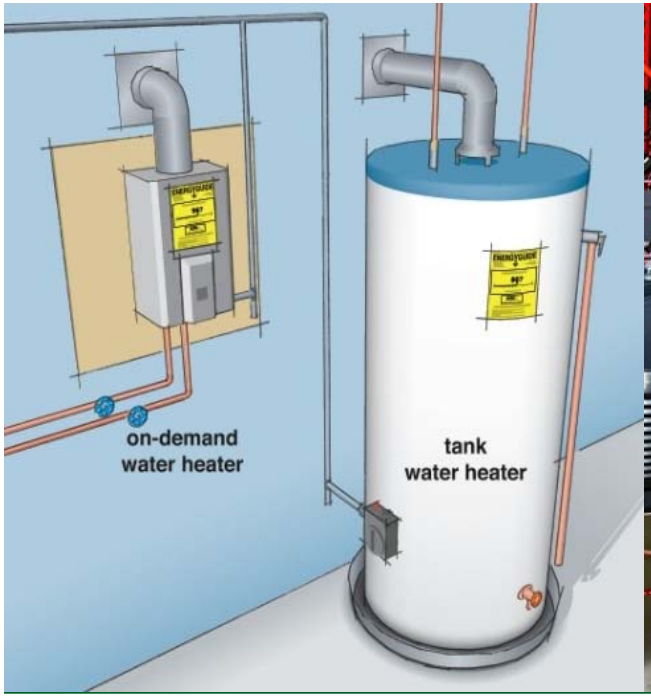

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ENERGY STAR Water Heaters Demand Response Test Procedure Check-In 1

August 15, 2019

12:00PM – 2:00PM

Department of Energy
Building Technologies Program

Agenda

1. Introduction/History
2. Applicability
3. Definitions
4. Test Setup/Water Heater Preparation
5. Demand Response Tests
6. Wrap-Up

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History of Specification/Test Procedure Development

- March 20, 2018 – Specification Kick-Off Meeting (Portland, OR)
- February 14, 2019 – Large Load Products Discussion Guide
- March 7, 2019 – Large Load Product Discussion Guide Webinar
- March 27, 2019 – Specification Workshop (ACEEE Nashville, TN)
- April 16, 2019 – Draft 1 of Version 3.3 Specification published
- May 21, 2019 – Connected Water Heater Test Procedure Kick-Off Webinar

Anticipated Timeline

- Specification (EPA) and Test Procedure (DOE) developed concurrently
  - Specification finalizes when test method is mostly done
- Stakeholder meeting September 10, 2:15 pm to 5:30 pm at the ENERGY STAR Products Partner Meeting, Westin Charlotte, NC
- Anticipated Q4-2019: Specification Draft 2 and Test Method Draft 1
- Anticipated Q1-2020: Specification and Test Method Draft Final; not necessarily at exactly the same time
- Anticipated Q2-2020: Test Method Final

Goal of the Test Procedure Check-In 1

- To walk through the Preliminary Draft test procedure
  - This is NOT the official Draft 1 of the test procedure.
- Verify that the procedure is going in the correct direction
- Establish areas of concern for stakeholders
  - Comments received in meeting and separately through email will be considered
- Major comments/concerns to be addressed by and discussed in the ENERGY STAR Products Partner Meeting

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1. Introduction/History
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Test Procedure Applicability

- Must be an ENERGY STAR water heater
  - Included
    - Electric Heat Pump Water Heaters (HPWH)
    - Gas Storage & Instantaneous Water Heaters
  - Excluded
    - Electric Resistance Water Heaters (ERWH),
      - including DOE Grid-Enabled Water Heaters
    - Products intended only for commercial applications
    - Combination space-heating and water-heating appliances
    - Add on heat pump water heaters
    - 3rd party water heater controllers
  - Meet the criteria as stated in ENERGY STAR Product Specification for Residential Water Heaters Version 3.3, Sections 1-3
    - Criteria typically include UEF rating, warranty, and safety certifications
- **Test procedure is being designed to be applicable to Non-ENERGY STAR water heaters as well.**

Connected Criteria in the Draft Specification

ENERGY STAR Specification Connected Criteria Sections

4) Connected Product Criteria - Optional
   A. Communications
   B. Remote Management and Consumer Feedback
   C. Demand Response (DR)
   D. Additional Information for Consumers

Section 4.C is the only section that is being tested.

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Definitions

- Includes all definitions from ENERGY STAR Specification, DOE Test Procedure, and those defined in the CHWP test procedure.

- Important from ENERGY STAR Specification
  - Connected Water Heater Product (CWHP)

- Important from DOE Test Procedure
  - Cut-in
  - Cut-out
  - First-Hour Rating (FHR)
  - Recovery Period (recovery)
  - Uniform Energy Factor (UEF)

CWHP Definitions

- Defined in the Preliminary Draft Test Procedure and within the presentation where appropriate.
  - Acceptable Response
  - Appliance Communication Module (ACM)
  - Load Shift (LS)
  - Normal Mode of Operation
  - Operation State Query
  - Rated Draw Pattern
  - Response Time
  - User Interface
  - Utility Equivalent Communication Device (UECD)

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Test Setup

- Unless otherwise specified, all test setup and condition requirements shall be identical to sections 2, 3, and 4 of the DOE Test Procedure.
  - Section 2: Test Conditions
  - Section 3: Instrumentation
  - Section 4: Installation

- Additional setup requirements
  - ACM and UECD shall be set up in accordance with manufacturer instructions
  - Connection between ACM and UECD can be wired or wireless.
    - If both wired and wireless communications are available then the CWHP will be tested using the wireless communication
  - ACM must be able to both send and receive messages from the UECD

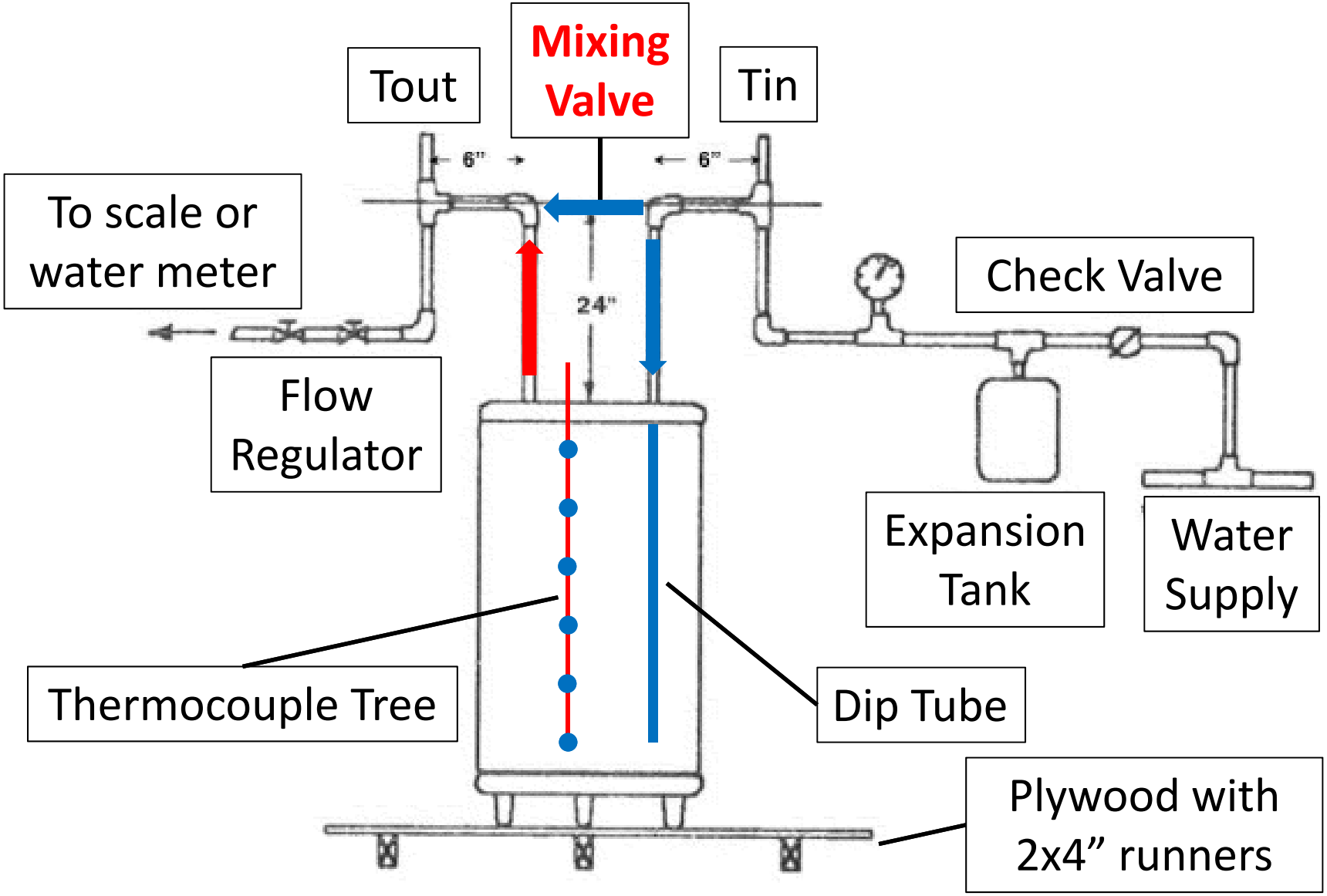
DOE Test Procedure: Test Conditions and Instrumentation

Ambient Temperature	67.5°F ± 2.5°F
Supply Water Temperature	58°F ± 2°F
Outlet/Setpoint Water Temperature	125°F ± 5°F

- Accuracy and precision of the instruments are specified for all measurements necessary to measure and calculate the stored energy, energy delivered, and energy received by the water heater

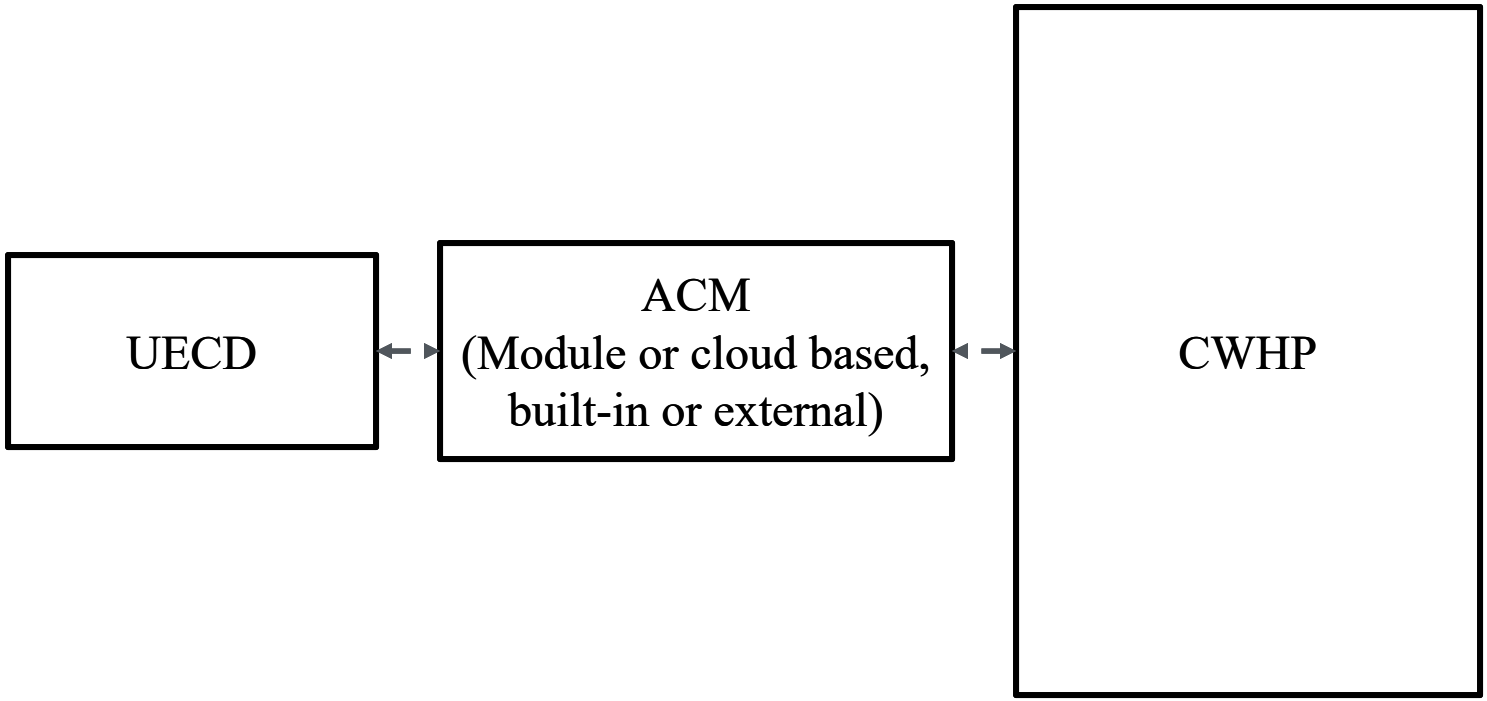
- The outlet/setpoint water temperature is initially set between 120°F to 130°F but over the entire test there is no requirement for the outlet water to be between 120°F to 130°F

DOE Test Procedure: Installation



Additional Setup Requirements

Setup according to manufacturer instructions



Water Heater Preparation

- Perform the procedures found in section 5.2 of the DOE Test Procedure. These include the
  - Determination of Storage Tank Volume
    - Used in calculations to check the stored energy in the CWHP
  - Setting the Outlet Discharge Temperature
    - Desired outlet temperature of 125 °F (120 °F – 130 °F)
  - Power Input Determination
    - For gas-fired water heaters only
  - Soak-In Period for Water Heaters with Rated Storage Volumes Greater than or Equal to 2 Gallons
    - 12 hours after initially being energized
    - Not required if DOE Test Procedure was done immediately prior to the CWHP test procedure (i.e., power was not removed)

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Demand Response Tests

- Initialization/User Interface (section 4.C.b)
- Consumer Override (section 4.C.b)
- Loss of Connectivity (section 4.C.c)
- Load Up Test (section 4.C.e)
- Curtailment Tests (section 4.C.e)
- DR Information and Messaging (section 4.C.d)
- Potential CWHP Metrics
    - Response Time
    - Accuracy of Current Available Energy Storage Capacity
    - Load Shift
    - DR Hot Water Capacity
    - DR UEF

Initialization/User Interface

- Verify that one of the open standards from section 4.C.a of the ENERGY STAR Specification is used by the CWHP.

- Verify that the manufacturer literature supplied with the CWHP and/or ACM includes instructions for the user to override DR requests.

Consumer Override Test

- Verifies that the appropriate signals are being sent.
    - Verification of the correct CWHP operation is done during the Load Up and Curtailment tests.
- Verifies that a DR event can be overridden during the event.
- Verifies that a DR request will not be performed during when the override is in place.
- **Does a signal verification test, in conjunction with operational verifications elsewhere in the test procedure, adequately check that the consumer override function works?**

Loss of Connectivity

- Verifies that the appropriate signals are being sent.
    - Verification of the correct CWHP operation is done during the Load Up and Curtailment tests.
- Verifies that a DR event will continue after a loss of connectivity.
- Verifies that a stored DR request will be performed during when connectivity is lost.

- **Does a signal verification test, in conjunction with operational verifications elsewhere in the test procedure, adequately check that the Loss of Connectivity function works?**
- **Is a simple delayed DR request a robust enough check on the Loss of Connectivity or should a more complex signal be sent (e.g., Price Signal)?**

Load Up and Curtailment Tests

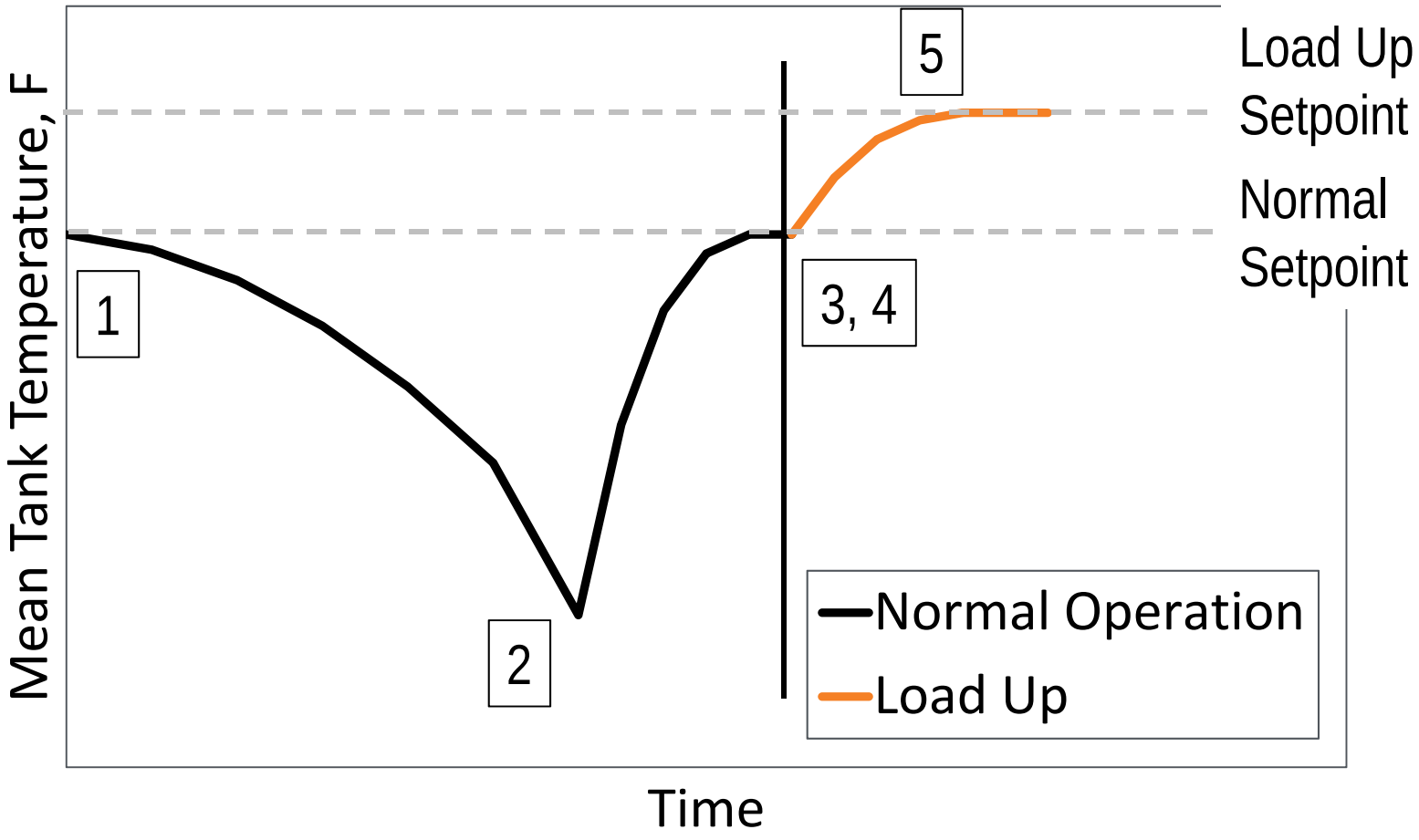
- 1 Load Up test is performed
  - Verify that energy consumption increases
  - Verify that stored thermal energy in the tank increases
- 3 Curtailment tests are performed
  - General Curtailment
  - Emergency Curtailment
  - Grid Emergency
  - Verify that energy consumption decreases
  - Verify that stored thermal energy in the tank decreases
- Results are used to determine
  - Appropriate DR Information and Messaging is being used.
  - Accuracy of Current Available Energy Storage Capacity
  - Load Shift

Load Up Test Steps

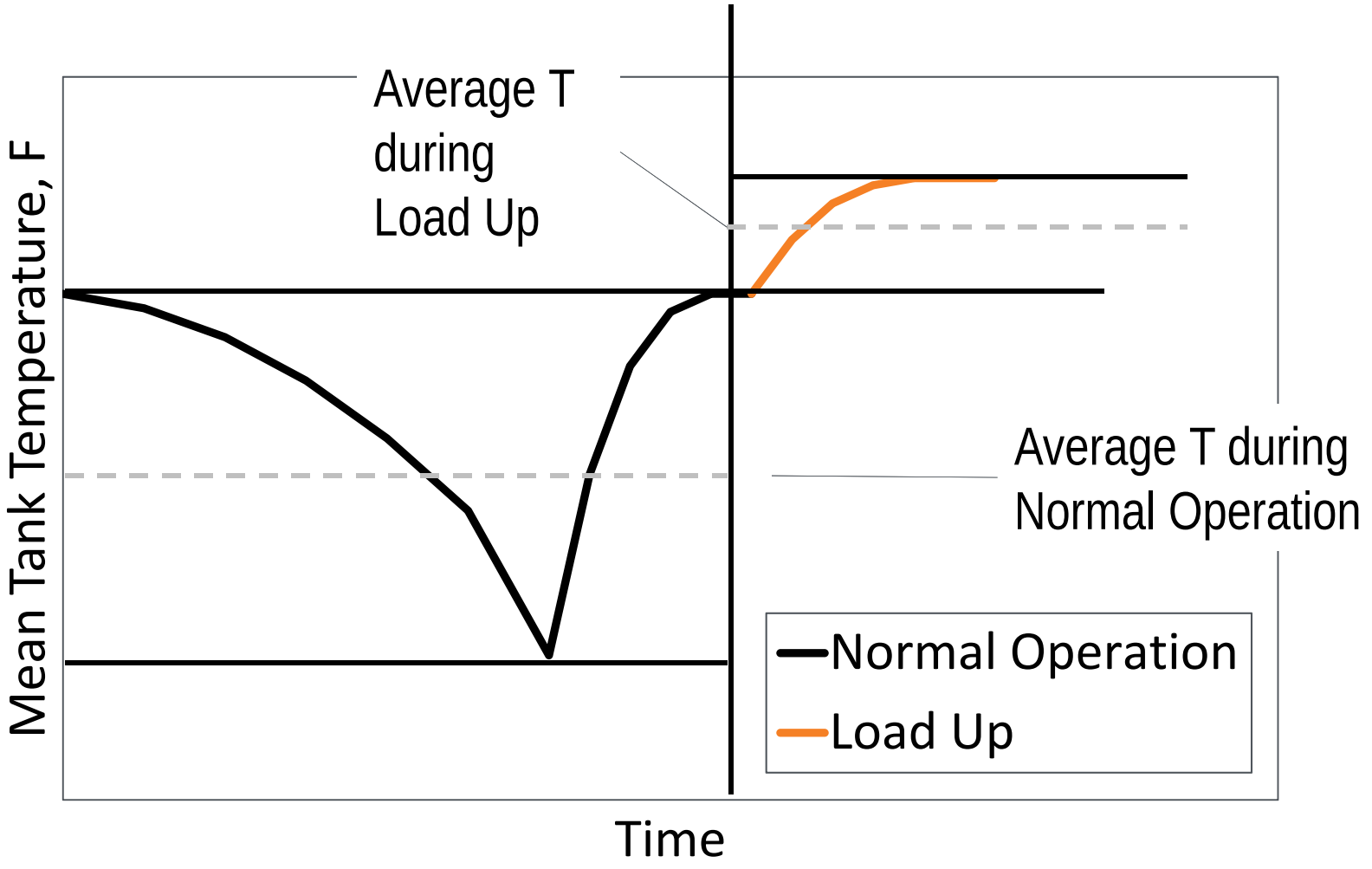
1. Draw off water at 3 gpm.
2. When the first cut-in occurs after beginning the draw, stop drawing off water.
3. Wait until a maximum mean tank temperature is observed after cut-out.
4. Send a Load Up request.
5. Wait until a maximum mean tank temperature is observed after cut-out.

*The actual procedure currently has 16 steps which check signals and send other requests.

Load Up Test Steps



Load Up - Verification



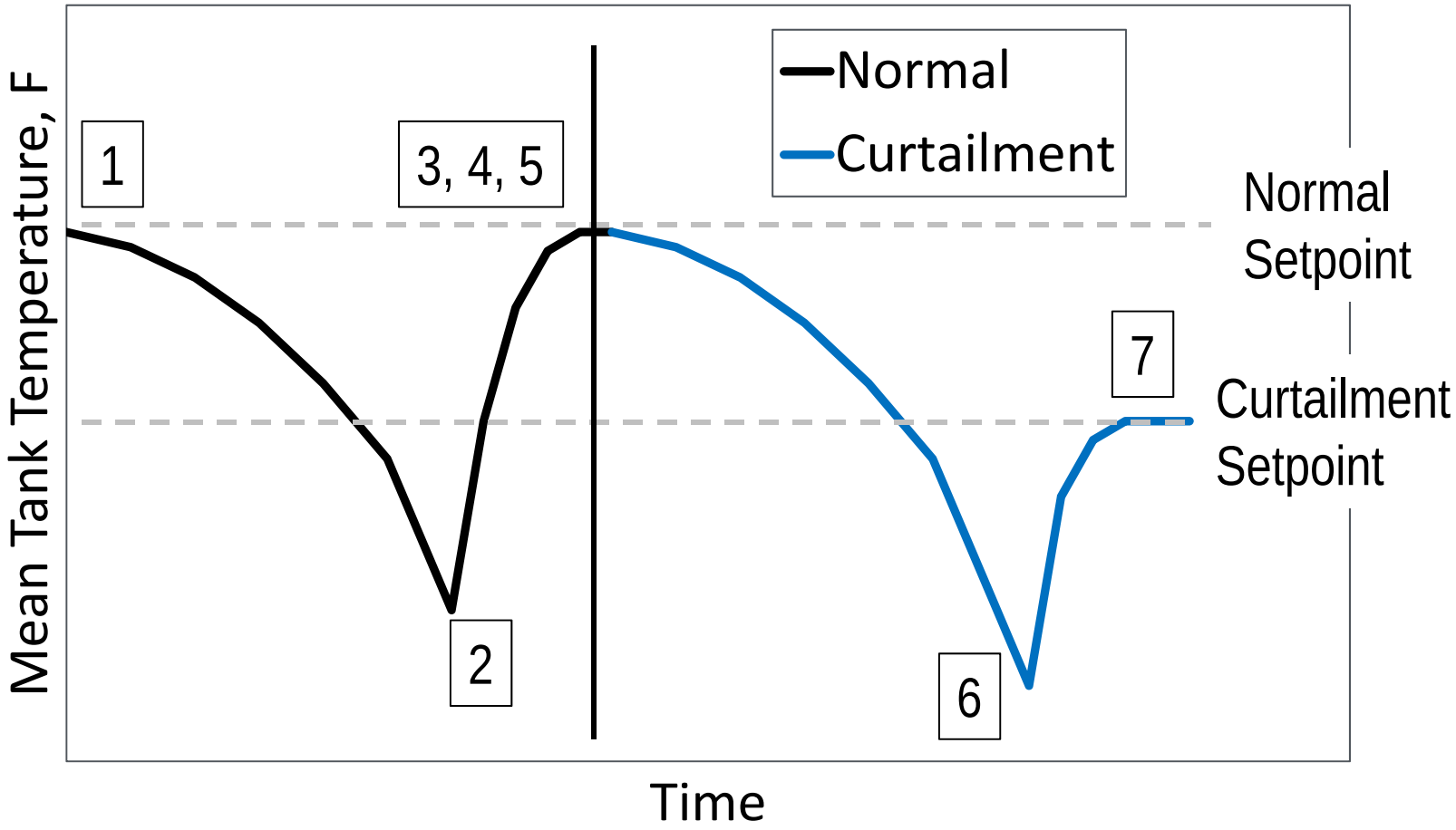
Verification of increased energy consumption assumed from increased energy content of the CWHP

Curtailment Test Steps

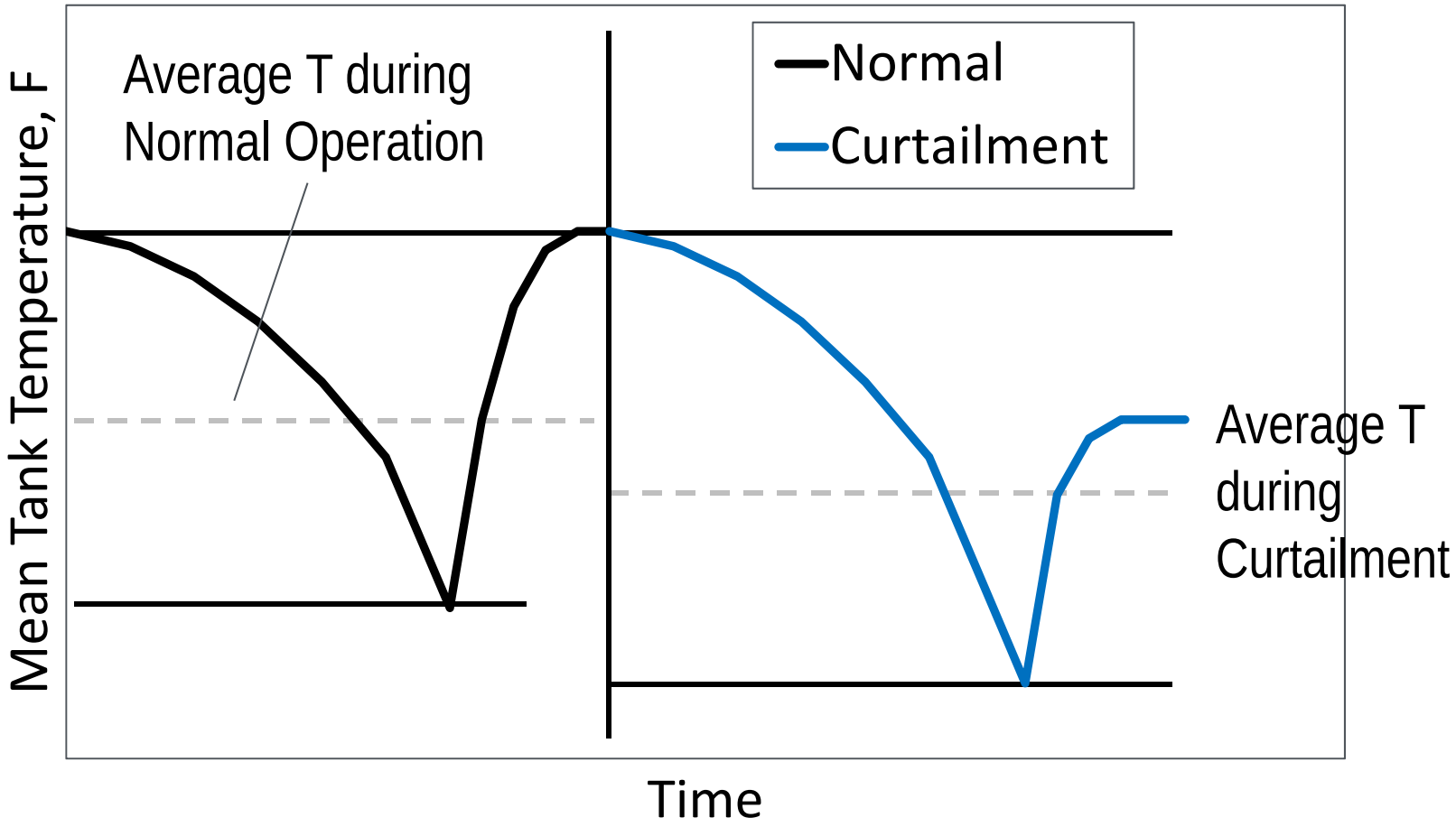
1. Draw off water at 3 gpm.
2. When the first cut-in occurs after beginning the draw, stop drawing off water.
3. Wait until a maximum mean tank temperature is observed after cut-out.
4. Send a DR request.
    1. Either General Curtailment, Emergency Curtailment, or Grid Emergency.
5. Draw off water at 3 gpm.
6. Stop drawing water when
    1. For General Curtailment and Emergency Curtailment: the first cut-in occurs
    2. For Grid Emergency: delivery temperature drops below 60 °F (37.8 °C).
7. Wait until a maximum mean tank temperature is observed after cut-out
    1. For Grid Emergency: no action required.

*The actual procedure currently has 19 steps which check signals and send other requests.

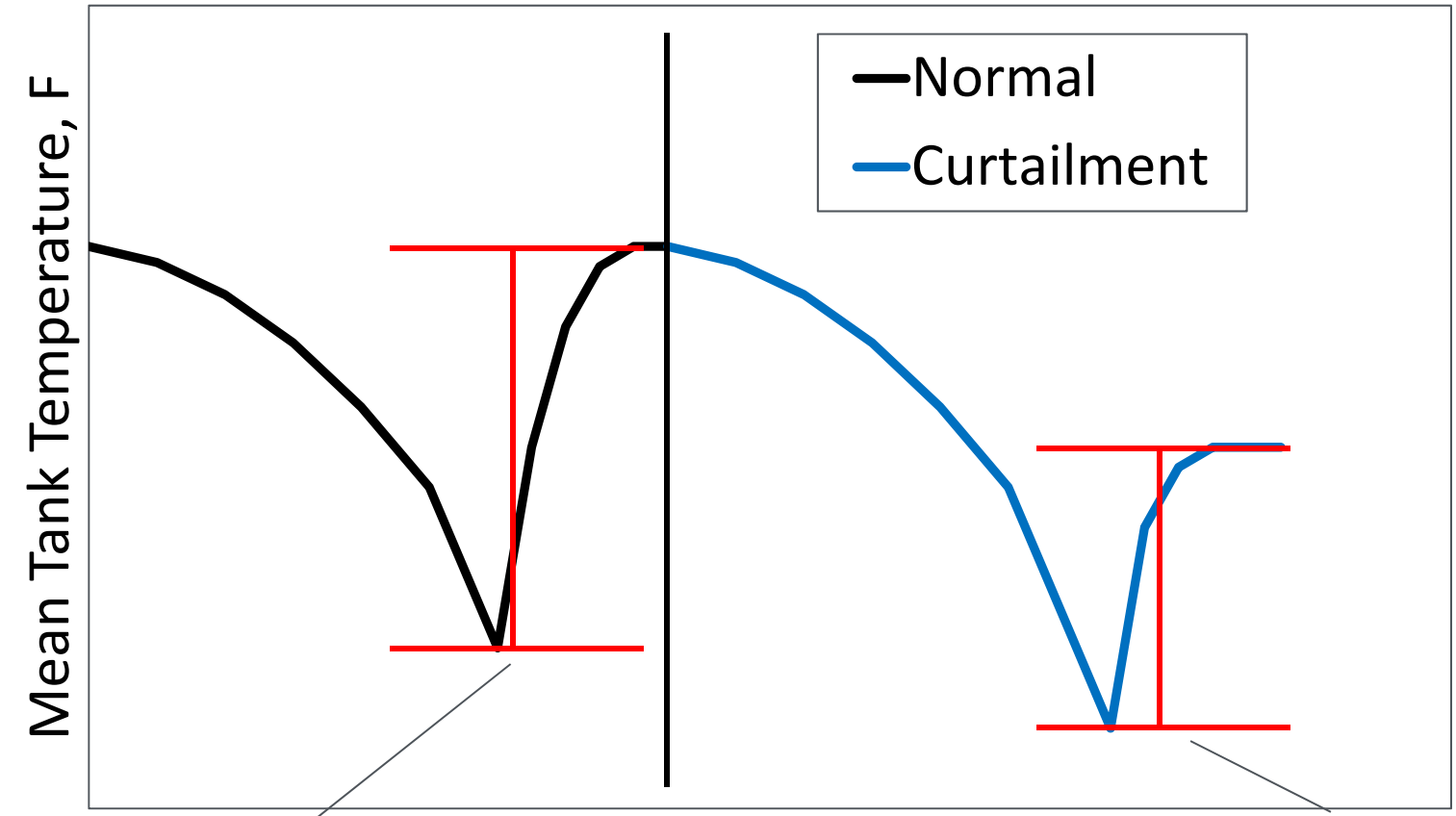
Curtailment Tests



Curtailment Tests – Decreased Stored Thermal Energy



Curtailment Tests – Decreased Energy Consumption



Curtailment Test Options

- The curtailment test only covers 1 recovery period

- Should a longer curtailment period be used to capture more than one recovery period or until the next cut-in?
    - This would significantly increase the test time and associated test burden.

- For HPWH, the recovery period could last several hours, so 1 recovery period might be reasonable and represent a “typical” curtailment length.

DR Information and Messaging

- Verified at various stages of the Load Up and Curtailment tests.

- Device Type
- Operational State
- Current Available Energy Storage Capacity
- Power/Demand (Instantaneous)

Response Time

- Response Time:
  - The amount of time required for the CWHP and ACM to respond to a DR signal from the UECD, as measured during this test.

- Shall be measured throughout the testing.

- **Do all CHWP acknowledge when a signal is received?**
- **Is there a reasonable maximum response time?**
- **Should the maximum response time be set by the ENERGY STAR Specification?**

Current Energy Storage Capacity

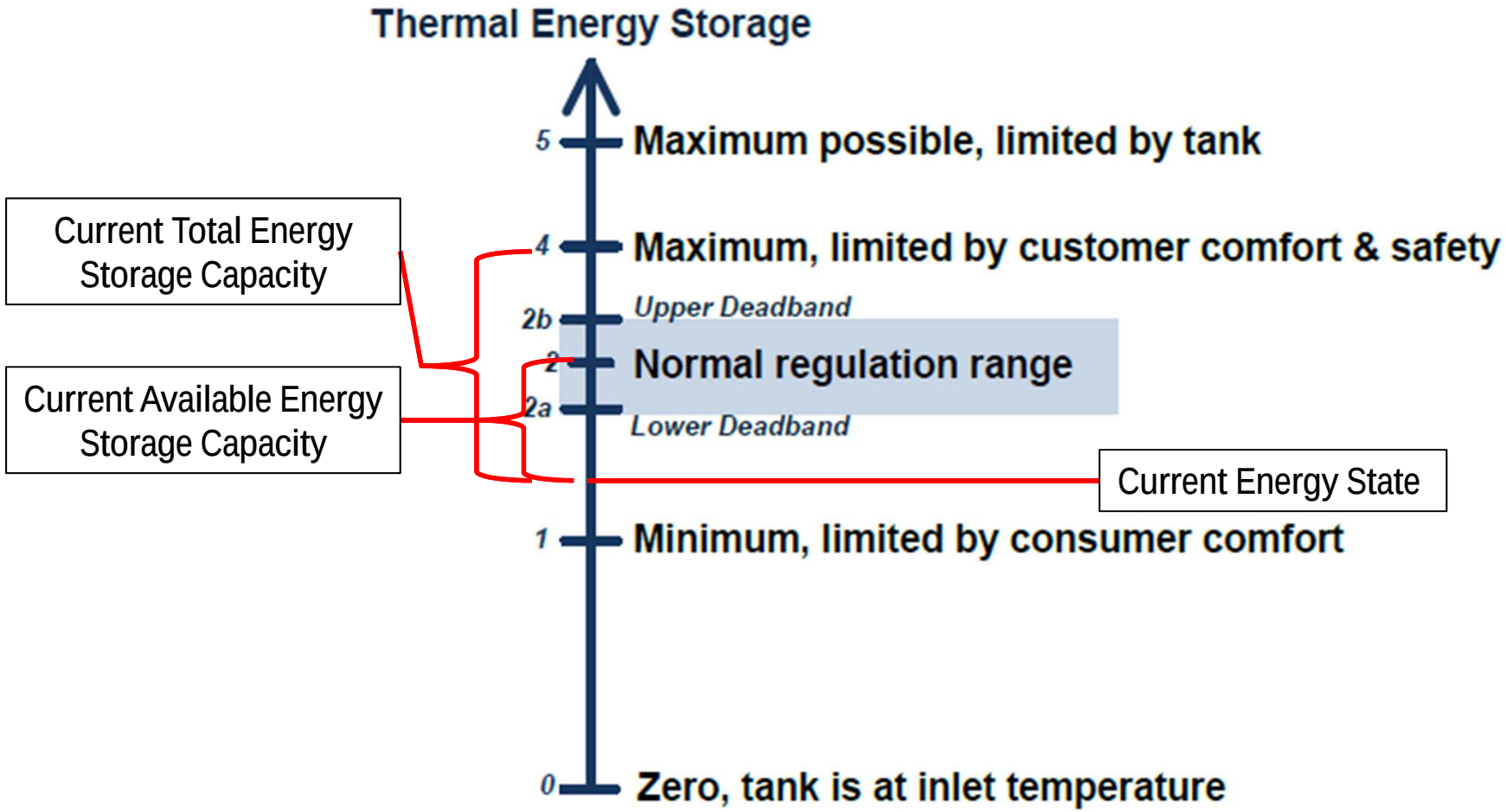


Figure 3-1
Reference Points for Stored Energy Levels

Demand Response-Ready Heat Pump Water Heater Specification: Preliminary Requirements for CEA-2045 Field Demonstration. EPRI, Palo Alto, CA: 2014. 3002002719.

Accuracy of Current Available Energy Storage Capacity

- Current **A**vailable **E**nergy Storage Capacity (AE) is requested at multiple times during the Load Up and Curtailment tests.
- Calculate the energy content of the CWHP at different times
  - $E = V\rho\ C_p\bar{T}$
    - Where, V=measured storage volume, gal; ρ=density, lb/gal; Cp=specific heat, Btu/lb °F; and T=mean tank temperature
- Calculate the average setpoint ($\bar{E}_{Setpoint}$) energy content of the tank
  - At 1 and 3 for the Load Up test and 3 Curtailment tests.
- Calculate the measured AE for each DR event
  - $AE_{M,DR\ Event} = \bar{E}_{Setpoint} - E_{DR\ Event}$
- Calculate the root-mean-square difference (RMSD) between the measured and recorded AE
  - $RMSD_{AE} = \sqrt{\frac{\sum\left(AE_{M,DR\ Event,Step} - AE_{R,DR\ Event,Step}\right)^2}{19}}$

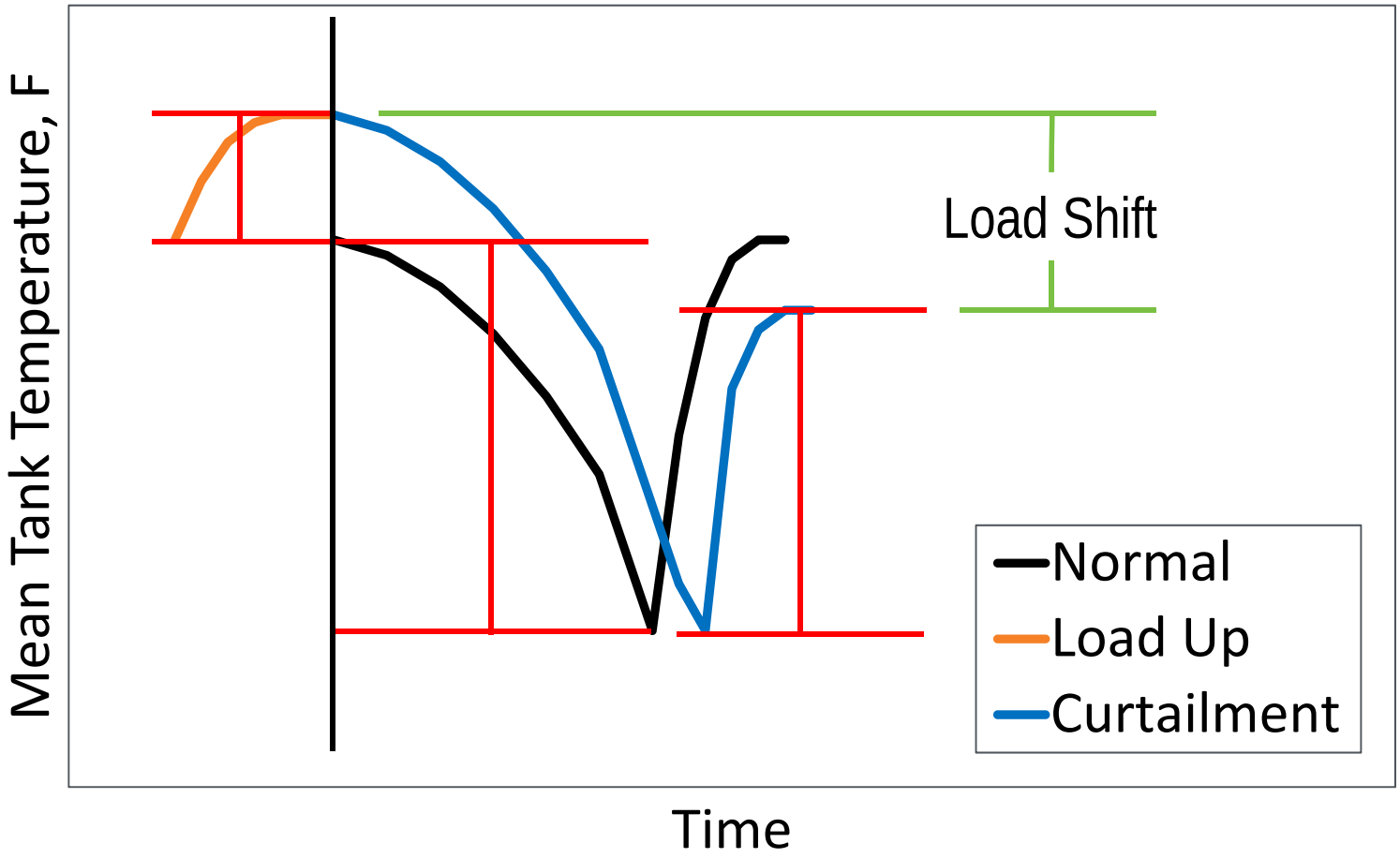
Load Shift

- Load Shift (LS):
  - Amount of energy moved, relative to a normal operation period, by using the Load Up request and then a curtailment request after the CWHP has completed the Load Up, kWh.

- $LS_{Curtailment} = Q_{Load\ Up} + (\bar{Q}_{Normal} - Q_{Curtailment})$
  - Where, Q=energy consumption, Btu (Wh), including auxiliary energy use.

- An LS value is calculated for each curtailment
  - General Curtailment, Emergency Curtailment, and Grid Emergency

Load Shift



Load Shift: Other Considerations

- Auxiliary energy use is currently included in the energy consumption measurements.
  - Is this negligible?
  - Separating auxiliary and heating energy could be difficult at times.
- Should the energy of water delivered be accounted for in some way?
- A CWHP could be designed to have many shorter recovery periods, so if the curtailment period was extended the energy used could actually be greater than in the normal mode of operation.
  - Increasing the length of the curtailment test could account for this but would increase the test length significantly.

DR Hot Water Capacity

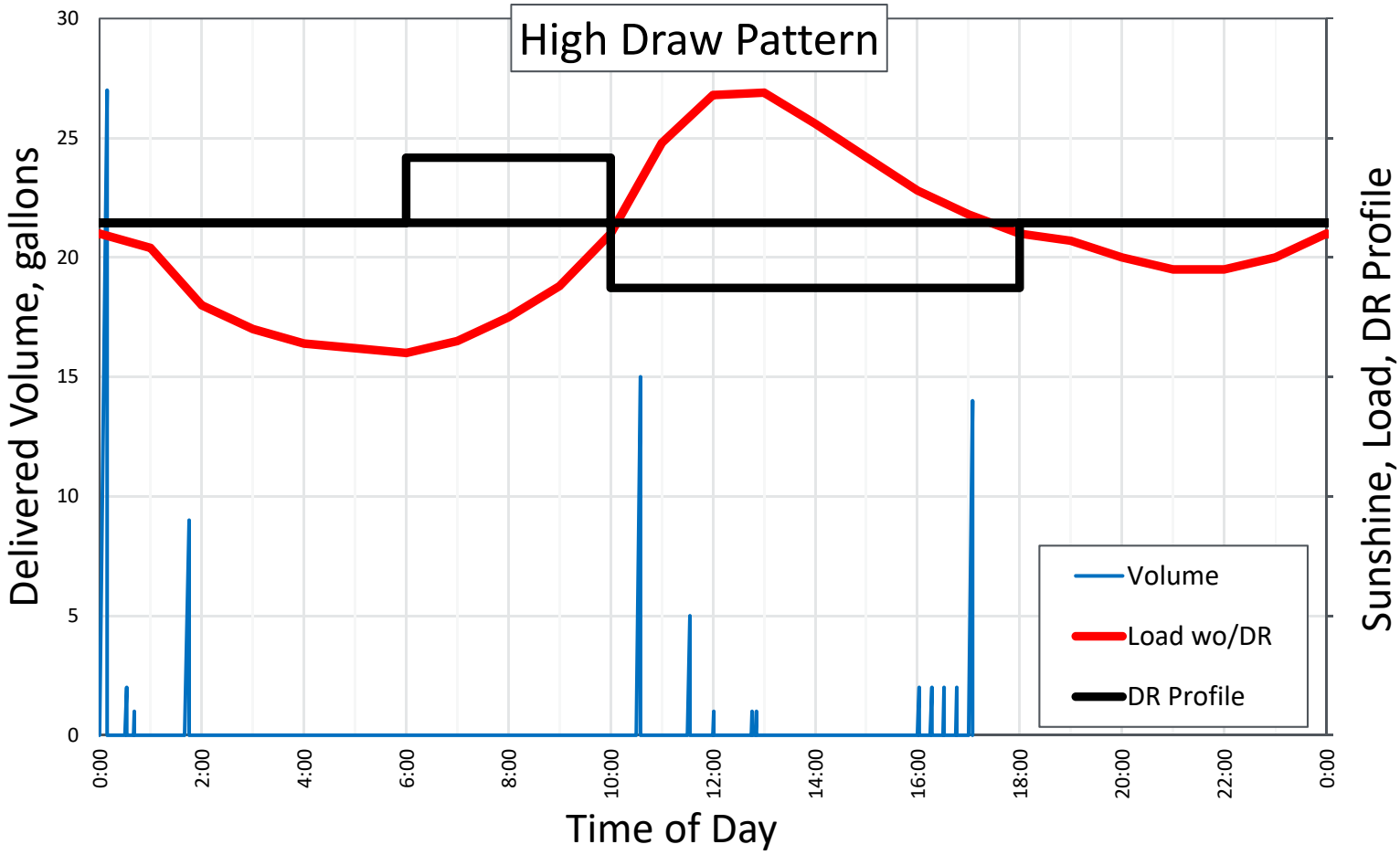
- CWHP Procedure
  - Load Up
  - Send Curtailment request
  - Perform FHR test from DOE Test Procedure
- FHR test from DOE Test Procedure
  - Start with a heated up tank (i.e., at setpoint)
  - Draw water until the delivery temperature drops by 15 °F
  - Stop draw and wait for cut-out
  - Initiate the next draw
  - Continue until 1 hour has elapsed
- Other Potential Criteria (since CWHP may not be in recovery at end of draw)
  - Stop draw at cut-in
    - No limit on what is “hot” water (e.g., 80 °F could be considered “hot”)
  - Increase the drop in delivery temperature (e.g., 25 °F)
    - Limit on what is “hot” water (e.g., min “hot” water approximately 100 °F)
  - Change nothing
    - “Hot” water is ≥110 °F and meets the same criteria as the rated FHR

DR UEF

- Run the UEF test with the addition of sending DR requests at certain times

- If the UEF test must start with a Loaded Up tank then alternative procedures must still be developed
  - Offset the start time of the test to allow for a Load Up
  - Run draws at the offset times
  - Extend test past 24 hours if the conditions for measuring the standby loss coefficient (UA) are not met.

DR UEF: Draw Profile



Which Metrics are Actually Useful?

	Response Time	Accuracy of AE Btu (Wh)	Load Shift Btu (Wh)	DR Hot Water Capacity gal (L)	DR UEF
Pros	No extra testing	No extra testing	No extra testing Useful to utilities for peak management.	Addresses customer comfort requirements	Only DR efficiency metric
Cons		Will this actually be useful to utilities in practice?		Extra testing	Extra testing Limited to 1 DR profile

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Anticipated Timeline

- Specification and Test Procedure (DOE) developed concurrently
- Stakeholder meeting ENERGY STAR Products Partner Meeting, September 10-12, Charlotte, NC
- **Mid November: Test Procedure Check-In 2 (If necessary)**
- Anticipated Q4-2019: Specification Draft 2 and Test Method Draft 1
- Anticipated Q1-2020: Specification and Test Method Draft Final; not necessarily at exactly the same time, then Specification Final
- Anticipated Q2-2020: Test Method Final

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