ENERGY STAR® Program Requirements Product Specification for Residential Refrigerators and Freezers

Draft Test Method to Validate Demand Response Rev. Feb-2012

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1 OVERVIEW

The following test method shall be used for determining product compliance with requirements for Demand Response (DR) functionality in the ENERGY STAR Eligibility Criteria for Connected Refrigerators, Freezers, and Refrigerator-Freezers (herein referred to as Connected R/F).

Note: In September 2011, the Association of Home Appliance Manufacturers (AHAM) shared a draft test procedure for Connected R/F with DOE and EPA titled, "AHAM Smart Refrigerator, Refrigerator-Freezer, and Freezer Test Procedure (AHAM SRF-0.5-2011). DOE utilized the AHAM test procedure as a starting point for this proposed Connected R/F Draft 1 Test Method.

DOE performed a market evaluation to better understand the Connected R/F market. DOE found that no units exist on the commercial market, but meetings with manufacturers and AHAM provided insights into connected feature applications, including consumer controls, notifications, and energy management. DOE used this information to better inform its testing and validation process.

Throughout 2011, DOE requested pre-market Connected R/F units from manufacturers in an effort to validate the proposed Connected R/F test method; however, only one manufacturer provided DOE with a Connected R/F for testing. While DOE is seeking input on this draft test method, DOE does not plan to finalize the test method until it can obtain additional Connected R/F products for testing. DOE wants to ensure that the Connected R/F test method is applicable to a wide cross-section of the market.

Throughout this test method, DOE references the current DOE Test Procedure in 10 CFR Part 430 Subpart B Appendix A1 and Appendix B1 (DOE Test Procedure). DOE notes that this method and all references within will continue to be valid when the amended DOE Test Procedure in 10 CFR Part 430 Subpart B Appendix A and Appendix B are required to be used in 2014.

Please send comments via email to appliances@energystar.gov no later than March 23, 2012.

2 APPLICABILITY

This test method is applicable to refrigerators, refrigerator-freezers, and freezers intending to meet the Connected appliance requirements in the ENERGY STAR Version 5.0 Program Requirements.

3 DEFINITIONS

Unless otherwise specified, all terms used in this document are consistent with the definitions in the ENERGY STAR Eligibility Criteria for Residential Refrigerators and Freezers Version 5.0 and in the DOE Test Procedure in 10 CFR Part 430 Subpart B Appendix A1 and Appendix B1 (DOE Test Procedure).

Note: The acronyms, definitions, and discussion below are included in the test method for initial discussion. Most definitions are reproduced from the AHAM Smart Refrigerator, Refrigerator-Freezer, and Freezer Test Procedure (AHAM SRF-0.5-2011). All definitions and acronyms will eventually be moved to the specification document when ENERGY STAR Residential Refrigerators and Freezers Version 5.0 is published.

A) Utility Equivalent Communication Device: Device capable of communicating with the connected appliance and emulating signals sent from a utility. It will be controlled by the technician and will allow the technician to deliver the Delay Appliance Load and Temporary Appliance Load Reduction signals.

B) Communication Module (Appliance): A built-in or external device that enables appliance bi-directional communication with a utility or equivalent communication device.

Note: There are currently no universally accepted standards for connected appliance communication and network architecture, although many efforts are underway including those by the National Institute of Standards and Technology (NIST) Smart Grid Interoperability Panel.

The above definitions broadly outline the requirements for testing a connected device for the ENERGY STAR specification. EPA has proposed new "connected" criteria in the Version 5.0 ENERGY STAR Program Requirements for Residential Refrigerators and Freezers currently under development.

C) Connected Signal Simulation Hardware: Self-contained or Power Computer (PC) based hardware that will allow the operator to execute necessary communication and commands and receive necessary feedback from the Unit Under Test (UUT).

D) Consumer Override: The capability for an end-user to cancel a product's response to a demand response (DR) signal.

E) Signals: Communications to a connected product indicating that it should modify its operation or providing information. Signals include, but are not limited to, delay appliance load, time-based pricing, and notifications for load-shedding to meet temporary energy reduction requirements.

F) Signal Type - Delay Appliance Load: Capability of an appliance to reduce its average energy input over a specified time period. The delay load command provides the start time and duration of the delay load time period.

G) Signal Type - Temporary Appliance Load Reduction: Capability of an appliance to reduce its average energy input over a short specified time period. The temporary load reduction command provides the start time and duration of the temporary load reduction time period..

H) Acronyms:

- DR: Demand Response
- DAL: Delay Appliance Load
- TALR: Temporary Appliance Load Reduction
- Hz: Hertz
- Wh: Watt Hours
- W: Watts
- UUT: Unit Under Test
- F: Fahrenheit
- C: Celsius
- R/F: Refrigerators, Freezers, and Refrigerator-Freezers

4 TEST REQUIREMENTS

Unless otherwise specified, all test conditions and requirements shall be identical to 10 CFR Part 430, Subpart B, Appendices A1 and B1, Section 2.

A) Input Power: Products intended to be powered from an ac mains power source shall be connected to a voltage source appropriate for the intended market, as specified in Table .

Table 1: Input Power Requirements for Products with Nameplate Rated Power Less Than or Equal to 1500 watts (W)

Market	Voltage	Voltage Tolerance	Maximum Total Harmonic Distortion	Frequency	Frequency Tolerance
North America, Taiwan	115 volts (V) ac	+/- 1.0 %	2.0 %	60 Hertz (Hz)	+/- 1.0 %
Europe, Australia, New Zealand	230 V ac	+/- 1.0 %	2.0 %	50 Hz	+/- 1.0 %
Japan	100 V ac	+/- 1.0 %	2.0 %	50 Hz/60 Hz	+/- 1.0 %

B) Ambient Temperature: Ambient temperature shall be 90 °F ± 1 °F (32.2°C ± 0.6°C).

C) Relative Humidity: Relative humidity shall be from 40-60% and shall be measured at a location three feet above the floor and approximately 10 inches from the front of the UUT.

D) Radiation Shield: Shields shall be provided to prevent direct radiation from or to any heated or cooled surfaces whose temperature differs from the air temperature by more than 10 °F.

E) Watt Hour Meter: Watt hour meters shall comply with parameters described in 10 CFR Part 430, Subpart B, Appendices A1 and B1, Section 2.

5 PRE-TEST UUT CONFIGURATION

5.1 General Configuration

A) The UUT shall be setup as described in 10 CFR Part 430, Subpart B, Appendices A1 or B1, Section 3.

5.2 Communication Setup

A) Connect the UUT to the utility equivalent communication device via wired or wireless connection depending on the unit's capability. A wireless connection is preferred if both are available.

B) Ensure that the unit is properly connected and can both receive and send data to a utility equivalent communication device.

Note: The utility equivalent communication device used during testing was provided with the UUT. Connection and data transfer were verified using the communication equipment's data monitoring capability. This equipment is necessary for connectivity and data monitoring and is vital for troubleshooting and verifying connectivity.

5.3 UUT Steady State Stabilization

A) All compartment temperature controls shall be set at their median position, midway between their warmest and coldest setting for the entirety of the test.

B) Prior to the start of testing, the UUT shall be stabilized according to 10 CFR Part 430, Subpart B, Appendix A1 Section 2.9 or Appendix B1 Section 2.7.

Note: Although the DOE Test Procedure requires testing at the median, warmest and coldest compartment temperature settings to determine the energy consumption, the tests validating an appliance's connected features are compared to the DOE Test Procedure at the median temperature setting. This provides a comparable baseline setting for comparing average power reduction in response to a demand response signal, while minimizing test burden.

DOE and EPA request stakeholder feedback on using only the median compartment temperature setting as a baseline for the Connected Test Method.

C) The icemaker shall be on with harvesting inoperative, as described in 10 CFR Part 430, Subpart B, Appendices A1 or B1, Section 2.2 No water line installation is required. The UUT shall remain in this configuration throughout testing.

Note: There is currently no standard method for measuring the energy consumption of automatic icemakers. Although ice-making delay has been suggested as an alternative to a reduction in overall energy consumption, DOE is unable to verify that it is equivalent to a 13% reduction in overall energy consumption. Therefore, all ice-making operations are disabled throughout testing in accordance with the DOE Test Procedure.

6 BASELINE ENERGY CONSUMPTION

6.1 DOE Baseline Test

The DOE Test Procedure for Residential Refrigerators and Freezers (10 CFR Part 430, Subpart B, Appendix A1 or B1) shall be performed in its entirety to provide a baseline energy profile for energy reduction from a DR request. All connected features and network modes must be enabled in accordance with manufacturer instructions during the DOE test.

Note: The DOE Test Procedure calls for setting up the test unit in accordance with manufacturer instructions. As the instructions will likely include the installation of connected features, the DOE Baseline Test for verifying DR capability requires enabling all connected features in accordance with manufacturer instructions. This ensures that any steady energy consumption feature is not disabled during testing and that units will reduce energy consumption in accordance with connected criteria based on the intended setup, with no steady energy consumptive feature disabled.

The following data shall be obtained to determine the average power reduction from DR compliance.

A) The typical compressor duration, D_{comp}, and compressor cycle interval, I_{comp}, shall be determined per Section 4.2 of Appendix A1 or B1 of the DOE Test Procedure. Compressor duration is defined as the typical compressor on-time (in minutes), or time between the compressor turning on and the corresponding compressor turning off. Compressor cycle interval is defined as the typical compressor off time (in minutes), or time between the compressor turning off and the compressor turning on.

B) The type of defrost cycle, duration of defrost cycle, $D_{defrost}$, and defrost cycle interval, $I_{defrost}$, shall be determined per Section 4.2 of Appendix A1 or B1 of the DOE Test Procedure. Defrost cycle duration is defined as the typical defrost on time (in minutes), or time between the defrost turning on and the corresponding defrost turning off. Defrost cycle interval is defined as the typical defrost off time (in hours), or time between the defrost turning off and the defrost turning on.

C) In accordance with Section 4.2 of Appendices A1 and B1, the energy consumption, EP_{BL}, in Wh, and length of time, T_{BL}, in minutes, shall be recorded based on the first of two parts of the DOE Test Procedure for automatic defrost units.

D) Measure the internal refrigerator and freezer compartment temperatures and record the maximum temperatures.

7 DELAY APPLIANCE LOAD TEST

Note: The current requirements for Delay Appliance Load (DAL) included in the ENERGY STAR Program Requirements for Residential Refrigerators and Freezers Version 5.0 Draft 1 are as follows:

Upon receipt of a delay load signal requesting the delay of a load for a time duration not exceeding four hours, the product shall:

A) shift defrost cycles beyond the delay period, and

B) either, shift ice maker cycles beyond the delay period, ***or*** *reduce average wattage during the delay period by at least 13% relative to the baseline average wattage as defined by the DOE Test Procedure (10 CFR Part 430 Subpart B, Appendix A1 and/or B1), and may shift this energy consumption beyond the delay period.*

DOE's current test procedure does not include a test method for estimating the actual ice maker energy consumption of each individual model. While DOE is currently conducting a rulemaking to address this issue, DOE is not proposing a method of validating the ice maker delay as a substitution for a 13% reduction in energy consumption. Consequently, any response to a delay load signal must be confirmed based on a reduction in energy consumption. This approach is consistent with EPA's Draft 2 specification (published February 23, 2012), where EPA is proposing to remove the separate pathway for shifting ice maker cycles beyond the delay period.

DOE and EPA also request feedback on the interchangeability of ice making and overall energy reduction.

7.1 Delay Appliance Load Test

A) Initiate a 4-hour DAL signal 15 minutes before the start of a predicted defrost cycle. For products with manual defrost or off-cycle defrost (in which evaporator surfaces are defrosted during the compressor off-cycle without energizing a heater), send the DAL signal at any time and skip to step C.

B) If no reliable prediction for the defrost cycle can be determined, follow the steps below to initiate a defrost cycle.

1) Based on the energy consumption profile obtained during the DOE Test Procedure, determine when the next defrost may occur;

2) Within two hours of the predicted defrost cycle, open the refrigerator or freezer door to a 90 degree angle for a total of 15 seconds;

3) Shut the door;

4) Wait five minutes;

5) Repeat steps 2 – 4 above four times, for a total of five door openings;

6) Send delay signal.

Note: The requirements for a Connected R/F in Section 4C of the ENERGY STAR Program Requirements for Residential Refrigerators and Freezers Version 5.0 Draft 1 include "*the product shall…shift defrost cycles beyond the delay period*." To verify that a defrost cycle has been delayed it is important to reliably predict the occurrence of a defrost cycle. A delay signal can then be sent and the DR capabilities of the Connected R/F can be confirmed. Manual and off-cycle defrost units are predictable and a delay can easily be verified; however, defrost occurrence is not easily predicted for units that utilize an automatic defrost. In these cases, it is necessary to manually induce a defrost cycle to verify the Connected R/F requirements.

The proposal for triggering a defrost is based on DOE testing of a single UUT using approaches found in 10 CFR Part 431, Subpart C, "Uniform Test Method for the Measurement of Energy Consumption of Commercial Refrigerators, Freezers, and Refrigerator-Freezers (70 FR 60414). Unlike the DOE 431 Subpart C Test Procedure, the process above is performed at the point when a defrost would likely occur instead of immediately following a defrost cycle.

DOE conducted extensive testing to induce defrost on the UUT, including: combinations of door openings, signal timing, and increasing the chamber ambient humidity. However, it was not possible to consistently initiate defrost on the UUT.

To verify that defrost is delayed with a DR signal, there must be a reliable method that predicts the defrost cycle. The final method must minimize test burden and the potential for circumvention, while clearly identifying and predicting defrost cycles at independent test labs.

DOE and EPA request feedback from stakeholders on the proposed defrost initiation method and on alternate methods for determining and predicting defrost cycles for variable defrost units.

C) Measure and record the energy consumption, EP_{DL}, and internal temperatures during the four-hour defrost delay test period.

D) Verify no defrost cycle occurs four hours after the initiation of the delay load signal.

8 TEMPORARY APPLIANCE LOAD REDUCTION TEST

Note: The current requirements for Temporary Appliance Load Reduction (TALR) included in the ENERGY STAR Program Requirements for Residential Refrigerators and Freezers Version 5.0 Draft 1 are as follows:

Upon receipt of this signal, except as permitted below, the product shall restrict its average energy consumption during the load reduction period to no more than 50 percent of that consumed during an average load over a 24-hour period as defined by the DOE Test Procedure.

Exceptions - under the following conditions, the product is not required to restrict its average energy consumption in response to a temporary appliance load reduction signal.

1. If the temporary appliance load reduction signal is received during a defrost cycle, that defrost cycle may finish. However, no additional defrost cycles shall occur during the time period.

2. If there is a consumer initiated function such as a door opening or ice/water dispensing during the load reduction period.

The product shall be able to respond to at least one TALR signal in a 24-hour period.

The requirements above state that no additional defrost cycles shall occur during the time period. The method for initiating a defrost proposed in section 7.1.B may be effective for predicting a defrost within a few hours, but it cannot estimate a defrost cycle occurrence in 10 minutes. Additionally, testing did not produce a situation where a defrost would occur within 10 minutes of a previous defrost cycle. For these reasons, DOE does not propose a test to verify that a defrost does not occur during the TALR signal duration; however, the test lab shall record and verify that no defrost cycles occur during TALR signals.

8.1 Temporary Appliance Load Reduction Test

A) Initiate a 10-minute TALR signal within five minutes after the start of a compressor On cycle.

Note: In an effort to minimize test burden and reproduce a worst-case scenario, the TALR signal is sent shortly after the start of a compressor cycle. At this time, compartment temperatures have risen and the compressor is necessary. If the unit is able to operate according to TALR requirements in this case, then it is assumed to satisfy all other TALR situations (compressor off, the end of a compressor “on” cycle).

B) Verify no defrost cycle occurs during the TALR signal test period.

C) Measure and record the energy consumption, EP_{TALR}, and average internal temperatures during the 10-minute TALR test period.

9 CONSUMER OVERRIDE

Note: The requirements for a Connected R/F in Section 4C of the ENERGY STAR Program Requirements for Residential Refrigerators and Freezers Version 5.0 Draft 1 include: *"The consumer shall be allowed to override the product's response to the Delay Appliance Load and Temporary Appliance Load signals."* EPA and DOE are sensitive to the needs and satisfaction of the consumer. Although not directly related to energy consumption, the consumer override is an integral feature that consumers will find highly valuable and necessary. Therefore, DOE has investigated several approaches for verifying the consumer override functionality of Connected R/Fs.

The following steps outline a method for verifying consumer override effectiveness. These steps are written for a TALR signal but are adjustable for Delay Loads.

1. Send a 10-minute TALR signal within XX minutes after the start of a compressor On cycle, as determined in 6.1.A.
2. Following the initiation of the TALR signal, activate the consumer override.
3. Verify the override is activated and the UUT returns to normal compressor cycle operation for the duration of the TALR signal.

Although the consumer override is an important feature, DOE is hesitant to include it as a feature required for testing as it will increase test burden. Consumer override is a feature, which DOE believes manufacturers will address during the development process. DOE and EPA request feedback from stakeholders on the importance and possible inclusion of consumer override testing.

10 CALCULATIONS

10.1 Baseline Average Power

Calculate the average baseline power, AP_{BL}.

Equation 1: Baseline Average Power

$$AP_{BL} = \frac{(EP_{BL} \times 1000)}{\left(\frac{T_{BL}}{60}\right)}$$

Where:

- *AP_{BL} is the average baseline power in W*
- *EP_{BL} is the baseline energy consumption in kWh*
- *1000 is the conversion factor from kWh to Wh*
- *T_{BL} is the baseline time period in minutes*
- *60 is the conversion factor from minutes to hours*

10.2 Delay Load Period Average Power

Calculate the average delay load power, AP_{DL}.

Equation 2: Delay Load Average Power

$$AP_{DL} = \frac{(EP_{DL} \times 1000)}{\left(\frac{T_{DL}}{60}\right)}$$

Where:

- *AP_{DL} is the average delay load power in W*
- *EP_{DL} is the delay load energy consumption in kWh*

- *1000 is the conversion factor from kWh to Wh*
- *T_{DL} is the delay load duration in minutes*
- *60 is the conversion factor from minutes to hours*

10.3 Percent Delay Load Average Power Reduction

Calculate the percent average delay load power reduction compared to the DOE Test Procedure.

Equation 3: Percent Delay Load Average Power Reduction

$$Percent\ Wattage\ Reduction = \frac{(AP_{BL} - AP_{DL})}{AP_{BL}} \times 100$$

Where:

- *AP_{BL} is the average baseline power, calculated in section 10.1 (W)*
- *AP_{DL} is the average delay load power calculated in section 10.2 (W)*

10.4 Temporary Appliance Load Reduction Average Power

Calculate the average TALR power, AP_{TALR}.

Equation 4: TALR Average Power

$$AP_{TALR} = \frac{(EP_{TALR} \times 1000)}{\left(\frac{10}{60}\right)}$$

Where:

- *$AP_{TA:LR}$ is the average TALR power in W*
- *EP_{TALR} is the TALR energy consumption in kWh*
- *10/60 is the time duration of the TALR period in hours*

10.5 Percent TALR Signal Average Power Reduction

Calculate the percent average TALR power reduction compared to the DOE Test Procedure.

Equation 5: Percent TALR Average Power Reduction

$$Percent\ Wattage\ Reduction = \frac{(AP_{BL} - AP_{TALR})}{AP_{BL}} \times 100$$

Where:

- *AP_{BL} is the average baseline power, calculated in section 10.1 (W)*
- *AP_{TALR} is the average TALR power calculated in section 10.4 (W)*

11 REFERENCES

A) 10 CFR Part 430, Subpart B, Appendix A1. Uniform Test Method for Measuring the Energy Consumption of Electric Refrigerators and Electric Refrigerator-Freezers.

B) 10 CFR Part 430, Subpart B, Appendix B1. Uniform Test Method for Measuring the Energy Consumption of Freezers.

C) AHAM SRF-0.5-2011. AHAM Smart Refrigerator, Refrigerator-Freezer, and Freezer Test Procedure. Draft shared with DOE September 2011.

D) ENERGY STAR Program Requirements for Residential Refrigerators and Freezers - Eligibility Criteria Draft 1 Version 5.0. Published November 2011.

E) 10 CFR Part 431, Subpart C. Uniform Test Method for the Measurement of Energy Consumption of Commercial Refrigerators, Freezers, and Refrigerator-Freezers. .