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

## Final Draft Test Method Rev. Mar-2014

# 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 defined in Section 3:

This test method does not include portable laboratory refrigerators and freezers, explosion proof refrigerators and freezers, chromatography refrigerators and freezers, and walk-in laboratory refrigerators and freezers. This test procedure is applicable to units with manual, automatic-timed, and automatic-smart or on demand defrost systems.

# 3 DEFINITIONS

A) Product Types:

1) Laboratory Grade Freezer (LGF): A refrigerated cabinet used for storing volatile reagents and biological specimens at setpoint temperatures between -40 °C and 0 °C (-40 °F and 32 °F), typically marketed through laboratory equipment supply stores for laboratory or medical use.

2) Laboratory Grade Refrigerator (LGR): A refrigerated cabinet used for storing non-volatile reagents and biological specimens at setpoint temperatures between 0 °C and 12 °C (32 °F and 53.6 °F), typically marketed through laboratory equipment supply stores for laboratory or medical use.

3) Ultra-Low-Temperature Laboratory Freezer (ULT): A freezer designed for laboratory application that is capable of maintaining setpoint storage temperatures between -70 °C and -80 °C (-94 °F and -112 °F).

B) Defrost-related Terms:

1) 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 disposed of automatically.

2) Variable Defrost: A system in which successive defrost cycles are determined by an operating condition variable or variables other than compressor operating time. This includes any electrical or mechanical device performing this function.

3) Manual Defrost: A system in which the defrost cycle is initiated and terminated manually.

4) Semi-Automatic Defrost: A system in which the defrost cycle is manually initiated and automatically terminated, with automatic resumption of normal refrigeration at the conclusion of the defrost operation.

C) Additional Terms:

5) Cabinet Temperature: The average of all temperature measurements taken inside a product's cabinet at any given time.

6) 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.

7) 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.

8) Stability: The difference between the maximum and minimum temperature measured by an individual TMD over the course of the entire test period.

9) 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.

10) Uniformity: The difference between the maximum and minimum temperature measured inside of a unit's cabinet at any given time.

**Note:** DOE has removed the definition for "Running Cycle" from the ENERGY STAR Laboratory Grade Refrigerators and Freezers and Ultra-Low Temperature Freezers Final Draft Test Method (Final Draft Test Method) because it is not relevant to the discussion in this document.

Stakeholders commented that the Draft 2 Test Method Steady-State requirements were still too stringent and that specifying the allowable fluctuation in overall Cabinet Temperature represented an unnecessary performance requirement. DOE agrees with stakeholders that the Steady-State requirements represent a performance requirement and has removed the definition for Steady-State from the Final Draft Test Method. DOE has updated Section 6 with a new method for cooling units down prior to testing. Please see the discussion in Section 6 for additional information regarding the new pull down period requirements.

D) 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. 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 ºC ± 1.0 ºC (75.2 ºF ± 1.8 ºF), when measured in accordance with Section 5 of this test procedure. Individual recorded temperatures shall be 24.0 ºC ± 2.0 ºC (75.2 ºF ± 3.6 ºF).

2) Wet-bulb Temperature: The test-room wet-bulb temperature shall be 18.0 ºC ± 1.0 ºC (64.4 ºF ± 1.8 ºF), when measured in accordance with Section 5 of this test procedure. Individual recorded temperatures shall be 18.0 ºC ± 2.0 ºC (64.4 ºF ± 3.6 ºF).

3) Dry-bulb Temperature Gradient: The dry-bulb temperature gradient shall be less than 2.0 ºC per m (1.0 ºF 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 ± 0.8 °C (± 1.4 °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 dry-bulb temperature shall be measured at the following locations:

1) For Upright UUTs: Two locations 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 ± 50 mm (5.9 in. ± 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 ± 15 mm (36 in. ± 2 in.) out from the door opening.

2) For Chest-type UUTs: Two locations along a horizontal line at the centerline of the UUT. The ambient measurement line across the door in the longest dimension (either width or depth) from a point, $T_A$, which is 150 mm ± 50 mm (5.9 in. ± 2 in.) beyond the door edge farthest from the door's geometric center, across to the geometric center of the door opening, $T_B$, Both points are located 915 mm ± 15 mm (36 in. ± 2 in.) above the door opening.

3) For pass-thru UUTs, the ambient temperature shall be measured only on one side of the UUT.

4) If placing a TMD at any point, $T_A$ or $T_B$, interferes with the opening of the 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.

5) These points shall be selected such that they are not affected by external or UUT heat sources, such as condensing units, ballasts, heaters, or lights.

F) Placement of TMDs: The UUT shall be filled with TMDs placed inside a sealable plastic container (such as polyethylene) of at least 10 milliliters volume filled with any natural or artificial sponge material that is saturated with a heat transfer solution consisting of a 50/50 ± 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.

**Note:** In Draft 2, DOE specified using un-weighted TMDs for all testing. Some stakeholders agreed with DOE's proposal, stating that using un-weighted TMDs reduces the test setup burden. Other stakeholders commented that using un-weighted TMDs would result in unrepresentative and misleading values for Stability and Uniformity and would make maintaining the Cabinet Temperature within the specified tolerances extremely difficult. Upon further evaluation of the data obtained from testing performed prior to the publication of Draft 2, DOE found that the results showed Stability and Uniformity values that were significantly worse when using un-weighted TMDs. In addition, while DOE understands that using weighted TMDs increases test setup burden, DOE believes that using them will reduce overall test burden by making it easier for units to maintain the specified Cabinet Temperatures. As such, DOE is now proposing to use weighted TMDs for testing.

1) TMD Locations (Upright UUTs with shelves/drawers): TMDs shall be placed on three planes located 3 in. ± 1 in. above the topmost shelf/drawer, the middle shelf/drawer, and the bottom of the UUT, or 3 in. ± 1 in. above the bottom drawer or basket. TMDs shall be placed in the geometric center and 3 in. ± 1 in. diagonally from each corner of each plane (5 sensors per plane). For level, adjacent shelves within a UUT, the plane shall extend across all shelves. For level, adjacent baskets within a UUT, TMDs shall be placed at the geometric center of each basket.

   a. If the UUT does not have inner doors, three shelves/drawers should be placed in the (1) top allowable position, (2) geometric center, and (3) lowest allowable position.

   b. If the UUT has inner doors, shelves should be evenly placed in the standard locations based on the inner doors. If placing the TMDs in three planes as instructed above would result in any compartment created by the inner doors not containing TMDs, add one plane of TMDs 3 in. ± 1 in. from the bottom of that compartment.

   c. If the location of any TMD interferes with any hardware built into the UUT, move that plane of TMDs up or down until the TMDs are at least 2 inches away from the hardware.

2) TMD Locations (Upright UUTs without shelves/drawers): If a UUT is sold without shelving/drawers, then the lab may test it without shelves/drawers. TMDs shall be placed a plane located 3 in. ± 1 in. from the top of the UUT, 3 in. ± 1 in. from the bottom of the UUT, and at the geometric center of the UUT, If this configuration is such that the distance between planes is greater than either the interior width or the interior depth of the UUT, add additional planes and evenly space the middle planes between the top and bottom plane until the distance between planes is less than either the height or depth of the UUT. TMDs shall be placed in the geometric center and 3 in. ± 1 in. diagonally from each corner of each plane (5 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.

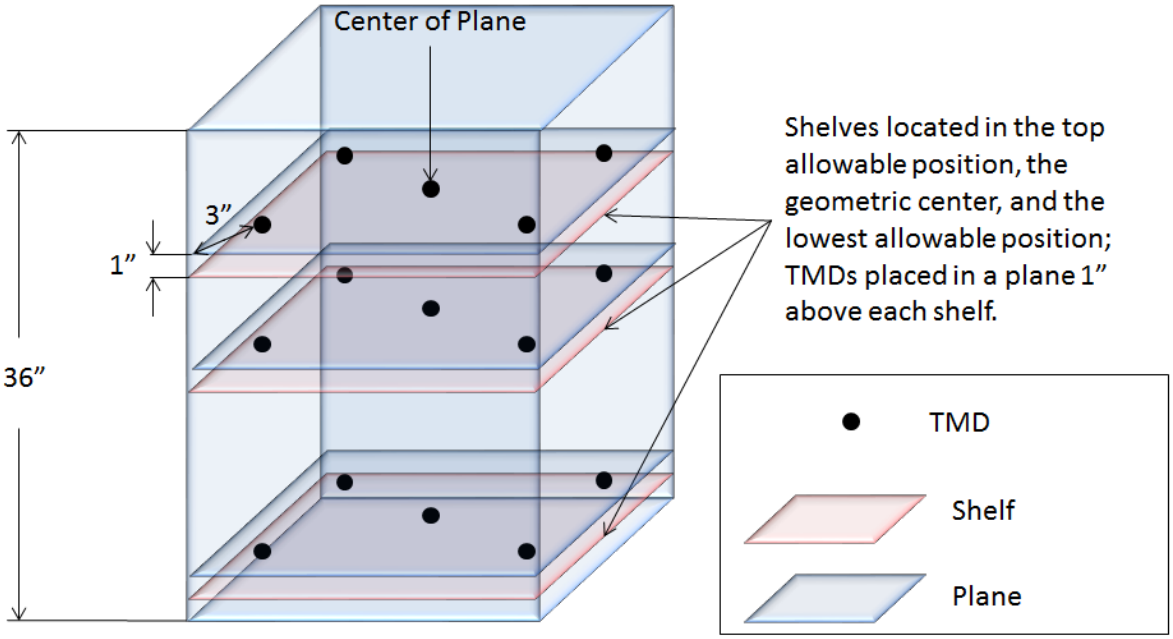


**Figure 1: Example of Placement of TMDs in Upright Refrigerator with Shelves**

3) TMD Locations (Chest UUTs): TMDs shall be located in planes 3 in. ± 1 in. from the left end, 3 in. ± 1 in. from the right end, and at the geometric center of the depth of the refrigerator. If this configuration is such that the distance between planes is greater than either the interior height or the interior depth of the UUT, add additional planes and evenly space the middle planes between the leftmost and rightmost plane until the distance between planes is less than either the height or depth of the UUT. At each location, TMDs shall be placed in the geometric center of each plane and 3 in. ± 1 in. diagonally from each corner of each plane (5 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 length of the UUT until the TMDs are at least 2 inches away from the hardware.

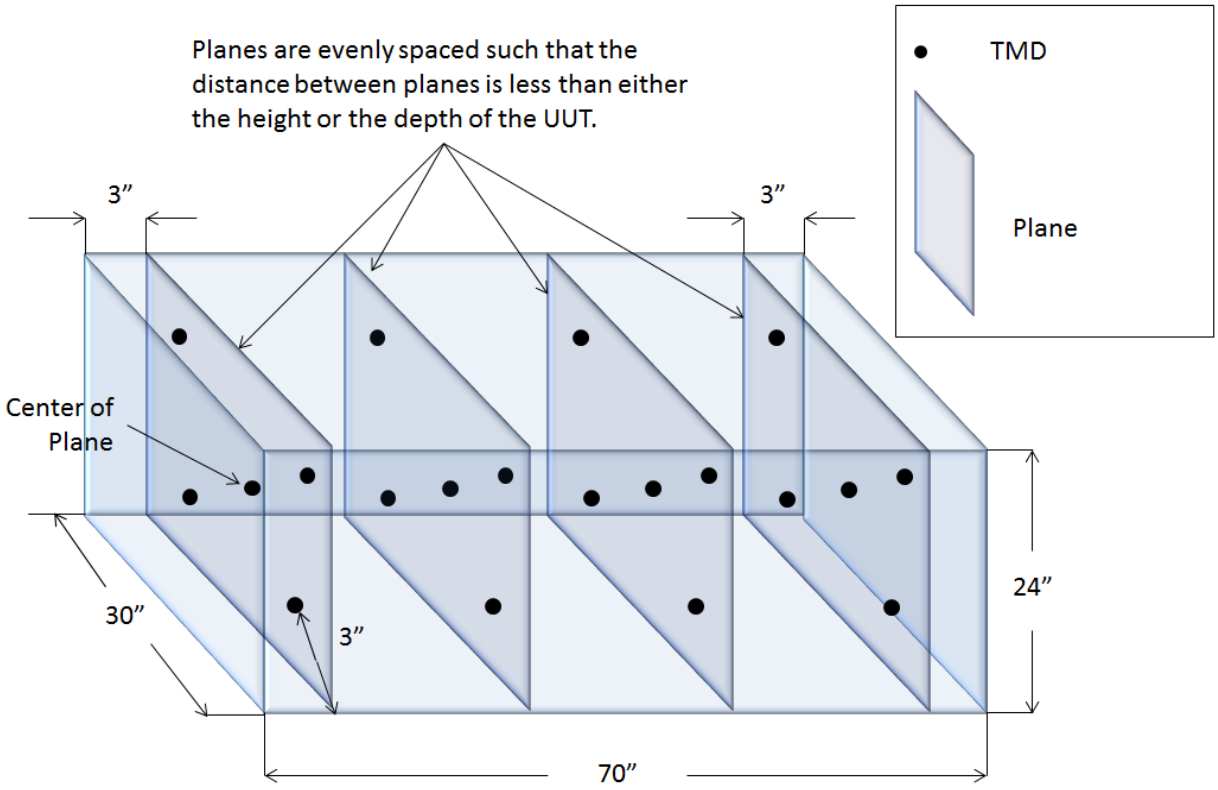


**Figure 2: Example of Placement of TMDs in Chest Freezer Without Shelves or Baskets**

# 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 tested so that the average Cabinet Temperature, 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 (ºC) |
|---|---|
| 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) 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 ± 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 ± 10 degrees, and the main door shall be opened to an angle of 90 degrees ± 10 degrees or to the smallest angle that will allow inner doors to be opened to an angle of 90 degrees ± 10 degrees, whichever is largest.

**Note:** Stakeholders commented that the door opening angle tolerance was too stringent and would be extremely difficult to meet in a normal testing situation. DOE agrees with stakeholders and has updated the door opening requirements to specify opening doors to an angle of 90 degrees ± 10 degrees. DOE believes this update will ensure that all doors are fully opened during testing, while minimizing test burden.

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: A door shall be opened a total of 24 times during the test—three times per hour, every 20 minutes, for eight consecutive hours. The door shall be opened at a constant rate over a period of two seconds, held open for 15 seconds, and closed at a constant rate over a period of two seconds.

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

1) If the UUT has inner doors:

a. Open the main door at a constant rate over a period of two seconds.

b. Open 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 of those doors (for upright freezers) or the rightmost 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 main door at a constant rate over a period of two seconds.

2) If the UUT does not have inner doors:

a. Open the main door at a constant rate over a period of two seconds.

b. Leave door open for 15 seconds.

c. Close main door at a constant rate over a period of two seconds.

**Note:** DOE continued to receive widely ranging comments regarding the door opening requirements. To further evaluate door openings, DOE performed an analysis of data taken during a separate DOE technology demonstration project. The analyzed data tracked the general usage of several ULTs at three separate labs over the course of three months. The data included a wide range of information, including the number of door openings per day and total energy consumption per day. DOE analyzed this data and found that doors were opened on average between two and eight times per day, and these door openings resulted in an average increase in daily energy consumption of between 2.5 to 6 percent. Based on these data, DOE proposes to maintain door openings within the test as evidence suggests that door openings are a regular part of normal operation and doing so ensures that the increased energy consumption resulting from door openings is measured. In addition, DOE proposes to reduce the required number of door openings for LGFs and ULTs based on its analysis.

Stakeholders also requested clarification regarding how door openings should be performed for units with multiple outer doors (e.g., two-door refrigerators and pass-thrus). As detailed in the Draft 2 Test Method note regarding door openings, DOE testing showed that using the same inner door for each opening was more repeatable. DOE believes that the same principles apply to outer doors as well. As such, DOE has updated the door opening requirements to clarify that only one door shall be opened at each door opening and has included specifications regarding which door to use.

## 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 Cabinet Temperature 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.

**Note:** As noted in Section 3, DOE has removed the Draft 2 Test Method Steady-State requirements. DOE is now proposing to require that all units be cooled down until the average Cabinet Temperature measured over the course of two periods lies within the Cabinet Temperature requirements specified in Table 1 prior to testing. DOE believes that the proposed pull down requirements will ensure that the unit is operating at the desired testing temperature and do not represent an additional performance requirement, as only the average Cabinet Temperature and not the change in average Cabinet Temperature is evaluated. Fluctuations in individual temperature measurements or the Cabinet Temperature over time are allowed, as long as the average Cabinet Temperature over each of the two periods lies within the ranges specified in Table 1.

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) UUTs with No Defrost, Manual Defrost, or Semi-Automatic Defrost: The test period shall be 24 hours with no defrost.

2) UUTs with Automatic or Variable 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) Test Cabinet Temperature: The overall average of all Cabinet Temperatures measured during the 24-hour test period shall be reported.

B) 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.

C) 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.

D) 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 being three hours after the last door opening occurs.

1) Test Uniformity: The overall test Uniformity shall be calculated for the specified periods and reported by taking the average of the Uniformities calculated for each one minute measurement interval.

2) Test Stability: The overall test 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.

E) Accessories: A list of the accessories installed prior to testing.

F) Energy Consumption:

1) For LGRs and LRFs, the total energy consumption measured during the 24-hour test period shall be reported, 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. 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**

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

Where:

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

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

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

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

# 8 REFERENCES

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