September 8th, 2011
Via Electronic Mail

Ms. Abigail Daken
Energy Star Water Heater Program Manager
U.S. Environmental Protection Agency
Office of Air and Radiation
Washington, DC 20460

Re: Energy Star Water Heaters; Proposed Product Specification, Draft 1

The following comments are submitted for the record of the Agency's above-captioned proceeding regarding the product specification framework for Energy Star water heaters. They are submitted as a follow-up to our original Framework document comments (http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/comments_2011/NEEA_Comments_2.pdf) which were provided by numerous members of the Northern Climate Heat Pump Water Heater Task Force (Task Force)[1]. Because the Task Force is focused entirely on heat pump water heater technology, our comments here will be confined to that element of the draft Energy Star specifications. NEEA will also submit a separate set of comments dealing with other aspects of the draft specification.

Heat Pump Water Heater Specifications

In our June 24th comments on the specification framework, we said the following with regard to the performance rating of heat pump water heaters (HPWHs):

> "The most important thing EPA should do is ensure that its specification certifies products that will actually deliver the performance promised by their ratings, with high levels of consumer satisfaction…We strongly endorse the Task Force's work and urge EPA to adopt its specifications, or key elements thereof, for these products. The associated test procedure and rating conditions may or may not be adequately addressed in changes to the federal test procedure, but **EPA should ensure that its own specifications are appropriate to the field use of this technology, including the conditions under which they are rated and the features that will maintain the energy savings and consumer satisfaction."**

Since that time, the Northern Climate Heat Pump Water Heater specification has been more fully developed, and a Northern Climate rating method has been designed. This rating method is based on the USDOE water heater test method, but adds a critical second set of rating points that allows a HPWH to be rated in the lower-temperature ambient conditions expected in the northern half of the country. The Northern Climate specification is expected to be finalized by the end of

[1] The Northern Climate Heat Pump Water Heater Task Force is a NEEA-facilitated stakeholder group working to encourage the development and adoption of heat pump water heater technologies that deliver superior energy efficiency performance and consumer satisfaction in the more severe operating environments of the northern half of the United States.

September 2011, with final rounds of feedback currently being solicited from stakeholders, including heat pump water heater manufacturers.

Once again we urge EPA to make use of this rating method and specification so that Energy Star water heaters can provide consumers in the northern half of the country a high level of performance and satisfaction. In order to make this possible, EPA should:

- Adopt the Northern Climate EF rating methodology for heat pump water heaters that will be Energy Star-rated in the northern part of the country. The Northern Climate test method uses the current DOE test method draw patterns but adds a second set of rating conditions that are more appropriate for colder climates – 50-degree F ambient air temperature and 50-degree F inlet water temperature. The COP performance at standard DOE conditions and at the Northern Climate conditions are then combined with a compressor cut-off test to establish COP performance in a set of ambient temperature bins that are representative of those likely to be found in northern climate installations to generate a bin-weighted COP for computing the water heater EF. The rating methodology is described in Appendix A of the near final updated version of the Northern Climate Specification (provided as an attachment to this document.)
- Adopt a minimum Northern Climate EF (EF_{NC}), based on the Northern Climate rating method. We recommend a minimum EF_{NC} of 1.8.
- Establish a climate-based minimum electric water heater EF specification for the northern and southern half of the country, with the northern minimum being the above-suggested EF_{NC} of 1.8 and the southern minimum being a standard DOE test method-rated EF of 2.0 (as in the current draft Energy Star specification). We strongly suggest adopting the northern states specified by USDOE in the most recent climate-based furnace efficiency standards for the Energy Star program.[2]
- Adopt the other Northern Climate specification elements (freeze protection, exhaust ducting for integral models, compressor shutdown/notification, warranty, condensate management, air filter management, and sound levels). The most recent version of the Northern Climate specification is provided as an attachment to this document.

Members of the Task Force believe that the Northern Climate specification is critical to ensuring reliable energy savings from heat pump water heaters and consumer satisfaction with these products. We believe that Energy Star should be equally concerned about reliability of energy savings and high levels of marketplace acceptance of these products, and that adoption of the Northern Climate specification and its test methods will go a long way toward ensuring this. We welcome the opportunity to work with EPA as we continue to work closely with the manufacturers of these products to bring Northern Climate-compliant models to market.

Sincerely,

Dave Kresta

Senior Manager for Product Development, NEEA

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[2] These states are Alaska, Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Dakota, Utah, Vermont, Washington, West Virginia, Wisconsin, and Wyoming. See **TABLE I.1—AMENDED ENERGY CONSERVATION STANDARDS FOR FURNACE, CENTRAL AIR CONDITIONER, AND HEAT PUMP ENERGY EFFICIENCY** in FR 76, No. 123, p.37410.

A Specification for
Residential Heat Pump Water Heaters
Installed in Northern Climates
Version 4.0

Updated Version: Draft for Discussion

August 22, 2011

Background.
In the early 1980's, electric utilities in colder, northern portions of North America introduced heat pump technology into the residential water heating market. These programs have spanned three generations of technology and produced detailed measurement of technical performance and consumer acceptance. The experience gained from these programs yields definitive direction about key consumer needs as well as important technical criteria for proper application of this technology in cold climates.

The ENERGY STAR program released its first specification for residential water heaters in 2008, which included qualifying criteria for heat pump water heaters (HPWHs). The DOE 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 adoption of HPWHs in northern climates. In 2009, several major manufacturers launched integrated HPWH units in North American markets which were ENERGY STAR qualified but failed to address key northern climate issues.

This specification, while focused on "Northern" climates, also provides a framework which could be extended in the future for other climate types as appropriate.

1.0 Purpose

This specification provides guidance to manufacturers 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 cooler, northern climates. The end goal of this effort is to ensure that the North American introduction of this new generation of HPWH products will be as successful as possible in order to pave the way for HPWHs to become the standard product for the electric water heating market.

Utilities and other entities that invest in market transformation programs and/or incentives will require effective energy savings. Accordingly, the specification is also intended as a foundational document for utility program efforts that will work in partnership with manufacturers to accelerate market adoption of HPWH for northern climates. Using this specification will help improve market acceptance and ensure the expected savings materialize.

This specification addresses key issues that fall in two main categories:

- Performance - Northern climate energy efficiency and savings, condensate management, freeze protection, user controls, reliability.
- Comfort/Satisfaction – exhaust air, noise, hot water delivery rates, ease of installation, serviceability.

2.0 Scope

2.1 Equipment Type. This specification covers residential, integrated (with tank) heat pump water heaters with storage volumes of 40-120 gallons. Heat pump water heaters configured to "add-on" to existing storage tanks are not covered by this specification. In addition to integrated units, there are currently several "split-system" HPWH units on the market These units consist of a heat pump that is located outdoors which transfers heat to a water storage tank that is usually located within the building. A future version of this specification (or a related specification) will address these split systems.

2.2 Applications. Focus 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 and installation 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 or 3 are expected to provide configuration options for semi-conditioned, unconditioned, AND conditioned spaces such as heated utility rooms. Outside applications are not covered by this specification.

2.3 Climate. This specification is intended for 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 with latitudes above 40 degrees herein referred to as "Northern climates"[1].

[1] Alaska, Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, 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. Three product tiers are incorporated into this specification recognizing variations in product performance and supported applications. The following table summarizes each tiering level:

	Minimum Northern Climate EF*	Minimum "Northern Climate" Features	Minimum supported installation locations	Sound levels**
Tier 1	**1.8**	• ENERGY STAR compliance	• Semi-conditioned • Unconditioned	dBA < 65
Tier 2	**2.0**	Tier 1 plus: • Minimal use of electric heating elements • Freeze protection • Exhaust ducting option • Compressor shut-down/notification • 10 year Warranty • Condensate Mgmt • Air Filter Mgmt	• Conditioned • Semi-conditioned • Unconditioned	dBA < 60
Tier 3	**2.4**	Tier 2 plus: • Intake ducting option	• Conditioned • Semi-conditioned • Unconditioned	dBA < 55

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

4.0 Requirements for All Units (Tiers 1, 2, 3)

4.1 ENERGY STAR Compliance. The unit shall meet ENERGY STAR criteria in effect at time of manufacture under default (out of the box) operating mode settings.

4.2 Northern Climate Energy Factor. The unit shall meet minimum Northern Climate Energy Factor values under default operating mode settings according to the table in section 3.1 above. See **Appendix A** for the Northern Climate Performance EF Test Procedure and corresponding Northern Climate EF Calculation Method.

4.3 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 under default operating mode settings. Reported in "number of showers" rounded to the nearest ½ shower. See **Appendix B** for details.

4.4 Sound Levels. The unit shall not exceed maximum sound levels according to the table in section 3.1 above. See **Appendix D** for Sound Measurement Test Method.

5.0 Additional Requirements for Tiers 2 and 3

5.1 Freeze Protection Test. The unit shall pass 24 hour power-off freeze protection test as specified in **Appendix C**.

5.2 Compressor Shut-down and Notification. The unit shall provide notification to the consumer that the heat-pump operation of the product has been disabled in the event of a compressor shut down or failure.

> **5.2.1 Normal, Temporary Event.** The unit shall display to the consumer 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 be able to 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.** The unit shall provide a maximum override period of 48 hours before resetting to normal operating parameters if the compressor is temporarily disabled due to consumer override.

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

> **5.3.1 Contact Information.** The unit shall include clear 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 Exhaust Ducting. The unit shall have a manufacturer-supplied optional ducting kit to provide for exhaust air ducting (“ducting kit”), available from same distribution/retail channels as the unit.

> **5.4.1 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.

5.4.2 Minimum Flow Rate/Pressure Drop. The unit shall be capable of delivering its rated air-flow across the evaporator at a minimum intake (if present) and exhaust duct static pressure drop of 0.25 inch water gauge.

5.4.3 Application Options. The unit shall be capable of operating with or without ducting installed. Manufacturers shall clearly identify which models are configured for which applications 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.

5.5 Condensate Management. Condensate must be drained away according to local plumbing codes.

5.5.1 Acceptable Condensate Piping. The unit shall include a minimum piping connection for condensate drainage of ¾ inch (inside diameter) or greater. 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.

5.5.2 Condensate Overflow Shut-off and Alarm. Units shall include a safety switch to shut off compressor operation in the event of a blockage of the condensate removal system. 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.

5.5.3 Condensate Collection Pan and Drain Service. The condensate collection pan and drain shall be designed to be self-cleaning without regular maintenance or interaction by the consumer. 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.

5.6 Air Filters: Routine Maintenance and Homeowner Notification. Any air filters shall be either 1) permanent, washable media or 2) replaceable, standard furnace filters in shape and form that are obtainable at a typical home improvement store. The unit shall provide visible and alarm 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.

5.7 Minimal Use of Electric Resistance Heating Elements. In default operating mode, units shall make minimal 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, 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 volume is defined as the amount of water the unit under test actually stores and not the rated tank volume.

6.0 Additional Requirements Tier 3

6.1 Intake ducting. The unit shall have a manufacturer-supplied optional ducting kit to provide for intake air ducting. Requirements for exhaust ducting in 5.4 above shall also apply to intake ducting.

Appendix A: Northern Climate Energy Factor

Overview: Measure and calculate a Northern Climate Energy Factor (EF_{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 Northern Climate Energy Factor (EF_{NC}) consists of lab measurement of Energy Factors at 67°F and 50°F (EF_{67} and EF_{50}), compressor cut-off temperature, and a temperature bin-based calculation procedure.

1.0 Test setup and procedure:

EF_{67}: Follow standard DOE 24-hour test procedure (Section 6 of 10 CFR Pt. 430, Subpart B, App. E).

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

- Ambient conditions shall be 50°F dry bulb, 44°F wet bulb (58% R.H.).
- Inlet water temperature: 50°F

C_{cutoff} : Compressor cut-off temperature. See Appendix E.

2.0 Calculation Methodology:

The Northern Climate EF utilizes a temperature bin weighted calculation. The method is based on the Heating Seasonal Performance Factor (HSPF) method for space conditioning heat pumps.

Definitions:

EF_{67} is the energy factor from the standard DOE 24-hour test, at 67°F.
EF_{50} is the energy factor based on the standard DOE 24-hour test, at 50°F.
EF_R is the energy factor for the HPWH operating in resistance-only heat mode.

The temperature bins for use in the EF weightings are given in Table 1 below.

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

Table 1. Temperature Bins[2].

The Northern Climate Energy Factor is calculated as:

$$EF_{NC} = \sum_{j=1}^{10} EF_j * f_j \quad (1)$$

Where:

j is the bin number from Table 1,

f_j is the fraction of hours for that bin, and

$$EF_j = (T_j - 50) * m_{EF} + EF_{50} \quad (2)$$

Where:

T_j is the bin temperature

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

$$m_{EF} = (EF_{67} - EF_{50}) / (67-50) \quad (3)$$

[2] Tj gives the bin center. For example, the 62F bin covers the 5 degree range 59.5F to 64.5F. "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.

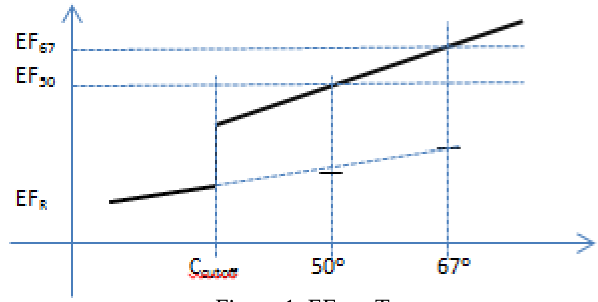


Figure 1. EF vs. Temperature

For equipment that limits heat pump operation below a certain temperature (C_{cutoff}), the EF for those temperature bins shall be assigned a value of EF_R, where EF_R is based on resistance element only operation and the measured heat loss rate of the tank obtained during the EF_{67} test.

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

$$EF_{R,j} = Q_{wtr}/(Q_{wtr} - Q_{stbdy,j}) \quad (4)$$

Where:

Q_{wtr} is the energy input into the water heater used to heat water over one day
Q_{stbdy} is the standby energy lost over one day.

$$Q_{wtr} = m^* \, c_p * \Delta T / \eta_{elem} = 45{,}445 \text{ Btu} \quad (5)$$

Where:

m is daily water mass of 525 lbs (64 gpd at 135°F),

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

ΔT is 85°F (135°F set point temperature - 50°F inlet water temperature),

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

$$Q_{stdby,j} = UA * (T_{tank} - T_j) * 24 \text{ hrs} \quad (6)$$

Where:
UA is the measured tank heat loss rate in Btu/hr°F observed from the EF_{67} test
T_{tank} is 135°F (the tank setpoint temperature),
T_j is the bin temperature.

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 efficiency drops significantly (indicated by resistance element turning on).

1.0 Test setup:

Follow setup procedure for standard DOE 24-hour test (Section 6 of 10 CFR Pt. 430, Subpart B, App. E) with the following changes to test conditions:

T_{amb}= 50°F, $T_{set\ point}$ = 120°F, $T_{inlet\ water}$ = 50°F, Airflow = unrestricted.

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.

Test ending sequence:

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

a) Outlet water temperature, T_{out}, falls below 105°F or
b) Any resistance element in the tank turns on

After these conditions occur, 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:

If ending condition (a) is encountered, note the time as t_{end}.

If ending condition (b) is encountered, further calculation is required to determine t_{end}. Calculate the cumulative COP of the test. Determine the time when cumulative COP falls below 2.0 and note that time as t_{end}. The cumulative COP at any given time since the start of the test is defined as:

$$COP_{t=n} = [\sum_{t=0}^{n} Eout_t + (Etank_{t=n} - Etank_{t=0})] / \sum_{t=0}^{n} Ein_t$$

Where:

t is time

n is the time since the start of the test

Eout is the energy leaving the tank in the outlet water

Etank is energy of the water inside the tank

Ein is the equipment input energy.

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 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: 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 30°F dry bulb and 28°F wet bulb (80% R.H.) for the duration of the test.
- Set tank water temperature set point to 120°F.
- Inlet and outlet water lines shall be insulated with 1" thick pipe insulation.

2.0 Test procedure:

- Establish normal water heater operation: If water heater not operating, initiate a draw. Terminate that draw when heater 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 24hr 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 Measurement Test Method

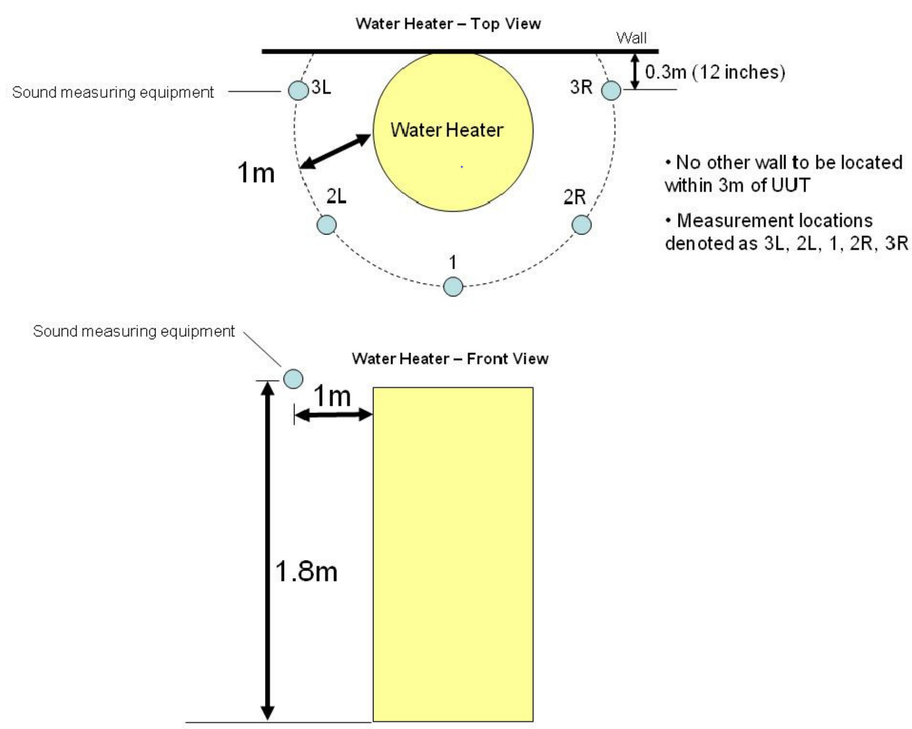
Overview: A simplified, repeatable test to measure sound level.

1.0 Test setup:

- Place the water heater against a wall in a room with low ambient noise
    - All other walls (including ceilings) or objects shall be at least 1.5 meters away from the water heater.
    - Ambient noise should be less than or equal to 35dbA.
    - Unit should be run without ducting attached for those units where this is an option.
- Turn on water heater in an operating mode which uses all moving components including but not limited to the compressor, fan, or pumps.

2.0 Test procedure:

- Measure the A-weighted noise 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.
- Average all five measurements into a single sound level.



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:

To start the test, establish normal water heater operation with the water heater at a set point of 135°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 47°F. If the compressor does not turn on in response to the draw at the first ambient condition, 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.