

ENERGY STAR Residential Water Heater Specification and Test Method for Connected Residential Water Heaters

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Test Method to Validate Demand Response for Connected Water Heaters

ENERGY STAR is developing a new version of the **Product Specification for Residential Water Heaters**. This new version includes definition for Connected Water Heater Products, the Connected Product Criteria, and a Test Method to Validate Demand Response, developed by DOE.

This presentation focuses on the Test Method.

- Overview of the test method
- Results from two connected water heaters
- Status of the draft Product Specification and Test Method

Overview of the Test Method

In terms of time, the Load Shift test makes up the bulk of Test Method.

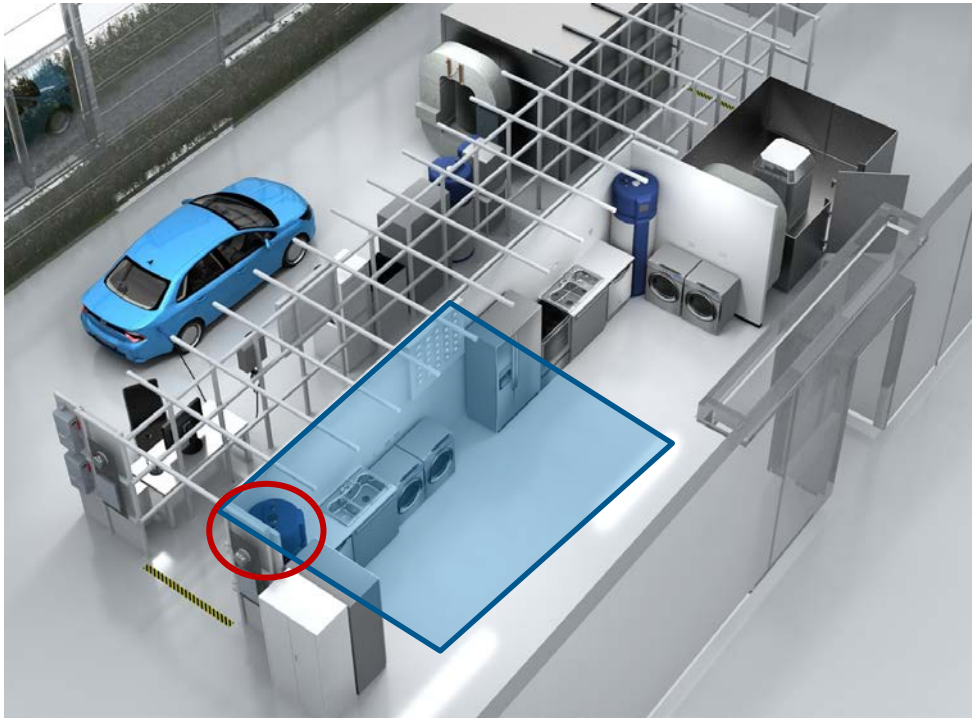
- There are two versions:
 - Load Shift with Basic Load up (No change in set point)
 - Load Shift with Advanced Load Up (Greater load shift - allows set point increase during Load Up portion)

Other tests in the test method include:

- Consumer Override
- Loss of Connectivity
- Emergency Curtailment & Grid Emergency

Installation Location

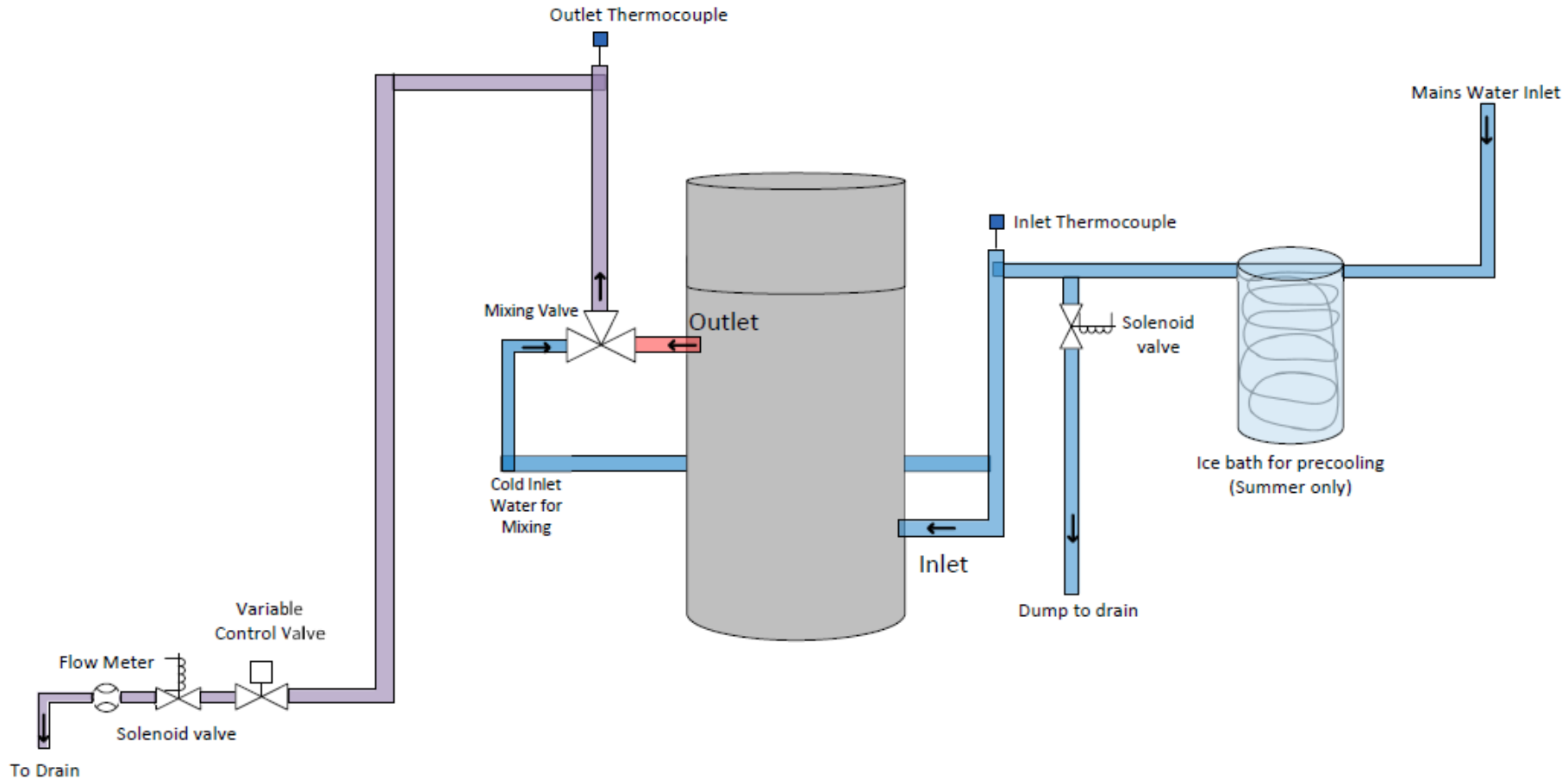
- The connected water heaters were installed in one ‘home’ within the Systems Performance Lab, shown below.
- The home’s existing water infrastructure was leveraged for these experiments, with modifications to match the DOE test procedures as close as possible.



Rendering of the Systems Performance Laboratory, with Home 2 shaded in blue. Connected water heater installed in the location of red circle.

	Communication Details
Unit A	CTA-2045, tested with EPRI test cable
Unit B	Wi-Fi connection to manufacturer’s web portal

Laboratory Infrastructure



- Mains water supplies the water heater. Ice bath needed to precool inlet water in the summer.
- Mixing valve was installed on the outlet and was set to 125°F.
- A variable control valve was used to change the flowrate.
- Solenoid valve used to start and stop draws.
- Flowmeter located at the outlet; 6 thermocouple tree inside tank; Inlet and Outlet temperature measurements in locations specified by DOE UEF Test Procedure.

Load Shift Test with Basic Load Up

Load Shift Test with Basic Load Up has three sections:

1. Normal Operation (4-hour period)
2. Basic Load Up (no change in set point)
3. Load Curtailment (4-hour period)

Normal Operation:

1. To begin the test, draw water to initiate heating. After heating is complete, wait for the water heater to settle.
2. Begin Load Shift Draw Pattern (first cluster of draws from Rated Draw Pattern for UEF Test Procedure)

Basic Load Up:

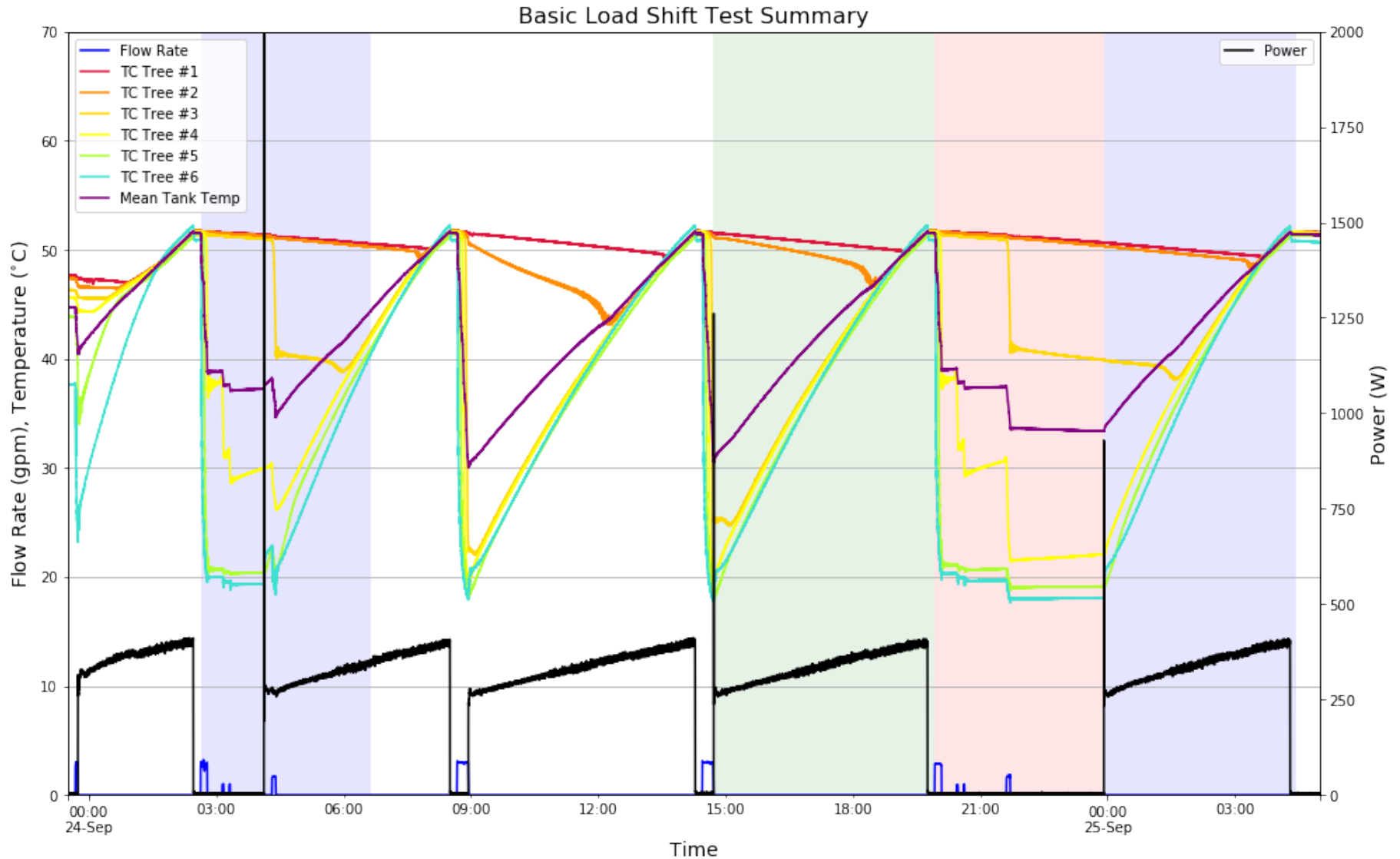
3. After 4 hours, draw water to initiate heating. Wait for settling and then do a draw that is 2 gallons less than amount that triggered heating in first draw of the normal test.*
 - If water heater is still heating at the end of 4 hours, wait until heating finished. Then do the draw less 2 gallons.
4. Send Basic Load Up command – heating should begin.

Curtailment:

5. After heating cycle is complete, wait for settling, then send Load Shed command and start Load Shift Draw Pattern.
6. After 4 hours, send return to normal command.

$$Q_{Basic\ Load\ Up} + (Q_{Normal} - Q_{General\ Curtailment}) \geq 0.5\ kWh$$

Load Shift with Basic Load Up



Load Shift Test with Advanced Load Up

Load Shift Test with Advanced Load Up has three sections:

1. Normal Operation (4-hour period)
2. Advanced Load Up (increase in set point)
3. Load Curtailment (4-hour period)

Normal Operation:

1. To begin the test, draw water to initiate heating. After heating is complete, wait for the water heater to settle.
2. Begin Load Shift Draw Pattern (first cluster of draws from Rated Draw Pattern for UEF Test Procedure)

Advanced Load Up:

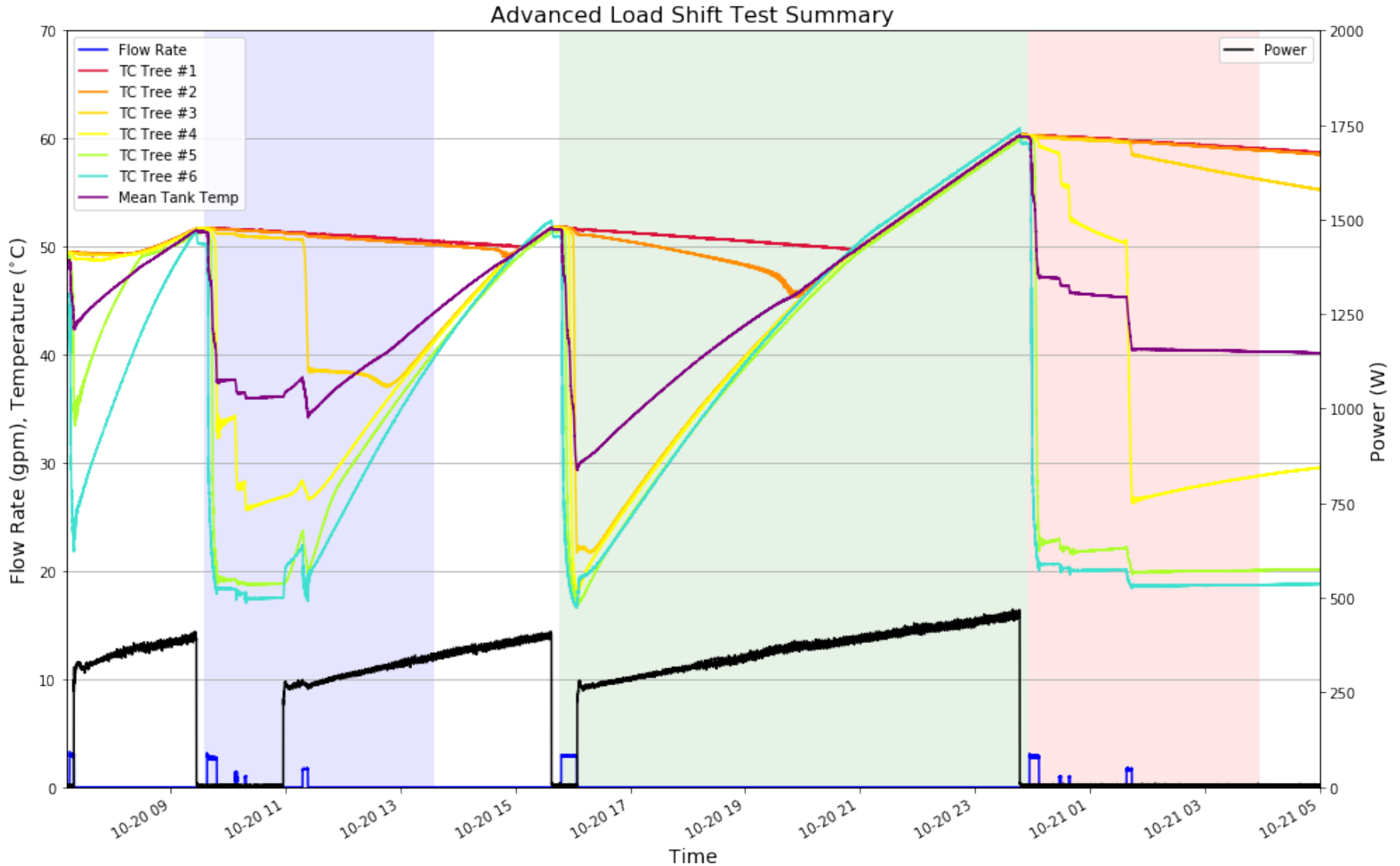
3. After 4 hours, draw water to initiate heating. Wait for settling and then do a draw that is 2 gallons less than amount that triggered heating in first draw of the normal test.*
 - If water heater is still heating at the end of 4 hours, wait until heating finished. Then draw heating volume less 2 gallons.
4. Send Advanced Load Up command – heating should begin.

Curtailment:

5. After heating cycle is complete, wait for settling, then send Load Shed command and start Load Shift Draw Pattern.
6. After 4 hours, send return to normal command.

$$Q_{Adv\ Load\ Up} + (Q_{Normal} - Q_{General\ Curtailment}) \geq 1.0\ kWh$$

Load Shift with Advanced Load Up



Other Tests

Consumer Override: How do you opt-out of DR events?

- If Load Up or Curtailment event is occurring, can consumer opt out?
- If Load Up or Curtailment event is requested, will an overridden water heater start the request?
- If Load Up or Curtailment event is scheduled, can consumer opt out?

Loss of Connectivity: If communication module loses connection to DRMS, how does the water heater respond?

- If DR event is sent without an end time and the communication module loses connectivity, how does the water heater respond? (It should revert to normal operation after some elapsed time.)
- If DR event is sent with an end time and connectivity is lost, what happens? (The water heater should implement the DR event as scheduled.)

Emergency Curtailment and Grid Emergency Verification:

- A large draw is started and “Emergency Curtailment” command is sent.
- Once outlet water temperature gets to 80°F, send “Grid Emergency” command.
- When outlet temperature drops to 60°F, stop draw and send Return to Normal command.

Messaging

The connected WH product must provide messaging in response to certain commands. Test procedure requires the following data to be collected throughout the different portions of the test:

- **Operational State Query** – Return operating state and mode of operation of the water heater, such as “Running Normal” or “Idle Curtailed”
- **Current Available Energy Storage Capacity** – Effectively treats water heater like thermal battery and asks how much energy storage is available now.
- **Current Total Energy Storage Capacity** – How much energy total can this thermal battery store?
- **Power** – How much power is the water heater drawing now?

These values are compared to values collected by testing laboratory.

- Available Energy Capacity is calculated and Root-Mean-Square-Difference is calculated between reported Available Energy Capacity and measured values.
- Current Total Energy Storage Capacity is calculated using the energy content at highest tank temp and lowest tank temp. RMSD is calculated between reported and measured values.

Status of ENERGY STAR Specification

Status Update:

- ENERGY STAR Product Specification for Residential Water Heaters is still in draft form (Version 4.0, Final Draft is latest version)
- Associated 'Test Method to Validate Demand Response' is also still in draft form (Final Draft is latest version).
- The Product Specification and Test Method are expected to be finalized by Q2 2021
- Until then, the draft versions are available online at ENERGY STAR website:
https://www.energystar.gov/products/spec/residential_water_heaters_specification_version_4_0_pd

Thank you!

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