m_{UEF} is the slope of the line connecting the two measured energy factors:

$$m_{UEF} = (UEF_{67} - UEF_{50}) / (67.5 - 50) \qquad (3)$$

If resistance heat is used during the UEF_{50} test:

For bin temperatures <50°F:

$$UEF_j = (T_j - 50)*m_{compT50} + UEF_{50} \qquad (4)$$

where:

j is the temperature bin below 50°F and

[9] Tj gives the bin center. For example, the 62°F bin covers the 5 degree range 59.5°F to 64.5°F. "f" is fractional number of days per year in each of the temperature bins. The temperatures are daily averages for the dry bulb temperature in the buffer space. Climate data comes from TMY datasets of six northern climate cities (Boston, Chicago, Indianapolis, Minneapolis, Omaha and Seattle). These temperatures are based on typical garage and unheated basement temperatures for houses in northern climates (weighting between garages and basement locations is 50/50). Temperature data is derived from simulated garage and unheated basement temperatures in different climates using SUNCODE (for garages) and SEEM (for basements) modeling tools. The garage scenario shares 1.5 of the walls with the house and 2/3 of the ceiling area. The other surface areas are exposed to the outside, attic or ground. The garage area is 484ft^2t with two car doors. The outside walls are insulated to a nominal value of R-19. The basement scenario has a 1344ft^2 basement with 7ft ceilings. As the basement is unconditioned neither the basement walls nor floor are insulated.

$m_{compT50} = (UEF_{50} – UEF_{R,Ccutoff}) / (50 – C_{cutoff})$ (5)

(the slope of the line connecting the measured UEF_{50} and $UEF_{R,Ccutoff}$ at the compressor cutoff temperature)

For bin temperatures ≥50°F and ≤67°F:

$UEF_j = (T_j-50)*m_{UEF} + UEF_{50}$ (6)

where:

j is the temperature bin at, or between, 50°F and 67°F and

m_{UEF} is as defined in equation 3

For bin temperatures >67°F:

$UEF_j = UEF_{67}$ (7)

(the UEF beyond 67°F is capped at the 67°F value)

where:

j is the temperature bin above 67°F

For equipment that limits heat pump operation within the range of temperatures covered in Table 2, (regardless of resistance heat use at other temperatures), the UEF for those temperature bins shall be assigned a value of UEF_R, where UEF_R is based on resistance element only operation and the measured heat loss rate of the tank obtained during the UEF_{67} test.

UEF_R is calculated for each temperature bin of resistance element only operation as follows:

$UEF_{R,j} = Q_{wtr}/(Q_{wtr} + Q_{stbdy,j})$ (8)

where:

Q_{wtr} is the energy input used to heat water over one day

Q_{stbdy} is the standby energy lost over one day

$Q_{wtr} = m^* c_p * \Delta T / \eta_{elem}$ (9)

where:

m is daily water mass corresponding to the draw pattern used in UEF_{67} test (either very low, small, medium, or high; 10, 38, 55, or 84 gallons; 82.4, 313.1, 453.2, or 692.2 pounds)

c_p is 0.998 Btu/lb°F (heat capacity of water at 96.5°F)

ΔT is 75°F (125°F set point temperature – 50°F inlet water temperature)

η_{elem} is 0.98 heating efficiency of electric element per DOE test procedure

$Q_{stdby,j} = UA * (T_{tank} – T_j) * 24$ hrs (10)

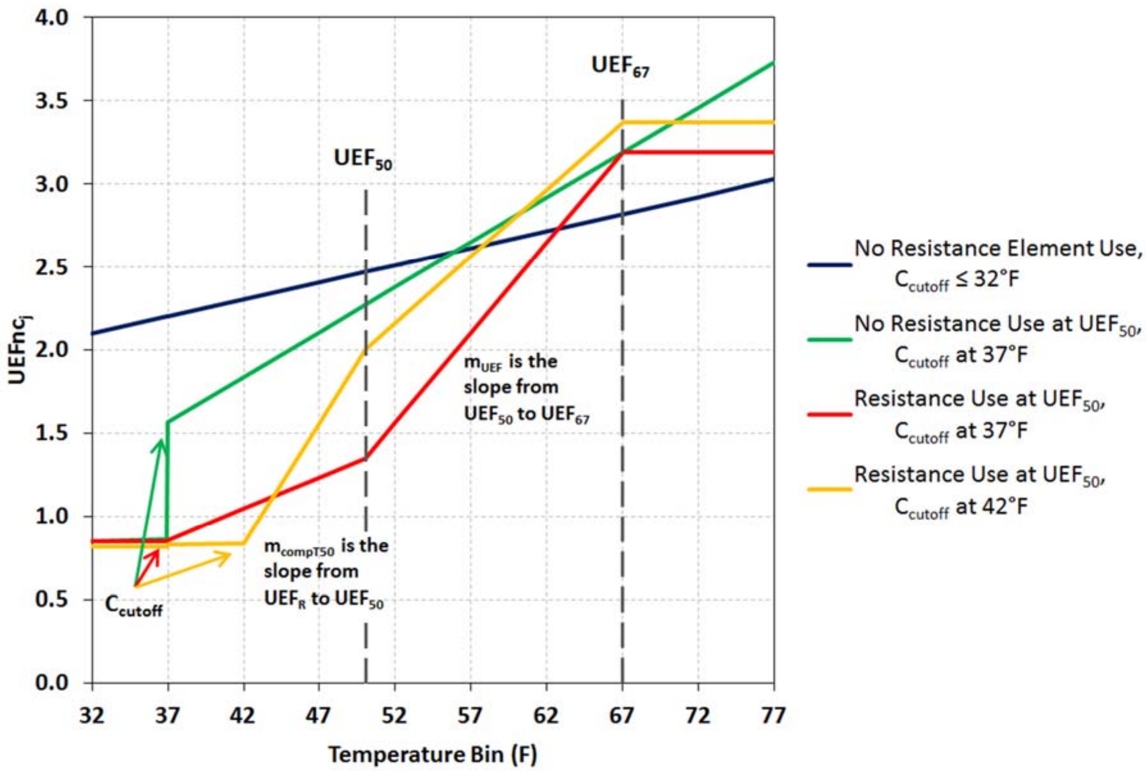
where:

UA is the measured tank heat loss rate (Btu/hr°F) from the UEF_{67} test

T_{tank} is 125°F (the tank setpoint temperature)

T_j is the bin temperature

Figure 1. UEF_{NC} vs Temperature[10]



[10] Note that while having two ambient temperature test conditions provides significantly more information about performance than one, additional tests would provide even more information. In lieu of more testing points, the UEF_{NC} calculation procedure is designed to avoid giving undue benefit to using resistance elements at the 50°F condition. With the two test points, if no resistance element is used at 67.5°F but it is used at 50°F, the slope of the line connecting the two test points will be artificially steep. An unduly steep slope leads to over-prediction of performance at temperatures above 67.5°F. Consequently, if resistance heat is used at 50°F but not 67.5°F, the calculation procedure caps the predicted performance in the warmest temperature bins. Generally, the highest UEF_{NC} is achieved with no resistance element use and a compressor operating temperature as low as possible.

Appendix B: Northern Climate Delivery Rating

Overview: Rate units on ability to deliver hot water in cool ambient conditions while maintaining high efficiency operation in the default operating mode. Reported in number of showers the water heater can provide until the outlet water temperature drops below acceptable levels or the resistance element turns on.

1.0 Test Setup:

Follow setup procedure for DOE tests (Section 5.2 of 10 CFR Pt. 430, Subpart B, App. E) with the following changes to test conditions:

- Ambient conditions shall be 50°F dry bulb, 43.5°F wet bulb (58% R.H.)
- Inlet water, $T_{inlet\ water}$, shall be 50°F
- Per the DOE test procedure, set outlet discharge temperature to 125°F

2.0 Test Procedure:

Draw Pattern: draw 2 gpm for 8 minutes followed by 5 minutes with no draw. Repeat this segment as many times as necessary until the test ending conditions are met.

Begin the test ending sequence when either of the following conditions occurs:

a) Outlet water temperature, T_{out}, falls below 15°F[11] below the maximum outlet discharge temperature observed during the first draw or
b) Any resistance element in the tank turns on

When either of these occurs, note the time as t_{end} and finish the current draw cycle . Allow the tank to recover (tank reaches set-point temperature and all heating components turn off). Terminate data collection when recovery complete. During recovery, note the time when each heating component (resistance heaters, compressor, etc.) switches off.

3.0 Calculation Methodology:

Count the number of fully completed draws between test start and t_{end} . The number of showers shall be counted to the nearest ½ shower. If t_{end} occurs less than ¼ of the way through the draw, do not count the draw towards a shower. If

[11] Nominally, this threshold is 110°F which is 15°F below the required outlet discharge temperature. The set points, conditions, and methods to be used are those of the DOE First Hour rating test except where noted in the text.

t_{end} occurs between ¼ and ¾ of the way through the draw, count the draw as ½ shower. If t_{end} occurs after ¾ of the way through the draw, count the draw as 1 shower.

Appendix C: Freeze Protection Test

Overview: For units circulating water outside the hot water tank for purposes other than delivery to the house (i.e. to a heat exchanger for heating), test the water heater's ability to withstand adverse environmental events and still remain functional afterwards as defined in 3.0 below.

1.0 Test Setup:

- The ambient air in which the water heater is located shall be maintained at 20°F dry bulb for the duration of the test.
- Set tank delivery water temperature set point to 125°F.
- Set equipment to the default operating mode
- Inlet and outlet water lines shall be insulated to provide an R value between 4 and 8 h-ft^2-F/Btu for a minimum of 2 feet from the tank with 1" thick pipe insulation.

2.0 Test Procedure:

- Establish normal water heater operation: If water heater is not operating, initiate a draw. Terminate that draw when equipment cut-in occurs. When the tank recovers and the heaters cut-out, wait 5 minutes. Then shut off all power to the water heater for 24 hours.
- After 24 hours, turn on power to the water heater and allow it to recover to the set point.
- Initiate a draw until the water heater compressor cuts in. Allow tank to recover to the set point.
- Shut off power to the water heater and inspect for damage.

3.0 Functionality. The water heater will have passed the test if all the following criteria are met:

- The compressor runs and the tank recovers after the 24-hour off period.
- There is no freezing or rupture of any water-related connections or components including but not limited to heat exchangers, pumps, condensate lines, or other heat pump components apart from the standard plumbing connections required for a traditional electric resistance water heater.

Appendix D: Sound Pressure Measurement Test Method

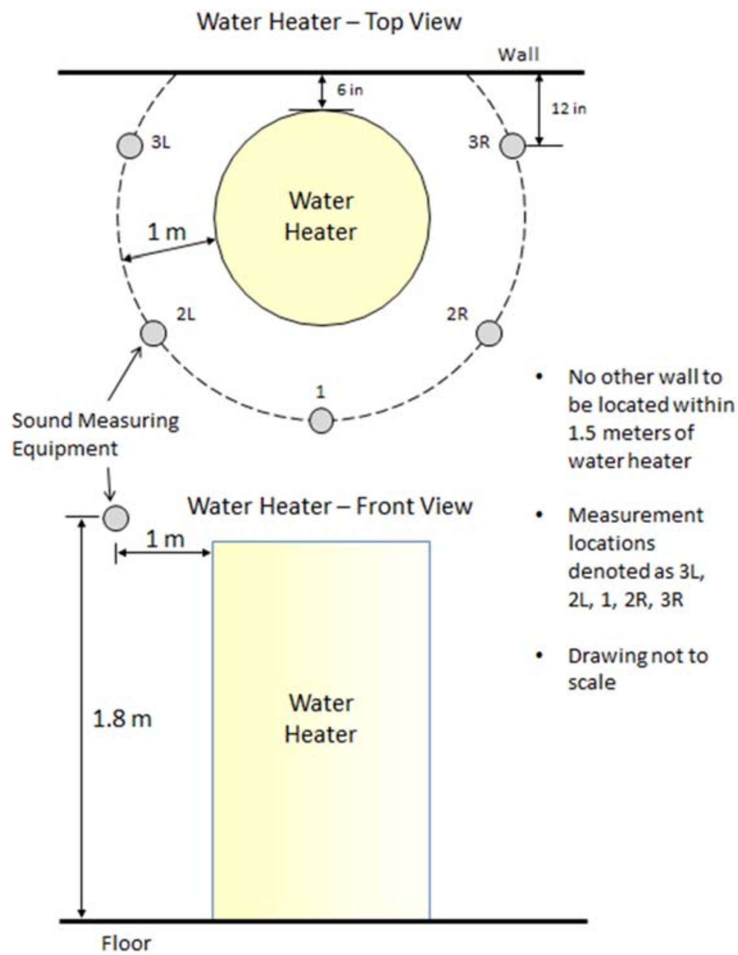
Overview: A simplified, repeatable test to measure sound pressure level

1.0 Test Setup:

- The testing room shall approximate a reverberation chamber. The approximate reverberation room is defined as follows: most surfaces are relatively hard — standard laboratory flooring materials such as concrete or linoleum, and cinder block or drywall walls. The room need not be empty of other equipment, though other noise sources should be turned off. Efforts to dampen noise, such as applying anechoic tiles or baffles shall not be done. Measurements made in an anechoic or semi-anechoic style chamber are not valid. The test concept is to approximate a typical garage, basement or house utility room.
- Place the water heater 6” away from one wall in the room.
  - All other walls or objects shall be at least 1.5 meters away from the water heater.
  - Ambient noise shall be less than or equal to 35dBA.
  - Unit shall be run without ducting attached for those units where this is an option.
- Initiate normal water-heater operation under an operating mode which uses all moving components simultaneously including, but not limited to, the compressor, fan and pumps. Allow the unit to operate in this mode for one minute before proceeding and ensure that a steady state of operation is maintained during the entire sound measurement procedure.
  - Inlet water temperature shall be 58 °F ±10°F
  - Ambient air conditions shall be 67°F ±18°F

2.0 Test Procedure:

- Measure the A-weighted sound pressure level:
  - At five points 1 meter distant from the water heater surface at 1.8 meter height above the base of the water heater. Points 3L and 3R should be 12” from the wall.
  - If the water heater has an airflow intake or exhaust flow path around the circumference of the equipment, position the unit, as follows, so the air flow is not directly aimed at a measurement point: aim the intake or exhaust between either points (3L, 2L), (2L, 1), (1, 2R), and/or (2R, 3R). In no case should the flow path be directed towards the wall between points (3L, 3R).
- Average all five measurements into a single sound value.


Water Heater – Top View
Wall
6 in
12 in
3L
3R
Water Heater
1 m
2L
2R
1
Sound Measuring Equipment
Water Heater – Front View
1 m
1.8 m
Water Heater
Floor
• No other wall to be located within 1.5 meters of water heater
• Measurement locations denoted as 3L, 2L, 1, 2R, 3R
• Drawing not to scale

Appendix E: Compressor Cut-off Temperature:

Overview: A method to determine the low-end ambient temperature below which the compressor does not operate. The cut-off temperature is used within the Northern Climate Energy Factor calculation. Determine the compressor cutoff temperature to within 5°F corresponding to the following temperature bin centers: 27°F, 32°F, 37°F, 42°F, 47°F, 52, °F 57°F, etc.

1.0 Test Setup:

Set inlet water temperature, $T_{inlet\ water}$, to 50°F.

To start the test, establish normal water-heater operation with the water heater outlet temperature at a set point of 125°F. Initiate a draw at 3gpm and withdraw a minimum of 10 gallons. More water shall be withdrawn if needed to achieve compressor cut-in. For example, a large capacity storage tank may require more water to be withdrawn to achieve a compressor cut-in depending on the water heater thermostat dead band.

2.0 Test Procedure:

The ambient conditions shall be varied as necessary to determine the cut-off temperature. To start, the ambient temperature shall be the closest temperature bin center to the cut-off temperature specified by the manufacturer. For example, if the specified cut-off temperature is 45°F, the test shall be started at 47°F. If the compressor does not turn on in response to the draw at the first ambient condition, or fails to completely recover the tank with the compressor only, increase the ambient temperature by 5°F and repeat the test. Repeat this procedure until an ambient condition is achieved under which the compressor operates. All test shall be conducted with an ambient RH of 60%. Record the lowest temperature bin in which the compressor operates. For purposes of calculations in the Northern Climate Energy Factor, the compressor shall be assumed to operate over the entire temperature bin.

Appendix F Airflow Measurement

Overview: For units with a ducting kit, measure and verify the airflow in a simulated duct system. Per section 6.2.2 of the Specification, the equipment shall maintain its nominal airflow, so as not to reduce heat pump performance, when attached to a duct system subject to 0.2” water column of total external static pressure. The external static pressure (ESP), is measured across the complete airflow path of the system. Conceptually, for exhaust ducting, with a typical HPWH, this includes the filter at the air intake, the evaporator coil, the duct attachment kit, the exhaust duct itself, and an end cap. For dual-ducted systems, this could also include intake ducting and intake air grills.

Definitions:

Nominal Airflow – is the airflow across the evaporator at which the equipment is rated in the UEF_{67} test.

1.0 Test Setup:

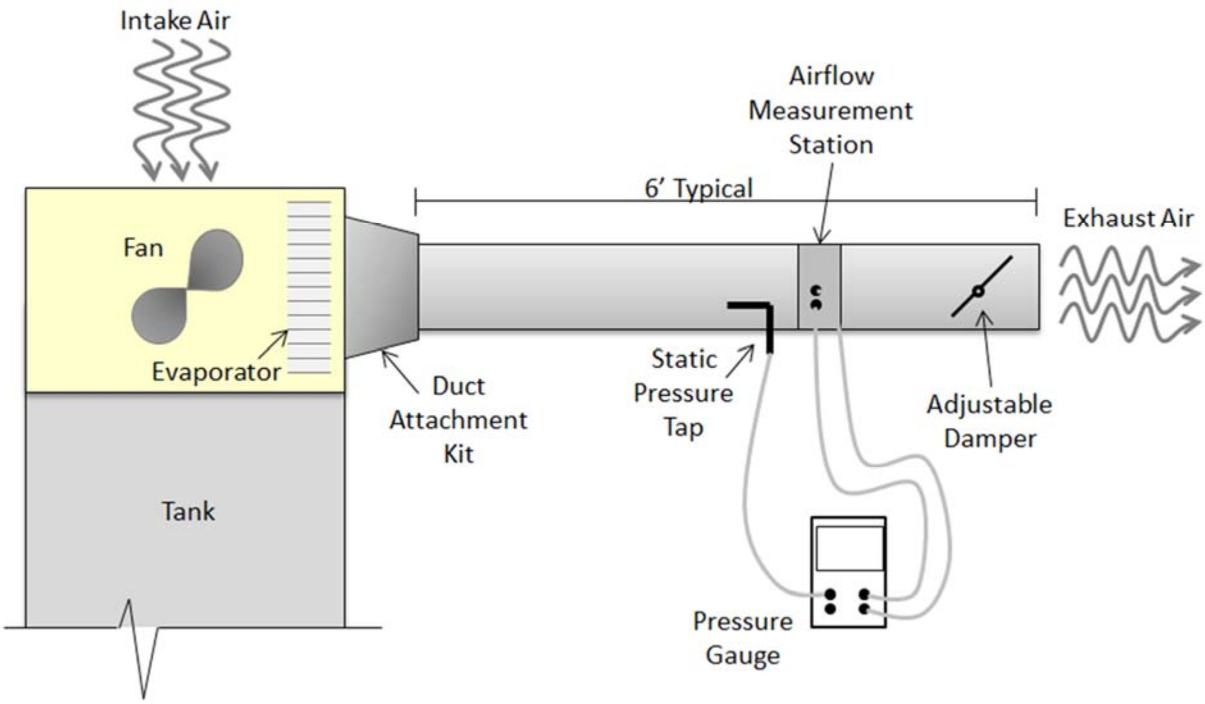
Each HPWH may have a unique airflow path and, therefore, measurement setup. The setup presented in this section is done so as one possible example. Refer to Figure 2 for a diagram. For specific questions and clarifications contact NEEA.

- Attach ducting kit to airflow outlet
- Attach an approximately 6 foot length of straight, round, sheet metal duct to the duct kit at a diameter matching the two.
- Install an adjustable damper at the outlet end of the duct
- Insert an airflow measurement station and a static pressure tap in the middle section of the duct. Connect each to a pressure gauge

2.0 Test Procedure:

- Adjust damper position, to increase ESP to 0.2” w.c. and record the airflow
- Compare airflow at 0.2” w.c. to nominal airflow.
    - If airflow at 0.2” w.c. at least 80% of the nominal airflow, the equipment passes the requirement.

Figure 2. Example Airflow Measurement Setup



Appendix G Demand Response Validation

The DR Validation Test Method shall be provided by Bonneville Power Administration, Portland General Electric, Tennessee Valley Authority, Duke Energy, PJM, Electric Power Research Institute and USNAP Alliance as they are developed. The anticipated physical-connection requirement is AC or DC connection as per CTA 2045. All products will be compliant with either UL, ETL and or CSA.

Appendix H Qualification Process

The qualification process for the Advanced Water Heater Specification begins when a manufacturer submits the "Heat Pump Water Heater Product Assessment Worksheet" to the managing agency (currently NEEA, HPWH_Assessments@neea.org) . The most current version of this worksheet is at http://neea.org/advancedwaterheaterspec.

Manufacturers are encouraged to perform their own Advanced Water Heater Specification testing through any third-party EPA-recognized laboratory (see https://www.energystar.gov/index.cfm?fuseaction=recognized_bodies_list.show_RCB_search_form). In the event that the manufacturer does not perform this testing (and submits an incomplete assessment worksheet), qualification will be delayed until managing agency or the manufacturer performs the requisite testing. The manufacturer must be self-certified and validated by NEEA or the designated managing agency.

Upon meeting all qualification requirements, a product will be added to the Qualified Products List (QPL) and classified into the appropriate tier level. For the current list, and for a complete description of the current process flow for the qualification process, see http://neea.org/advancedwaterheaterspec.

Appendix I Disqualification and Re-qualification Process

NEEA and/or the managing agency may test a product at any time to ensure that the product meets the requirements of the Advanced Water Heater Specification. Testing may occur in the following scenarios:

1) Products that have previously been qualified to the Specification may no longer qualify, or qualify for a different tier level. This may be the result of re-testing new versions of the product in a lab, or by inspection of the product in the event that certain product features are no longer commercially available that were available at the time of initial qualification.
2) Challenge to Qualified Products:
   In the event that an entity (manufacturer, regulatory agency, advocacy group, etc.) does not believe the test results of a QPL-listed product, it may trigger a challenge event. A challenge event consists of the entity challenging the results contacting the QPL managing agency (currently NEEA) in writing that potential discrepancies in test results may exist. The managing agency will notify the challenged party in writing and will coordinate a mutually agreeable testing lab for verification testing. Random units will be pulled from distribution and sent to the testing lab. The full cost of conducting the test (including procurement, shipping and testing) will be borne by the entity found in error.
   In the event that a previously qualified product is found to not meet specifications and/or the specified tier level, the product will be delisted and units of the product will need to be pulled from distribution. All costs for pulling inventory from distribution will be the burden of the manufacturer or supplier.
3) In-field testing reveals substantial differences between in-field performance and lab-tested performance (greater than 5%). "Substantial" is here defined as having a material impact on the aggregate performance in the population of products under study, such that the product in aggregate no longer qualifies to meet the minimum tier (Tier 1) of the Specification or qualifies for a different tier.
4) Product safety issues are observed in the field, or otherwise discovered in lab or field testing.

In all of the above scenarios, NEEA and/or the managing agency will share the information with the HPWH Program and Technical Workgroups for review. Upon review, NEEA and/or the managing agency may decide to proceed with the disqualification/tier-reclassification, or to proceed no further for reasons such as lab or field testing errors, insufficient confidence in testing results or administrative errors in the testing process. NEEA and/or the managing agency may request that the manufacturer provide additional information, or perform additional third-party testing, to determine the outcome.

Upon deciding to proceed with disqualification/tier-reclassification, NEEA and/or the managing agency shall inform the manufacturer and provide 20 days for a written response from the date of notice. NEEA and/or the managing agency shall share the written response (if any) with the HPWH Program and Technical Workgroups, gather feedback, make a final decision and inform the manufacturer of the decision.

Once products are disqualified or have been reclassified to a different tier, the manufacturer may petition for requalification or reclassification to the original tier level. The information provided in the petition (such as updated lab and field tests, manufacturing process or design changes) will be analyzed by NEEA and/or the managing agency and shared with the HPWH Program and Technical Workgroups. At that point a decision will be made and communicated to the manufacturer.