



ENERGY STAR[®] Program Requirements Product Specification for Laboratory Grade Refrigerators and Freezers, and Ultra-Low Temperature Freezers

Final Test Method

1 OVERVIEW

The following test method shall be used for determining product compliance with requirements in the ENERGY STAR Eligibility Criteria for Laboratory Grade Refrigerators (LGR) and Freezers (LGF), and Ultra-Low Temperature Freezers (ULT).

2 APPLICABILITY

ENERGY STAR test requirements are dependent upon the feature set of the product under evaluation. The following guidelines shall be used to determine the applicability of each section of this document

This test method is applicable to LGRs, LGFs, and ULTs as established in the ENERGY STAR Eligibility Criteria.

This test method is not applicable to portable laboratory refrigerators and freezers, explosion proof refrigerators and freezers, chromatography refrigerators and freezers, and walk-in laboratory refrigerators and freezers.

3 DEFINITIONS

Unless otherwise specified, all terms used in this document are consistent with the definitions in the ENERGY STAR eligibility criteria for laboratory grade refrigerators and freezers.

A) Additional Terms:

- 1) Cabinet Temperature: The average of all temperature measurements taken inside a product's cabinet at any given time.
- 2) Defrost terms:
 - a) Automatic Defrost: A system in which the defrost cycle is automatically initiated and terminated, with resumption of normal refrigeration at the conclusion of the defrost operation. The defrost water is removed using a means that requires no user action (e.g., built-in drainage or natural evaporation).
 - b) Manual Defrost: A system in which the defrost cycle is initiated and terminated manually by the user.
 - c) Semi-Automatic Defrost: A system in which the defrost cycle is manually initiated and automatically terminated, with automatic resumption of the normal refrigeration cycle at the conclusion of the defrost operation.
- 3) Peak Variance: The difference between the maximum and minimum temperatures measured across all temperature measurement devices (TMD) over the course of a given measurement period.
- 4) Refrigeration Cycle: The period of time starting when a unit's refrigeration system turns on, through the time it turns off, and ending when the refrigeration system turns on again.

- 5) Stability: The difference between the maximum and minimum temperature measured by an individual TMD over the course of the entire test period.
- 6) Test: A 24-hour period over which measurements are taken and energy use evaluated under one set of conditions after the pull down period occurs as described in this test procedure.
- 7) Uniformity: The difference between the maximum and minimum temperature measured inside of a unit's cabinet at any given time.

B) Acronyms:

- 1) AHAM: Association of Home Appliance Manufacturers
- 2) ANSI: American National Standards Institute
- 3) LGF: Laboratory Grade Freezer
- 4) LGR: Laboratory Grade Refrigerator
- 5) NIST: National Institute of Standards and Technology
- 6) TMD: Temperature Measurement Device
- 7) ULT: Ultra-Low Temperature Laboratory Freezer
- 8) UUT: Unit Under Test

4 TEST CONDITIONS

- A) Power Supply: The power supply shall be maintained at the rated voltage ± 4.0 percent and rated frequency ± 1 percent. For units rated to operate at multiple voltages, test the unit at the lowest voltage included in the rating. The actual voltage and power factor shall be measured and reported at the product service connection with the refrigeration system in operation (for units with multiple compressors, with all compressor motors in operation).

B) Ambient Conditions:

- 1) Dry-bulb Temperature: The average test-room dry-bulb temperature shall be $24.0\text{ }^{\circ}\text{C} \pm 1.0\text{ }^{\circ}\text{C}$ ($75.2\text{ }^{\circ}\text{F} \pm 1.8\text{ }^{\circ}\text{F}$), when measured in accordance with Section 5 of this test procedure.
- 2) Wet-bulb Temperature: The test-room wet-bulb temperature shall be $18.0\text{ }^{\circ}\text{C} \pm 1.0\text{ }^{\circ}\text{C}$ ($64.4\text{ }^{\circ}\text{F} \pm 1.8\text{ }^{\circ}\text{F}$), when measured in accordance with Section 5 of this test procedure.
- 3) Dry-bulb Temperature Gradient: The dry-bulb temperature gradient shall be less than $2.0\text{ }^{\circ}\text{C}$ per m ($1.0\text{ }^{\circ}\text{F}$ per foot) from 2 inches above the floor or supporting platform to a height 30.5 cm (1.0 ft) above the top of the cabinet.
- 4) Air Currents: Test room air currents across the door opening shall not exceed 0.25 meters per second (49 feet per minute) as measured at T_B . No external air drafts shall blow directly into the refrigerated zone.

C) Instrument Requirements:

- 1) Electrical energy measurements shall be made with instruments accurate to ± 2 percent of the quantity measured.
- 2) Accuracy of all temperature measurements shall be within $\pm 0.8\text{ }^{\circ}\text{C}$ ($\pm 1.4\text{ }^{\circ}\text{F}$) of the measured value.
- 3) Time measurements shall be made with an accuracy of ± 0.5 percent of the time period being measured.
- 4) Air velocity shall be measured with an instrument having an accuracy of ± 10 percent.

5 TEST SETUP

- A) Volume Measurements: The volume of each covered LGR, LGF, or ULT shall be determined using the methodology set forth in ANSI/AHAM HRF-1-2008. Computer-aided design (CAD) models can be used to determine the useable volume, as long as the drawings allow measurements and calculations to be made based on the volume measurement requirements specified in ANSI/AHAM HRF-1-2008.
- B) UUT Configuration: The cabinet with its refrigerating mechanism shall be assembled and set up in accordance with the printed instructions supplied with the cabinet. All packing materials and skid boards shall be removed. Outer door gaskets shall be checked for adequacy of seal to the cabinet and adjusted, if required. Built-in containers, covers, and shelves shall not be removed. Unless otherwise specified, the following conditions apply:
- 1) Any operational mode that reduces energy usage during energy consumption testing and not during normal usage shall be disabled for energy consumption testing.
- C) UUT Location: The space between the back of the cabinet and a vertical surface (the test room wall or simulated wall) shall be the minimum distance in accordance with the manufacturer's instructions.
- 1) For pass-thru units, the UUT shall be placed in a way that allows both doors to be fully opened.
- D) Accessories: All accessories that come standard with the unit, as-shipped, and that consume energy shall be installed and used as recommended by the manufacturer.
- 1) All manually controlled accessories that come standard with the equipment shall be installed and turned "ON" and set to the most energy consumptive setting during testing.
- E) Ambient Temperatures: The ambient temperatures shall be measured at the following locations
- 1) For Upright UUTs: Ambient temperature measurements shall be made at two locations, T_A and T_B , in front of the UUT along a vertical line at the centerline of the UUT. The ambient measurement line extends from a point, T_A , which is 150 mm \pm 50 mm (5.9 in. \pm 2 in.) above the highest point on the UUT, down to the geometric center of the door opening, T_B . If there are multiple outer doors, T_B shall be at the geometric center of all door openings. Both points are located 915 mm \pm 15 mm (36 in. \pm 2 in.) out from the door opening.
 - 2) For Chest-type UUTs: Ambient temperature measurements shall be made at two locations, T_A and T_B , above the UUT along a horizontal line at the centerline of the UUT in the door's longest dimension (either width or depth). T_A shall be placed 150 mm \pm 50 mm (5.9 in. \pm 2 in.) away from the door edge farthest along the door's centerline. T_B shall be placed at the geometric center of the door opening. Both points shall be located 915 mm \pm 15 mm (36 in. \pm 2 in.) above the door opening.
 - 3) For pass-thru UUTs, the ambient temperature shall be measured only on the side of the door opened during testing.
 - 4) If the placement of a TMD at either T_A or T_B interferes with the opening of the unit's door, the TMD shall be moved away from the UUT, perpendicular to the plane of the door opening, until it no longer interferes with the door opening.
- F) Temperature Measurement Devices:
- 1) Weighting: TMDs shall be placed inside a sealable plastic container (such as polyethylene) between 2 - 5 milliliters in volume and filled with any natural or artificial sponge material that is saturated with a heat transfer solution consisting of a 50/50 \pm 2% mixture (by volume) of propylene glycol and distilled water. The temperature shall be measured as closely as possible to the volumetric center of the container. TMDs shall be routed into the cabinet using an access port whenever possible.
 - 2) TMD Locations (Upright UUTs): TMDs shall be placed in 3 separate planes, one located 3 in. \pm 1 in. from the top of the UUT, one 3 in. \pm 1 in. from the bottom of the UUT, and one at the geometric center of the UUT. TMDs shall be placed in the geometric center and 3 in. \pm 1 in. diagonally from two opposite corners of each plane (3 sensors per plane).

- a. If the location of any TMD interferes with any hardware built into the UUT, move that plane of TMDs along the height of the UUT until the TMDs are at least 2 inches away from the hardware.
- b. If the UUT has inner doors, and a compartment created by the inner doors does not contain at least one TMD, place at least one TMD 3 in. \pm 1 in. above the geometric center of the bottom of that compartment.

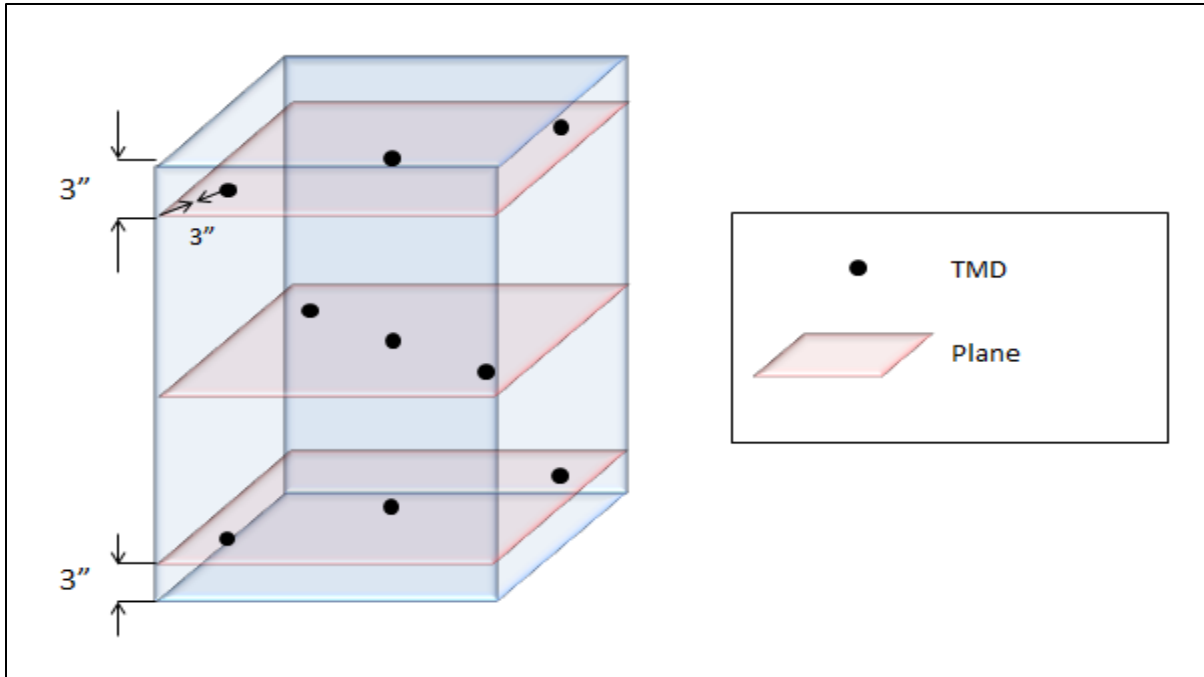


Figure 1. TMD Locations for Upright UUTs

- 3) **TMD Locations (Chest UUTs):** TMDs shall be located in planes 3 in. \pm 1 in. from the left end, 3 in. \pm 1 in. from the right end, and at the geometric center of the width of the unit. At each location, TMDs shall be placed in the geometric center of each plane and 5 in. \pm 1 in. diagonally from two opposite corners of each plane (3 sensors per plane).
 - a. If the location of any TMD interferes with any hardware built into the UUT, move that plane of TMDs along the width of the UUT until the TMDs are at least 2 inches away from the hardware.
 - b. If the UUT has multiple inner compartments, and one (or more) does not contain at least one TMD, place at least one TMD in the geometric center of each empty compartment.

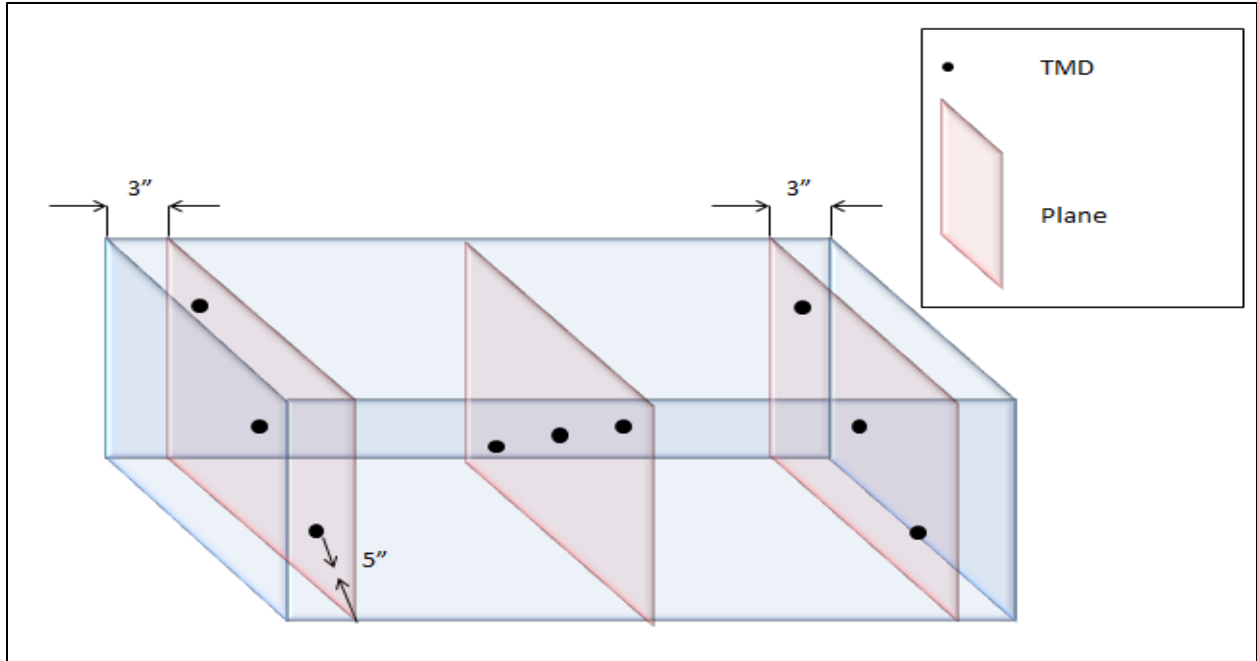


Figure 2. TMD Locations for Chest UUTs

6 TEST METHODOLOGY FOR ALL PRODUCTS

6.1 General Principles

A) Measurements:

- 1) The following data shall be measured and reported at the beginning of the test:
 - a. Air velocity across the face of the door opening measured at point T_B .
- 2) The following data shall be recorded at one-minute intervals during the test:
 - a. Time: The time elapsed from the beginning of the test.
 - b. Temperature recorded by each TMD in the cabinet.
 - c. Dry bulb temperature at points T_A and T_B .
 - d. Wet bulb temperature at points T_A and T_B .

- B) Cabinet Temperature Requirements: UUTs shall be calibrated so that the average of all Cabinet Temperature measurements, as defined in Section 3, over the course of the entire test period falls within the following ranges based on product type:

Table 1. Cabinet Temperature Requirements

Product Type	Cabinet Temperature and Acceptable Tolerance (°C)
LGR	4 ± 1
-20 °C LGF	-20 ± 1
-30 °C LGF	-30 ± 1
-40 °C LGF	-40 ± 1
ULT	-70 ± 1.5
	-80 ± 1.5

- 1) ULTs shall be tested at both -70 °C and -80 °C.
- 2) Non-ULT products that are capable of operating at multiple temperatures shall be tested at the lowest temperature listed in Table 1 at which the product is capable of operating.

6.2 Door Opening Requirements

A) Doors shall be opened as follows:

- 1) For UUTs with swinging doors: If the UUT does not have inner doors, the main door shall be opened to an angle of 90 degrees \pm 10 degrees (relative to the closed-door position). If the UUT has inner doors, inner doors shall be opened to an angle of 90 degrees \pm 10 degrees, and the main door shall be opened to an angle of 90 degrees \pm 10 degrees or to the smallest angle that will allow inner doors to be opened to an angle of 90 degrees \pm 10 degrees, whichever is largest.
- 2) For UUTs with sliding doors: Doors shall be opened as far as possible.
- 3) For UUTs with multiple outer doors: Only one outer door shall be opened at each door opening, and the largest shall be used for all door openings during a test.
 - a. For units with multiple doors of the same size, use the uppermost or rightmost door available depending on the unit's configuration.
 - b. For pass-thru UUTs, the door used for each opening shall be on the side of the UUT with TMDs for measuring the ambient temperature.

B) For Refrigerators: The UUT's door(s) shall be opened a total of 24 times during the test—three times per hour, every 20 minutes, for eight consecutive hours.

- 1) If the UUT has inner doors:
 - a. Open the outer door, as specified in Section 6.2.3), at a constant rate over a period of two seconds.
 - b. Open only the largest inner door at a constant rate over a period of two seconds. If more than one door is the same size, open the uppermost one of those doors (for upright freezers) or the rightmost one of the doors (for chest freezers).
 - c. Leave doors open for 15 seconds.
 - d. Close inner door at a constant rate over a period of two seconds.
 - e. Close outer door at a constant rate over a period of two seconds.
- 2) If the UUT does not have inner doors:
 - a. Open the outer door, as specified in Section 6.2.3), at a constant rate over a period of two seconds.
 - b. Leave door open for 15 seconds.
 - c. Close outer door at a constant rate over a period of two seconds.

C) For Freezers and ULTs: The UUT's door(s) shall be opened a total of six times during the test—once per hour, every 60 minutes, for a period of six consecutive hours.

- 2) If the UUT has inner doors:
 - a. Open the outer door, as specified in Section 6.2.3), at a constant rate over a period of two seconds.
 - b. Open only the largest inner door at a constant rate over a period of two seconds. If more than one door is the same size, open the uppermost one of those doors (for upright freezers) or the rightmost one of the doors (for chest freezers).
 - c. Leave doors open for 15 seconds.

- d. Close inner door at a constant rate over a period of two seconds.
 - e. Close outer door at a constant rate over a period of two seconds.
- 3) If the UUT does not have inner doors:
- a. Open the outer door, as specified in Section 6.2.3), at a constant rate over a period of two seconds.
 - b. Leave door open for 15 seconds.
 - c. Close outer door at a constant rate over a period of two seconds.

6.3 Energy Consumption Test

- A) UUT Pull Down: The UUT shall be plugged in and turned on and the controls adjusted to ensure the UUT begins cooling to the appropriate Cabinet Temperature specified in Table 1. Prior to testing, the UUT shall be operated until the average of all Cabinet Temperatures measured during each of two periods separated by at least three hours lies within the Cabinet Temperature requirements, as specified in Table 1. The measurement periods are as follows:
- 1) For units that do not cycle, each measurement period shall be two hours.
 - 2) For units that do cycle, each measurement period shall comprise a number of complete, repetitive compressor cycles occurring through a period of no less than two hours.
- B) Test Periods: The test period shall be performed as described below based on the UUT's as-shipped defrost setting, after completion of the pull down period. Door openings, as specified in Section 6.2, shall begin three hours after the start of a defrost period, if one occurs. Otherwise they must start at the beginning of the 24-hour period.
- 1) LGRs or LGFs with No Defrost, Manual Defrost, or Semi-Automatic Defrost: The test period shall be 24 hours with no defrost.
 - 2) LGRs or LGFs with Automatic Defrost: The test period shall be 24 hours starting at the beginning of a defrost period.
 - 3) ULTs: The test period shall be 24 hours.

7 REPORTING

- A) Cabinet Volume: The cabinet volume measured in Section 5.A shall be reported in cubic feet.
- B) Test Cabinet Temperature: The average Cabinet Temperature measured during the entire 24-hour test period shall be reported.
- C) Ambient Temperature: The average dry-bulb and wet-bulb temperatures measured at locations T_A and T_B shall be reported for the entire 24-hour test period.
- D) Power Factor: The average power factor over the course of a specified period, based on unit type, shall be reported.
- 1) For units that cycle, the average power factor measured during compressor "on" periods over the duration of the test.
 - 2) For units that do not cycle, the average power factor measured over the duration of the test.
- E) The following values shall be calculated and reported for two three hour periods during the test. The first period shall begin when the first door opening occurs. The second shall begin three hours after the last door opening occurs.
- 1) Test Uniformity: The cabinet Uniformity shall be calculated for the specified periods and reported by taking the average of the Uniformities calculated for each individual measurement.

- 2) Test Stability: The cabinet Stability shall be calculated for the specified periods and reported by taking the average of the Stabilities calculated for each TMD.
 - 3) The maximum and minimum measured temperatures and the Peak Variance measured across all TMDs.
- F) Accessories: A list of the accessories installed prior to testing.
- G) Energy Consumption:
- 1) For LGRs and LRFs:
 - a. The total energy consumption measured during the 24-hour test period shall be reported, in kWh/day.
 - b. The total energy consumption measured during the steady state portion of the test period, which starts one hour after the final door opening occurs, in kWh/day.
 - 2) For ULTs:
 - a. The total energy consumption measured during the 24-hour test period at both Cabinet Temperatures (as noted in Table 1) shall be reported, in kWh/day.
 - b. The total energy consumption measured during the steady state portion of the test period, which starts one hour after the final door opening occurs, at both Cabinet Temperatures, in kWh/day.
 - c. In addition, the energy consumption per day, in kWh/day, at Cabinet Temperature of -75 °C shall be calculated and reported as the weighted average of the test results at -70 °C and -80 °C, as follows:

Equation 1. ULT Energy Consumption Calculation

$$Energy\ consumption = E1 + \left[(-75 - T1) \times \frac{(E2 - E1)}{(T2 - T1)} \right]$$

Where:

T1 = Overall average of all recorded interior temperature measurements over the course of the test at -70 °C test condition.

T2 = Overall average of all recorded interior temperature measurements over the course of the test at -80 °C test condition.

E1 = Total energy consumption during the test at -70 °C test condition.

E2 = Total energy consumption during the test at -80 °C test condition.

8 REFERENCES

- A) AHAM. 2008. AHAM HRF-1-2008, Energy and Internal Volume of Refrigerating Appliances. Washington, DC: Association of Home Appliance Manufacturers.