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An American National Standard

Standard Test Method for Performance of Underfired Broilers[1]

This standard is issued under the fixed designation F 1695; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

~~1.3.6Cooking energy efficiency and product cook time (see~~

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

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

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]

A~~36/A36 M Specification for Structural Steel~~ 36/A 36M Specification for Carbon Structural Steel

D 3588 Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels

2.2 *ANSI Standard:*[3]

ANSI Z83.11~~for Gas Food Service Equipment—Ranges and Unit Broilers~~ 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

~~[1] This test method is under the jurisdiction of ASTM Committee F-26 on Food Service Equipment and is the direct responsibility of Subcommittee F26.06 on Productivity and Energy Protocol.~~

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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* ~~, Vol 01.04.~~volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from ~~the~~ American National Standards ~~Institute, 11~~ Institute (ANSI), 25 W. ~~42nd~~43rd St., ~~13th~~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 ~~the~~ American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329.

~~[6] Available from Pacific Gas and Electric Co., 3400 Crow Canyon Road, San Ramon, CA 94583.~~

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

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.

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.

~~3.1.11~~

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.~~

~~NOTE 1—Because there is no recovery time associated with cooking on underfired broilers, product cook time is reported for the specified food product instead of production capacity.~~ -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 A 36/A 36M~~/A 36 M~~,, 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 ~~2—Fresh~~ 1—Fresh or tempered hamburger patties may be used for the purposes of this test method.

NOTE ~~3—It~~ 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.

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

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

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.).~~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 ~~4—It~~ 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 ~~5—Using~~ 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 ~~6—The~~ 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 ~~7—This~~ 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 ~~8—It~~ 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.

10.4 *Preheat Energy and Time*:

NOTE ~~9—The~~ 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.

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 ~~10—The~~ 9—The underfired broiler should be set such that the broiling temperature is as high as possible without exceeding 600°F (315°C).

NOTE 1~~1~~0—Research conducted by ~~PG&E~~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.

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

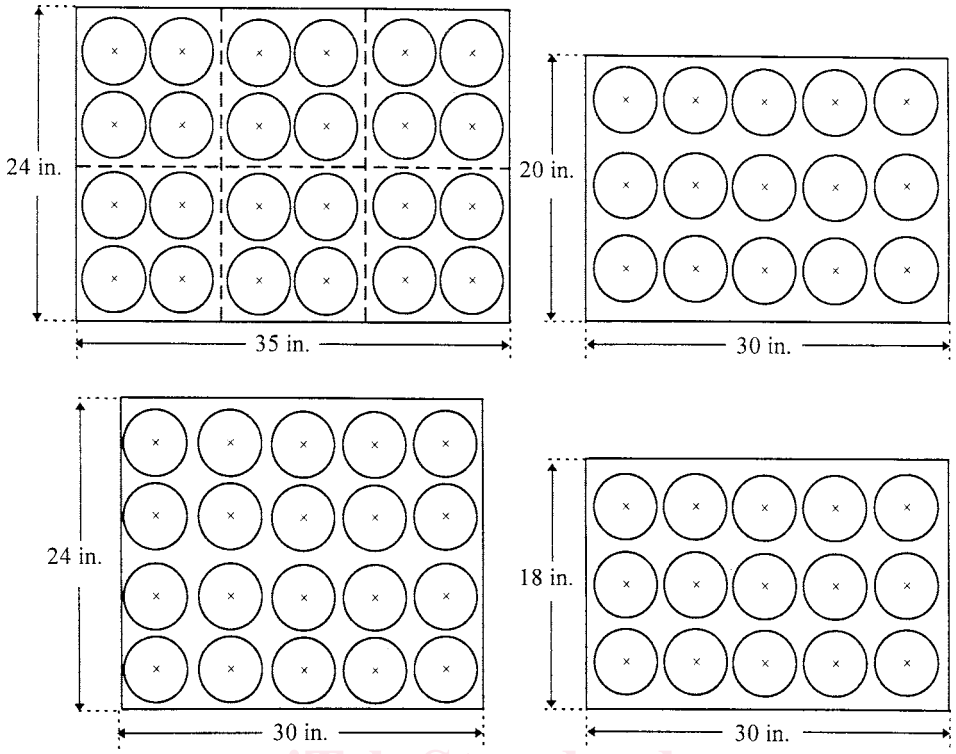

FIG. 1 Example of Disk Positions for the Temperature Distribution Test on Different Nominal 36-in. (915 mm) Broiler Grates

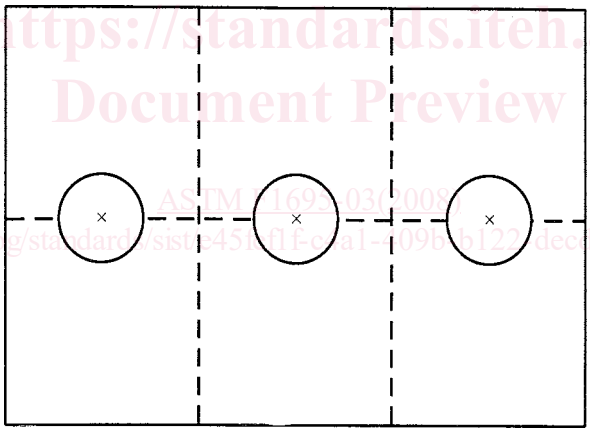

FIG. 2 Disk Positions for the Preheat Test on a Nominal 36 by 24-in. (915 by 610 mm) Underfired Broiler

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,