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An American National Standard

Standard Test Method for Performance of Staff-Serve Hot Deli Cases[1]

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1. Scope

1.1 This test method evaluates the energy consumption and performance of staff-serve hot deli cases with heated wells located within a fully or partially enclosed heated cavity. The food service operator can use this evaluation to select a staff served hot deli case and understand its energy consumption and performance.

1.2 This test method is applicable to electric powered, hot deli cases that have been designed for staff service of prepared hot food items that are held in open hotel pans.

1.3 The deli case can be evaluated with respect to the following (where applicable):

1.3.1 Energy input rate (10.2),

1.3.2 Holding capacity (10.3),

1.3.3 Holding temperature calibration (10.3),

1.3.4 Preheat energy rate, (10.4),

1.3.5 Idle energy rate (10.5), and

1.3.6 Holding energy rate (10.6).

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This test method may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASHRAE Document:*[2]

ASHRAE Guideline 2-1986 (RA90) Engineering Analysis of Experimental Data

2.2 *NSF Standards:*[3]

NSF Listing Food Equipment and Related Components and Material

NSF/ANSI 4 Commercial Cooking, Rethermalization and Powered Hot Food Holding and Transport Equipment

3. Terminology

3.1 *Definitions:*

3.1.1 *calibrated setting, n*—temperature setting at which the lowest temperature of the food in the holding pans is at 142 ± 2°F (61 ± 1°C).

3.1.2 *capacity, n*—amount of food product that can be held in the unit's heated wells within standard 4-in. (102-mm) deep steam table pans.

3.1.3 *energy input rate, n*—peak rate at which a deli case consumes energy (kW), typically reflected during preheat.

3.1.4 *holding energy, n*—energy consumed by the deli case as it is used to hold cooked food product under full load conditions.

3.1.5 *holding energy rate, n*—average rate of energy consumption (kW) during the holding energy tests.

3.1.6 *idle energy rate, n*—rate of energy consumed (kW) by the deli case while holding or maintaining the appliance at the thermostat set point without any food product.

3.1.7 *preheat energy, n*—amount of energy consumed by the deli case while preheating the appliance from ambient room temperature (73 ± 3°F (22 ± 2°C)) to a temperature at the calibrated setting.

3.1.8 *preheat rate, n*—average rate (°F/min) at which the deli case is heated from ambient temperature (73 ± 3°F (22 ± 2°C)) to holding temperature with the thermostat set to the calibrated setting.

3.1.9 *preheat time, n*—time required for the deli case to preheat from ambient room temperature (73 ± 3°F (22 ± 2°C)) to the calibrated setting.

3.1.10 *staff-serve hot deli case, n*—(hereafter referred to as deli case) an appliance, with heated wells located in a fully or partially enclosed heated cavity, which is designed for the

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[2] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

[3] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140, http://www.nsf.org.

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display and service of hot food product in standard hotel pans. Also known as hot food merchandisers, display merchandisers or hot display cases.

3.1.11 *uncertainty, n*—measure of systematic and precision errors in specified instrumentation or measure of repeatability of a reported test result.

4. Summary of Test Method

4.1 The deli case is connected to the appropriate metered energy source, and energy input rate is determined to confirm that the appliance is operating within 5 % of the nameplate energy input rate.

4.2 Capacity is determined by loading the deli case's heated wells with 4-in. (100-mm) deep half-size steam table pans.

4.3 The calibrated setting is determined by using pre-cooked food product (macaroni and cheese) in 4-in. (100-mm) deep half-size steam pans and setting controls such that lowest temperature in the center of the food pans is 142 ± 2°F (61 ± 1°C).

4.4 The amount of energy and time required to preheat the deli case to calibrated setting is determined.

4.5 The idle energy rate is determined with the deli case set at calibrated setting and no food in the unit.

4.6 The deli case is used to hold 4-in. (100-mm) deep half-size steam pans filled with hot food for 3 h. Food temperature and deli case energy consumption are monitored during this testing.

5. Significance and Use

5.1 The energy input rate is used to confirm that the deli case is operating properly prior to further testing.

5.2 Capacity is used by food service operators to choose a deli case that matches their food holding requirements.

5.3 Preheat energy and time can be useful to food service operators to manage energy demands and to know how quickly the deli case can be ready for operation.

5.4 Holding energy rate and idle energy rate can be used by the food service operator to estimate deli case energy consumption.

6. Apparatus

6.1 *Analytical Balance Scale,* for measuring weights up to 20 lb (9 kg), with a resolution of 0.01 lb (0.005 kg) and an uncertainty of 0.01 lb (0.005 kg).

6.2 *Data Acquisition System,* for measuring energy and temperatures, capable of multiple channel displays updating at least every 2 s.

6.3 *Thermocouple(s),* industry standard type T or type K thermocouple wire with a range of 0 to 250°F (−17 to 121°C) and an uncertainty of ±1°F (±0.5°C).

6.4 *Thermocouple Probe,* "fast response" type T or type K thermocouple probe, 1⁄16 in. (1.6 mm) or smaller diameter, with a 3-s or faster response time, capable of immersion with a range of 0 to 250°F (−17 to 121°C) and an uncertainty of ±1°F (±0.5°C). The thermocouple probe's active zone shall be at the tip of the probe.

6.5 *Watt-Hour Meter,* for measuring the electrical energy consumption of a deli case, shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 1.5 % of the measured value for any demand greater than 100 W. For any demand less than 100 W, the meter shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 10 %.

7. Reagents and Materials

7.1 *Macaroni and Cheese,* a sufficient quantity of frozen, ready to cook, traditional macaroni and cheese, in half-size pans weighing approximately 4.5 lb (2.0 kg) obtained from a food distributor.

7.2 *Pans,* a sufficient quantity of stainless steel half-size steam pans, measuring 10 by 12 by 4 in. (250 by 300 by 100 mm) and weighing 1.8 ± 0.2 lb (0.8 ± 0.1 kg), to fill the deli case's heated wells.

7.3 *Small Pans,* a sufficient quantity of stainless steel 1⁄3-size steam pans, measuring 10 by 8 by 4 in. (250 by 200 by 100 mm) and weighing 1.5 ± 0.2 lb (0.7 ± 0.1 kg), to fill the deli case's heated wells as necessary.

8. Sampling and Test Units

8.1 *Deli Case*—Select a representative production model for performance testing.

9. Preparation of Apparatus

9.1 Install the deli case according to the manufacturer's instructions in an appropriate space. All sides of the deli case shall be a minimum of 12 in. (305 mm) from any side wall, side partition, or other operating appliance. The associated heating or cooling system for the space shall be capable of maintaining an ambient temperature of 73 ± 3°F (22 ± 2°C) within the testing environment.

9.2 The testing environment during energy tests shall be maintained in accordance with the section on performance for open top hot food holding equipment room specifications of NSF/ANSI 4. The NSF/ANSI 4 test room conditions are an ambient temperature of 73 ± 3°F (22 ± 2°C), no vertical temperature gradient exceeding 1.5°F/ft (2.5°C/m), and maximum air current velocity of 50 ft/min (0.25 m/s) across the surfaces of the test pans (partially enclosed units).

9.3 Connect the deli case to a calibrated energy test meter. A voltage regulator may be required during tests if the voltage supply is not within ±2.5 % of the manufacturer's nameplate voltage.

9.4 Confirm (while the elements are energized) that the supply voltage is within ±2.5 % of the operating voltage specified by the manufacturer. Record the test voltage for each test.

NOTE 1—It is the intent of the testing procedure in this test method to evaluate the performance of a deli case at its rated electric voltage. If the unit is rated dual voltage (that is, designed to operate at either 240 or 480 V with no change in components), the voltage selected by the manufacturer or tester, or both, shall be reported. If a deli case is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the unit (for example, preheat time) may differ at the two voltages.

9.5 Prepare the half and third-size pans for the holding energy rate test by attaching a temperature sensor in the center of each pan, 1.5 in. (38 mm) from the bottom. A convenient method is to have thermocouple probes with a stainless-steel protective sheath fabricated in the shape shown in Fig. 1. The sensing point is exposed and isolated thermally from the stainless-steel sheath. The probe is strapped to the pan using steel shim stock welded to the pan using a strain gage welder. The thermocouple lead is long enough to allow connection to the monitoring device while the pans are in the deli case.

10. Procedure

10.1 *General:*

10.1.1 Record the following for each test run:

10.1.1.1 Voltage while elements are energized,

10.1.1.2 Ambient temperature, and

10.1.1.3 Energy input rate during or immediately prior to the test.

10.1.2 For each test run, confirm that the peak input rate is within ±5 % of the rated nameplate input. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the deli case.

10.2 *Energy Input Rate:*

10.2.1 Set the temperature controls to the maximum setting.

10.2.2 Start recording time and energy consumption when the elements are energized and stop recording when the elements commence cycling.

10.2.3 Confirm that the measured input rate or power, (kW) is within 5 % of the rated nameplate input or power (it is the intent of the testing procedures in this test method to evaluate the performance of a deli case at its rated energy input rate). If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the deli case or supply another deli case for testing.

10.3 *Holding Temperature Calibration:*

10.3.1 Determine the number of 4-in. (100 mm) deep half-size pans that will fit inside the holding wells of the deli case. If necessary, mix small (third-size) pans with the half-size pans to fill the wells. Use the minimum number of small pans when making this determination. Note the number of each size of pan used.

NOTE 2—The objective of this step is to determine the smallest number of pans required to fill the deli case. For example, if the wells are 10 by 32-in. (250 by 810-mm), then each well will contain two half-size pans and one third-size pan.

10.3.2 Preheat deli case for 1 h at the manufacturer's recommended settings. If not specified by the manufacturer, then set the controls halfway between the minimum and maximum settings.

10.3.3 Prepare enough macaroni and cheese to fill the number of containers determined in 10.3.1 by following directions on the food packages.

10.3.4 Quickly transfer 9.0 ± 0.01 lb (4.1 ± 0.005 kg) of macaroni and cheese to each half-size pan and 5.5 ± 0.01 lb (2.5 ± 0.005 kg) of macaroni and cheese to each small (third-size) pan. Place the filled pans into the deli case's heated wells. If any small pans are used, these shall be located as close to the center of the wells as possible.

10.3.5 The temperature for each pan of macaroni and cheese at the beginning of the test shall be 160 ± 5°F (71 ± 3°C).

10.3.6 Monitor the temperature of each pan and deli case energy consumption for 3 h.

10.3.7 If the lowest temperature is not 142 ± 2°F (61 ± 1°C), then adjust the controls as appropriate and repeat 10.3.6 until the lowest pan temperature is 142 ± 2°F (61 ± 1°C).

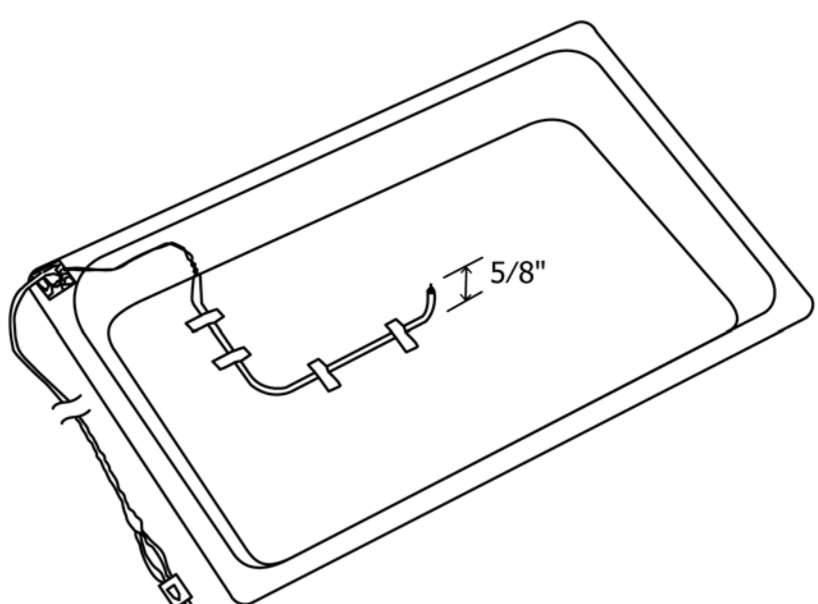


FIG. 1 Hotel Pan with Thermocouple Probe (not to scale)

10.3.8 To facilitate further testing, make a mark on the dial or a notation of this setting. Record the settings. This will be referred to as the calibrated setting.

10.4 *Preheat Energy Consumption and Time:*

NOTE 3—The preheat test should be conducted as the first appliance operation on the day of the test, starting with the appliance at room temperature (73 ± 3°F (22 ± 2°C)).

10.4.1 Load the case with empty pans. If any small pans are used, these shall be located as close to the center of the wells as possible.

10.4.2 Record ambient temperature and pan temperature at the start of the test. Both the ambient and pan temperatures shall be 73 ± 3°F (22 ± 2°C) at the start of the test.

10.4.3 Turn the unit on with controls set to the calibrated setting determined in 10.3.8. Begin recording pan temperature and deli case energy consumption when the unit is turned on.

10.4.4 Record the empty pan temperatures over a minimum of 5-s intervals during the course of preheat until the temperature at the center of each pan stabilizes. Record the final stabilization temperature for each pan.

10.4.5 Record the energy and time to preheat the deli case. Preheat is judged complete when the average pan temperature reaches 95 % of the final stabilized pan temperature, as indicated by the temperature at the center of each pan.

10.5 *Idle Energy Rate:*

NOTE 4—The idle test may be conducted immediately following the preheat test (10.4).

10.5.1 Load the case with empty pans. If any small pans are used, these shall be located as close to the center of the case as possible.

10.5.2 Set the deli case controls to the calibrated setting.

10.5.3 Allow the unit to stabilize for a minimum of 1 h.

10.5.4 Monitor pan temperature and deli case energy consumption for 2 h.

10.6 *Holding Energy Rate:*

10.6.1 The holding energy rate test is to be conducted a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (Annex A1). The reported values of holding energy rate shall be the average of the replications (runs).

10.6.2 Preheat deli case and allow it to stabilize for 1 h at the calibrated setting.

10.6.3 Prepare enough macaroni and cheese to fill the number of containers determined in 10.4.1 by following directions on the food packages.

10.6.4 Quickly transfer 9.0 ± 0.01 lb (4.1 ± 0.005 kg) of macaroni and cheese to each half-size pan and 5.5 ± 0.01 lb (2.5 ± 0.005 kg) of macaroni and cheese to each small (third-size) pan. Place the filled pans into the deli case's heated wells. If any small pans are used, these shall be located as close to the center of the case as possible.

10.6.5 The temperature for each pan of macaroni and cheese at the beginning of the test shall be 160 ± 5°F (71 ± 3°C).

10.6.6 Monitor food temperature and energy consumption for 3 h.

10.6.7 At the end of 3 h, check the temperature of the macaroni and cheese. The temperature in each pan shall be greater than 140°F (60°C). If any pan temperature is less than 140°F (60°C), then the test is invalid. Adjust the controls accordingly, note the new settings, and repeat 10.6.2 through 10.6.6.

10.6.8 Repeat 10.6.2 through 10.6.7 for replicates #2 and 3.

11. Calculation and Report

11.1 *Deli Case*—Summarize the physical and operating characteristics of the deli case. If needed, describe other design or operating characteristics that may facilitate interpretation of the test results.

11.2 *Apparatus and Procedure:*

11.2.1 Confirm that the testing apparatus conformed to all of the specifications in Section 6. Describe any deviations from those specifications.

11.2.2 Report the voltage for each test.

11.3 *Energy Input Rate:*

11.3.1 Report the manufacturer's nameplate energy input rate in kW.

11.3.2 Calculate and report the measured energy input rate (kW) based on the energy consumed by the deli case during the period of peak energy input according to the following relationship:

$$q_{input} = \frac{E \times 60}{t} \quad (1)$$

where:

q_{input} = measured peak energy input rate, kW,
E = energy consumed during period of peak energy input, kWh, and
t = period of peak energy input, min.

11.3.3 Calculate and report the percent difference between the manufacturer's nameplate energy input rate and the measured energy input rate.

11.4 *Holding Temperature Calibration:*

11.4.1 Report the settings used to attain the calibrated setting.

11.4.2 Calculate and report the average pan temperature at the calibrated setting.

11.5 *Preheat Energy and Time:*

11.5.1 Report the preheat energy consumption (kWh) and preheat time (min).

11.5.2 Report the starting pan temperature and the final stabilized pan temperature, based on the average temperature of all the pans.

11.5.3 Calculate and report the average preheat rate (°F/min (°C/min)) based on the preheat period.

11.5.4 Generate a graph showing the pan temperature vs. time based on the preheat period.

11.6 *Idle Energy Rate:*

11.6.1 Calculate and report the average pan temperature during the idle test.

11.6.2 Calculate and report the idle energy rate (kW) at the calibrated setting based on:

$$q_{idle} = \frac{E \times 60}{t} \quad (2)$$

where:

q_{idle} = idle energy rate, kW,
E = energy consumed during the test period, kWh, and
t = test period, min.

11.7 *Holding Energy Rate:*

11.7.1 Calculate and report the holding energy rate (kW) at the calibrated setting based on:

$$q_{holding} = \frac{E \times 60}{t} \quad (3)$$

where:

$q_{holding}$ = holding energy rate, kW,
E = energy consumed during the test period, kWh, and
t = test period, min.

11.7.2 Calculate and report the minimum, maximum, and average food temperature at the end of the 3-h holding test.

11.7.3 Calculate and report the maximum temperature difference between the hottest and coldest pans, based on the average temperature of each pan during the test.

11.7.4 Calculate and report the average energy use per pound of food product during the holding energy rate test based on:

$$E_{per\ pound} = \frac{E_{appliance}}{W} \quad (4)$$

where:

$E_{per\ pound}$ = energy per pound, W/lb,
$E_{appliance}$ = energy consumed during holding test, Wh, and
W = total initial weight of the food product, lb (kg).

11.8 *Capacity:*

11.8.1 Report the number of half-size and third-size pans used to fill the deli case, as determined in 10.3.1.

11.8.2 Report the deli case holding capacity in pounds (kg) of food product, based on the number of pans held in the deli case's heated wells.

12. Precision and Bias

12.1 *Precision:*

12.1.1 *Repeatability, (within laboratory, same operator, and equipment):*

12.1.1.1 For the holding energy rate results, the percent uncertainty in each result has been specified to be no greater than ±10 % based on at least three test runs.

12.1.1.2 The repeatability of each remaining reported parameter is being determined.

12.1.2 *Reproducibility (multiple laboratories)*—The interlaboratory precision of the procedure in this test method for measuring each reported parameter.

12.2 *Bias*—No statement can be made concerning the bias of the procedures in this test method because there are no accepted reference values for the parameters reported.

13. Keywords

13.1 holding energy rate; performance; staff-serve, deli case; test method

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

NOTE A1.1—This procedure is based on the ASHRAE method for determining the confidence interval for the average of several test results (ASHRAE Guideline 2-1986(RA90)). It should only be applied to test results that have been obtained within the tolerances prescribed in this method (for example, thermocouples calibrated, appliance operating within 5 % of rated input during the test run).

A1.1 For the holding energy rate results, the uncertainty in the averages of at least three test runs is reported. The uncertainty of the holding energy rate must be no greater than ±10 % before any of the parameters for test can be reported.

A1.2 The uncertainty in a reported result is a measure of its precision. If, for example, the holding energy rate for the appliance is 3.0 kW, the uncertainty must not be greater than ±0.3 kW. Thus, the true holding energy rate is between 2.7 and 3.3 kW. This interval is determined at the 95 % confidence level, which means that there is only a 1 in 20 chance that the true holding energy rate could be outside of this interval.

A1.3 Calculating the uncertainty not only guarantees the maximum uncertainty in the reported results, but is also used to determine how many test runs are needed to satisfy this requirement. The uncertainty is calculated from the standard deviation of three or more test results and a factor from Table A1.1, which lists the number of test results used to calculate the

TABLE A1.1 Uncertainty Factors

Test Results, *n*	Uncertainty Factor, *Cn*
3	2.48
4	1.59
5	1.24
6	1.05
7	0.92
8	0.84
9	0.77
10	0.72

average. The percent uncertainty is the ratio of the uncertainty to the average expressed as a percent.

A1.4 *Procedure*:

NOTE A1.2—Section A1.5 shows how to apply this procedure.

A1.4.1 *Step 1*—Calculate the average and the standard deviation for the test result (holding energy rate) using the results of the first three test runs, as follows:

A1.4.1.1 The formula for the average (three test runs) is as follows:

$$Xa_3 = \left(\frac{1}{3}\right) \times (X_1 + X_2 + X_3) \quad \text{(A1.1)}$$

where:

Xa_3 = average of results for three test runs, and
X_1, X_2, X_3 = results for each test run.

A1.4.1.2 The formula for the sample standard deviation (three test runs) is as follows:

$$S_3 = \left(\frac{1}{\sqrt{2}}\right) \times \sqrt{(A_3 - B_3)} \quad \text{(A1.2)}$$

where:

S_3 = standard deviation of results for three test runs,
A_3 = $(X_1)^2 + (X_2)^2 + (X_3)^2$, and
B_3 = $(1/3) \times (X_1 + X_2 + X_3)^2$.

NOTE A1.3—The formulas may be used to calculate the average and sample standard deviation. However, a calculator with statistical function is recommended, in which case be sure to use the sample standard deviation function. The population standard deviation function will result in an error in the uncertainty.

NOTE A1.4—The "A" quantity is the sum of the squares of each test result, and the "B" quantity is the square of the sum of all test results multiplied by a constant (1⁄3 in this case).

A1.4.2 *Step 2*—Calculate the absolute uncertainty in the average for each parameter listed in Step 1. Multiply the standard deviation calculated in Step 1 by the Uncertainty Factor corresponding to three test results from Table A1.1.

A1.4.2.1 The formula for the absolute uncertainty (three test runs) is as follows:

$$U_3 = C_3 \times S_3 \quad \text{(A1.3)}$$

$$U_3 = 2.48 \times S_3$$

where:

U_3 = absolute uncertainty in average for three test runs, and
C_3 = uncertainty factor for three test runs (Table A1.1).

A1.4.3 *Step 3*—Calculate the percent uncertainty in each parameter average using the averages from Step 1 and the absolute uncertainties from Step 2.

A1.4.3.1 The formula for the percent uncertainty (three test runs) is as follows:

$$\%U_3 = \left(\frac{U_3}{Xa_3}\right) \times 100\,\% \quad \text{(A1.4)}$$

where:

$\%U_3$ = percent uncertainty in average for three test runs,
U_3 = absolute uncertainty in average for three test runs, and
Xa_3 = average of three test runs.

A1.4.4 *Step 4*—If the percent uncertainty, $\%U_3$, is not greater than ±10 % for the cooking-energy efficiency and holding energy rate, report the average for these parameters along with their corresponding absolute uncertainty, U_3, in the following format:

$$Xa_3 \pm U_3$$

A1.4.4.1 If the percent uncertainty is greater than ±10 % for the cooking energy efficiency or holding energy rate, proceed to Step 5.

A1.4.5 *Step 5*—Run a fourth test for each loading scenario whose percent uncertainty was greater than ±10 %.

A1.4.6 *Step 6*—When a fourth test is run for a given loading scenario, calculate the average and standard deviation for test results using a calculator or the following formulas:

A1.4.6.1 The formula for the average (four test runs) is as follows:

$$Xa_4 = \left(\frac{1}{4}\right) \times (X_1 + X_2 + X_3 + X_4) \quad \text{(A1.5)}$$

where:

Xa_4 = average of results for four test runs, and
X_1, X_2, X_3, X_4 = results for each test run.

A1.4.6.2 The formula for the standard deviation (four test runs) is as follows:

$$S_4 = \left(\frac{1}{\sqrt{3}}\right) \times \sqrt{(A_4 - B_4)} \quad \text{(A1.6)}$$

where:

S_4 = standard deviation of results for four test runs,
A_4 = $(X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$, and
B_4 = $(1/4) \times (X_1 + X_2 + X_3 + X_4)^2$.

A1.4.7 *Step 7*—Calculate the absolute uncertainty in the average for each parameter listed in Step 1. Multiply the standard deviation calculated in Step 6 by the Uncertainty Factor for four test results from Table A1.1.

A1.4.7.1 The formula for the absolute uncertainty (four test runs) is as follows

$$U_4 = C_4 \times S_4 \quad \text{(A1.7)}$$

$$U_4 = 1.59 \times S_4$$

where:

U_4 = absolute uncertainty in average for four test runs, and
C_4 = the uncertainty factor for four test runs (Table A1.1).

A1.4.8 *Step 8*—Calculate the percent uncertainty in the parameter averages using the averages from Step 6 and the absolute uncertainties from Step 7.

A1.4.8.1 The formula for the percent uncertainty (four test runs) is as follows:

$$\%U_4 = \left(\frac{U_4}{Xa_4}\right) \times 100\,\% \quad \text{(A1.8)}$$

where:

$\%U_4$ = percent uncertainty in average for four test runs,
U_4 = absolute uncertainty in average for four test runs, and
Xa_4 = average of four test runs.

A1.4.9 *Step 9*—If the percent uncertainty, $\%U_4$, is not greater than ±10 % for the cooking energy efficiency and holding energy rate, report the average for these parameters along with their corresponding absolute uncertainty, U_4, in the following format:

$$Xa_4 \pm U_4$$

A1.4.9.1 If the percent uncertainty is greater than ±10 % for the cooking energy efficiency or holding energy rate, proceed to Step 10.

A1.4.10 *Step 10*—The steps required for five or more test runs are the same as those described above. More general formulas are listed below for calculating the average, standard deviation, absolute uncertainty, and percent uncertainty.

A1.4.10.1 The formula for the average (n test runs) is as follows:

$$Xa_n = \left(\frac{1}{n}\right) \times (X_1 + X_2 + X_3 + X_4 + \ldots + X_n) \quad \text{(A1.9)}$$

where:

n = number of test runs,
Xa_n = average of results n test runs, and
$X_1, X_2, X_3, X_4, \ldots X_n$ = results for each test run.

A1.4.10.2 The formula for the standard deviation (n test runs) is as follows:

$$S_n = \left(\frac{1}{\sqrt{(n-1)}}\right) \times \left(\sqrt{(A_n - B_n)}\right) \quad \text{(A1.10)}$$

where:

S_n = standard deviation of results for n test runs,
A_n = $(X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2 + \ldots + (X_n)^2$, and
B_n = $(1/n) \times (X_1 + X_2 + X_3 + X_4 + \ldots + X_n)^2$.

A1.4.10.3 The formula for the absolute uncertainty (n test runs) is as follows:

$$U_n = C_n \times S_n \quad \text{(A1.11)}$$

where:

U_n = absolute uncertainty in average for n test runs, and
C_n = uncertainty factor for n test runs (Table A1.1).

A1.4.10.4 The formula for the percent uncertainty (n test runs) is as follows:

$$\%U_n = \left(\frac{U_n}{Xa_n}\right) \times 100\,\% \quad \text{(A1.12)}$$

where:

$\%U_n$ = percent uncertainty in average for n test runs,
U_n = absolute uncertainty in average for n test runs, and
Xa_n = average of n test runs.

A1.4.10.5 When the percent uncertainty, $\%U_n$, is less than or equal to ±10 % for the cooking energy efficiency and holding energy rate, report the average for these parameters along with their corresponding absolute uncertainty, U_n, in the following format:

$$Xa_n \pm U_n$$

NOTE A1.5—The researcher may compute a test result that deviates significantly from the other test results. Such a result should be discarded only if there is some physical evidence that the test run was not performed according to the conditions specified in this method. For example, a thermocouple was out of calibration, the appliance's input capacity was not within 5 % of the rated input, or the food product was not within specification. To assure that all results are obtained under approximately the same conditions, it is good practice to monitor those test conditions specified in this method.

A1.5 *Example of Determining Uncertainty in Average Test Result*:

A1.5.1 Three test runs for the full-load cooking scenario yielded the following holding energy rate results:

Test	Holding Energy Rate
Run #1	3.38 kW
Run #2	3.41 kW
Run #3	3.10 kW

A1.5.2 *Step 1*—Calculate the average and standard deviation of the three test results for the PC.

A1.5.2.1 The average of the three test results is as follows:

$$Xa_3 = \left(\frac{1}{3}\right) \times (X_1 + X_2 + X_3) \quad \text{(A1.13)}$$

$$Xa_3 = \left(\frac{1}{3}\right) \times (3.38 + 3.41 + 3.10)$$

$$Xa_3 = 3.30\ \text{kW}$$

A1.5.2.2 The standard deviation of the three test results is as follows. First calculate "A_3" and "B_3":

$$A_3 = (X_1)^2 + (X_2)^2 + (X_3)^2 \quad \text{(A1.14)}$$

$$A_3 = (3.38)^2 + (3.41)^2 + (3.10)^2$$

$$A_3 = 32.66$$

$$B_3 = \left(\frac{1}{3}\right) \times \left[(X_1 + X_2 + X_3)^2\right]$$

$$B_3 = \left(\frac{1}{3}\right) \times \left[(3.38 + 3.41 + 3.10)^2\right]$$

$$B_3 = 32.60$$

A1.5.2.3 The new standard deviation for the PC is as follows:

$$S_3 = \left(\frac{1}{\sqrt{2}}\right) \times \sqrt{(32.66 - 32.60)} \quad \text{(A1.15)}$$

$$S_3 = 0.17\ \text{kW}$$

A1.5.3 *Step 2*—Calculate the uncertainty in average.

$$U_3 = 2.48 \times S_3 \quad \text{(A1.16)}$$

$$U_3 = 2.48 \times 0.17$$

$$U_3 = 0.42\ \text{kW}$$

A1.5.4 *Step 3*—Calculate percent uncertainty.

$$\%U_3 = \left(\frac{U_3}{Xa_3}\right) \times 100\,\% \quad \text{(A1.17)}$$

$$\%U_3 = \left(\frac{0.42}{3.30}\right) \times 100\,\%$$

$$\%U_3 = 12.9\,\%$$

A1.5.5 *Step 4*—Run a fourth test. Since the percent uncertainty for the holding energy rate is greater than ±10 %, the precision requirement has not been satisfied. An additional test is run in an attempt to reduce the uncertainty. The holding energy rate from the fourth test run was 3.25 kW.

A1.5.6 *Step 5*—Recalculate the average and standard deviation for the PC using the fourth test result:

A1.5.6.1 The new average PC is as follows:

$$Xa_4 = \left(\frac{1}{4}\right) \times (X_1 + X_2 + X_3 + X_4) \quad \text{(A1.18)}$$

$$Xa_4 = \left(\frac{1}{4}\right) \times (3.38 + 3.41 + 3.10 + 3.25)$$

$$Xa_4 = 3.29 \text{ kW}$$

A1.5.6.2 The new standard deviation is. First calculate "A_4" and "B_4":

$$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2 \quad \text{(A1.19)}$$

$$A_4 = (3.38)^2 + (3.41)^2 + (3.10)^2 + (3.25)^2$$

$$A_4 = 43.23$$

$$B_4 = \left(\frac{1}{4}\right) \times [(X_1 + X_2 + X_3 + X_4)^2]$$

$$B_4 = \left(\frac{1}{4}\right) \times [(3.38 + 3.41 + 3.10 + 3.25)^2]$$

$$B_4 = 43.16$$

A1.5.6.3 The new standard deviation for the PC is as follows:

$$S_4 = \left(\frac{1}{\sqrt{3}}\right) \times \sqrt{(43.23 - 43.16)} \quad \text{(A1.20)}$$

$$S_4 = 0.14 \text{ kW}$$

A1.5.7 *Step 6*—Recalculate the absolute uncertainty using the new standard deviation and uncertainty factor.

$$U_4 = 1.59 \times S_4 \quad \text{(A1.21)}$$

$$U_4 = 1.59 \times 0.14$$

$$U_4 = 0.22 \text{ kW}$$

A1.5.8 *Step 7*—Recalculate the percent uncertainty using the new average.

$$\%U_4 = \left(\frac{U_4}{Xa_4}\right) \times 100\,\% \quad \text{(A1.22)}$$

$$\%U_4 = \left(\frac{0.22}{3.29}\right) \times 100\,\%$$

$$\%U_4 = 6.8\,\%$$

A1.5.9 *Step 8*—Since the percent uncertainty, $\%U_4$, is less than ±10 %; the average for the holding energy rate is reported along with its corresponding absolute uncertainty, U_4 as follows:

$$\text{Holding Energy Rate:} \quad 3.29 \pm 0.22 \text{ kW} \quad \text{(A1.23)}$$

APPENDIX

(Nonmandatory Information)

X1. RESULTS REPORTING SHEETS

Manufacturer ______________________
Model ______________________
Date ______________________
Test Reference Number (optional) __________

X1.1 Test Deli Case

Description of operational characteristics: ____

____

____

____

____

____

____

____

X1.2 Apparatus

________ Check if testing apparatus conformed to specifications in Section 6.

Deviations: ____

____

____

____

____

X1.3 Energy Input Rate

Test Voltage (V)	________
Measured (kW)	________
Rated (kW)	________
Percent Difference between Measured and Rated (%)	________

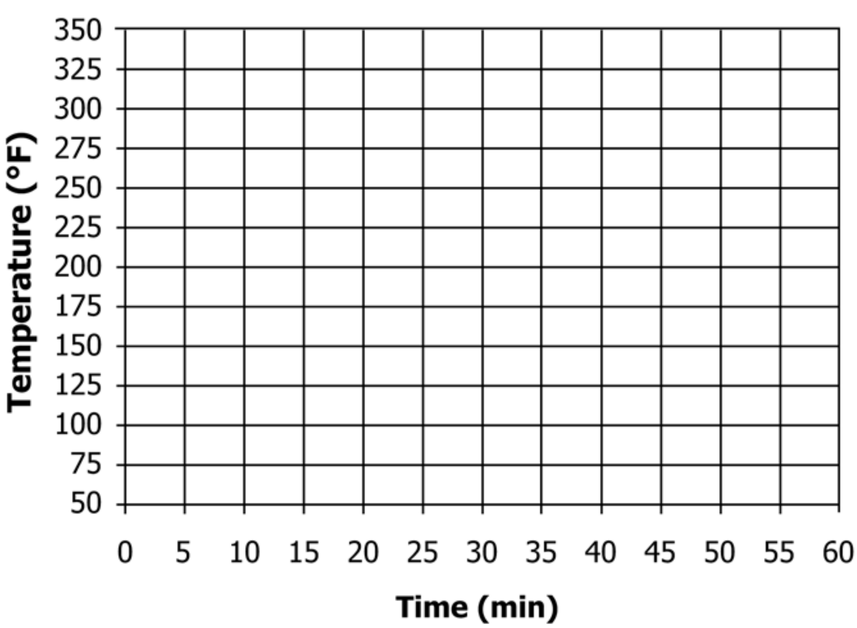
X1.4 Holding Temperature Calibration

Thermostat settings required to maintain calibrated temperature (from left):

Thermostat #1	________
Thermostat #2 (if required)	________
Thermostat #3 (if required)	________
Thermostat #4 (if required)	________
Thermostat #5 (if required)	________
Thermostat #6 (if required)	________
Test Voltage (V)	________
Calibrated Pan Temperature (°F)	________

X1.5 Preheat Energy and Time

Test Voltage (V)	________
Starting Temperature (°F)	________
Stabilized Pan Temperature (°F)	________
Energy Consumption (kWh)	________
Duration (min)	________
Preheat Rate (°F/min)	________



Preheat Curve

X1.6 Idle Energy Rate

Test Voltage (V)	________
Idle Energy Rate (kW)	________
Average Pan Temperature (°F)	________

X1.7 Holding Energy Rate

Test Voltage (V)	________
Holding Energy Rate (kW)	________
Energy per Pound of Food (kW/lb)	________

Minimum Food Temperature (°F)	_______
Maximum Food Temperature (°F)	_______
Average Food Temperature (°F)	_______
Maximum Temperature Difference	_______
Between the Hottest and Coldest Pans (°F)	_______

X1.8 Capacity

Number of Half-Size Pans	_______
Number of Third-Size Pans	_______
Holding Capacity (lb)	_______

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