Standard Test Method for Performance of Underfired Broilers[1]

1. Scope

1.1 This test method covers the evaluation of the energy consumption and cooking performance of underfired broilers. The food service operator can use this evaluation to select an underfired broiler and understand its energy performance.

1.2 This test method is applicable to gas and electric underfired broilers.

1.3 The underfired broiler can be evaluated with respect to the following (where applicable):

1.3.1 Energy input rate (see 10.2),

1.3.2 Temperature distribution across the broiling area (see 10.3),

1.3.3 Preheat energy and time (see 10.4),

1.3.4 Pilot energy rate, if applicable (see 10.5),

1.3.5 Cooking energy rate (see 10.6), and

1.3.6 Cooking energy efficiency and production capacity (see 10.7).

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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 *ASTM Standards:*[2]

A36/A36M Specification for Carbon Structural Steel

D3588 Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels

2.2 *ANSI Standard:*[3]

ANSI Z83.11 American National Standard for Gas Food Service Equipment

2.3 *AOAC Documents:*[4]

AOAC Official Action 950.46 Air Drying to Determine Moisture Content of Meat and Meat Products%

AOAC Official Action 960.39 Fat (Crude) or Ether Extract in Meat

2.4 *ASHRAE Document:*[5]

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

2.5 *Other Document:*[6]

Development and Application of a Uniform Testing Procedure for Griddles, 1989

Development and Validation of a Standard Test Method for Underfired Broilers, 1997

3. Terminology

3.1 *Definitions:*

3.1.1 *cooking energy, n*—energy consumed by the underfired broiler as it is used to cook hamburger patties under heavy- and light-load conditions.

3.1.2 *cooking energy efficiency, n*—quantity of energy imparted to the hamburgers, expressed as a percentage of energy consumed by the underfired broiler during the cooking event.

3.1.3 *cooking energy rate, n*—average rate of energy consumption (Btu/h (kJ/h) or kW) during the cooking energy efficiency tests, with the underfired broiler set such that the broiling area does not exceed 600°F (315°C) as measured by 5-in. diameter steel disks.

3.1.4 *cook time, n*—time required to cook fresh hamburgers as specified in 7.4 to a 35 ± 2 % weight loss during a cooking energy efficiency test.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from the Association of Official Analytical Chemists, 1111 N. 19th Street, Arlington, VA 22209.

[5] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329.

[6] Available from the Food Service Technology Center, 12949 Alcosta Blvd., #101, San Roman, CA 94583.

3.1.5 *energy input rate, n*—peak rate at which an underfired broiler consumes energy (Btu/h (kJ/h) or kW).

3.1.6 *pilot energy rate, n*—average rate of energy consumption (Btu/h (kJ/h)) by an underfired broiler's continuous pilot (if applicable).

3.1.7 *preheat energy, n*—amount of energy consumed by the underfired broiler while preheating the broiling area from ambient room temperature to 500°F (260°C).

3.1.8 *preheat rate, n*—average rate (°F/min (°C/min)) at which the broiling area temperature is heated from ambient temperature to 500°F (260°C).

3.1.9 *preheat time, n*—time required for the broiling area to preheat from ambient room temperature to 500°F (260°C).

3.1.10 *production capacity, n*—the maximum rate (lb/h (kg/h)) at which the broiler can cook fresh hamburgers as specified in 7.4 to a 35 ± 2 % weight loss.

3.1.11 *production rate, n*—the average rate (lb/h (kg/h)) at which the broiler brings the specified food product to a specified "cooked" condition. It does not necessarily refer to the maximum rate. The production rate varies with the amount of food being cooked.

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

3.1.13 *underfired broiler, n*—an appliance with a high temperature radiant heat source below a grate for cooking food, similar to the barbecue, also known as radiant or charbroilers.

4. Summary of Test Method

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

4.2 The broiler grate is covered with 5-in. (127 mm) diameter metal disks and the temperature distribution of the broiling area is determined by the disk temperatures with the underfired broiler controls set to achieve maximum input rate.

4.3 The amount of energy and time required to preheat the broiling area to 500°F (260°C) is determined with the controls set to achieve maximum input rate.

4.4 The pilot energy rate is determined, when applicable, for gas underfired broilers.

4.5 The underfired broiler controls are set such that the broiling area does not exceed a maximum temperature of 600°F (315°C) and a cooking energy rate is established at this setting.

4.6 With the controls set such that the broiling area does not exceed 600°F (315°C), the underfired broiler is used to cook thawed, ⅓-lb (0.15-kg), 20 % fat, pure beef hamburger patties to a well-done condition (35 ± 2 % weight loss, corresponding to an internal temperature of 175°F (79°C)). Cooking energy efficiency is determined for heavy- and light-load conditions and production capacity is determined for heavy-load conditions.

5. Significance and Use

5.1 The energy input rate test is used to confirm that the underfired broiler is operating properly prior to further testing.

5.2 Temperature distribution of the broiling area may be used by food service operators to select an underfired broiler with the desired temperature gradients.

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

5.4 Cooking energy efficiency is a precise indicator of underfired broiler energy performance under various loading conditions. This information enables the food service operator to consider energy performance when selecting an underfired broiler.

5.5 Production capacity allows the food service operator to select an underfired broiler that meets their food output requirements.

6. Apparatus

6.1 *Analytical Balance Scale,* for measuring weights up to 15 lb (6.8 kg), with a resolution of 0.01 lb (0.004 kg) and an uncertainty of 0.01 lb (0.004 kg).

6.2 *Barometer,* for measuring absolute atmospheric pressure, to be used for adjustment of measured gas volume to standard conditions. It shall have a resolution of 0.2 in. Hg (670 Pa) and an uncertainty of 0.2 in. Hg (670 Pa).

6.3 *Canopy Exhaust Hood,* 4 ft (1.2 m) in depth, wall-mounted with the lower edge of the hood 6 ft, 6 in. (1.98 m) from the floor and with the capacity to operate at a nominal net exhaust ventilation rate of 400 cfm per linear foot (620 L/s per linear metre) of active hood length. This hood shall extend a minimum of 6 in. (152 mm) past both sides and the front of the cooking appliance and shall not incorporate side curtains or partitions. Makeup air shall be delivered through face registers or from the space, or both.

6.4 *Convection Drying Oven,* with temperature controlled at 215 to 220°F (101 to 104°C), used to determine moisture content of both the raw and cooked food product.

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

6.6 *Gas Meter,* for measuring the gas consumption of an underfired broiler. It shall be a positive displacement type with a resolution of at least 0.01 ft^3 (0.0003 m^3) and a maximum uncertainty no greater than 1 % of the measured value for any demand greater than 2.2 ft^3/h (0.06 m^3/h). If the meter is used for measuring the gas consumed by the pilot lights, it shall have a resolution of at least 0.01 ft^3 (0.0003 m^3) and a maximum uncertainty no greater than 2 % of the measured value.

6.7 *Pressure Gage,* for monitoring gas pressure. Shall have a range from 0 to 15 in. H_2O (0 to 3.7 kPa), a resolution of 0.5 in. H_2O (125 Pa), and a maximum uncertainty of 1 % of the measured value.

6.8 *Steel Disks,* (four for each square-foot of broiler grate) composed of structural-grade carbon steel in accordance with Specification A36/A36M, free of rust or corrosion, 5-in. (127 mm) diameter, and ¼ in. (6.3 mm) thick. The disks shall be flat to within 0.010 in. (0.25 mm) over the diameter.

6.9 *Stopwatch,* with a 1-s resolution.

6.10 *Strain Gage Welder,* capable of welding thermocouples to steel.[7]

6.11 *Temperature Sensor,* for measuring gas temperature in the range from 50 to 100°F (10 to 38°C) with an uncertainty of ±1°F (0.56°C).

6.12 *Thermocouple(s),* fiberglass insulated, 24-gage, Type K thermocouple wire, peened flat at the exposed ends and spot welded to surfaces with a strain gage welder.

6.13 *Thermocouple Probe(s),* industry standard Type T or Type K thermocouples capable of immersion with a range from 30 to 200°F (10 to 93°C) and an uncertainty of ±1°F (0.56°C).

6.14 *Watt-Hour Meter,* for measuring the electrical energy consumption of an underfired broiler. It 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 *Drip Rack,* large enough to hold a full load of hamburger patties in a single layer (that is, 24 patties for a 24 by 36-in. (610 by 915 mm) underfired broiler).

7.2 *Freezer Paper,* waxed commercial grade, 18 in. (460 mm) wide.

7.3 *Half-Size Sheet Pans,* measuring 18 by 13 by 1 in. (460 by 130 by 25 mm), for use in packaging hamburger patties.

7.4 *Hamburger Patties*—A sufficient quantity of hamburger patties shall be obtained from a meat purveyor to conduct the heavy- and light-load cooking tests. Specifications for the patties shall be three per pound, 20 ± 2 % fat (by weight), finished grind, pure beef patties with a moisture content between 58 and 62 % of the total hamburger weight. The ⅓-lb (0.15 kg) patties shall be machine prepared to produce ⅝-in. (16 mm) thick patties with a nominal diameter of 5 in. (127 mm).

NOTE 1—Fresh or tempered hamburger patties may be used for the purposes of this test method.

NOTE 2—It is important to confirm by laboratory tests that the hamburger patties are within the above specifications because these specifications impact directly on cook time and cooking energy consumption.

7.5 *Plastic Wrap,* commercial grade, 18 in. (460 mm) wide.

8. Sampling, Test Units

8.1 *Underfired Broiler*—Select a representative production model for performance testing.

[7] Eaton Model W1200 Strain Gauge Welder, available from Eaton Corp., 1728 Maplelawn Road, Troy, MI 48084, has been found satisfactory for this purpose.

9. Preparation of Apparatus

9.1 Install the appliance according to the manufacturer's instructions under a 4-ft (1.2 m) deep canopy exhaust hood mounted against the wall, with the lower edge of the hood 6 ft, 6 in. (1.98 m) from the floor. Position the underfired broiler with front edge of appliance inset 6 in. (152 mm) from the front edge of the hood at the manufacturer's recommended working height. The length of the exhaust hood and active filter area shall extend a minimum of 6 in. (152 mm) past both sides of the underfired broiler. In addition, both sides of the appliance shall be a minimum of 3 ft (0.9 m) from any side wall, side partition, or other operating appliance. The exhaust ventilation rate shall be 400 cfm/linear foot (620 L/s per linear metre) of hood length (for example, a 3-ft (0.9 m) underfired broiler shall be ventilated, at a minimum, by a hood 4 by 4 ft (1.2 by 1.2 m) with a nominal air flow rate of 1600 cfm (745 L/s). The application of a longer hood is acceptable, provided the ventilation rate is maintained at 400 cfm/linear foot (620 L/s per linear metre) over the entire length of active hood. The associated heating or cooling system shall be capable of maintaining an ambient temperature of 75 ± 5°F (24 ± 2.8°C) within the testing environment (outside the vertical area of the broiler and hood) when the exhaust ventilation system is operating.

9.2 Connect the underfired broiler to a calibrated energy test meter. For gas installations, install a pressure regulator downstream from the meter to maintain a constant pressure of gas for all tests. Install instrumentation to record both the pressure and temperature of the gas supplied to the underfired broiler and the barometric pressure during each test so that the measured gas flow can be corrected to standard conditions. For electric installations, a voltage regulator may be required during tests if the voltage supply is not within ±2.5 % of the manufacturer's nameplate voltage.

9.3 For a gas underfired broiler, adjust (during maximum energy input) the gas supply pressure downstream from the appliance's pressure regulator to within ±2.5 % of the operating manifold pressure specified by the manufacturer. Make adjustments to the appliance following the manufacturer's recommendations for optimizing combustion. Proper combustion may be verified by measuring air-free CO in accordance with ANSI Z83.11.

9.4 For an electric underfired broiler, 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 3—It is the intent of the testing procedure herein to evaluate the performance of an underfired broiler at its rated gas pressure or electric voltage. If an electric unit is rated dual voltage (that is, designed to operate at either 208 or 240 V with no change in components), the voltage selected by the manufacturer or tester, or both, shall be reported. If an underfired broiler 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 Condition the broiler grate in accordance with the manufacturer's instructions. If not specified by the manufacturer, follow the procedure described in 9.5.1.

9.5.1 Set the underfired broiler controls to achieve maximum input. Allow the underfired broiler to heat for 30 min. Using a wire brush, thoroughly brush down the grate, making sure to knock off any stuck particles. The broiler grate is now conditioned for testing.

10. Procedure

10.1 *General:*

10.1.1 For gas appliances, record the following for each test run:

10.1.1.1 Higher heating value,

10.1.1.2 Standard gas pressure and temperature used to correct measured gas volume to standard conditions,

10.1.1.3 Measured gas temperature,

10.1.1.4 Measured gas pressure,

10.1.1.5 Barometric pressure,

10.1.1.6 Ambient temperature, and

10.1.1.7 Energy input rate during or immediately prior to test.

NOTE 4—Using a calorimeter or gas chromatograph in accordance with accepted laboratory procedures is the preferred method for determining the higher heating value of gas supplied to the underfired broiler under test. It is recommended that all testing be performed with natural gas having a higher heating value of 1000 to 1075 Btu/ft^3 (37 300 to 40 100 kJ/m^3).

10.1.2 For gas underfired broilers, add any electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (10.2).

10.1.3 For electric underfired broilers, record the following for each test run:

10.1.3.1 Voltage while elements are energized,

10.1.3.2 Ambient temperature, and

10.1.3.3 Energy input rate during or immediately prior to test run.

10.1.3.4 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 underfired broiler.

10.2 *Energy Input Rate:*

10.2.1 For gas underfired broilers, set the controls to achieve maximum input. Allow the unit to run for a period of 15 min, then monitor the time required for the underfired broiler to consume 5 ft^3 (0.14 m^3) of gas.

10.2.2 For electric underfired broilers, monitor the energy consumption for 15 min with the controls set to achieve maximum input. If the unit begins cycling during the 15-min interval, record the time and energy consumed for the time from when the unit was first turned on until it begins cycling.

10.2.3 Confirm that the measured input rate or power, (Btu/h (kJ/h) for a gas underfired broiler and kW for an electric underfired broiler) is within 5 % of the rated nameplate input or power. (It is the intent of the testing procedures herein to evaluate the performance of an underfired broiler 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 underfired broiler or supply another underfired broiler for testing.

10.3 *Temperature Distribution:*

10.3.1 Using a strain gage welder, attach one thermocouple to the center of one side on each 5-in. (127 mm) diameter, ¼-in. (6.3 mm) thick steel disk. Add a strain relief to each disk to facilitate handling of the disks.

NOTE 5—The 28-gage (0.3-mm) stainless steel shims wrapped over the thermocouple wire and tack-welded to the disk make effective strain reliefs for this application.

10.3.2 Determine the number of disks required for the broiler under test as follows:

10.3.2.1 Measure the actual width and depth of the broiler grate,

10.3.2.2 Each column of disks (from front to back) shall have one disk for every 5¼ in. (133 mm) of grate depth,

10.3.2.3 Each row of disks (from side to side) shall have one disk for every 5¼ in. (133 mm) of grate width (see Table 1), and

10.3.2.4 Record the number of disks used. This number shall comprise a heavy load.

NOTE 6—This determination accounts for differences between nominal broiler size and actual grate size. It is the intent of this test method to determine a reasonable heavy-load for the broiler under test while still allowing space between the disks.

10.3.3 Position the thermocoupled disks thermocoupled-side up on the broiler grate. Arrange the disks in a grid pattern and ensure that they are evenly spaced upon the broiler grate (see Fig. 1).

10.3.4 Set the underfired broiler controls to achieve maximum input and allow the unit to stabilize for 60 min.

10.3.5 Monitor the disk temperatures for a minimum of 1 h. Determine the average temperature for each disk.

10.3.6 Record the maximum temperature difference across the broiling area. The maximum difference is the highest average temperature minus the lowest average temperature for the two extreme disks.

NOTE 7—It is the intent of this test method to determine the effective temperature distribution of the underfired broiler as it could be used in production with the controls set to achieve maximum energy input.

TABLE 1 Number of Disks for Temperature Uniformity Test

	Grate Width, in.						
	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40
Grade Depth, in.							
6 to 10	1	2	3	4	5	6	7
11 to 15	2	4	6	8	10	12	14
16 to 20	3	6	9	12	15	18	21
21 to 25	4	8	12	16	20	24	28

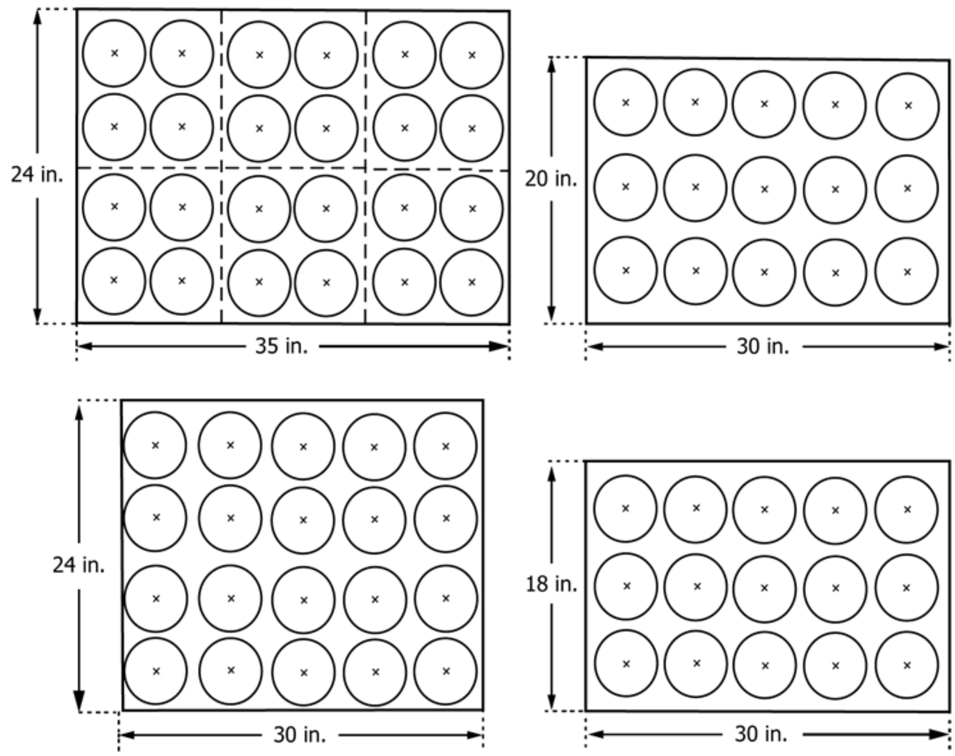

FIG. 1 Example of Disk Positions for the Temperature Distribution Test on Different Nominal 36-in. (915 mm) Broiler Grates

10.4 *Preheat Energy and Time:*

NOTE 8—The preheat test should be conducted as the first appliance operation on the day of the test, starting with the broiler grate at room temperature.

10.4.1 Place one disk from 10.3.1 in the center of each linear foot (305 mm) of broiler grate, thermocouple side up (see Fig. 2).

10.4.2 Record the disk temperature(s) and the ambient kitchen temperature at the start of the test (each temperature shall be 75± 5°F (24 ± 2.8°C) at start of the test).

10.4.3 Turn the unit on with controls set to achieve maximum input.

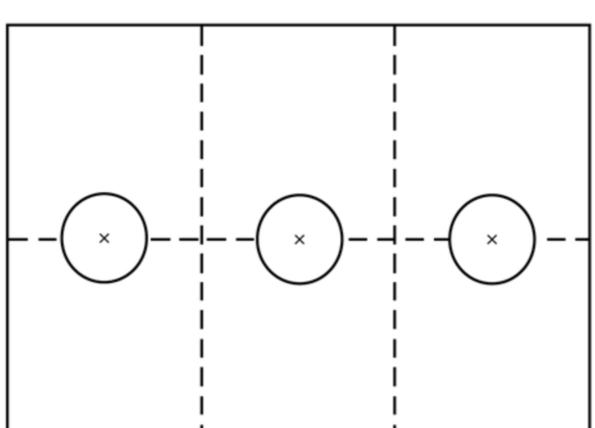

FIG. 2 Disk Positions for the Preheat Test on a Nominal 36 by 24-in. (915 by 610 mm) Underfired Broiler

10.4.4 Record the energy and time to preheat all sections of the underfired broiler jointly. Preheat is judged complete when the last of the disks reaches 500°F (260°C).

10.5 *Pilot Energy Rate (Gas Models with Standing Pilots):*

10.5.1 Where applicable, set the gas valve that controls gas supply to the appliance at the "pilot" position. Otherwise, set the underfired broiler temperature controls to the "off" position.

10.5.2 Light and adjust pilots according to the manufacturer's instructions.

10.5.3 Record the gas reading after a minimum of 8 h of pilot operation.

10.6 *Cooking Energy Rate:*

10.6.1 Position the thermocoupled disks from 10.3.1 on the broiler grate, thermocoupled side up. Use the number of disks determined in 10.3.2.4, and ensure that the disks are evenly spaced upon the broiler grate (see Fig. 1).

10.6.2 Set the underfired broiler controls to achieve maximum input, then, adjust the controls back so that the temperature of each disk does not exceed 600°F (315°C). Mark this position on the control knobs.

NOTE 9—The underfired broiler should be set such that the broiling temperature is as high as possible without exceeding 600°F (315°C).

NOTE 10—Research conducted by the Food Service and Technology Center determined that calibrating the broiling area to a maximum of 600°F (315°C) for the cooking tests greatly reduces the effects of flare-up and improves the repeatability of the tests.

10.6.3 Allow the broiling area to stabilize at this setting for 1 h, then, monitor the energy consumption for an additional 2 h.

10.7 *Cooking Energy Efficiency:*

10.7.1 Run the cooking energy efficiency test a minimum of three times for each loading scenario. Additional test runs may be necessary to obtain the required precision for the reported test results (Annex A1).

10.7.2 Verify fat and moisture content of hamburger patties in accordance with recognized laboratory procedures (AOAC Official Action 960.39 and Official Action 950.46). Record the average weight of the hamburger patties to determine the total raw weight for each load.

10.7.3 Prepare patties for the test by loading them onto half-size 18 by 13 by 1-in. (460 by 330 by 25-mm) sheet pans (see Fig. 3). Package 24 patties per sheet (6 patties per level by 4 levels), separating each level by a double sheet of waxed freezer paper (see Fig. 4). To facilitate verification that the patties are at the required temperature for the beginning of the test, implant a thermocouple probe horizontally into at least one hamburger patty on a sheet pan. Cover the entire package with a commercial-grade plastic wrap. Place the sheet pans in a refrigerator near the underfired broiler test area until the temperature of the patties has stabilized at 38 to 40°F (3 to 4°C).

10.7.4 Monitor the temperature of a hamburger patty with a thermocouple probe. Its internal temperature must reach 38 to 40°F (3 to 4°C) before the hamburger patties can be removed from the refrigerator and loaded onto the underfired broiler. If necessary, adjust the refrigerator temperature to achieve this required internal temperature.

NOTE 11—The hamburger patties should not remain in the refrigerator for more than three days prior to testing after they have stabilized at the 38 to 40°F (3 to 4°C) refrigerator temperature.

10.7.5 Prepare a minimum number of loads for the three test runs. For the heavy-load tests, refer to 10.3.2.4 for the number of hamburger patties required; for light-load tests, use one patty per square-foot (930 cm^2) of broiler grate (see Fig. 5). Count on seven to ten loads per test run.

10.7.6 Set the underfired broiler controls to the setting determined in 10.6.2. Allow the broiling area to stabilize at this setting for 1 h.

10.7.7 Sequentially load patties on the broiler grate over a 15-s time period for each linear foot of broiler grate (for example, 45 s for a 36-in. (915 mm) broiler grate, 60 s for a 48-in. (1220 mm) broiler grate).

10.7.8 Cook patties for 4½ min on the first side, starting from the time the first hamburger patty is placed on the broiler grate.

10.7.9 Turn patties in the same order that they were loaded over a 15-s time period for each linear foot of broiler grate. Cook for an additional 3 min (including time to flip hamburger patties).

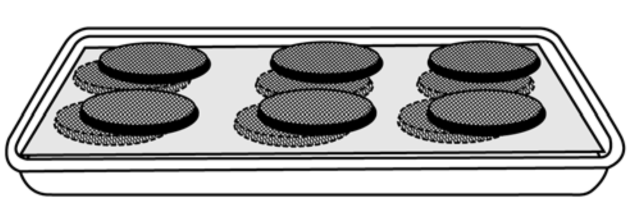

FIG. 3 Example of Hamburger Patty Packaging

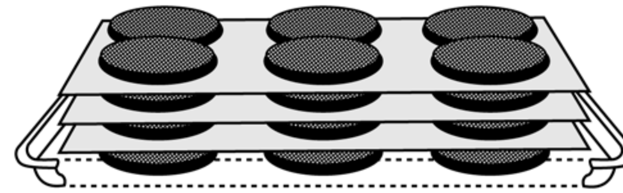

FIG. 4 Cutaway View of Packaged Hamburgers

NOTE 12—Because mechanical pressing varies from operator to operator, it is a difficult variable to specify and apply consistently. It has therefore been eliminated from the test procedure. It is recognized that this approach may establish cooking times that are in excess of the time that might be required using the same underfired broiler in an actual food service operation. However, the objective is to determine cooking times and associated cooking energy efficiency values based on a procedure that decreases the bias from one laboratory to another.

10.7.10 Remove patties in the order placed on the broiler. Allow for a 20-s time period for each linear foot (305 mm) of broiler grate for removing the cooked patties and brushing (cleaning) the broiler grates with a wire brush.

10.7.11 Hamburger patties shall be cooked to an internal temperature of 175°F (79°C) to confirm a well-done condition. This can be accomplished by cooking the patties to a 35 % weight loss.

NOTE 13—Research conducted by the Food Service and Technology Center determined that the final internal temperature of cooked hamburger patties may be approximated by the percent weight loss incurred during cooking. The two are connected by a linear relationship (see Fig. 6) as long as the hamburger patties are within the specifications described in 7.4.

10.7.12 Using tongs, spread patties on a drip rack. Turn the patties over after 1 min. After another minute, transfer the patties to a separate pan for weighing. Calculate the weight loss using the average patty weight determined in 10.7.2. The percent weight loss shall be 35 ± 2 %.

NOTE 14—The actual cook time depends on the length of time the patties remain on the underfired broiler and the average temperature of the broiling area.

10.7.13 If the percent weight loss is not 35 ± 2 %, repeat 10.7.7 – 10.7.12, adjusting the total cooking time to attain the 35 ± 2 % weight loss. Ensure even cooking on both sides of the hamburger patties (approximately 60 % of the total cook time should be on the first side). Reload the broiler with uncooked patties within 20-s per linear foot (305 mm) of broiler grate. As required and as time permits, brush the broiler grates with a wire brush during this period.

10.7.14 Remove each patty load separately from the refrigerator. Do not hand-hold patties until loading takes place.

10.7.15 Run at least two stabilization loads (10.7.7 – 10.7.12) to stabilize the broiler grates. After the underfired broiler has stabilized, run an additional three loads. Monitor the total test time for the final three loads (including cook, removal, and brush time). Record the percent weight loss for each load. Ensure that the average weight loss for the three-load test is 35 ± 2 %.

NOTE 15—If the average weight loss for the three-load test is not 35 ± 2 %, the test is invalid and must be repeated.

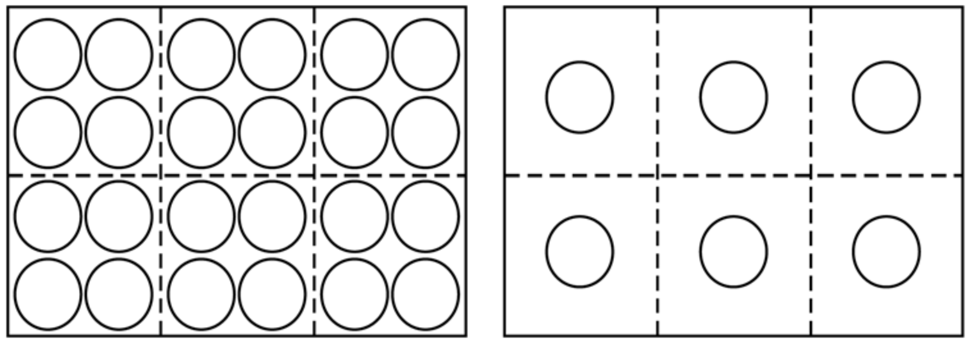

FIG. 5 Patty Positions for Heavy- and Light-Load Tests on a 36 by 24-in. (915 by 610 mm) Broiler Grate

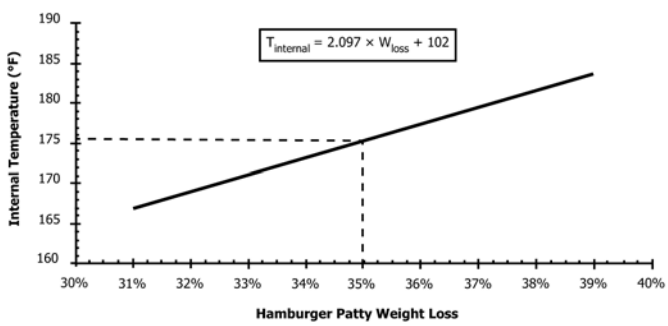

FIG. 6 Bulk Internal Temperature versus Weight Loss of Cooked Hamburger Patties

10.7.16 Allow 20-s per linear foot (305 mm) of broiler grate for removal of the cooked hamburger patties and brushing the broiler grate after the last load before terminating the test. **Do not terminate the test (and time monitoring) after removing the last patty from the last load.**

10.7.17 Reserve three cooked patties (one from each load) to determine moisture content. Place patties in a freezer inside self-sealing plastic bags unless moisture content test is conducted immediately.

10.7.18 Determine the moisture content of the cooked patties in accordance with recognized laboratory procedures (AOAC Official Action 950.46) and calculate the moisture loss based on the initial moisture content of the patties (10.7.2). This will be used to determine the energy of vaporization component of the cooking energy efficiency equation.

10.7.19 Perform runs Nos. 2 and 3 by repeating 10.7.15 – 10.7.18. Follow the procedure in Annex A1 to determine whether more than three test runs are required.

10.7.20 Repeat 10.7.1 – 10.7.19, for the light-load scenario.

11. Calculation and Report

11.1 *Test Underfired Broiler*—Summarize the physical and operating characteristics of the underfired broiler, including grate dimensions. If needed, describe other design or operating characteristics that may facilitate interpretation of the test results.

11.2 *Apparatus and Procedures:*

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 For electric underfired broilers, report the voltage for each test.

11.2.3 For gas underfired broilers, report the higher heating value of the gas supplied to the underfired broiler during each test.

11.3 *Gas Energy Calculations:*

11.3.1 For gas underfired broilers, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (10.2).

11.3.2 For all gas measurements, calculate the energy consumed based on the following:

$$E_{gas} = V \times HV \tag{1}$$

where:

E_{gas} = energy consumed by the appliance,
HV = higher heating value,
= energy content of gas measured at standard conditions, Btu/ft^3 (kJ/m^2), and
V = actual volume of gas corrected for temperature and pressure at standard conditions, ft^3 (m^3)
= $V_{meas} \times T_{cf} \times P_{cf}$,

where:

V_{meas} = measured volume of gas, ft^3 (m^3),
T_{cf} = temperature correction factor,

$$= \frac{\text{absolute standard gas temperature, } {}^\circ R\ ({}^\circ K)}{\text{absolute actual gas temperature, } {}^\circ R\ ({}^\circ K)}$$

$$= \frac{\text{absolute standard gas temperature, } {}^\circ R\ ({}^\circ K)}{[\text{gas temperature } {}^\circ F\ ({}^\circ C) + 459.67\ (273)]\ {}^\circ R\ ({}^\circ K)},$$

and

P_{cf} = pressure correction factor

$$= \frac{\text{absolute actual gas pressure, psia (kPa)}}{\text{absolute standard pressure, psia (kPa)}}$$

$$= \text{gas gage pressure, } \frac{\text{psig (kPa)} + \text{barometric pressure, psia (kPa)}}{\text{absolute standard pressure, psia (kPa)}}$$

NOTE 16—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Standard conditions using Practice D3588 are 14.696 psia (101.33 kPa) and 60°F (519.67°R (288.71°K)).

11.4 *Energy Input Rate:*

11.4.1 Report the manufacturer's nameplate energy input rate in Btu/h (kJ/h) for a gas underfired broiler and kW for an electric underfired broiler.

11.4.2 For gas or electric underfired broilers, calculate and report the measured energy input rate (Btu/h (kJ/h) or kW) based on the energy consumed by the underfired broiler during the period of peak energy input according to the following relationship:

$$E_{input\ rate} = \frac{E \times 60}{t} \quad (2)$$

where:

$E_{input\ rate}$ = measured peak energy input rate, Btu/h (kJ/h) or kW,
E = energy consumed during period of peak energy input, Btu (kJ) or kWh, and
t = period of peak energy input, min.

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

11.5 *Temperature Distribution:*

11.5.1 Report the average temperature of each disk on a plan drawing of the broiling area.

NOTE 17—A topographical temperature map of the broiling area may be used to enhance interpretation of the temperature distribution test results.

11.5.2 Report the maximum temperature difference across the broiling area. The maximum difference is the highest average temperature minus the lowest average temperature for any disk.

11.6 *Preheat Energy and Time:*

11.6.1 Report the preheat energy consumption (Btu (kJ) or kWh) and preheat time (min).

11.6.2 Calculate and report the average preheat rate (°F/min (°C/min)) based on the preheat period. Also report the starting temperature of the broiling area.

11.6.3 Generate a graph showing surface temperature versus time for the preheat time.

11.7 *Pilot Energy Rate*—Calculate and report the pilot energy rate (Btu/h (kJ/h)) based on:

$$E_{pilot\ rate} = \frac{E \times 60}{t} \quad (3)$$

where:

$E_{pilot\ rate}$ = pilot energy rate, Btu/h (kJ/h),
E = energy consumed during the test period, Btu (kJ), and
t = test period, min.

11.8 *Cooking Energy Rate*—Calculate and report the cooking energy rate (Btu/h (kJ/h) or kW) based on:

$$E_{cook\ rate} = \frac{E \times 60}{t} \quad (4)$$

where:

$E_{cook\ rate}$ = cooking energy rate, Btu/h (kJ/h) or kW,
E = energy consumed during the test period, Btu (kJ) or kWh, and
t = test period, min.

11.9 *Cooking Energy Efficiency:*

11.9.1 Calculate and report the cooking energy efficiency for heavy- and light-load cooking tests based on the following:

$$\eta_{cook} = \frac{E_{food}}{E_{appliance}} \times 100 \quad (5)$$

where:

η_{cook} = cooking energy efficiency, %, and
E_{food} = energy into food, Btu (kJ)
= $E_{sens} + E_{evap}$

where:

E_{sens} = quantity of heat added to the hamburger patties, which causes their temperature to increase from the starting temperature to the average bulk temperature of a well-done patty, Btu (kJ)
= $W_i \times C_p \times (T_f - T_i)$

where:

W_i = initial weight of hamburger patties, lb (kg), and
C_p = specific heat of hamburger patty, Btu/lb, °F (kJ/kg, °C),
= 0.72 (0.93).

NOTE 18—For this analysis, the specific heat (C_p) of a hamburger patty is considered to be the weighted average of the specific heat of its components (for example, water, fat, and nonfat protein). Research conducted by the Food Service and Technology Center[7] determined that the weighted average of the specific heat for hamburger patties specified as in 7.4 was approximately 0.72 Btu/lb°F (0.93 kJ/kg, °C).

T_f = final internal temperature of the cooked hamburger patties, °F (°C)
= $2.097 \times W_{tl} + 102$

where:

W_{tl} = average percent weight loss for the three-load run, %

NOTE 19—Research conducted by PG&E determined that the final internal temperature of cooked hamburger patties and the percent weight loss are connected by the above relationship provided that the hamburger patties are within the specifications described in 7.4. Weight loss is expressed as a percentage, and the internal temperature is in degrees Fahrenheit.

T_i = initial patty temperature, °F (°C)
E_{evap} = latent heat (of vaporization) added to the hamburger patties, which causes some of the moisture contained in the patties to evaporate. The heat of vaporization cannot be perceived by a change in temperature and must be calculated after determining the amount of moisture lost from a well-done patty.
= $W_{loss} \times H_v$

where:

W_{loss} = weight loss of water during cooking, lb (kg),
H_v = heat of vaporization, Btu/lb (kJ/kg),
= 970 Btu/lb (2256 kJ/kg) at 212°F (100°C), and
$E_{appliance}$ = energy into the appliance, Btu (kJ)
= $\dfrac{E_{cook\ rate} \times t_{cook}}{60}$

where:

$E_{cook\ rate}$ = appliance cooking energy rate (from 11.8), Btu/h (kJ/h) or kW and
t_{cook} = cook time, min.

11.9.2 Calculate and report the energy consumption per pound of food cooked for heavy- and light-load cooking tests based on the following:

$$E_{per\ pound} = \frac{E_{appliance}}{W} \quad (6)$$

where:

$E_{per\ pound}$ = energy per pound, Btu/lb (kJ/kg) or kWh/lb (kWh/kg),
$E_{appliance}$ = energy consumed during cooking test, Btu (kJ) or kWh, and
W = total initial weight of the hamburger patties, lb (kg).

11.9.3 Calculate the production capacity (lb/h (kg/h)) based on the following:

$$PC = \frac{W \times 60}{t} \quad (7)$$

where:

PC = production capacity of the broiler, lb/h (kg/h),
W = total raw weight of food cooked during the heavy-load cooking test, lb (kg), and
t = total time of heavy-load cooking test, including cook time and reload time, min.

11.9.4 Calculate the production rate (lb/h (kg/h)) for the light-load tests using the relationship from 11.9.3, where W = the total weight of food cooked during the test run, and t = the total time of the light-load test run.

11.9.5 Report the average cook time for the heavy- and light-load cooking tests. Also report the number of hamburger patties used for each load of the heavy-load test.

12. Precision and Bias

12.1 *Precision:*

12.1.1 *Repeatability (Within Laboratory, Same Operator and Equipment):*

12.1.1.1 For the cooking energy efficiency and production capacity 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, with the exception of temperature distribution, is being determined. The repeatability of the temperature distribution test cannot be determined because of the descriptive nature of the test result.

12.1.2 *Reproducibility (Multiple Laboratories)*—The interlaboratory precision of the procedure in this test method for measuring each reported parameter, with the exception of temperature distribution, is being determined. The reproducibility of the temperature distribution test cannot be determined because of the descriptive nature of the test result.

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 cook time; energy efficiency; performance; test method; underfired broiler

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, hamburger patty fat content within the 20 ± 2 % specification).

A1.1 For the cooking energy efficiency and production capacity results, the uncertainty in the averages of at least three test runs is reported. For each loading scenario, the uncertainty of the cooking energy efficiency and production capacity must be no greater than ±10 % before any of the parameters for that loading scenario can be reported.

A1.2 The uncertainty in a reported result is a measure of its precision. If, for example, the heavy-load efficiency for the appliance is 30 %, the uncertainty must not be greater than ±3 percentage points. Thus, the true heavy-load efficiency is between 27 and 33 %. This interval is determined at the 95 % confidence level, which means that there is only a 1 in 20 chance that the true heavy-load efficiency 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 average. The percent uncertainty is the ratio of the uncertainty to the average expressed as a percent.

A1.4 *Procedure:*

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

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 cooking-energy efficiency 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:

$$Xa_3 = (1/3) \times (X_1 + X_2 + X_3) \quad (A1.1)$$

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:

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

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 the cooking energy efficiency. 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:

$$U_3 = C_3 \times S_3, \quad (A1.3)$$

$$U_3 = 2.48 \times S_3$$

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 the average cooking energy efficiency using the average from Step 1 and the absolute uncertainty from Step 2.

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

$$\%\ U_3 = (U_3/Xa_3) \times 100\ \% \quad (A1.4)$$

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 If the percent uncertainty, $\%\ U_3$, is not greater than ±10 % for the cooking-energy efficiency, report the average along with its corresponding absolute uncertainty, U_3, in the following format:

$$Xa_3 \pm U_3$$

If the percent uncertainty is greater than ±10 % for the cooking energy efficiency, 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:

$$Xa_4 = (1/4) \times (X_1 + X_2 + X_3 + X_4) \quad (A1.5)$$

where:

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

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

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

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 cooking energy efficiency. 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:

$$U_4 = C_4 \times S_4, \quad (A1.7)$$

$$U_4 = 1.59 \times S_4$$

where:

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

A1.4.8 *Step 8*—Calculate the percent uncertainty in the average cooking energy efficiency using the average from Step 6 and the absolute uncertainty from Step 7.

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

$$\%\ U_4 = (U_4/Xa_4) \times 100\ \% \quad (A1.8)$$

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, report the average along with its corresponding absolute uncertainty, U_4, in the following format:

$$Xa_4 \pm U_4$$

If the percent uncertainty is greater than ±10 % for the cooking energy efficiency, 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 for calculating the average, standard deviation, absolute uncertainty, and percent uncertainty are as follows:

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

$$Xa_n = (1/n) \times (X_1 + X_2 + X_3 + X_4 + \ldots + X_n) \quad (A1.9)$$

where:

n = number of test runs,
Xa_n = average of results for 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:

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

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:

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

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:

$$\%\ U_n = (U_n / Xa_n) \times 100\ \% \quad (A1.12)$$

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.

When the percent uncertainty, % *Un*, is less than or equal to ±10 % for the cooking energy efficiency, report the average along with its corresponding absolute uncertainty, *Un*, 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 test method. For example, a thermocouple was out of calibration or the food product was not within specification. To ensure that all results are obtained under approximately the same conditions, it is good practice to monitor those test conditions specified in this test method.

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

A1.5.1 Three test runs for the heavy-load cooking scenario yielded the following cooking energy efficiency results:

Test	Cooking Energy Efficiency, %
Run No. 1	33.8
Run No. 2	34.1
Run No. 3	31.0

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

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

$$Xa_3 = (1/3) \times (X_1 + X_2 + X_3), \quad (A1.13)$$

$$Xa_3 = (1/3) \times (33.8 + 34.1 + 31.0),$$

$$Xa_3 = 33.0\ \%$$

A1.5.2.2 The standard deviation of the three test results is as follows. First calculate *A*3 and B_3.

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

$$A_3 = (33.8)^2 + (34.1)^2 + (31.0)^2$$

$$A_3 = 3266$$

$$B_3 = (1/3) \times [(X_1 + X_2 + X_3)^2],$$

$$B_3 = (1/3) \times [(33.8 + 34.1 + 31.0)^2],$$

$$B_3 = 3260$$

A1.5.2.3 The new standard deviation for the cooking energy efficiency is as follows:

$$S_3 = \left(1/\sqrt{2}\right) \times \sqrt{(3266 - 3260)}, \quad (A1.15)$$

$$S_3 = 1.71\ \%$$

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

$$U_3 = 2.48 \times S_3, \quad (A1.16)$$

$$U_3 = 2.48 \times 1.71,$$

$$U_3 = 4.24\ \%$$

A1.5.4 *Step 3*—Calculate percent uncertainty as follows:

$$\%\ U_3 = (U_3 / Xa_3) \times 100\ \%, \quad (A1.17)$$

$$\%\ U_3 = (4.24/33.0) \times 100\ \%,$$

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

A1.5.5 *Step 4*—Run a fourth test. Since the percent uncertainty for the cooking energy efficiency is greater than ±10 %, the precision requirement has not been satisfied. An additional test is run in an attempt to reduce the uncertainty. The cooking energy efficiency from the fourth test run was 32.5 %.

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

A1.5.6.1 The new average cooking energy efficiency is as follows:

$$Xa_4 = (1/4) \times (X_1 + X_2 + X_3 + X_4), \quad (A1.18)$$

$$Xa_4 = (1/4) \times (33.8 + 34.1 + 31.0 + 32.5),$$

$$Xa_4 = 32.9\ \%$$

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

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

$$A_4 = (33.8)^2 + (34.1)^2 + (31.0)^2 + (32.5)^2,$$

$$A_4 = 4323$$

$$B_4 = (1/4) \times [(X_1 + X_2 + X_3 + X_4)^2],$$

$$B_4 = (1/4) \times [(33.8 + 34.1 + 31.0 + 32.5)^2],$$

$$B_4 = 4316$$

A1.5.6.3 The new standard deviation for the cooking energy efficiency is as follows:

$$S_4 = \left(1/\sqrt{3}\right) \times \sqrt{(4323 - 4316)}, \quad (A1.20)$$

$$S_4 = 1.42\ \%$$

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

$$U_4 = 1.59 \times S_4, \quad (A1.21)$$

$$U_4 = 1.59 \times 1.42,$$

$$U_4 = 2.25\ \%$$

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

$$\%U_4 = (2.25/32.9) \times 100\ \%, \quad (A1.22)$$

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

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

$$\text{cooking energy efficiency}: 32.9 \pm 2.25\ \% \quad (A1.23)$$

APPENDIX

(Nonmandatory Information)

X1. RESULTS REPORTING SHEETS

Manufacturer ____

Model ____

Date ______________________________

Test Reference Number (optional) ____________________________

Section 11.1 Test Underfired Broiler

Description of operational characteristics: ____

____

____

____

____

____

____

Section 11.2 Apparatus

_________Check if testing apparatus conformed to specifications in Section 6.

Deviations ____

____

____

____

Section 11.4 Energy Input Rate

Test Voltage (V) __________

Gas Heating Value (Btu/ft^3 (kJ/m^3)) __________

Measured (Btu/h (kJ/h) or kW) __________

Rated (Btu/h (kJ/h) or kW) __________

Percent Difference between Measured and Rated (%) __________

Section 11.5 Temperature Distribution

FIG X1.1 Average Broiling Area Temperatures

Maximum temperature difference across broiling area (°F (°C)): __________

Section 11.6 Preheat Energy and Time

Test Voltage (V) __________

Gas Heating Value (Btu/ft^3 (kJ/m^3)) __________

Starting Temperature (°F (°C)) __________

Energy Consumption (Btu (kJ) or kWh) __________

Duration (min) __________

Preheat Rate (°F/min (°C/min)) __________

Section 11.7 Pilot Energy Rate (If Applicable)

Gas Heating Value (Btu/ft^3 (kJ/m^3)) __________

Pilot Energy Rate (Btu/h (kJ/h) or kW) __________

Section 11.8 Cooking Energy Rate

Test Voltage (V) __________

Gas Heating Value (Btu/ft^3 (kJ/m^3)) __________

Cooking Energy Rate (Btu/h (kJ/h) or kW) __________

Electric Energy Rate (kW, gas underfired broilers only) __________

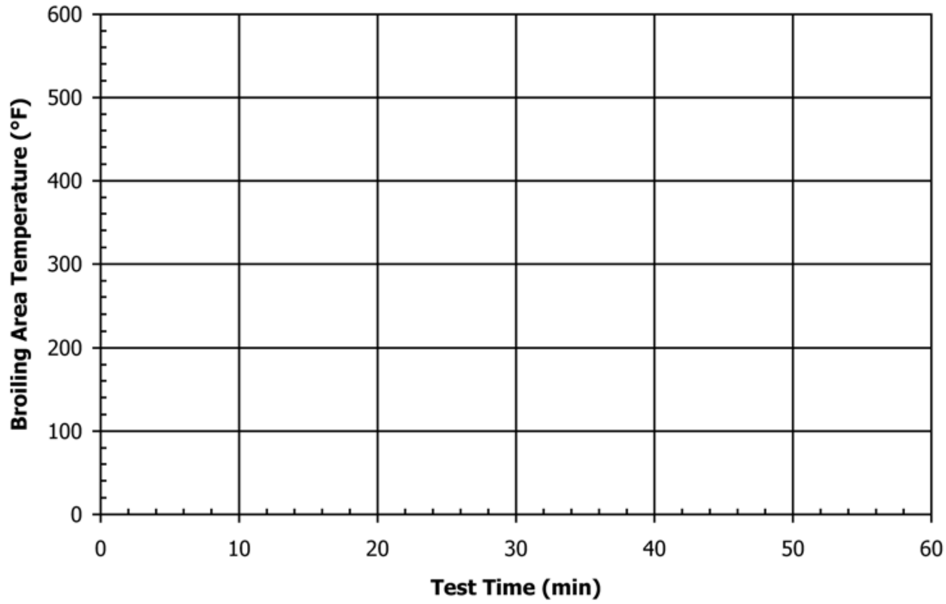

FIG. X1.1 Broiler Preheat Curve

Section 11.9 Cooking Energy Efficiency

Heavy-Load:

Test Voltage (V) __________

Gas Heating Value (Btu/ft^3 (kJ/m^3)) __________

Number of Hamburger Patties per Load __________

Cooking Time (min) __________

Energy to Food (Btu/lb (kJ/kg)) __________

Energy per Pound of Food Cooked (Btu/lb (kJ/kg) or Wh/lb (Wh/kg)) __________

Cooking Energy Efficiency (%) __________

Production Capacity (lb/h (kg/h)) __________

Light-Load:

Test Voltage (V) __________

Gas Heating Value (Btu/ft^3 (kJ/m^3)) __________

Cooking Time (min) __________

Energy to Food (Btu/lb (kJ/kg)) __________

Energy per Pound of Food Cooked (Btu/lb (kJ/kg) or Wh/lb (Wh/kg)) __________

Cooking Energy Efficiency (%) __________

Production Rate (lb/h (kg/h)) __________