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Energy and Internal Volume of Consumer Refrigeration Products

AHAM HRF-1- 2019

ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

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PREFACE

The Association of Home Appliance Manufacturers develops standards in accordance with AHAM's "Policy and Procedures Governing Technical Standards" which states:

> "AHAM Standards shall be in the best interest, mutually, of consumers who use appliances, the industries which provide and service appliances, and other interested parties. They shall relate to actual use conditions and be technically and scientifically sound."

Use or observance of AHAM standards is voluntary.

This standard contains test procedures that may be applied to any brand or model of electric (single-phase, alternating current) refrigerator, refrigerator-freezer, freezer or miscellaneous refrigeration products for measuring energy consumption. Results of tests in accordance with this standard may be publicly stated. This standard is a technical revision of AHAM HRF-1-2016.

AHAM welcomes comments and suggestions regarding this standard. Any standard may be reviewed and improved as needed. All standards shall be updated or reconfirmed at least every five years. Any interested party, at any time, may request a change in an AHAM standard. Such request should be addressed to AHAM's President, and should be accompanied by a statement of reason for the request and a suggested alternate proposal.

CONTENTS

1 PURPOSE

The purpose of this standard is to establish a uniform and repeatable procedure or standard method for measuring specified product characteristics of **refrigerators**, **refrigerator-freezers, miscellaneous refrigeration products**, and **freezers** (Consumer Refrigeration Products). The standard methods and the recommended levels of performance, where they appear, are intended to provide a means by which different brands and models of Consumer Refrigeration Products can be compared and evaluated.

The standard methods are not intended to inhibit improvement and innovation in product testing, design or performance.

The following principles of interpretation shall be applied to AHAM HRF-1, and shall apply to and guide any revisions to the test procedure. The intent of the energy test procedure is to simulate typical room conditions (72°F (22.2°C)) with door openings, by testing at 90°F (32.2°C) without door openings. This measurement standard only applies to Refrigeration Products which operate in an equivalent manner under 90°F (32.2°C) ambient conditions as they would under typical room conditions,.

NOTE: The following guidance shall be used for determining if this measurement standard is applicable to the unit under test.

Energy consuming components that operate in typical room conditions (including as a result of door openings, or a function of humidity), and that are not exempted by this standard, shall operate in an equivalent manner during energy testing under this standard, or be accounted for by all calculations as provided for in the standard.

Examples of Consumer Refrigeration Products for which the measurement standard is not applicable:

1. Consumer Refrigeration Products, which have energy saving features designed to be activated by a lack of door openings or which operate differently at 90°F (32.2 °C) compared to under typical room conditions (72 °F (22.2 °C)).
2. Consumer Refrigeration Products where the defrost heater(s) either function or turn off differently during the energy test than it would under typical room conditions.
3. Consumer Refrigeration Products with electric heaters that would normally operate at typical room conditions with door openings but which operate differently during the energy test.
4. Consumer Refrigeration Products that have an Icemaker area temperature exceeding the temperature necessary for the storage of ice.

NOTE: Energy used during adaptive defrost shall continue to be tested and adjusted per the calculation provided for in this standard.

2 SCOPE

This standard applies to Consumer Refrigeration Products as defined in definitions in section 3 of this standard. This standard covers definitions, methods for computing volumes, methods for determining energy consumption and energy factor, and safety recommendations.

3 DEFINITIONS

For the purposes of this document, the following definitions apply. All definitions apply to products having a source of refrigeration requiring a single phase, alternating current electric energy input only, and which are not intended for commercial use.

NOTE:

1. All definition terms are identified in **bold** throughout this document.
2. All temperatures are measured in accordance with Sections 5.5.5 and 5.5.6 when tested at 90°F (32.2° C) ambient.
3. Definitions in DOE 10CFR430.2 will supersede any definition in this document that may be in conflict.

3.1 Adjusted Volume

The sum of the **fresh food compartment** volume, the **cooler compartment** volume, and the product of an adjustment factor and the **freezer compartment** volume, in cubic feet.

3.2 Air Ducts

Enclosed passages which direct the flow of air.

3.3 All-Refrigerator

A cabinet which is capable of maintaining **compartment** temperatures warmer than 32°F (0°C) and colder than 39°F (3.9° C) and is not a **cooler compartment**. However, it may include a **compartment** of 0.50 cubic-foot capacity (14.2 liters) or less for the freezing and storage of ice.

3.4 Anti-Sweat Heater

A device incorporated into the design of a Consumer Refrigeration Product to prevent the accumulation of moisture on the exterior or interior surfaces of the cabinet. This heater may be switchable from fully-on to fully-off or to some condition of operation in-between.

3.5 Automatic Icemaker

A device that can be supplied with water without user intervention, either from a pressurized water supply system or by transfer from a water reservoir located inside the cabinet, that automatically produces, **harvest**s, and stores ice in a storage bin, with means to automatically interrupt the harvesting operation when the **ice storage bin** is filled to a pre-determined level.

3.5.1 Harvest

The process of freeing or removing ice pieces from an icemaker.

3.6 Baffle

A plate, wall or partition which is designed to perform one or more of the following functions:

a) prevent contact of contents with refrigerated surfaces;
b) prevent dripping of condensate;
c) regulate and/or direct circulation of refrigerated air.

3.7 Chiller or Drip Tray

A tray or drawer, which is located beneath the refrigerated surfaces of a manual defrosting Consumer Refrigeration Product for cooling items and/or collecting water during defrost. It may also serve as a **baffle** to regulate **compartment** temperature.

3.8 Compartment

Enclosed space within a refrigerating appliance, which is directly accessible through one or more external doors, which may itself be divided into **sub-compartments**

NOTE: Throughout this standard, unless specified otherwise, "**compartment**" shall be taken to mean **compartment** and/or **sub-compartment** as appropriate for the context.

3.8.1 Cooler Compartment

Compartments that are capable of maintaining **compartment** temperatures either (a) no colder than 39°F (3.9°C), or (b) in a range that extends no colder than 37 °F (2.8°C) but at least as warm as 60 °F (15.6°C).

3.8.2 Freezer Compartment

Compartments that are capable of maintaining temperatures colder than 0°F (-17.8°C) for **refrigerator-freezers** or **freezers**, or colder than 15ºF (-9.4ºC) in **refrigerator**s or **cooler-refrigerator**s. **Sub-compartment**s operating at average temperatures colder than 0°F (-17.8°C) shall be considered part of the **freezer compartment**.

3.8.3 Fresh Food Compartment

Compartments that are capable of maintaining an average temperature warmer than 32°F (0°C) and colder than 39°F (3.9°C). **Sub-compartment**s operating at average temperatures warmer than 0°F (-17.8°C) (or 15°F (-9.4°C) for **refrigerator**s or **cooler-refrigerator**s) shall be considered part of the **fresh food compartment**.

3.8.4 Sub-Compartment

Enclosed space within a **compartment** which may have a different operating temperature from the **compartment** within which it is located.

3.9 Compressor Cycle

A compressor cycle is a complete "on" and a complete "off" period of the motor.

3.10 Compressor Cycle Pattern:

A compressor cycle pattern is made up of two or more complete "on" and "off" periods of the motor, when a uniform repeating sequence of complete "on" and "off" periods occur. Within the pattern, one or more **compressor cycle**(s) will vary in its' duration relative to the other cycle(s).

3.11 Cycle

The period of 24 hours for which the energy use is calculated as though the consumer activated **compartment** temperature controls were set so that the standardized **compartment** temperatures were maintained.

3.12 Defrost cycle

Total time during which the refrigeration system is interrupted to remove the frost from the evaporator, including any **precooling** and **recovery**.

3.12.1 Precooling

Precooling means operating a refrigeration system before initiation of a **defrost cycle** to reduce one or more **compartment** temperatures significantly (more than 0.5°F (0.9°C)) below its minimum during stable operation between defrosts

3.12.2 Recovery

Recovery means operating a refrigeration system after the conclusion of a **defrost cycle** to reduce the temperature of one or more **compartment**s to the temperature range that the **compartment**(s) exhibited during stable operation between defrosts.

3.13 Defrost Cycle Type

A distinct sequence of control whose function is to remove frost and/or ice from a refrigerated surface. There may be variations in the defrost control sequence, such as the number of defrost heaters energized. Each such variation establishes a separate, distinct **defrost cycle type**. However, defrost achieved regularly during the compressor off-cycles by warming of the evaporator without active heat addition, although a form of automatic defrost, does not constitute a unique **defrost cycle type** for the purposes of identifying the test period in accordance with section 5 of this standard.

3.14 Defrost System

A means to remove frost and/or ice from the refrigerated surfaces. Types of defrost systems that apply to Consumer Refrigeration Products are defined in Sections 3.14.1 through 3.14.4 below.

3.14.1 **Manual Defrost**

A system in which defrosting of the refrigerated surface is accomplished by natural or manual means with manual initiation and manual or automatic termination of the overall defrost operation.

3.14.2 **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 system automatically prevents the permanent formation of frost on all refrigerated surfaces. Defrost achieved regularly during the compressor off-cycles by warming of the evaporator without active heat addition is a form of automatic defrost. The defrost water is disposed of automatically~~.~~

3.14.3 **Partial Automatic Defrost**

A system in which the refrigerated surfaces of the **freezer compartment** are defrosted manually and the refrigerated surfaces of the **fresh food compartment** are defrosted automatically. Defrost water from the **fresh food compartment** is disposed of automatically or collected in a container for subsequent manual removal.

3.14.4 **Long-Time Automatic Defrost**

An automatic defrost system where successive **defrost cycles** are separated by 14 hours or more of compressor-operating time.

3.15 **Drain Trap**

A curve or lowered section of the drain tube that is filled with water to prevent air from entering the cabinet.

3.16 **Fan Scroll**

Swept volume of the fan blade.

3.17 **Freezer**

A cabinet capable of maintaining temperatures of 0°F (-17.8°C) or colder.

3.17.1 **Chest** Freezer

A **freezer**, which is accessible from the top.

3.17.2 **Upright Freezer**

A **freezer**, which is accessible from the front

3.18 Ice Tray

A container that holds water while it turns to ice to be manually **harvest**ed.

3.19 Ice Storage Bin

A container in which ice can be stored.

3.20 Liner

The enclosure forming the interior of any **compartment**(s). The complete **liner** comprises the **compartment liner** in the cabinet, the exposed breaker strip surfaces and the door **liner**(s).

3.21 Miscellaneous Refrigeration Product

A Consumer Refrigeration Product other than a **refrigerator**, **refrigerator-freezer**, or **freezer,** which includes **cooler**s and combination **cooler** refrigeration products.

3.21.1 Cooler

A cabinet solely consisting of one or more cooler **compartment**s.

3.21.2 Cooler-Refrigerator

A cabinet that consists of at least one **cooler compartment**, which without the **cooler compartment**(s) would be considered a **refrigerator**.

3.21.3 Cooler-All-Refrigerator

A cabinet that consists of at least one **cooler compartment**, which without the **cooler compartment** would be considered an **all-refrigerator**.

3.21.4 Cooler-Refrigerator-Freezer

A cabinet that consists of at least one **cooler compartment**, which without the **cooler compartment(s)** would be considered a **refrigerator-freezer.**

3.21.5 Cooler-Freezer

A cabinet that consists of at least one **cooler compartment**, which without the **cooler compartment(s)** would be considered a **freezer**.

3.22 Multiple-compressor Product

A Consumer Refrigeration Product with more than one compressor.

3.23 Quick Cool

An optional feature on Consumer Refrigeration Products that is initiated manually. It bypasses the thermostat control and places the compressor in an extended run time operating condition. It operates continually until the feature is terminated either manually or automatically.

3.24 Refrigerator

A cabinet which is capable of maintaining **compartment** temperatures warmer than 32F (0C) and colder than 39°F (3.9°C). It must not include any **compartment**s capable of maintaining **compartmen**t temperatures of 0 °F (−17.8 °C) or below, or any **cooler compartment**s.

3.25 Refrigerator-Freezer

A cabinet which consists of two or more **compartment**s, with at least one of the **compartment**s capable of maintaining **compartment** temperatures colder than 39°F (3.9°C) and is not capable of maintaining **compartment** temperatures of 0°F (−17.8°C) or below, and with at least one other **compartment** capable of maintaining **compartment** temperatures of 0°F (-17.8°C) or below. It must not include any **cooler** compartment.

3.26 Shelf

Any generally horizontal surface within a **compartment**, which is provided for storage.

3.27 Standard Cycle

The **cycle type** in which the **anti-sweat heater** control, when provided, is set in the highest energy consuming position.

3.28 Stable/Steady State Condition

Stable/steady state conditions exist if the average temperatures in each measured **compartment** taken at 1 minute intervals, or less, are not changing at a rate greater than 0.042°F (0.023°C) per hour as determined by the applicable condition of (a) or (b) below.

a) The average of the measurements during a 2-hour period if no cycling occurs or during a number of complete repetitive **compressor cycles** through a period of no less than 2 hours is compared to the average over an equivalent time period with at least 3 hours elapsed between the two measurement periods. No portion of **defrost cycle**, such as **precooling** or **recovery** shall be included. If less than two **compressor cycles** occur during a 24-hour period, then a single complete **compressor cycle** may be used.

b) If defrost controls are operative during the test and (a) above cannot be used, the average of the measurements during a number of complete repetitive **compressor cycles** through a period of no less than 2 hours and including the last complete cycle prior to a **defrost cycle**, or if no cycling occurs, the average of the measurements during the last 2 hours prior to a **defrost cycle** is compared to the same averaging period prior to the following **defrost cycle**.

c) For **multiple compressor products**, the test shall start after a minimum 24 hour stabilization run for each temperature control setting or when the conditions of (a) are met.

NOTE: The data used to verify **stable/steady state conditions,** shall be used as data for part one of the **variable defrost control** test or as the non-automatic defrost test period.

3.29 Variable Anti-sweat Heater Control

An **anti-sweat heater** control that varies the average power input of the **anti-sweat heater**(s) based on operating condition variable(s) and/or ambient condition variable(s).

3.30 Variable Defrost Control

An **automatic defrost system**) where successive **defrost cycles** are determined by an operating condition variable or variables other than solely compressor operating time. This includes any electrical or mechanical device.

A control scheme that changes the defrost interval from a fixed length to an extended length (without any intermediate steps) is not a **variable defrost control**. Therefore, the times between defrost shall vary with different usage patterns and include a continuum of lengths of time between defrosts as inputs vary.

3.31 Volume

3.31.1 Fresh Food Compartment Volume

The refrigerated volume of the **fresh food compartment**(s)

3.31.2 Freezer Compartment Volume

The refrigerated volume of the **freezer compartment**(s)

3.31.3 Cooler Compartment Volume

The refrigerated volume of the **cooler compartment**(s)

3.31.4 Total Volume

The sum of the volumes of the fresh food compartments, the freezer compartments, and the cooler compartments.

4 METHOD FOR COMPUTING REFRIGERATED VOLUME OF CONSUMER REFRIGERATION PRODUCTS

4.1 Scope

This section describes methods for computing **total volume** of Consumer Refrigeration Products. These methods provide a means of measuring the volume that must be refrigerated for the purpose of energy calculation and labeling.

4.2 Total volume

4.2.1 Volume measurements

The **fresh food compartment**, **freezer compartment**, and **cooler compartment** volume shall be recorded to the nearest 0.01 cubic feet (nearest 0.1 liter).

The **total volume** shall be be recorded to the nearest 0.1 cubic feet (nearest 1.0 liter).

4.2.2 Determination of volume

The volume shall take into account the exact shapes of the insulated walls including all depressions or projections. For through-the-door ice and water dispensers, the ice chute will be included or not included as determined in Figures 4-2 and 4-3

When determining volume, internal fittings such as **shelve**s, removable partitions, containers, **automatic ice maker**s, interior light housings and the enclosed volume of **air duct**s that solely supply air to **sub-compartment**s that do not require temperature measurements, shall not be deducted.

Volumes of the item listed below shall be deducted:

- The enclosed volume of control housings.
- The enclosed volume of the evaporator space (see section 4.2.3).
- The enclosed volume of air ducts that supply air to **fresh food**, **freezer**, and **cooler compartment**s.

4.2.3 Volume of evaporator space

(a) In the case of a forced air evaporator, the total volume of and behind the evaporator cover including volume occupied by the evaporator, evaporator fan and the **fan scroll** is considered part of the evaporator space.

(b) In the case of plate style (or roll-bond) evaporators, the volume behind vertically installed plate style evaporators and the volume above horizontally installed plate style evaporators (if the distance between the horizontal plate style evaporator and the nearest above liner surface is less than 2 inches (50 mm)) is considered part of the evaporator space. Removable **drip trays**/troughs shall be considered as not present and shall not be deducted.

(c) In the case of refrigerant filled shelving, the volume above the uppermost **shelf** and below the lowermost **shelf**, (if the distance between the shelf and the nearest horizontal plane of the **compartment** inner wall is less than 2 inches (50 mm)) is considered part of the evaporator space. All other refrigerated shelves are considered as not present and shall not be deducted.

4.3 Legend for Figures 4-1 through 4-3

Figures 4-1 through 4-3 show typical configurations and are not intended to cover all design variations. A combination of components from the various figures may be used for other designs.

These figures graphically support procedures for determination of volume described in Sections 4.2.2 and 4.2.3.

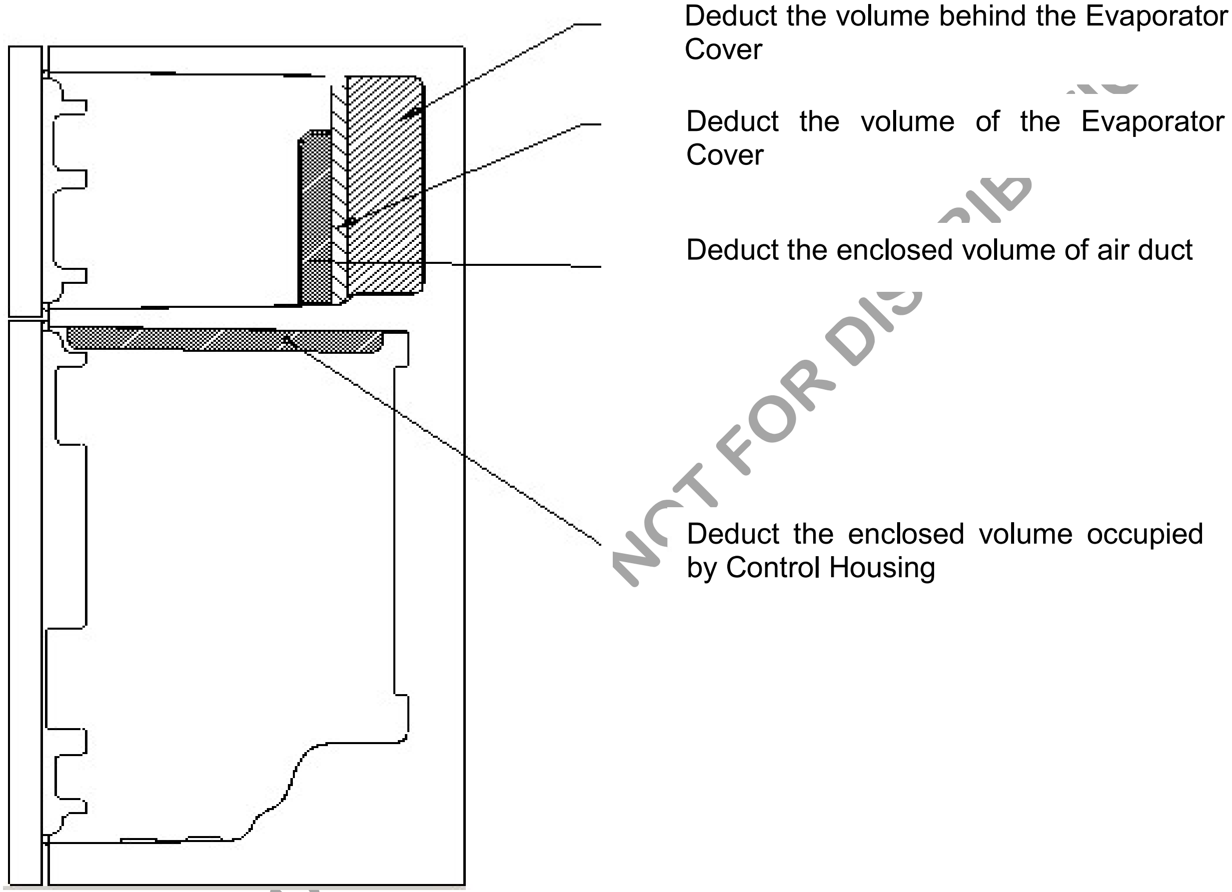


Figure 4-1: This view is an example of a basic model but shall apply to all model configurations

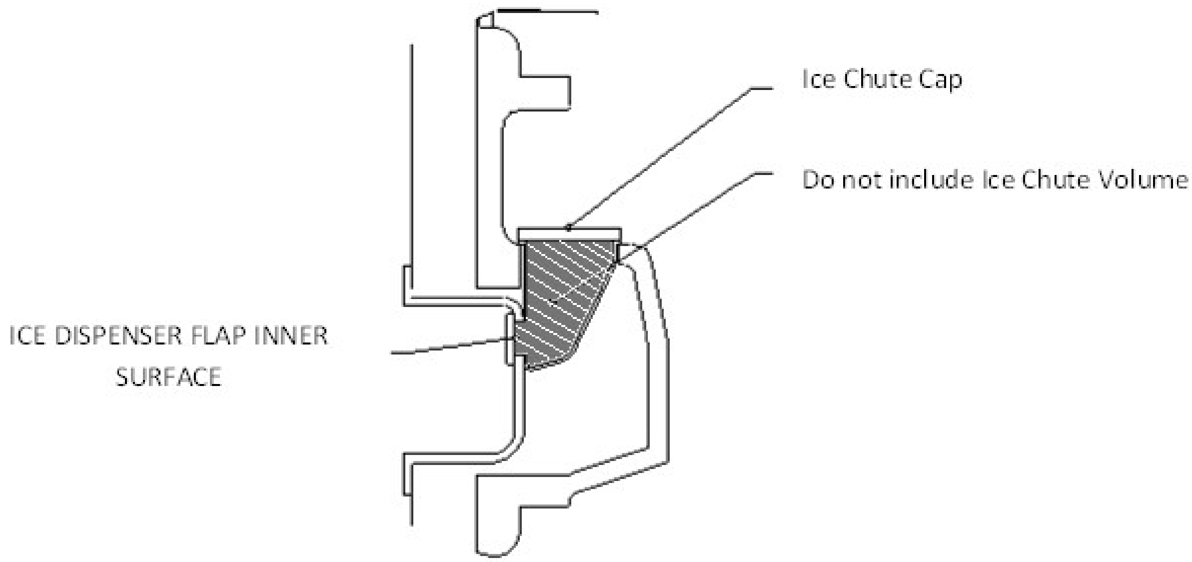


Figure 4-2: **Through-the-door dispenser with Plug or Cover over the Ice Chute**

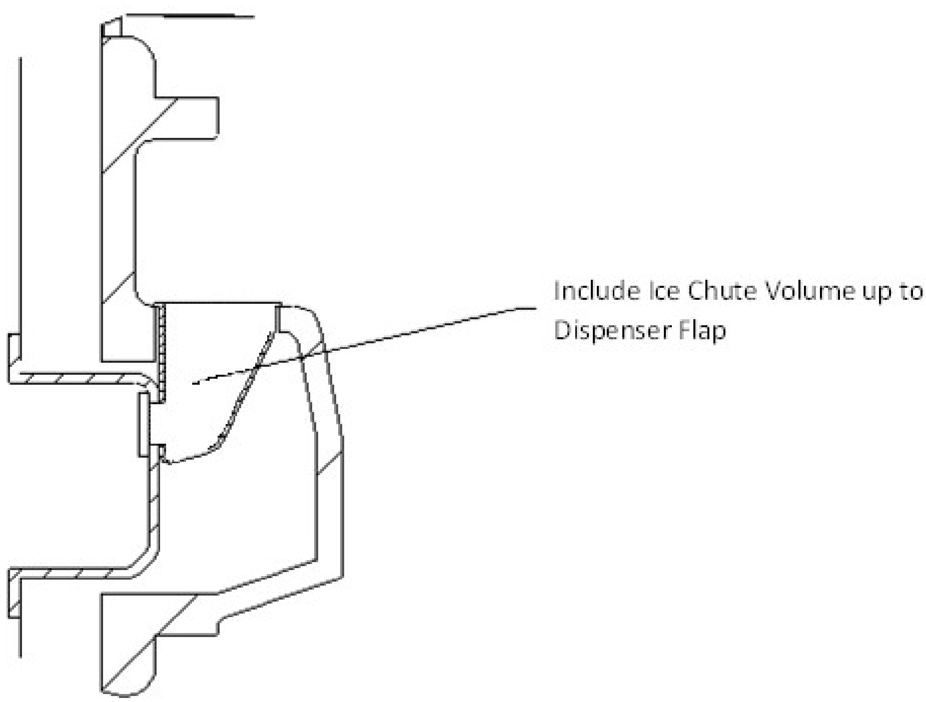


Figure 4-3: **Through-the-door dispenser with no Plug or Cover over the Ice Chute**

5 METHOD FOR DETERMINING THE ENERGY CONSUMPTION OF CONSUMER REFRIGERATION PRODUCTS

5.1 Scope

This section describes a standard method for determining the electrical energy consumption for Consumer Refrigeration Products.

5.2 Purpose

The purpose of this test method is to establish a uniform and repeatable procedure for determining energy consumption.

5.3 Test Conditions

5.3.1 Ambient Temperature

For a product height greater than 36 inches (91.5 cm) the ambient temperature shall be recorded at points located 3 feet (91.5 cm) above the floor or platform and 10 inches (25.4 cm) from the center of the two sides of the unit under test. For a product height of 36 inches (91.5 cm) or less the ambient temperature shall be recorded at points located at a distance of the product height divided by two above the floor or platform and 10 inches (25.4 cm) from the center of the two sides of the unit under test. The ambient temperature shall be 90.0 ± 1.0 °F (32.2 ± 0.6 °C) during the test period.

The test room vertical ambient temperature gradient in any foot of vertical distance from 2 inches (5.1 cm) above the floor or supporting platform to a height of 1 foot (30.5 cm) above the top of the unit under test is not to exceed 0.5 °F per foot (0.9 °C per meter). The vertical ambient temperature gradient at locations 10 inches (25.4 cm) from the centers of the two sides of the unit being tested is to be maintained during the test. To demonstrate that this requirement has been met, test data shall include measurements taken using three temperature sensors on each side at the following locations:

- at 2 inch (5.1 cm) above platform and 10 inches (25.4 cm) from the center of the two sides of the unit under test;
- at the ambient location described above; and,
- at a height of 1 foot above the unit and 10 inches (25.4 cm) from the center of the two sides of the unit under test.

The unit shall be located on a solid surface. If a platform is used, it is to have a solid top with all sides open for air circulation underneath, and its top shall extend at least 1 foot (30.5 cm) beyond each side and front of the cabinet and extend to the wall in the rear. A test chamber floor that allows for airflow (e.g., through a vent or holes) is considered a platform, and the airflow must not be within 1 foot (30.5 cm) of the base of the test unit.

This platform must be used if the floor temperature is not within 3°F (1.7°C) of the specified ambient temperature. Floor temperature must be verified on an annual basis if a platform is not used under the unit.

Temperature measuring devices shall be shielded so that indicated temperatures are not affected by the operation of the unit under test or adjacent units.

5.3.2 Ambient Relative Humidity

The ambient relative humidity does not need to be controlled.

5.3.3 Air Circulation

The unit under test shall be shielded from forced air currents having a velocity of more than 50 feet/minute (0.254 m/second). At a minimum, measurements shall be taken at a height of 36 inches (91.5 cm) from the floor and 10 inches (25.4 cm) from the centers of the two sides of the unit under test. Air circulation shall be verified at least annually.

5.3.4 Radiation

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 (5.6°C).

5.4 Instruments

5.4.1 Temperature

Temperature readings shall be accurate to ± 0.5°F (± 0.3°C).

5.4.2 Electrical

Electrical measurements shall be recorded with the following instruments or their equivalents:

(1) Watt-hour meters. Instruments shall have a resolution of 0.001 kWh or better.

(2) Voltmeters. The resolution shall be 0.1 V or better.

Instruments used for measuring voltage and energy shall be accurate to within ± 0.5% of the quantity measured.

5.4.3 Time

Time measurements shall be accurate to within 1 minute/24 hours.

5.5 General Test Requirements

For each test, the unit under test shall be operated at the specified test conditions until **stable/steady state condition**.

5.5.1 Power Supply

The electrical power supply shall be 115 ± 1 V, 60 Hz at the product service connection. The actual voltage shall be maintained and recorded throughout the test. Instantaneous voltage fluctuations caused by the turning on or off of electrical components shall not be considered.

5.5.2 **Test Set-up**

The unit under test with its refrigerating mechanism shall be assembled and set up as nearly as practical in accordance with the printed instructions supplied with the unit under test. All packing materials and skid boards shall be removed. The unit under test ,shall be given a "run-in" period of no less than 12 hours of compressor run time before running the energy test. The "run-in" may be made at any convenient room temperature. The product does not need to be anchored or otherwise secured to prevent tipping during energy testing.

Set up shall be to the following conditions

a) **Chiller or drip trays** shall be in their proper places during all tests.

b) Containers, covers, and **shelves** shall not be removed unless specified. **Shelves** and door bins shall be evenly spaced throughout the **compartment** unless otherwise specified in the manufacturer's instructions.

c) **Baffles** shall be open unless otherwise specified in the manufacturer's instructions.

d) **Ice trays** and ice buckets related to non-automatic ice making shall be removed from the **freezer** section. **Ice storage bins** of **automatic ice makers** shall remain in place.

e) Storage baskets in **chest type freezers** shall be removed if they are removable without the use of tools.

f) Movable subdividing barriers that separate **compartments**, shall be placed in the median position. If such a subdividing barrier has an even number of positions, the near-median position representing the smallest volume of the warmer compartment(s) shall be used.

g) Cabinet doors shall be kept closed during all tests

h) Outer door gaskets shall be checked for adequacy of the seal and adjusted, if required.

i) Leads from all measuring devices shall be brought outside of the cabinet in such a manner as to prevent air leakage.

j) **Automatic icemakers** shall be inoperative during the energy test. Only devices or components directly associated with the **harvesting** of ice shall be inoperative during the energy test. All components not explicitly associated with the **harvesting** of ice must be operative during the energy test and shall be energized in a manner necessary to perform their respective functions. Turning off the ice maker for the purposes of the energy test shall only stop the further harvesting of ice. Thus, an ice maker is inoperative when the ice maker has interrupted the harvesting operation, such as when the unit senses that the bin is filled to a predetermined amount.

k) Connection of water lines and installation of water filters are not required.

l) **Ice storage bins** shall be emptied of ice.

m) All the product's chutes and throats required for the delivery of ice shall be free of packing, covers, or other blockages that may be fitted for shipping or when the icemaker is not in use;

n) Any operational mode which reduces energy usage during energy consumption testing and not during normal usage shall be disabled for energy consumption testing.

o) Customer accessible features not required for maintaining temperature in the **refrigerator** and/or **freezer compartment**s, which are electrically powered, manually initiated, and manually terminated, shall be set at their lowest energy usage positions when adjustment is provided.

p) Features that are required to maintain temperature, which are electrically powered, manually initiated, and automatically terminated within 168 hours shall be operated at their lowest energy usage position.

q) The **quick cool** option shall be switched off.

r) Units shipped with communication devices, shall be tested with the communication device on, but not connected to any communication network

s) **Compartment**s that are convertible (e.g., from **fresh food** to **freezer**) shall be operated in the highest energy use position.

t) **Sub-compartment**s with a temperature control shall be tested with controls set to provide the coldest temperature. However, for **sub-compartment**s in which temperature control is achieved using the addition of heat (such as but not limited to resistive electric heating, refrigeration system waste heat, or heat from any other source, but excluding the transfer of air from another part of the interior of the product) for any part of the controllable temperature range of that **compartment**, the product energy use shall be determined by averaging two sets of tests. The first set of tests shall be conducted with such **sub-compartment**s at their coldest settings, and the second set of tests shall be conducted with such **sub-compartment**s at their warmest settings. The requirements for the warmest or coldest temperature settings of this section do not apply to features or functions associated with temperature control that are initiated manually and terminated automatically within 168 hours.

u) Defrost controls shall be operative for all tests.

v) If equipped with a **drain trap**, fill the trap with water.

w) The evaporator in **manual defrost** models need not be defrosted prior to each test unless frost accumulation exceeds ¼ inch (6 mm) in average thickness. **Chiller** or **drip tray** and interior of the unit under test shall be dried prior to start of test after evaporator has been manually defrosted.

x) Tests shall be run with the manual **anti-sweat heater** switch in the highest and lowest energy use positions for each temperature control setting if the product is shipped with the switch in the lowest energy use position. Otherwise, it shall be run only in the highest energy use position for each temperature control setting. Heaters used to prevent internal or external moisture build-up, to keep gaskets pliable, to keep water reservoirs or lines not directly related to ice production from freezing, or deemed as necessary for the operation and reliability of the product shall be functioning during the energy test, unless specifically excluded by the standard. In the case of a unit equipped with variable **anti-sweat heater** control, the standard cycle energy use shall be the result of the calculation described in section 5.9.6.

5.5.3 Rear Clearance

(a) General. The space between the lowest edge of the rear plane 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, unless other provisions of this section apply. The rear plane shall be considered to be the largest flat surface at the rear of the cabinet, excluding features that protrude beyond this surface, such as brackets or compressors.

(b) Maximum clearance. The clearance shall not be greater than 2 inches (51 mm) from the lowest edge of the rear plane to the vertical surface, unless the provisions of paragraph (c) of this section apply.

(c) If permanent rear spacers or other components that protrude beyond the rear plane extend further than the 2 inch (51 mm) distance, or if the highest edge of the rear plane is in contact with the vertical surface when the unit is positioned with the lowest edge of the rear plane at or further than the 2 inch (51 mm) distance from the vertical surface, the appliance shall be located with the spacers or other components protruding beyond the rear plane, or the highest edge of the rear plane, in contact with the vertical surface.

(d) Rear-mounted condensers. If the product has a flat rear-wall-mounted condenser (i.e., a rear-wall-mounted condenser with all refrigerant tube centerlines within 0.25 inches (6.4 mm) of the condenser plane), and the area of the condenser plane represents at least 25% of the total area of the rear wall of the cabinet, then the spacing to the vertical surface may be measured from the lowest edge of the condenser plane

5.5.4 Load Conditions for freezers of Automatic Defrost products

There shall be no loads in the **freezer compartments** of **automatic defrost freezers**, **refrigerator-freezers**, **all-refrigerators** and **cooler-refrigerators**.

5.5.5 Temperature Sensors

With the exception of temperatures measured in filled packages (Section 5.5.6.3), temperatures shall be measured using weighted temperature sensors. Weighting shall be a cylindrical brass or copper mass 1.12 ± 0.25 inches (2.9 ± 0.6 cm) in diameter and height, in good thermal contact with each temperature sensor. All temperature measuring sensors shall be centered in the mass, which shall be suspended in air or supported by low-thermally conductive material in such a manner that there will be at least 1 inch (2.5 cm) of air space separating the thermal mass from contact with any surface. In case of interference with any surface at the sensor locations specified in 5.8.1, place the sensors at the nearest adjacent location such that there will be a 1 inch (2.5 cm) air space separating the sensor mass from the surface.

5.5.6 Temperature Measurement

5.5.6.1 **Fresh Food Compartment** Temperature (**refrigerators** and **refrigerator-freezers**)

Temperatures shall be recorded at three locations as shown in Figure 5-1.

If the interior arrangements of the cabinet do not conform to those shown in Figure 5-1, measurements shall be taken at selected locations chosen to approximately represent the entire **fresh food compartment**. The locations selected shall be recorded.

The recorded temperature at any given point shall be the average temperature at that point during a cycle of operation with the temperatures being read at regular intervals not exceeding 1 minute.

5.5.6.2 **Freezer Compartment** Temperature (**Manual Defrost Refrigerator-Freezers** and **Freezers**)

Freezer compartment temperatures shall be measured at the geometric center of the filled packages described below, with the packages located so the temperature measurement stations approximate the locations shown in Figure 5-2.

Temperatures shall be measured by unweighted thermocouples, located in the geometric center of packages, measuring approximately 5 × 4 × 1½ inches (approximately 13 × 10 × 4 cm).

The packages shall be sealed and shall contain a liner or wrapper that makes them moisture and vapor-proof. The packages shall be filled to a density of 35 ± 5 lbs per cubic foot (560 ± 80 kg/m³) with hardwood sawdust that has been water-soaked or, alternately, is an equivalent package of frozen food such as chopped spinach.

The **freezer compartment** shall be loaded with 75% of the maximum number of filled packages that fit into the **compartment**. The number of packages comprising the 75% load shall be determined by filling the **compartment** completely with the packages that are to be used for the test, such that the packages fill as much of the usable refrigerated space within the **compartment** as is physically possible, and then removing from the **compartment** a number of packages so that the **compartment** contains 75% of the packages that were placed in the **compartment** to completely fill it. If multiplying the total number of packages by 0.75 results in a fraction, the number of packages used shall be rounded to the nearest whole number, rounding up if the result ends in 0.5. For multi-**shelf** units, this method shall be applied to each **shelf**. For both single- and multi-**shelf** units, the remaining packages shall be arranged as necessary to provide the required air gap and thermocouple placement. The number of packages comprising the 100% and 75% loading conditions shall be recorded in the test data. The 75% load shall be fit into the **compartment**(s) so as to permit air circulation around and above the load.

The air gap around the **freezer compartment** load shall be ½ to 1½ inches (1.5 to 4 cm) with the packages in a pyramid or tiered form if necessary to properly locate the thermocouples. Packages shall rest on the bottom of the **liner** or on top of a trivet if furnished.

NOTE 1: In order to keep packages from shifting and destroying the air gap, a wire grid with small, non-thermally conductive spacers for contact with **freezer** liner may be used.

NOTE 2: In order to keep the packages from shifting during test, a paper or similar material may be inserted between the layers of the packages.

Each **shelf** of **freezer**s and **freezer** sections of **combination refrigerator-freezers**, where applicable, shall be loaded to 75% of its capacity in pyramid or tiered form, as necessary, for the proper location of the thermocoupled frozen food package.

Freezer door **shelves** shall be loaded with the maximum number of filled packages that can be retained on each shelf without added restraints.

If the interior arrangements of the **freezer compartment shelves** do not conform with those shown in Figure 5-2, measurements shall be taken at locations selected to represent the intent of the standard. The locations selected shall be recorded. The recorded temperature at any given point during a cycle of operation with the temperature being read at regular intervals not exceeding 1 minute.

5.5.6.3 **Cooler compartment** Temperature (**Miscellaneous Refrigeration Products**)

Temperatures shall be recorded as in Section 5.5.6.1.

5.5.6.4 **Freezer Compartment** Temperature (**Automatic Defrost Freezer**)

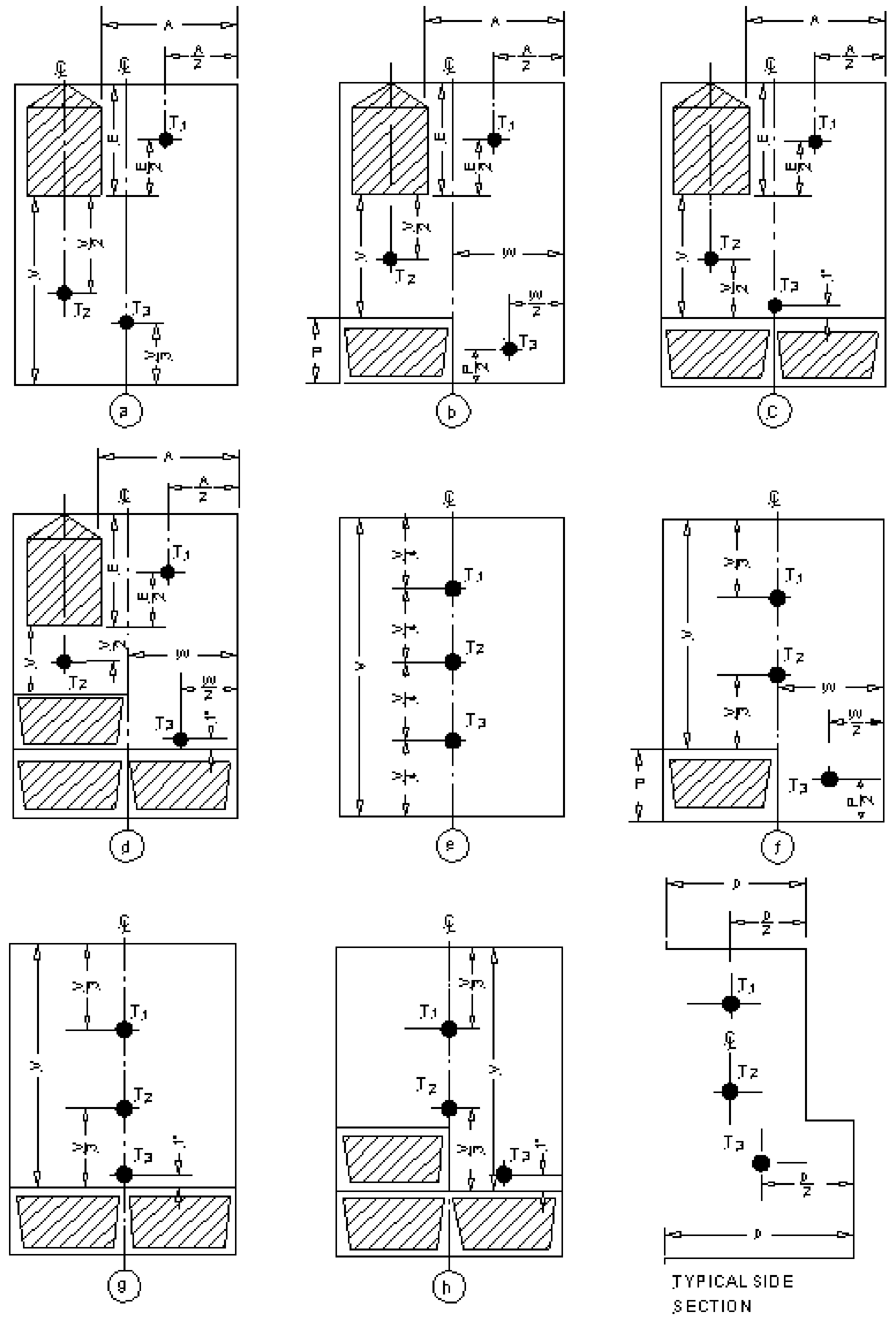
Temperatures shall be recorded at three or five locations as shown by Figure 5-2.

If the interior arrangements of the cabinet do not conform to those shown in Figure 5-2, measurements shall be taken at selected locations chosen to approximately represent the entire **freezer compartment**, the locations being recorded.

The recorded temperature shall be the average temperature at that point during a cycle of the operation with the temperatures being read at regular intervals not exceeding 1 minute.

5.5.6.5 **Ice Storage Compartment** Temperature

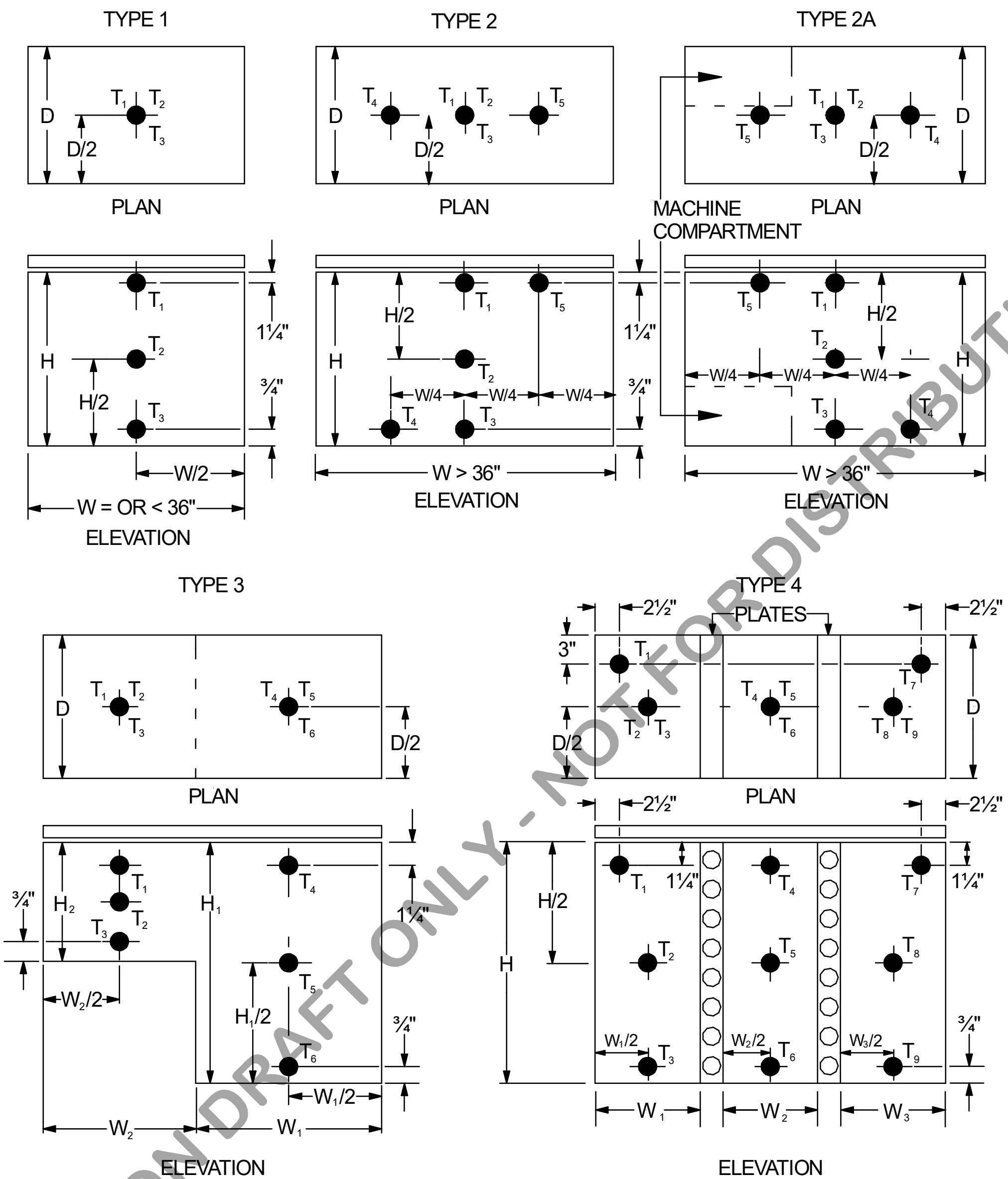
Place weighted thermocouple in the geometric center of the **ice storage compartment**. Move the thermocouple from that position as necessary to maintain 1 inch clearance between sensors and nearest surface.



"A", "D", "E", "W" and "V" are arbitrary designations for determining location at which temperatures are to be measured. The depth dimension shall be measured from the back of the liner to a plane defining the gasket sealing surface. T1, T2 and T3 indicate thermocouple locations.

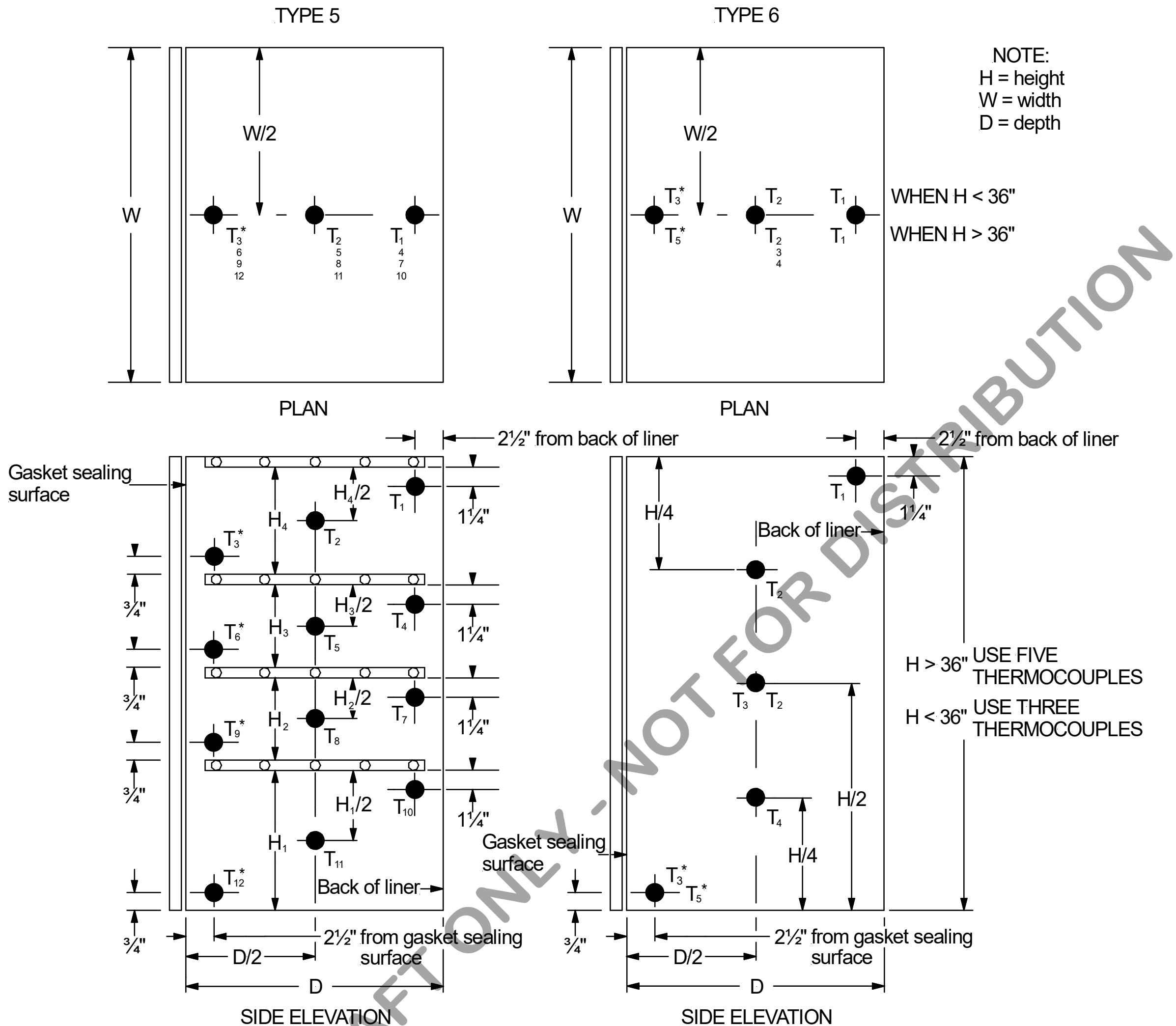
NOTE: If the **Compartment** volume is less than 2 cubic feet (0.06 cubic meter), then a single thermocouple shall be located at the geometric center of the **Compartment**.

Figure 5-1: Thermocouple Locations for Determination of Fresh Food/Cooler Compartment Temperatures



Type 1, 2 and 3	**Chest Freezer** (lift cover) with refrigerated walls
Type 4	**Chest Freezer** (lift cover) with refrigerated walls
Type 5	**Vertical Freezer** (front door/drawer) with refrigerated shelves (door/drawer located at left)
Type 6	Evaporator or **freezer Compartment** of **refrigerator**s (except All-Refrigerators) or Vertical Freezers (front door/drawer) with refrigerated walls or with concealed evaporator (door/drawer located at left)

Figure 5-2: Thermocouple Locations for Determination of Freezer Compartment Temperatures



* If a projection on the inner door interferes with these thermocouple locations, move them rearward to clear the projection.

- For types 1, 2, 3 and 4; the height dimension shall be measured from the bottom of the liner (or from the top of a trivet, if furnished) to a plane defining the gasket sealing surface.
- For types 5 and 6; the height dimension shall be measured from the bottom of the liner (or from the top of a trivet, if furnished).
- For types 5 and 6; the depth dimension shall be measured from the back of the liner to a plane defining the gasket sealing surface.
- For type 5; non-refrigerated shelves are treated as if they were not there.
- For type 6, in case of evaporator or **freezer Compartment** of **refrigerator**s (except all-refrigerators), the width, height and depth dimensions shall be measured in the same manner as refrigerated volume computation described in Section 4.
- For type 6; automatic defrost **freezer**s T1, T3, and T5 should allow 1 inch (2.54 cm) air space between sensors and nearest surface.

Note:

- For load tests, the thermocouple location designates the approximate geometric center of a 5 × 4 × 1 ½ inch (approximately 13 × 10 × 4 cm) frozen food package.
- If the **Compartment** volume is less than 2 cubic feet (0.06 cubic meter), then a single thermocouple shall be located at the geometric center of the **Compartment**.

Figure 5-2 (continued) — Thermocouple Locations for Determination of Freezer Compartment Temperatures

5.6 Temperature Control Settings

Testing shall be performed in accordance with one of the following sections using the appropriate standardized reference temperatures:

- **All-refrigerator** 39°F (3.9°C) **fresh food compartment** temperature.
- **Refrigerator** 39°F (3.9°C) **fresh food compartment** temperature and 15°F (-9.4°C) **freezer Compartment** temperature.
- **Refrigerator-freezer** 39°F (3.9°C) **fresh food compartment** temperature and 0°F (-17.8°C) **freezer compartment** temperature.
- **Freezer** 0°F (-17.8°C).
- **Miscellaneous refrigeration products** 55°F (12.8°C) **cooler compartment** temperature.

5.6.1 Model with No User Operable Temperature Control

Compartment temperature and energy consumption shall be measured:

(1) with the temperature control operating; and

(2) If the temperature with the control operating is warmer than the standardized reference temperature with the temperature control electrically short-circuited to cause the compressor to run continuously. If the model has the **quick cool** option, it shall be used to bypass the temperature control.

5.6.2 Model with User Operable Temperature Control

5.6.2.1 For mechanical control systems, (a) knob detents shall be mechanically defeated if necessary to attain a median setting, and (b) the warmest and coldest settings shall correspond to the positions in which the indicator is aligned with control symbols indicating the warmest and coldest settings. For electronic control systems, the test shall be performed with all compartment temperature controls set at the average of the coldest and warmest settings; if there is no setting equal to this average, the setting closest to the average shall be used. If there are two such settings equally close to the average, the higher of these temperature control settings shall be used.

5.6.2.2 Perform the following two tests:

(1) A first test shall be performed with all **compartment** temperature controls set at their median position midway between their warmest and coldest settings. For mechanical control systems, knob detents shall be mechanically defeated if necessary to attain a median setting. For electronic control systems, the test shall be performed with all **compartment** temperature controls set at the average of the coldest and warmest settings—if there is no setting equal to this average, the setting closest to the average shall be used. If there are two such settings equally close to the average, the higher of these temperature control settings shall be used.

(2) A second test shall be performed with all controls set at their warmest setting or all controls set at their coldest setting (not electrically or mechanically bypassed). This setting shall be the appropriate setting that attempts to achieve **compartment** temperatures measured during the two tests which bound (i.e., one is warmer than

and one is colder than) the standardized reference temperature. Refer to Table 5-1 for all configurations to determine which test results to use in the energy consumption calculation. If any **compartment** is warmer than its standardized temperature for a test with all controls at their coldest position, the tested unit cannot be rated.

TABLE 5-1: TEMPERATURE SETTINGS: GENERAL CHART FOR ALL PRODUCTS

First test		Second test		Energy calculation based on:
Setting	**Results**	**Setting**	**Results**	
Mid for all Compartments	all compartments below standard reference temperature	Warmest for all Compartments	all **compartment**s below standard reference temperature	Second Test Only
			One or more **compartment**s above standard reference temperature	First and Second Test
	One or more compartments above standard reference temperature	Coldest for all Compartments	all **compartment**s below standard reference temperature	First and Second Test
			One or more **compartment**s above standard reference temperature	No Energy Use Rating

(3) Alternatively, a first test may be performed with all temperature controls set at their warmest setting. If all **compartment** temperatures are below the appropriate standardized temperatures, then the result of this test alone will be used to determine energy consumption. If this condition is not met, then the unit shall be tested in accordance with 5.6.2 (1) & (2).

5.6.3 Temperature Settings for convertible Compartments:

(1) For convertible **compartment**s tested as **freezer compartment**s, the median setting shall be within 2°F (1.1°C) of the standardized reference temperature, and the warmest setting shall be above 5°F (−15°C) or warmest **freezer** setting (whichever is coldest).

(2) For convertible **compartment**s tested as **fresh food compartment**s, the median setting shall be within 2°F (1.1°C) of the standardized reference temperature, the

coldest setting shall be lower than 34°F (1.1°C) or the coldest fresh food setting (whichever is warmest) and the warmest setting shall be above 44°F (6.7°C) or warmest fresh food setting (whichever is coldest).

(3) For convertible **compartments** tested as **cooler compartments**, the median setting shall be within 2°F (1.1°C) of 55°F (12.8°C), and the coldest setting shall be lower than 50°F (10.0°C) or the coldest cooler setting (whichever is warmer).

(4) For **compartments** where control settings are not expressed as particular temperatures, the measured temperature of the convertible **compartment** rather than the settings shall meet the specified criteria.

(5) For **Compartment**s where control settings are not expressed as particular temperatures, the measured temperature of the convertible **compartment** rather than the settings shall meet the specified criteria.

(6) Optional Test for Models with two **compartment**s and user operable controls: as an alternative to section 5.6, perform three tests such that the set of tests meets the "minimum requirements for interpolation" of AS/NZS 4474.1:2007 appendix M, section M3, paragraphs (a) through (c) and as illustrated in Figure M1. The target temperatures t_{xA} and t_{xB} defined in section M4(a)(i) of AS/NZS 4474.1:2007 shall be the standardized temperatures defined in section 5.6.

5.7 Test Period

Perform tests by establishing the conditions set forth in Section 5.3, and using control settings as set forth in 5.6 above.

5.7.1 Non-Automatic Defrost

The test period shall be the time period used to verify **stable/steady state condition**s, as specified in section 3.28(a).

5.7.2 Automatic Defrost

If the model being tested has an **automatic defrost system**, the test time period shall be started after **stable/steady state condition**s have been achieved, and shall be from one point during a **defrost cycle** to the same point during the next **defrost cycle**. If the model being tested has a **long-time automatic defrost system**, the alternative provisions of section 5.7.2.1 may be used. If the model being tested has a **variable defrost control**, the provisions of section 5.7.2.2 shall apply. If the model is a **multiple-compressor product** with **automatic defrost**, the provisions of section 5.7.2.4 shall apply. If the model being tested has **long-time automatic** or variable defrost control involving multiple **defrost cycle type**s, such as for a product with a single compressor and two or more evaporators in which the evaporators are defrosted at different frequencies, the provisions of section 5.7.2.3 shall apply. If the model being tested has multiple **defrost cycle type**s for which compressor run time between defrosts is a fixed time of less than 14 hours for all such cycle types, and for which the compressor run times between defrosts for different **defrost cycle type**s are equal to or multiples of each other, the test period shall be from one point of the **defrost cycle type** with the longest compressor run time between defrosts to the same point during the next occurrence of this **defrost cycle type**. For such products not using the procedures of section 5.7.2.3, energy consumption shall be calculated as described in section 5.8.2.1.1.

5.7.2.1 **Long-Time Automatic Defrost**

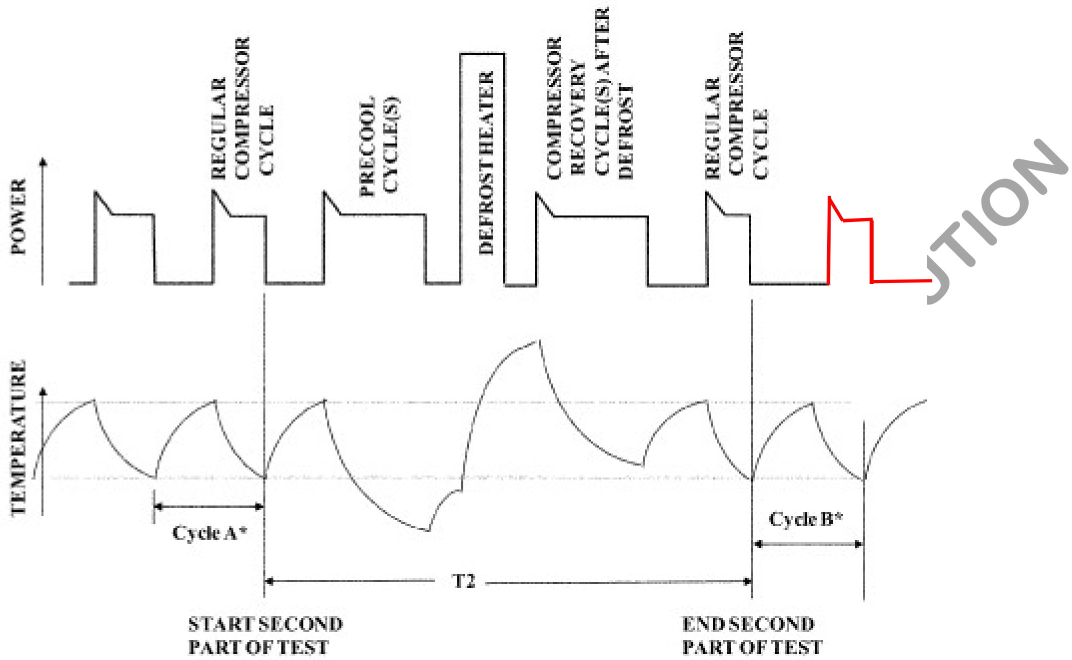
5.7.2.1.1 If steady state conditions were verified per section 3.28(a), the two part method may be used. The first part is the steady state verification period. The second part is designed to capture the energy consumed during all of the events occurring with the defrost control sequence that are outside of stable operation.

5.7.2.1.2 If steady state conditions were verified per section 3.28(b), the test period shall be from one point of the defrost cycle type with the longest compressor run time between defrosts to the same point during the next occurrence of this defrost cycle type.

5.7.2.1.3 Part 2 for a Cycling Compressor System: For a system with a cycling compressor, the second part of the test starts at the termination of the last regular compressor “on” cycle. The average temperatures of the fresh food compartment, freezer compartment and cooler compartment measured from the termination of the previous compressor “on” cycle to the termination of the last regular compressor “on” cycle must both be within 0.5°F (0.3°C) of their average temperatures measured for the first part of the test. If any compressor cycles occur prior to the defrost heater being energized that cause the average temperature in either compartment to deviate from its average temperature for the first part of the test by more than 0.5°F (0.3°C), these compressor cycles are not considered regular compressor cycles and must be included in the second part of the test. As an example, a “precooling” cycle, which is an extended compressor cycle that lowers the temperature(s) of one or both compartments prior to energizing the defrost heater, must be included in the second part of the test. The test period for the second part of the test ends at the termination of the first regular compressor “on” cycle after both compartment temperatures have fully recovered to their stable conditions. The average temperatures of the compartments measured from this termination of the first regular compressor “on” cycle until the termination of the next regular compressor “on” cycle must both be within 0.5°F (0.3°C) of their average temperatures measured for the first part of the test. See Figure 5-3. Note that Figure 5-3 illustrates the concepts of precooling and recovery but does not represent all possible defrost cycles.

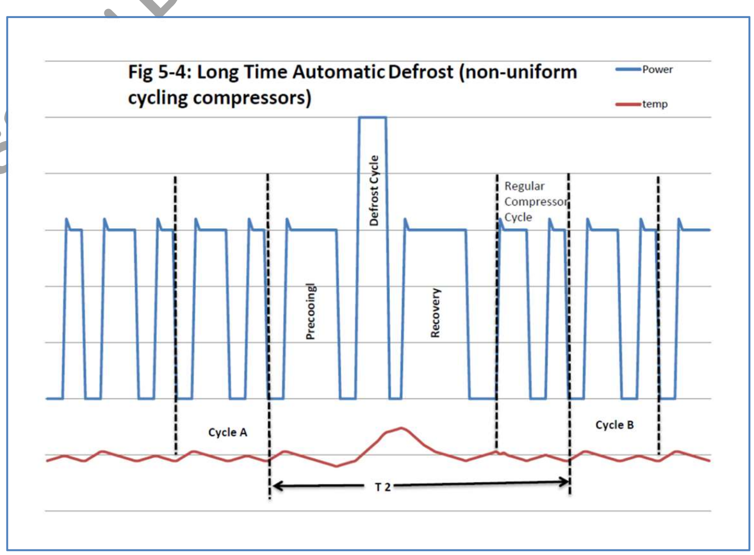
Fig 5-3

Long-time Automatic Defrost Diagram for Cycling Compressors



*Average compartment temperature(s) during cycles A & B must be within 0.5˚F of the average temperature(s) for the first part of the test.

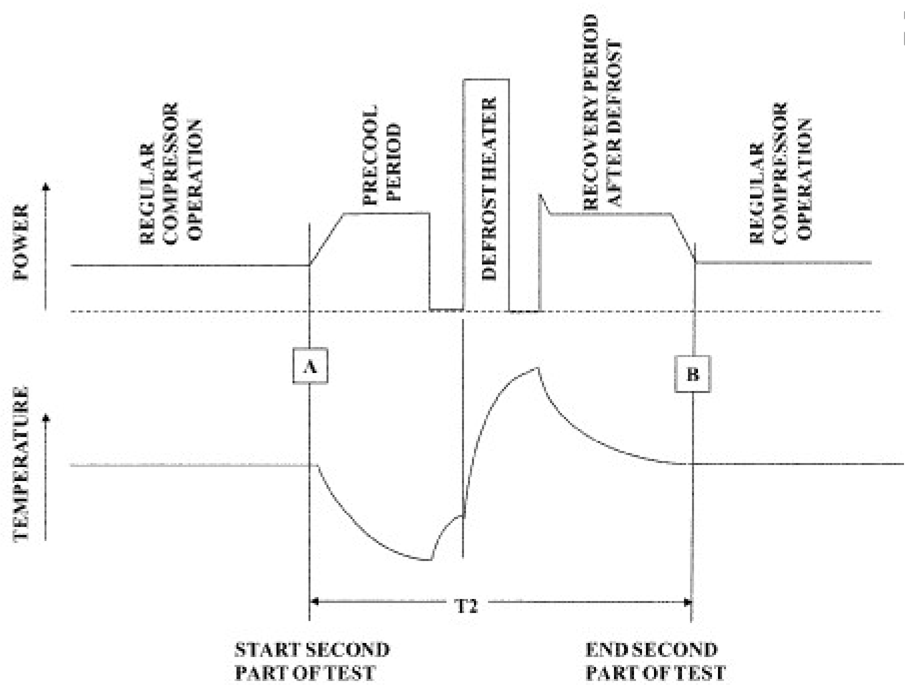
5.7.2.1.4 For systems with non-uniform cycling compressors: when using a compressor cycle pattern to establish cycle A, cycle B and the first part of the test, the compressor cycle pattern shall be the same for all (See figure 5-4). The compressor cycle pattern used to establish the first part of the test must include at least one whole repeating sequence or as many as necessary to meet the requirements in 3.28 (a).



5.7.2.1.5 Part 2 for a Non-cycling Compressor System: For a system with a non-cycling compressor, the second part of the test starts at a time before defrost during stable operation when the temperatures of both fresh food compartment and freezer compartments are within 0.5 °F (0.3 °C) of their average temperatures measured for the first part of the test. The second part stops at a time after defrost during stable operation when the temperatures of both compartments are within 0.5 °F (0.3 °C) of their average temperatures measured for the first part of the test. See Figure 5-5.

Fig 5-5

Long-time Automatic Defrost Diagram for Non-Cycling Compressors



*Average compartment temperature(s) at times A & B must be within 0.5 °F of the average temperature(s) for the first part of the test.

5.7.2.2 Variable Defrost Control: If the model being tested has a **variable defrost control** system, the test shall consist of the same two parts as the test for **long-time automatic defrost** (Section 5.7.2.1).

5.7.2.3 Systems with Multiple Defrost Frequencies: This section applies to models with **long-time automatic** or **variable defrost control** with multiple **defrost cycle types**, such as models with single compressors and multiple evaporators in which the evaporators have different defrost frequencies. The two-part method in 5.7.2.1 shall be used. The second part of the method will be conducted separately for each distinct **defrost cycle type**.

5.7.2.4 **Multiple-compressor Products** with Automatic Defrost

5.7.2.4.1 Measurement Frequency: Measurements of power input, cumulative electric energy consumption (watt-hours or kilowatt-hours), and Compartment temperature shall be taken at regular intervals not exceeding one minute.

5.7.2.4.2 Steady-state Condition: Steady state shall be considered to have been attained after 24 hours of operation after the last adjustment of the temperature controls.

5.7.2.4.3 Primary Compressor: If at least one compressor cycles, test periods shall be based on compressor cycles associated with the primary compressor system (these are referred to as "primary compressor cycles"). If the freezer compressor cycles, it shall be the primary compressor system.

5.7.2.4.4 Test Periods: The two-part test described in this section shall be used. The first part is a stable continuous period of compressor operation that includes no defrost cycles or events associated with a defrost cycle, such as precooling or recovery, for any compressor system. The second part is a continuous test period designed to capture the energy consumed during all of the events occurring with the defrost control sequence that are outside of stable operation. The second part of the test shall be conducted separately for each automatic defrost system present.

a) First Part of Test:

If at least one compressor cycles, the test period for the first part of the test shall include a whole number of complete primary **compressor cycles** comprising at least 24 hours of stable operation, unless a defrost occurs prior to completion of 24 hours of stable operation, in which case the first part of the test shall include a whole number of complete primary **compressor cycles** comprising at least 18 hours of stable operation. If no compressor cycles, the first part of the test shall comprise at least 24 hours of stable operation, unless a defrost occurs prior to completion of 24 hours of stable operation, in which case the first part of the test shall comprise at least 18 hours of stable operation.

b) Second Part of Test:

(i). If at least one compressor cycles, the test period for the second part of the test starts during stable operation before all portions of the **defrost cycle**, at the beginning of a complete primary **compressor cycle**. The test period for the second part of the test ends during stable operation after all portions of the **defrost cycle**, including **recovery**, at the termination of a complete primary **compressor cycle**. The start and stop for the test period shall both occur either when the primary compressor starts or when the primary compressor stops. For each compressor system, the **compartment** temperature averages for the first and last complete **compressor cycles** that lie completely within the second part of the test must be within 0.5°F (0.3°C) of the average **compartment** temperature measured for the first part of the test. If any one of the compressor systems is non-cycling, its **compartment** temperature averages during the first and last complete primary

compressor cycles of the second part of the test must be within 0.5°F (0.3°C) of the average **compartmen**t temperature measured for the first part of the test. If this criteria cannot be met, the test period shall comprise at least 24 hours, unless a defrost occurs prior to completion of 24 hours, in which case the test shall comprise at least 18 hours. The test period shall start at the end of a regular **freezer** compressor on-cycle after the previous defrost occurrence any **compartment** The test period also includes the target defrost and following **freezer compressor cycles**, ending at the end of a **freezer** compressor on-cycle before the next defrost occurrence of any **compartment**.

(ii). If no **compressor cycles**, the test period for the second part of the test starts during stable operation before all portions of the **defrost cycle**, when the **compartment** temperatures of all compressor systems are within 0.5°F (0.3°C) of their average temperatures measured for the first part of the test. The test period for the second part ends during stable operation after all portions of the **defrost cycle**, including **recovery**, when the **compartment** temperatures of all compressor systems are within 0.5°F (0.3°C) of their average temperatures measured for the first part of the test.

5.8 Test Measurements

5.8.1 Temperature Measurements.

Record temperature measurements at the locations prescribed in Figures 5-1 and 5-2. Temperature measurements shall be accurate to within ± 0.5°F (0.3°C) of true value. No **freezer** temperature measurements need be taken in an **all-refrigerator or cooler-all-refrigerator** models.

For **miscellaneous refrigeration products**, **refrigerators** and **refrigerator-freezers**, if the interior arrangements of the cabinet do not conform to those shown in Figure 5-1 and Figure 5-2, measurements shall be taken at selected locations chosen to represent approximately the entire refrigerated **compartment**. Each **compartment** shall have the number of thermocouples specified in Figure 5-1 and Figure 5-2. Record the locations selected.

5.8.1.1 Measured Temperature.

The measured temperature of a **compartment** shall be the average of all sensor temperature readings taken in that **compartment** at a particular time. Take measurements at regular intervals not to exceed 1 minute.

5.8.1.2 **Compartment** Temperature.

5.8.1.2.1 The **compartment** temperature for each test period shall be an average of the measured temperatures taken in a compartment during a complete cycle or several complete cycles of the compressor motor (one compressor cycle is one complete motor "on" and one complete motor "off" period).

5.8.1.2.2 For models using the two part method, compartment temperatures shall be those measured in the first part of the test period specified in Section 5.7.2.4.4. Otherwise, compartment temperature shall be an average of the measured temperatures taken in a compartment during a stable period of compressor operation that:

a) Includes no defrost cycles or events associated with a defrost cycle, such as **precooling** or **recovery**;

b) Is no less than three hours in duration; and

c) Includes two or more whole **compressor cycles**. If the compressor does not cycle, the stable period used for the temperature average shall be three hours in duration.

5.8.1.2.3 If incomplete cycling occurs (less than one cycle), the compartment temperatures shall be the average of the measured temperatures taken during the last 3 hours of the last complete "on" period.

5.8.1.2.4 **Fresh Food Compartment** Temperature

The **fresh food compartment** temperature shall be calculated as:

$$TR = \frac{\sum_{i=1}^{R}(TR_i) \times (VR_i)}{\sum_{i=1}^{R}(VR_i)}$$

Where:

R is the total number of applicable **fresh food compartment**s, which include the first **fresh food compartment** and any number of **fresh food compartment**s (including convertible **compartment**s tested as **fresh food compartment**s in accordance with section 5.5.2 (s));

TR_i is the **compartment** temperature of **fresh food Compartment** “i” determined in accordance with section 5.5.6.1;

VR_i is the volume of **fresh food compartment** “i”.

5.8.1.2.5 Freezer Compartment Temperature

The **freezer compartment** temperature shall be calculated as:

$$TF = \frac{\sum_{i=1}^{F}(TF_i) \times (VF_i)}{\sum_{i=1}^{F}(VF_i)}$$

Where:

F is the total number of applicable **freezer compartment**s, which include the first **freezer compartment** and any number of **freezer compartment**s (including convertible **compartment**s tested as **freezer compartment**s in accordance with section 5.5.2 (s);

TF_i is the **compartment** temperature of **freezer compartment** “i” determined in accordance with section 5.5.6.2;

VF_i is the volume of **freezer compartment** “i”.

5.8.1.2.6 Cooler Compartment Temperature.

The **cooler compartment** temperature shall be calculated as:

$$TC = \frac{\sum_{i=1}^{C}(TC_i) \times (VC_i)}{\sum_{i=1}^{C}(VC_i)}$$

Where:

C is the total number of applicable **cooler compartment**s, which include the first **cooler compartment** and any number of **cooler compartment**s (including convertible **compartment**s tested as **cooler compartment**s in accordance with section 5.5.2 (f);

TC_i is the **compartment** temperature of **cooler compartment** "i" determined in accordance with section 5.5.6.3;

VC_i is the volume of **cooler Compartment** "i".

5.8.2 Energy Consumption

5.8.2.1 Per-Day Energy Consumption. The energy consumption in kWh/day for each test period shall be the energy expended during the test period as specified in section 5.7 adjusted to a 24-hour period. This adjustment shall be determined as specified below.

5.8.2.1.1 Non-Automatic and Automatic Defrost Models. The energy consumption in kWh/day shall be calculated equivalent to:

$$ET = \frac{1440 \times EP \times K}{T}$$

Where:

ET = test cycle energy expended in kWh/day;

EP = energy expended in kWh during the test period;

T = length of time on the test period, in minutes;

1440 = conversion factor to adjust to a 24-hour period in minutes per day;

K = correction factor of 0.7 for chest **freezer**s and 0.85 for upright **freezer**s and 0.55 for **miscellaneous refrigeration products** (1.0 for all other models) to adjust for average usage, dimensionless.

5.8.2.1.2 Long-Time Automatic Defrost
If the two-part test method is used, the energy consumption in kWh/day shall be calculated equivalent to:

$$ET = \left(1440 \times K \times \frac{EP1}{T1}\right) + \left[EP2 - (EP1 \times \frac{T2}{T1})\right] \times K \times \frac{12}{CT}$$

Where:

ET, 1440 and K are defined in Section 5.8.2.1.1;

EP1 = energy expended during the first part of the test, in kilowatt-hours;

EP2 = energy expended during the second part of the test, in kilowatt-hours;

T1 and T2 = length of time in minutes of the first and second test parts respectively;

CT = compressor on time between defrost heater-on events in hours required to cause it to go through a complete cycle, rounded to the nearest tenth of an hour;

12 = factor to adjust for a 50% run time of the compressor in hours per day.

5.8.2.1.3 Variable Defrost Control

The energy consumption in kilowatt-hours per day shall be calculated equivalent to:

$$ET = \left(1440 \times \frac{EP1}{T1}\right) \times K + \left[EP2 - (EP1 \times \frac{T2}{T1})\right] \times K \times \frac{12}{CT}$$

Where:

1440 and K are defined in 5.8.2.1.1;

EP1, EP2, T1, T2, and 12 are defined in Section 5.8.2.1.2.

$$CT = \frac{(CT_L \times CT_M)}{[F \times (CT_M - CT_L) + CT_L]}$$

Where:

CT_L = Shortest cumulative compressor-on time between defrost heater-on events used in the variable defrost control algorithm, or the shortest cumulative compressor-on time between defrosts observed for the test (if it is shorter than the shortest cumulative on time used in the control algorithm), in hours rounded to the nearest tenth of an hour;

CT_M = Maximum cumulative compressor-on time between defrost heater-on events in hours rounded to the nearest tenth of an hour (greater than CTL but not more than 96 hours)

$0 < CT_L < CT_M \leq 96$

F = ratio of per day energy consumption in excess of the least energy and the maximum difference in per day energy consumption and is equal to 0.20.

5.8.2.1.4 For demand defrost models with no values for CT_L and CT_M in the algorithm, the default values of 6 and 96, respectively, shall be used,.

5.8.2.1.5 Multiple-compressor Products with Automatic Defrost

The two-part test method in Section 5.7.2.1 shall be used, the energy consumption in kilowatt per day shall be calculated equivalent to:

$$ET = \left(1440 \times K\ X\ \frac{EP1}{T1}\right) + \sum_{i=1}^{D}\left[\left(EP2_i - \left(EP1 \times \frac{T2_i}{T1}\right)\right) \times K\ X \left(\frac{12}{CT_i}\right)\right]$$

Where:

I = a variable that can equal 1, 2, or more that identifies each individual compressor system that has automatic defrost;

D = the total number of compressor systems with automatic defrost;

$EP2_i$ = energy expended in kilowatt-hours during the second part of the test for compressor system i;

$T2_i$ = length of time in minutes of the second part of the test for compressor system i;

CT_i = the compressor run time between defrosts for compressor system i in hours rounded to the nearest tenth of an hour, for **long-time automatic defrost** control equal to a fixed time in hours, and for variable defrost control equal to:

$$CT_i = \frac{(CT_{Li} \times CT_{Mi})}{[F \times (CT_{Mi} - CT_{Li}) + CT_{Li}]}$$

Where:

CT_{Li} = for compressor system i, the shortest cumulative compressor-on time between defrost heater-on events used in the variable defrost control algorithm, or the shortest ≤cumulative compressor-on time between defrosts observed for the test (if it is shorter than the shortest cumulative on time used in the control algorithm), in hours rounded to the nearest tenth of an hour;

CT_{Mi} = for compressor system i, Maximum cumulative compressor-on time between defrost heater-on events in hours rounded to the nearest tenth of an hour (greater than CT_{Li} but not more than 96 hours)

$$0 < CT_{Li} < CT_{Mi} \leq 96$$

F = default defrost energy consumption factor, equal to 0.20.

5.8.2.1.6 Long-time or Variable Defrost Control for Systems with Multiple Defrost Cycle Types

The energy consumption in kilowatt-hours per day shall be calculated equivalent to:

$$ET = \left(1440 \times K \times \frac{EP1}{T1}\right) + \sum_{i=1}^{D}[\left(EP2_i - \left(EP1 \times \frac{T2_i}{T1}\right)\right) \times K \times \left(\frac{12}{CT_i}\right)]$$

Where:

1440 and K are defined in section 5.2.1.1 of this appendix and EP1, T1, and 12 are defined in section 5.2.1.2 of this appendix;

i is a variable that can equal 1, 2, or more that identifies the distinct **defrost cycle type**s applicable for the product;

$EP2_i$ = energy expended in kilowatt-hours during the second part of the test for **defrost cycle type** i;

$T2_i$ = length of time in minutes of the second part of the test for **defrost cycle type** i;

CT_i is the compressor run time between instances of **defrost cycle type** i, for **long-time automatic defrost control** equal to a fixed time in hours rounded to the nearest tenth of an hour, and for variable defrost control equal to:

$$CT_i = \frac{(CT_{Li} \times CT_{Mi})}{(F \times (CT_{Mi} - CT_{Li}) + CT_{Li})}$$

CTLi = least or shortest compressor run time between instances of defrost cycle type i in hours rounded to the nearest tenth of an hour (CTL for the defrost cycle type with the longest compressor run time between defrosts must be greater than or equal to 6 but less than or equal to 12 hours);

CTMi = maximum compressor run time between instances of defrost cycle type i in hours rounded to the nearest tenth of an hour (greater than CTLi but not more than 96 hours);

For cases in which there are more than one fixed CT value (**for long-time automatic defrost** models) or more than one CTM and/or CTL value (for variable defrost models) for a given defrost cycle type, an average fixed CT value or average CTM and CTL values shall be selected for this cycle type so that 12 divided by this value or values is the frequency of occurrence of the defrost cycle type in a 24 hour period, assuming 50% compressor run time.

F = default defrost energy consumption factor, equal to 0.20.

5.8.2.1.7 For variable defrost models with no values for CT_{Li} and CT_{Mi} in the algorithm, the default values of 6 and 96 shall be used, respectively.

5.9 Determination of Results of Average Per-Cycle Energy Consumption

5.9.1 All-Refrigerator Models

The average per-cycle energy consumption is expressed in kWh per cycle to the nearest one hundredth (0.01) kWh and is to depend upon the temperature attainable in the **fresh food compartment** as shown below.

5.9.1.1 If the **fresh food compartment** temperature is always colder than 39°F (3.9°C), the average per-cycle energy consumption shall be equivalent to:

$$E = ET1$$

Where:

E = total per-cycle energy consumption in kWh/day;

ET is defined in Section 5.8.2.1;

Number 1 indicates the test period during which the highest **fresh food compartment** temperature is measured.

5.9.1.2 If the average **fresh food compartment** temperature measured for a test period is greater than 39°F (3.9°C), the average per-cycle energy consumption shall be equivalent to:

$$E = ET1 + (ET2 - ET1) \times \frac{(39.0 - TR1)}{(TR2 - TR1)}$$

Where:

E is defined in Section 5.9.1.1;

ET is defined in Section 5.8.2.1;

39.0 = standardized **fresh food compartment** temperature in °F;

TR = **fresh food compartment** temperature determined according to Section 5.8.1.2, in °F;

Number 1 and 2 indicate measurements taken during the first and second test period, as appropriate.

5.9.2 Refrigerators and Refrigerator Freezers

The average per-cycle energy consumption is expressed in kWh per cycle to the nearest one hundredth (0.01) kWh and is defined in the applicable following manner.

5.9.2.1 If the **fresh food compartment** temperature is at or colder than 39 °F (3.9 °C) in both tests and the freezer Compartment temperature is at or colder than 15 °F (-9.4 °C) in both tests of a refrigerator or at or colder than 0 °F (-17.8 °C) in both tests of a refrigerator-freezer, the per-cycle energy consumption shall be:

$$E = ET1 + IET$$

Where:

ET is defined in 5.8.2.1;

IET, expressed in kilowatt-hours per cycle, equals 0.0767 for a product with an automatic icemaker and otherwise equals 0 (zero);

The number 1 indicates the test period during which the highest **freezer compartment** temperature was measured.

5.9.2.2 If the conditions of 5.9.2.1 do not exist, the per-cycle energy consumption shall be defined by the higher of the two values calculated by the following two formulas:

$$E = ET1 + \left[(ET2 - ET1) \times \frac{(39.0 - TR1)}{(TR2 - TR1)}\right] + IET$$

and

$$E = ET1 + \left[(ET2 - ET1) \times \frac{(k - TF1)}{(TF2 - TF1)}\right] + IET$$

Where:

E is defined in 5.9.1.1;

ET is defined in 5.8.2.1;

IET is defined in 5.9.2.1;

TR and the numbers 1 and 2 are defined in 5.9.1.2;

TF = **freezer compartment** temperature determined according to 5.8.1.2.5 in degrees F;

39.0 is a standardized **fresh food compartment** temperature in degrees F;

k is a constant 15.0 for **refrigerators** or 0.0 for refrigerator-**freezer**s, each being standardized **freezer compartment** temperatures in degrees F.

5.9.3 Combination cooler-all-refrigerator, cooler-refrigerator or cooler-refrigerator-freezer

The average per-cycle energy consumption is expressed in kWh per cycle to the nearest one hundredth (0.01) kWh and is defined in the applicable following manner.

5.9.3.1 If the **fresh food compartment** temperature is at or colder than 39°F (3.9°C) in both tests, the **freezer compartment** temperature is at or colder than 15°F (-9.4°C) in both tests of a **refrigerator** or at or colder than 0°F (−17.8°C). in both tests of a **refrigerator-freezer** and the **cooler compartment** is at or colder than 55°F (12.8°C) in in both tests, the per-cycle energy consumption shall be:

$$E = ET1 + IET$$

Where:

ET is defined in 5.8.2.1;

IET, expressed in kilowatt-hours per cycle, equals 0.0767 for a product with an automatic icemaker and otherwise equals 0 (zero);

The number 1 indicates the test period during which the highest **freezer compartment** temperature was measured.

5.9.3.2 If the conditions of 5.9.3.1 do not exist, the per-cycle energy consumption shall be defined by the higher of the three values calculated by the following three formulas:

$$E = ET1 + \left[(ET2 - ET1) \times \frac{(39.0 - TR1)}{(TR2 - TR1)}\right] + IET$$

,

$$E = ET1 + \left[(ET2 - ET1) \times \frac{(k - TF1)}{(TF2 - TF1)}\right] + IET$$

and

$$\mathrm{E = ET1 + \left[(ET2 - ET1) \times \frac{(55.0 - TC1)}{(TC2 - TC1)}\right] + IET}$$

Where:

E is defined in 5.9.1.1;

ET is defined in 5.8.2.1;

IET is defined in 5.9.2.1;

TR and the numbers 1 and 2 are defined in 5.9.1.2;

TF = **freezer compartment** temperature determined according to 5.8.1.2.5 in degrees F;

TC = **Cooler compartment** temperature determined according to Section 5.8.1.2.6, in °F;

39.0 is a standardized **fresh food compartment** temperature in degrees F;

55.0 is standardized **cooler compartment** temperature in degrees F;

k is a constant 15.0 for **refrigerators** or 0.0 for **refrigerator-freezer**s, each being standardized **freezer Compartment** temperatures in degrees F.

5.9.4 **Upright and Chest Freezers**

The average per-cycle energy consumption is expressed in kWh per cycle to the nearest one hundredth (0.01) kWh and will depend upon the **compartment** temperature attainable as shown below.

5.9.4.1 If the **compartment** temperature is always colder than 0°F (-17.8°C), the average per-cycle energy consumption shall be equivalent to:

$$E = ET1 + IET$$

Where:

E is defined in Section 5.9.1.1;

ET is defined in Section 5.8.2.1;

IET is defined in Section 5.9.2.1;

Number 1 indicates the test period during which the highest **compartment** temperature is measured.

5.9.4.2 If one of the **compartment** temperatures measured for a test period is warmer than 0°F (-17.8°C), the average per-cycle energy consumption shall be the equivalent to:

$$\mathrm{E} = \mathrm{ET1} + \left[(\mathrm{ET2} - \mathrm{ET1}) \times \frac{(0.0 - \mathrm{TF1})}{(\mathrm{TF2} - \mathrm{TF1})}\right] + \mathrm{IET}$$

Where:

E is defined in Section 5.9.1.1;

ET is defined in Section 5.8.2.1;

IET is defined in Section 5.9.2.1;

TF = **freezer compartment** temperature determined according to Section 5.8.1.2.5, in °F;

Numbers 1 & 2 indicate measurements taken during the first and second test period as appropriate;

0.0 = standardized **compartment** temperature, in °F.

5.9.5 **Coolers**

The average per-cycle energy consumption is expressed in kWh per cycle to the nearest one hundredth (0.01) kWh and is to depend upon the temperature attainable in the **cooler compartment** as shown below.

5.9.5.1 If the **Cooler compartment** temperature is always at or colder than 55°F (12.8°C) in both of the tests, the per-cycle energy consumption shall be:

$$E = ET1$$

Where:

E is defined in section 5.9.1.1;

ET is defined in Section 5.8.2.1;

Number 1 indicates the test period during which the warmest **cooler compartment** temperature is measured.

5.9.5.2 If the average **cooler compartment** temperature measured for a test period is warmer than 55°F (12.8°C), the average per-cycle energy consumption shall be equivalent to:

$$E = ET1 + \left[(ET2 - ET1) \times \frac{(55.0 - TC1)}{(TC2 - TC1)}\right]$$

Where:

E is defined in Section 5.9.1.1;

ET is defined in Section 5.8.2.1;

TC = **cooler compartment** temperature determined according to Section 5.8.1.2.6, in °F;

55.0 is a standardized **cooler compartment** temperature, in °F.

5.9.6 Variable Anti-Sweat Heater Models

The standard cycle energy consumption of a **refrigerator-freezer** with a **variable anti-sweat heater** control (E_{std}), expressed in kilowatt-hours per day, shall be calculated equivalent to:

E_{std} = E + (Correction Factor) where E is determined by 5.9.1.1, 5.9.1.2, 5.9.2.1, or 5.9.2.2, whichever is appropriate, with the **anti-sweat heater** disabled (such as but not limited to: **anti-sweat heater** switch in the off position, disabling the heater using software, disabling the heater by physical disconnection, etc…).

Correction Factor = (**Anti-sweat Heater** Power × System-loss Factor) × (24 hrs/1 day) × (1 kW/1000 W)

Where:

Anti-sweat Heater Power = 0.034 * (Heater Watts at 5%RH);

+ 0.211 * (Heater Watts at 15%RH);

+ 0.204 * (Heater Watts at 25%RH);

+ 0.166 * (Heater Watts at 35%RH);

+ 0.126 * (Heater Watts at 45%RH);

+ 0.119 * (Heater Watts at 55%RH);

+ 0.069 * (Heater Watts at 65%RH);

+ 0.047 * (Heater Watts at 75%RH);

+ 0.008 * (Heater Watts at 85%RH);

+ 0.015 * (Heater Watts at 95%RH);

Heater Watts at a specific relative humidity = the nominal watts used by all heaters at that specific relative humidity, 72 °F (22.2 °C) ambient, and reference temperatures of **fresh food compartment** average temperature of 39 °F (3.9 °C), **cooler compartment** average temperature of 55°F (12.8°C), and **freezer compartment** average temperature of 0 °F (−17.8 °C);

System-loss Factor = 1.3.

5.10 Measurement of Annual Energy Consumption

5.10.1 Refrigerators and refrigerator-freezers

The annual energy use, expressed in kilowatt-hours per year, shall be the following, rounded to the nearest kilowatt-hour per year:

(1) For models without an **anti-sweat heater** switch, the representative average use cycle of 365 cycles per year multiplied by the average per-cycle energy consumption for the **standard cycle** in kilowatt-hours per cycle, determined according to section 5.9 of this standard; and

(2) For models having an **anti-sweat heater** switch, the representative average use cycle of 365 cycles per year multiplied by half the sum of the average per-cycle energy consumption for the **standard cycle** and the average per-cycle energy consumption for a test cycle type with the **anti-sweat heater** switch in the position set at the factory just before shipping, each in kilowatt-hours per cycle, determined according to section 5.9 of this standard.

5.10.2 Freezers

The annual energy use of all **freezers**, expressed in kilowatt-hours per year, shall be the following, rounded to the nearest kilowatt-hour per year:

(1) For **freezers** not having an **anti-sweat heater** switch, the representative average use cycle of 365 cycles per year multiplied by the average per-cycle energy consumption for the **standard cycle** in kilowatt-hours per cycle, determined according to section 5.9 of this standard

(2) For **freezers** having an **anti-sweat heater** switch, the representative average use cycle of 365 cycles per year multiplied by half the sum of the average per-cycle energy consumption for the **standard cycle** and the average per-cycle energy consumption for a test cycle type with the **anti-sweat heater** switch in the position set at the factory just before shipping, each in kilowatt-hours per cycle, determined according to section 5.9 of this standard.

5.10.3 Coolers and combination cooler refrigeration products

The annual energy use, expressed in kilowatt-hours per year, shall be the following, rounded to the nearest kilowatt-hour per year:

(1) For models without an **anti-sweat heater** switch, the representative average use cycle of 365 cycles per year multiplied by the average per-cycle energy consumption for the **standard cycle** in kilowatt-hours per cycle, determined according to section 5.9 of this standard; and

(2) For models having an **anti-sweat heater** switch, the representative average use cycle of 365 cycles per year multiplied by half the sum of the average per-cycle energy consumption for the **standard cycle** and the average per-cycle energy consumption for a test cycle type with the **anti-sweat heater** switch in the position set at the factory just before shipping, each in kilowatt-hours per cycle, determined according to section 5.9 of this standard.

6 METHOD FOR COMPUTING ADJUSTED VOLUME OF CONSUMER REFRIGERATION PRODUCTS

6.1 Scope

This section provides a standard method for calculating the adjusted volume of various types of refrigeration products.

6.2 Purpose

The purpose for calculating the adjusted volume is to provide a uniform means of comparing the relative energy efficiency between different products by relating all products to a common base. The adjusted volume is used for Minimum Energy Performance Standards calculations.

6.3 Adjusted Volume

The **adjusted volume** is calculated as follows:

$$\text{Adjusted Volume (AV)} = V_{Cooler} + V_{Fresh\ Food} + (V_{Freezer} \times \text{Adjustment Factor})$$

Where:

V_{Cooler} = Volume of the **cooler compartmen**ts as determined by Section 4;

$V_{Fresh\ Food}$ = Volume of the **fresh food compartmen**ts as determined by Section 4;

$V_{Freezer}$ = Volume of the **freezer compartment**s as determined by Section 4.

6.3.1 Adjustment Factor for Refrigerators and Cooler-refrigerator

(90 – 15) / (90 – 39) = 1.47

6.3.2 Adjustment Factor for All-Refrigerators and Cooler-all refrigerator

(90 – 39) / (90 – 39) = 1.00

6.3.3 Adjustment Factor for Refrigerator-Freezers, Cooler refrigerator-freezers

(90 – 0) / (90 – 39) = 1.76

6.3.4 **Adjustment Factor for Freezers and Cooler-freezer**

(90 – 0) / (90 – 39) = 1.76