Challenges in Testing and Rating Split-Unit Water Heaters

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Perceived Challenges for Heat Pump Water Heaters

- What are some of the perceived drawbacks to heat pump water heaters?
  - Remove heat from the space
  - Noisy

Why not put the refrigeration system outdoors to avoid these drawbacks?

Could also ease safety concerns with alternative refrigerants

Split System Heat Pump Water Heaters

- Move the evaporator outdoors
- Storage tank is indoors
- Generally water lines between the outdoor unit and indoor unit

Image courtesy of www.r744.com

Principles of Test Methods

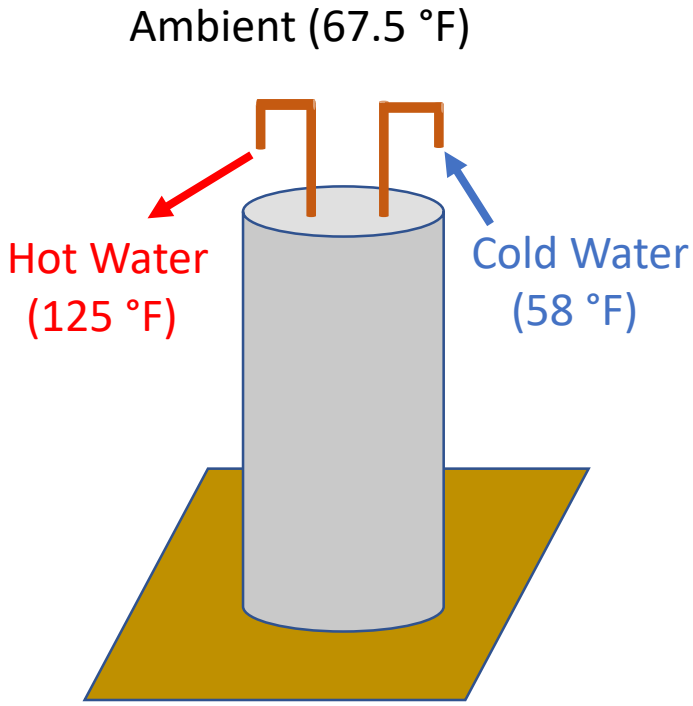
Purpose: Provide information to…

- Consumers to compare products
- Regulatory agencies in setting minimum efficiency standards
- Incentive providers to set levels for efficiency programs

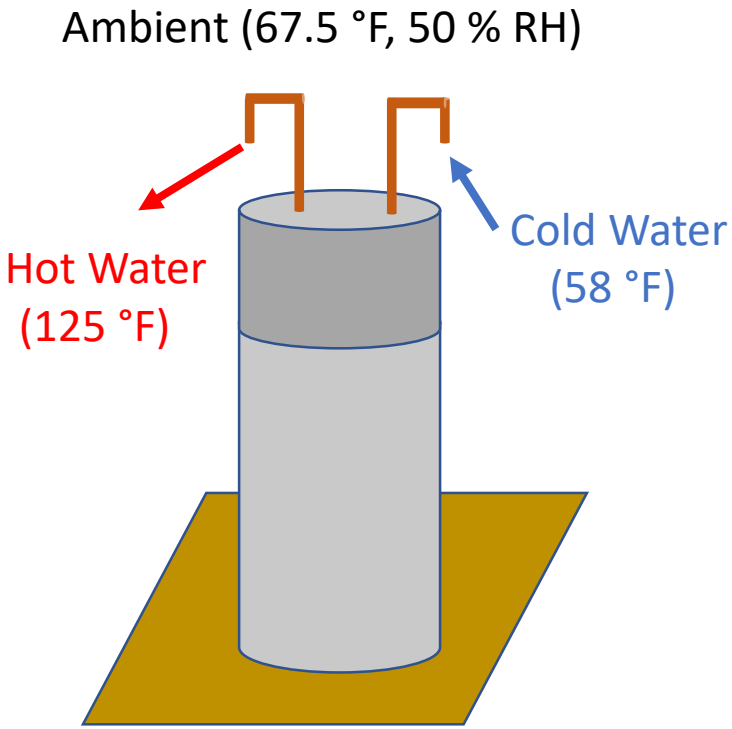
Test Methods Should Be:

- Representative
- Repeatable & Reproducible
- Not Unduly Burdensome

Testing Efficiency of Water Heaters



Electric Resistance or Gas Water Heater

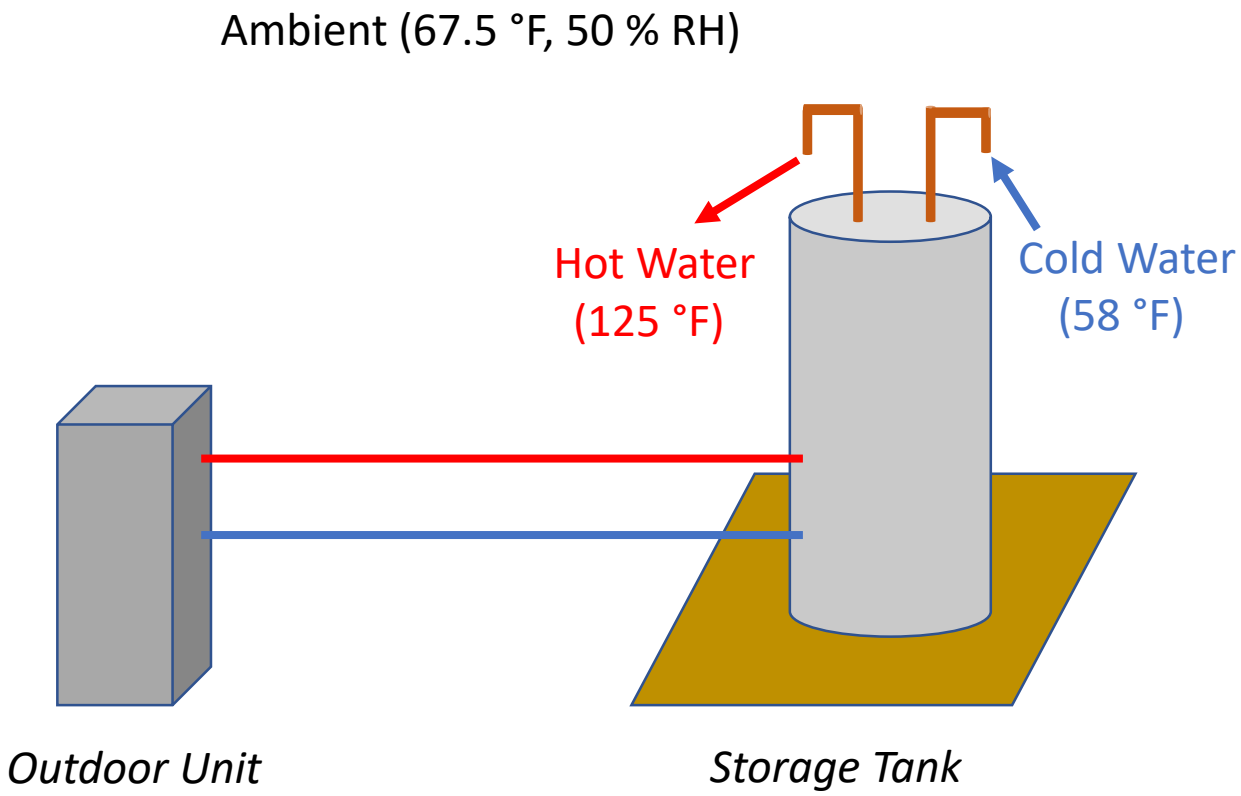


Heat Pump Water Heater

Subject to essentially the same conditions

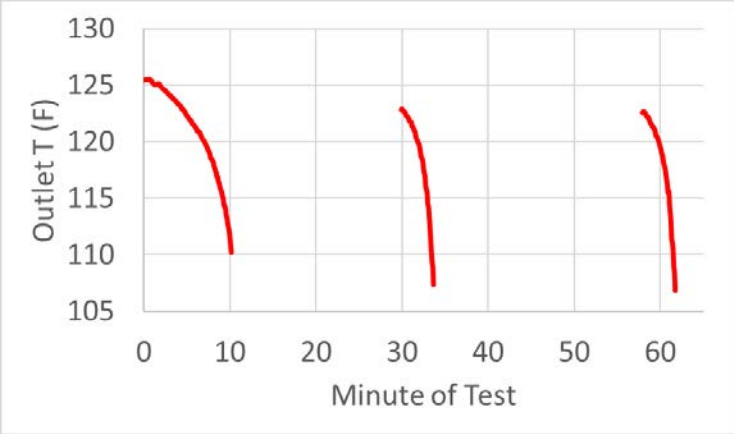
Testing Split System Water Heaters

- Current Default Approach

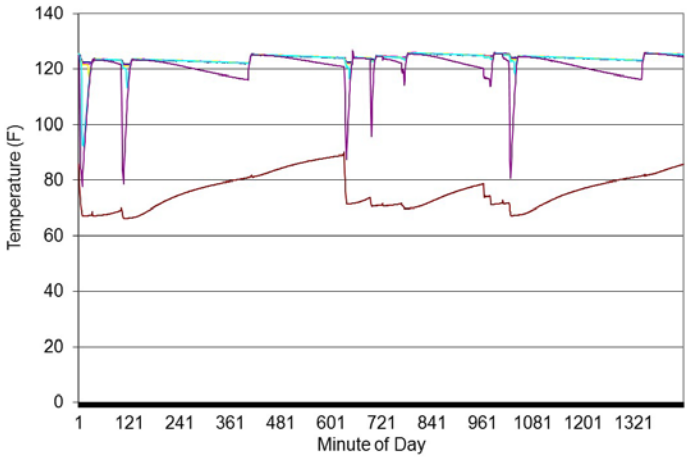


Current Test Method

- 12 Hour Soak-In Period (storage types)
- Delivery Capacity Test
  - First Hour Rating (storage type)
  - Maximum GPM (tankless)
- 24-hour Simulated Use Test
  - Subject to Draw Pattern based on Delivery Capacity



Sample Outlet Temperature Profile During First Hour Rating Test



Sample Tank Temperature Sensor Profiles During 24-hour SUT

Challenges in Properly Assessing Performance of Split HPWH's

1. Accounting for impact of large variations in ambient conditions

2. Accounting for (lack of) impact on space conditioning

3. Accounting for defrost mechanisms

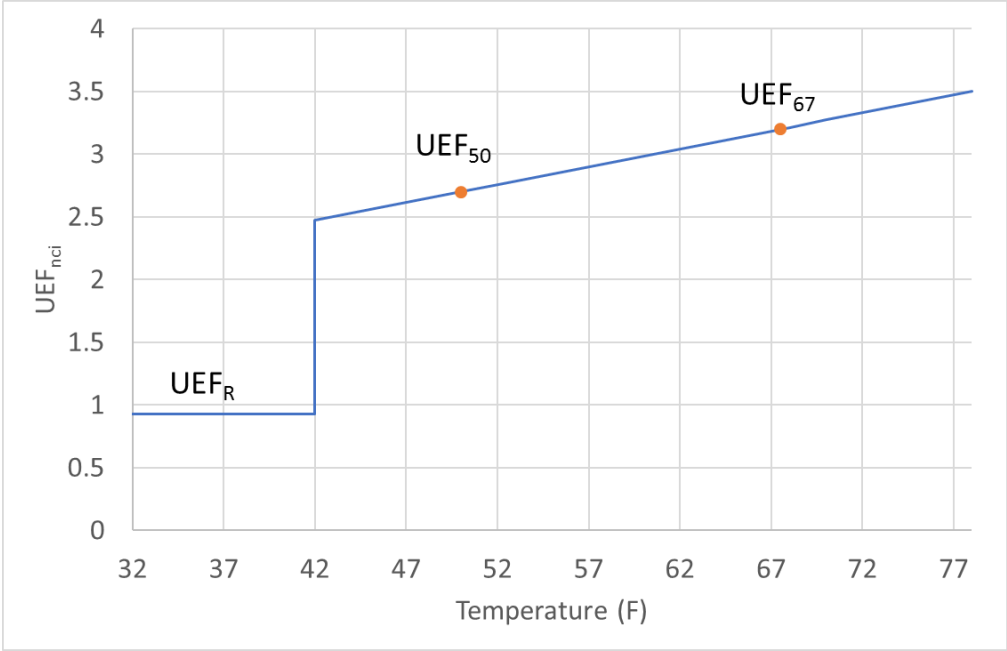
A Template: Advanced Water Heater Specification UEF

- Developed by Northwest Energy Efficiency Alliance
  - *"Representative of water heater performance for equipment installed in semi-conditioned and unconditioned locations in northern climates"*
  - Testing
    - FHR: tested at DOE conditions
    - UEF_{67}: tested at DOE conditions
    - UEF_{50}:
      - Ambient: 50 °F dry bulb, 43.5 °F wet bulb (50 % RH)
      - Inlet water: 50 °F
    - Compressor Cut-off temperature
      - *"Determine compressor cutoff temperature to within 5 °F"*
      - Use manufacturer's specified cut-off temperature as starting point to evaluate compressor cutoff during a recovery

AWHS UEF Calculations

- Estimate UEF_R: efficiency under resistance mode should compressor be cutoff
  - Based on results of UEF_{67} test (i.e., UA value, draw volume)
- Estimate UEF at any outdoor temperature:

Example of a UEF map at various ambient temperatures



Example Conditions:

UEF_{67} = 3.2

UEF_{50} = 2.7

No resistance heat during UEF tests

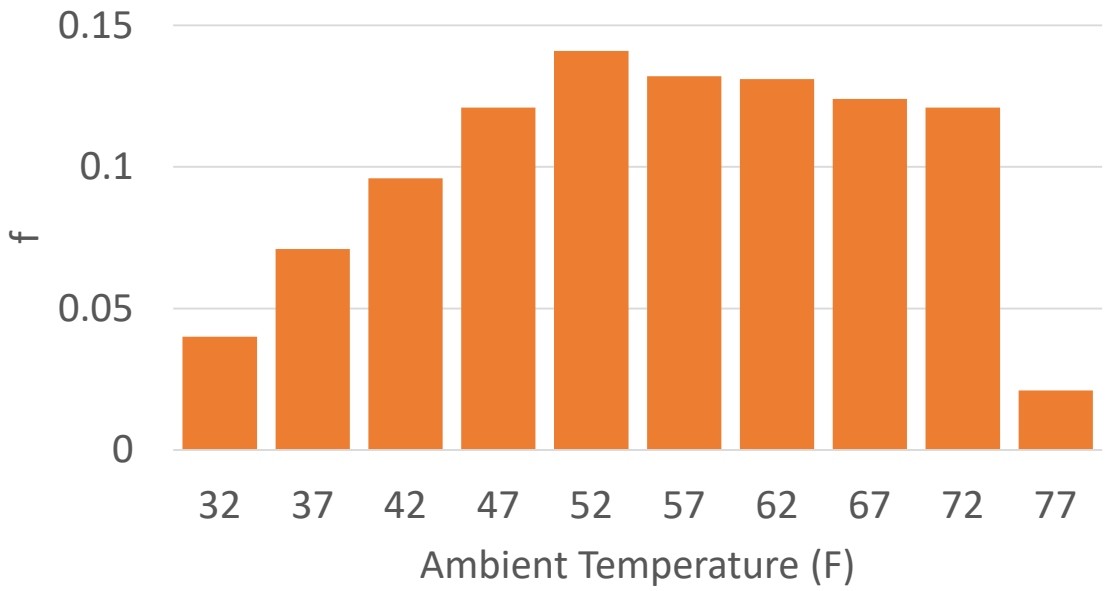
Compressor shutoff at 42 °F

Bin Approach

- Develop an integrated UEF:

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

- f's are the fraction of hours in the year within a 5 °F temperature bin



Space Conditioning Heat Pump Testing

- Previous analysis not meant for outdoor installations
- Compare to heat pump conditions:

AHRI STANDARD 210/240-2017

Table 8. Test Conditions for Air-cooled Products

Test Name	Air Entering Outdoor Unit [2] (°F)	Air Entering Indoor Unit [2] (°F)	Compressor Speed [3]	Indoor Airflow [4]
Cooling Mode				
A_{Full}	95.0 / 75.0 [5,6]	80.0 / 67.0	$Full_C$ [12]	$Full_C$ [12]
B_{Full}	82.0 / 65.0 [5,6]	80.0 / 67.0	$Full_C$	$Full_C$
B_{Low}	82.0 / 65.0 [5,6]	80.0 / 67.0	Low_C	Low_C
C_{Full}	82.0 / 58.0 [5,6]	80.0 / 57.0 [7]	$Full_C$	$Full_C$
C_{Low}	82.0 / 58.0 [5,6]	80.0 / 57.0 [7]	Low_C	Low_C
D_{Full}	82.0 / 58.0 [5,6]	80.0 / 57.0 [7]	$Full_C$	$Full_C$ [8]
D_{Low}	82.0			
E_{Int}	87.0			
F_{Low}	67.0			
G_{Low}	67.0			
I_{Low}	67.0			
Heating Mode				
$H0_{Low}$	62.0 / 56.5	70.0 / 60.0 [9]	Low_H	Low_H
$H0C_{Low}$	62.0 / 56.5	70.0 / 60.0 [9]	Low_H	Low_H
$H1_{Full}$	47.0 / 43.0	70.0 / 60.0 [9]	$Full_H$	$Full_H$
$H1_{Low}$	47.0 / 43.0	70.0 / 60.0 [9]	Low_H	Low_H
$H1C_{Full}$	47.0 / 43.0	70.0 / 60.0 [9]	$Full_H$	$Full_H$ [8]
$H1C_{Low}$	47.0 / 43.0	70.0 / 60.0 [9]	Low_H	Low_H [8]
$H1_{Nom}$	47.0 / 43.0	70.0 / 60.0 [9]	Nom_H [15]	Nom_H [10]
$H2_{Boost}$	35.0 / 33.0	70.0 / 60.0 [9]	$Boost_H$	$Full_H$
$H2_{Full}$	35.0 / 33.0	70.0 / 60.0 [9]	$Full_H$	$Full_H$
$H2_{Low}$	35.0 / 33.0	70.0 / 60.0 [9]	Low_H	Low_H
$H2_{Int}$	35.0 / 33.0	70.0 / 60.0 [9]	Int_H	Int_H
$H3_{Full}$	17.0 / 15.0	70.0 / 60.0 [9]	$Full_H$	$Full_H$
$H3_{Low}$	17.0 / 15.0	70.0 / 60.0 [9]	Low_H	Low_H
$H3_{Boost}$	17.0 / 15.0	70.0 / 60.0 [9]	$Boost_H$	$Full_H$
$H3C_{Boost}$	17.0 / 15.0	70.0 / 60.0 [9]	$Boost_H$	$Full_H$
$H4_{Boost}$	5.0 / 3.0 [11]	70.0 / 60.0 [9]	$Boost_H$	$Full_H$

Heat Pump Test Conditions

- Required Test Settings – Single Stage System

Cooling Mode

Dry Bulb Temperature	Wet Bulb Temperature
95 °F	75 °F
82 °F	65 °F

Heating Mode

Dry Bulb Temperature	Wet Bulb Temperature
47 °F	43 °F
35 °F	33 °F
17 °F	15 °F

- Additional Required Settings – Variable Stage System

Cooling Mode

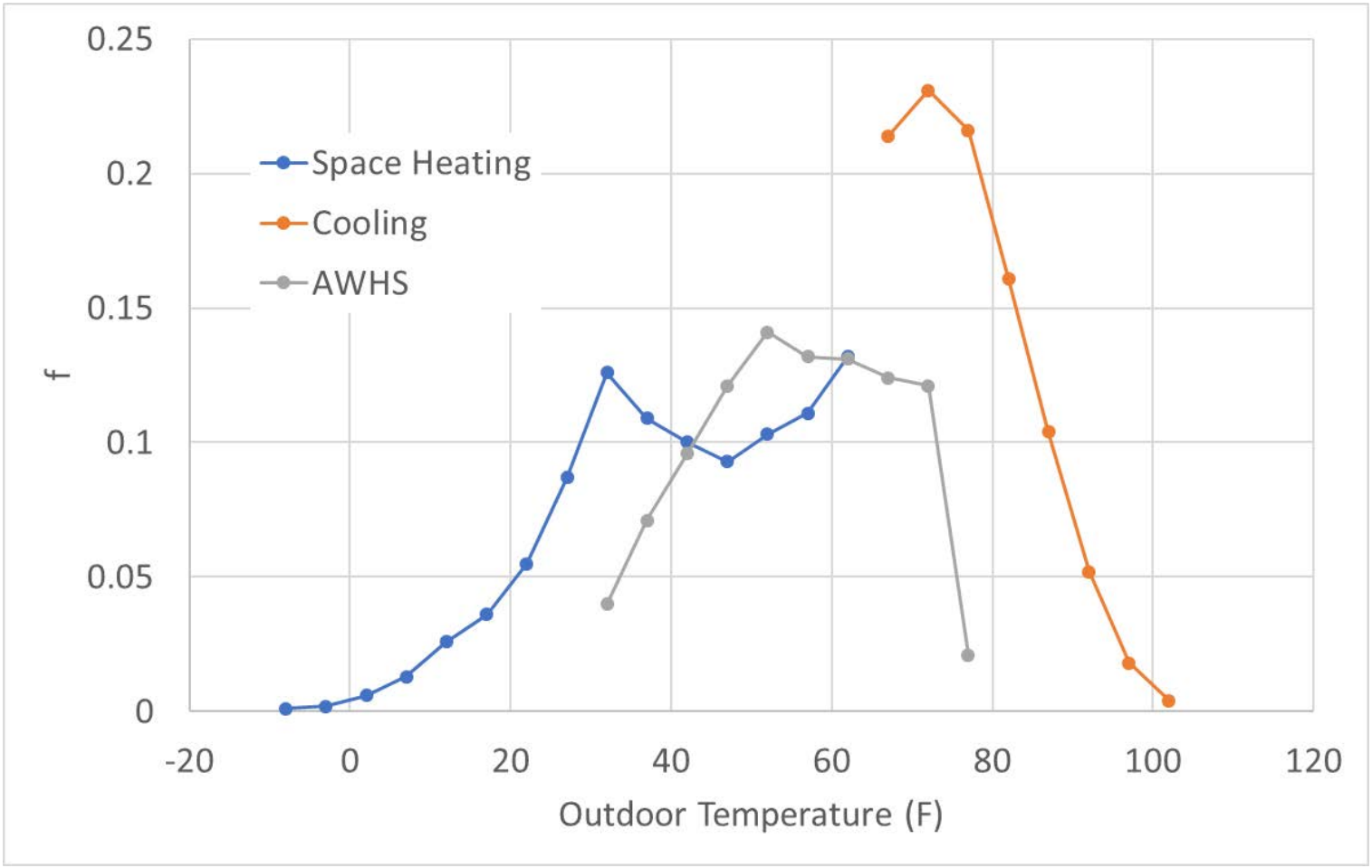
Dry Bulb Temperature	Wet Bulb Temperature
87 °F	69 °F
67 °F	53.5 °F

Heating Mode

Dry Bulb Temperature	Wet Bulb Temperature
62 °F	56.5

Note: Some single stage conditions must be repeated at different compressor speeds

Bin Method for Space Conditioning



Bin levels for AWHS and Space Conditioning

Split System Testing Options

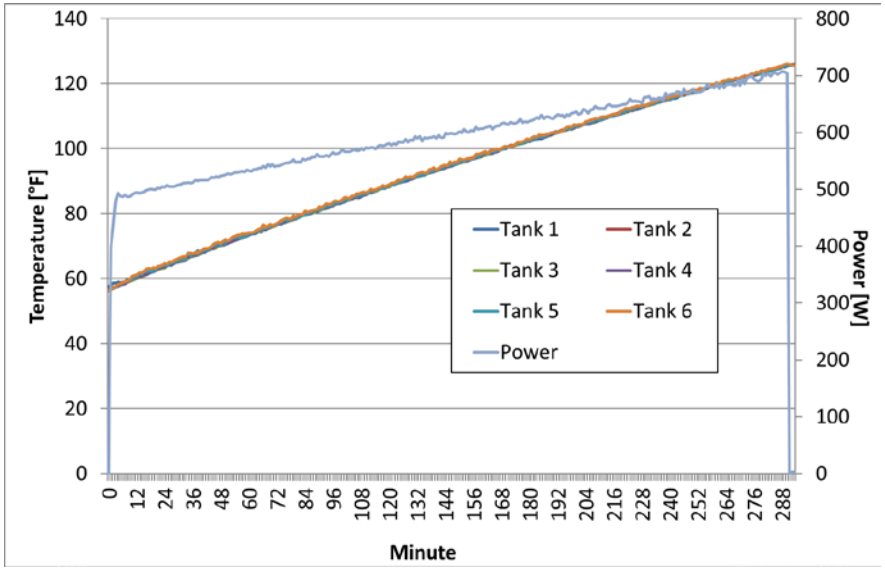
- Goal: “Thorough enough” information with minimal testing

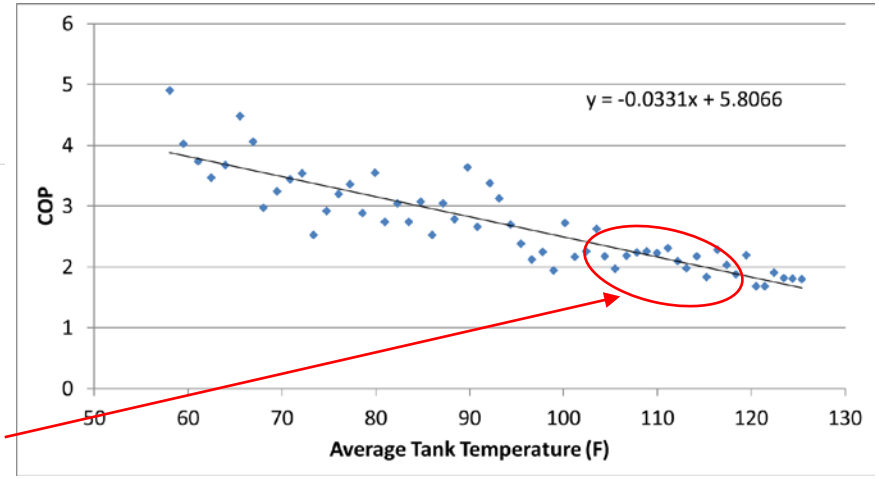
Options

- Apply a bin approach with new bins?
  - Are two UEF tests enough?
    - How linear is dependence?
    - More extreme conditions than used for AWHS?
    - More variation in RH?
  - Are there different bins for different regions?
- COP testing?
  - Instead of running multiple 24 hour SUT’s…
    - Run 1 SUT
    - Run multiple shorter tests to determine the COP of unit at different conditions and computationally determine UEF at alternative conditions.

COP Testing

- An example with a 50 gallon HPWH





Mean temperature while heating during an SUT somewhere in this region

Test Burdens

Estimated Time to Run a Test (Very Rough!)

Activity	Time
Check in and Setup	1 day
Soak in period	12 h
First Hour Rating and Recovery	3 h
Wait time prior to SUT	1 h
SUT	24 h
TOTAL	~3 days

Additional Outdoor conditions

- Add in time to reach equilibrium in environmental chamber

Some chambers may not be capable to going to sub-freezing temperatures

Discussion