Standard Test Method for Performance of Conveyor Broilers[1]

This standard is issued under the fixed designation F2239; 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 evaluates the energy consumption and cooking performance of conveyor broilers. The food service operator can use this evaluation to select a conveyor broiler and understand its energy consumption.

1.2 This test method is applicable to gas, electric, and hybrid gas/electric conveyorized broilers. This test method covers both units with continuously operating conveyors and batch-style units with intermittently operating conveyors.

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

1.3.1 Energy input rate (see 10.2),

1.3.2 Preheat energy consumption and time (see 10.3),

1.3.3 Idle energy rate and temperature uniformity (see 10.4),

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

1.3.5 Cooking energy efficiency, cooking uniformity and production capacity (see 10.8 and 10.9).

1.4 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

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 *ASTM Standards:*[2]

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 Standard:*[5]

ASHRAE Handbook of Fundamentals "Thermal and Related Properties of Food and Food Materials," Chapter 30, Table 1, 1989

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *broiler cavity, n*—that portion of the conveyor broiler in which food products are heated or cooked.

3.1.2 *continuous conveyor, n*—broiler with a belt or chain that moves constantly through the broiler cavity and does not halt during the cooking process.

3.1.3 *conveyor broiler, n*—device, with a continuous belt and a heat source above and below the belt, for cooking food by high heat, usually by direct or radiant heat. Conveyor broilers are used primarily, but not exclusively, for cooking meats.

3.1.4 *cooking energy efficiency, n*—quantity of energy imparted to the specified food product, expressed as a percentage of energy consumed by the conveyor broiler during the cooking event.

3.1.5 *cooking energy rate, n*—average rate of energy consumption (Btu/h or kW) during the cooking energy efficiency tests. Refers to both loading scenarios (heavy, light).

3.1.6 *cooking lane, n*—segment of broiler that food product passed through as it cooks. Each position on the conveyor where food product is placed represents a cooking lane.

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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 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.

3.1.7 *cooking uniformity, n*—calculated variation in cooked food product.

3.1.8 *energy input rate, n*—peak rate at which a conveyor broiler consumes energy (Btu/h or kW).

3.1.9 *idle energy rate, n*—conveyor broiler's rate of energy consumption (kW or Btu/h), when empty, required to maintain the broiler's temperature at the specified thermostat set point.

3.1.10 *intermittent conveyor, n*—broiler that operates the belt or chain only at the beginning or conclusion of a cooking cycle to move a batch of product through the broiler cavity.

3.1.11 *pilot energy rate, n*—rate of energy consumption (Btu/h) by a conveyor broiler's continuous pilot (if applicable).

3.1.12 *preheat energy, n*—amount of energy consumed (Btu or kWh), by the conveyor broiler while preheating its cavity from ambient temperature to the specified thermostat set point.

3.1.13 *preheat time, n*—time (min.) required for the conveyor broiler cavity to preheat from ambient temperature to the specified thermostat set point.

3.1.14 *production capacity, n*—maximum rate (lb/h) at which a conveyor broiler can bring the specified food product to a specified "cooked" condition.

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

3.1.16 *temperature uniformity, n*—measured variation in broiler cavity temperature.

3.1.17 *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 Energy input rate is determined to confirm that the conveyor broiler is operating within 5 % of the nameplate energy input rate. For gas and hybrid gas/electric conveyor broilers, the pilot energy rate and control energy rates are also determined (if applicable).

4.2 Preheat energy and time are determined.

4.3 Idle energy rate and temperature uniformity of each broiler cavity is determined while operating at manufacturer's recommended temperature setting.

4.4 Cooking energy efficiency is determined during light-load cooking tests using prefrozen hamburger patties as a food product.

4.5 Cooking energy efficiency, cooking uniformity, and production rate are determined during heavy-load cooking tests using prefrozen hamburger patties as a food product.

5. Significance and Use

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

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

5.3 Idle energy rate and pilot energy rate can be used to estimate energy consumption during non-cooking periods.

5.4 Temperature uniformity of the broiler cavity may be used by food service operators to understand the heat distribution throughout the broiler cavity and select a conveyor broiler that matches their required temperature characteristics.

5.5 Cooking energy efficiency is a precise indicator of conveyor broiler energy performance while cooking a typical food product under various loading conditions. If energy performance information is desired using a food product other than the specified test food, the test method could be adapted and applied. Energy performance information allows an end user to better understand the operating characteristics of a conveyor broiler.

5.6 Cooking uniformity of the broiler may be used by food service operates to select a conveyor broiler that provides a uniformly cooked product.

5.7 Production capacity information can help an end user to better understand the production capabilities of a conveyor broiler as it is used to cook a typical food product and this could help in specifying the proper size and quantity of equipment. If production information is desired using a food product other than the specified test food, the test method could be adapted and applied.

6. Apparatus

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

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

6.3 *Canopy Exhaust Hood,* 4 ft in depth, wall-mounted with the lower edge of the hood 6 ft, 6 in. from the floor and with the capacity to operate at a nominal exhaust ventilation rate of 300 cfm per linear foot of active hood length. This hood shall extend a minimum of 6 in. past both sides and the front of the cooking appliance and shall not incorporate side curtains or partitions.

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

6.5 *Data Acquisition System,* for measuring energy and temperatures, capable of multiple channel displays updating at least every 5 s.

6.6 *Gas Meter,* for measuring the gas consumption of a conveyor broiler, shall be a positive displacement type with a resolution of at least 0.01 ft^3 and a maximum uncertainty no greater than 1 % of the measured value for any demand greater than 2.2 ft^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 and a maximum uncertainty no greater than 2 % of the measured value.

6.7 *Pressure Gage,* for monitoring natural gas pressure. It shall have a range of 0 to 10 in. water, a resolution of 0.5 in. water, and a maximum uncertainty of 1 % of the measured value.

6.8 *Stop Watch,* with a 1-s resolution.

6.9 *Temperature Sensor,* for measuring natural gas temperature in the range of 50 to 100°F with an uncertainty of ±1°F.

6.10 *Thermocouple(s),* high temperature (>1200°F) fiberglass insulated, 24 gage, type K thermocouple wire, welded and calibrated.

6.11 *Watt-Hour Meter,* for measuring the electrical energy consumption of a conveyor broiler, 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 (25 patties for a 30 in. nominal width broiler), for dripping hamburger patties.

7.2 *Freezer Paper,* waxed commercial grade, 18 in. (460 mm) wide, for use in packaging hamburger patties.

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* shall be prefrozen, four 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 patties shall be machine prepared to produce ⅜-in. (9.5 mm) thick patties with a nominal diameter of 5 in. (127 mm).

NOTE 1—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 *Permanent Marker,* felt-tip, for labeling plastic bags.

7.6 *Plastic Bags,* self-sealing, 1 gal (3.79 L) size, for collecting cooked hamburger patties.

7.7 *Plastic Wrap,* commercial grade, 18 in. (460 mm) wide, for use in packaging hamburger patties.

7.8 *Tongs,* commercial grade, metal construction, for handling hot hamburger patties.

8. Sampling and Test Units

8.1 *Conveyor 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 canopy exhaust hood. Position the conveyor broiler so that a minimum of 6 in. is maintained between the edge of the hood and the vertical plane of the front and sides of the appliance. In addition, both sides of the conveyor broiler shall be a minimum of 3 ft from any side wall, side partition, or other operating appliance. The exhaust ventilation rate shall be 300 cfm per linear foot of active hood length. The associated heating or cooling system shall be capable of maintaining an ambient temperature of 75 ± 5°F within the testing environment when the exhaust ventilation system is operating.

NOTE 2—The ambient temperature requirements are designed to simulate real world kitchen temperatures and are meant to provide a reasonable guideline for the temperature requirements during testing. If a facility is not able to maintain the required temperatures, then it is reasonable to expect that the application of the procedure may deviate from the specified requirements (if it cannot be avoided) as long as those deviations are noted on the Results Reporting Sheets.

NOTE 3—It is acknowledged that custom hood and catalyst configurations exist for some conveyor broilers. This test method may still be applied when the chain broiler is used with a custom hood configuration or a catalyst, or both, as long as the configuration is noted on the Results Reporting Sheets.

9.2 Connect the conveyor 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 conveyor 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 an electric or hybrid gas/electric conveyor broiler, confirm (while the conveyor broiler 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 is the intent of the test procedure within this test method to evaluate the performance of a conveyor 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 a conveyor 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, the preheat time) may differ at the two voltages.

9.4 For a gas or hybrid gas/electric conveyor 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.

10. Procedure

10.1 *General:*

10.1.1 For gas or hybrid gas/electric conveyor broilers, 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 Energy input rate during or immediately prior to test (for example, during the preheat for that day's testing), and

10.1.1.7 Ambient temperature.

NOTE 5—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 conveyor broiler under test. It is recommended that all testing be performed with gas having a higher heating value of 1000 to 1075 Btu/ft^3.

10.1.2 For gas or hybrid gas/electric conveyor broilers, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (see 10.2).

10.1.3 For electric or hybrid gas/electric conveyor broilers, record the following for each test run:

10.1.3.1 Voltage while elements are energized,

10.1.3.2 Energy input rate during or immediately prior to test (for example, during the preheat for that day's testing), and

10.1.3.3 Ambient temperature.

10.1.4 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 conveyor broiler.

10.2 *Energy Input Rate:*

10.2.1 Install a thermocouple 1 in. above the conveyor, at the center of the broiler cavity (side to side and front to back). For broilers with multiple cooking cavities, install a thermocouple 1 in. above the conveyor, at the center of each additional broiler cavity.

NOTE 6—The number of cooking cavities is equal to the number of chambers separated by a solid wall or partition within the broiler. Each chamber typically uses a separate conveyor.

10.2.2 Set the temperature control for each cooking cavity to the manufacturer's recommended temperature setting and turn all cavities of the conveyor broiler on. Record the time and energy consumption from the time when the unit is turned on for a period of at least 10 min, or until any of the elements first cycle off.

10.2.3 Calculate and record the conveyor broiler's energy input rate and compare the result to the rated nameplate input. For gas conveyor broilers, only the burner energy consumption is used to compare the calculated energy input rate with the rated gas input. Any electrical energy use shall be calculated and recorded separately as the control energy rate.

10.2.4 In accordance with 11.4, calculate and report the conveyor broiler energy input rate, control energy rate where applicable, and rated nameplate input.

10.3 *Preheat Energy Consumption and Time:*

10.3.1 Verify that the cavity temperature is 75 ± 5°F. Set the temperature control to the manufacturer's recommended temperature setting for each broiler cavity and turn all cavities of the conveyor broiler on. Record the thermostat setting(s) for all thermostats.

10.3.2 Record the time, temperature and energy consumption until the temperature at the center of each cavity stabilizes and the unit is thoroughly heated. Record the stabilization temperature of each cavity. Stop monitoring time and energy. The preheat time is determined as the time for each cavity to reach 25°F of the stabilized operating temperature using the temperature reading of the cavity that took the longest amount of time to reach its maximum temperature. The preheat time for the broiler is the amount of time the slowest cavity took to reach 25°F below the stabilized operating temperature, as measured by its respective thermocouple. Preheat energy consumption is the total energy consumed by the broiler during the preheat time.

NOTE 7—Individual cavities in a multiple cavity broiler may preheat at different rates and stabilize at different temperatures. It is the intent of this test to judge preheat complete when the slowest preheating cavity is within 25°F of the maximum temperature measured by the thermocouple in that particular cavity.

NOTE 8—Preheat time includes any delay between the time the unit is turned on and the time the burners actually ignite.

10.3.3 In accordance with 11.5, calculate and report the conveyor broiler preheat energy consumption and time, the thermostat setting(s), and generate a preheat temperature versus time graph.

10.4 *Idle Energy Rate:*

10.4.1 Set the temperature control(s) to the manufacturer's recommended temperature setting(s) and preheat the conveyor broiler. Allow the conveyor broiler to stabilize for 60 min after the last broiler cavity reaches its thermostat set point.

10.4.2 At the end of 60 min, begin recording the conveyor broiler's idle energy consumption and the elapsed time for a minimum of 2 h. Record the length of the idle period.

10.4.3 In accordance with 11.6, calculate and report the conveyor broiler idle energy rate.

10.5 *Pilot Energy Rate:*

10.5.1 For a gas conveyor broiler with a continuous standing pilot, set the gas valve at the "pilot" position and set the conveyor broiler's temperature control to the "off" position.

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

10.5.3 Monitor gas consumption for a minimum of 8 h of pilot operation.

10.5.4 In accordance with 11.8, calculate and report the conveyor broiler pilot energy rate.

10.6 *Hamburger Patty Preparation:*

10.6.1 Note the nominal width of each conveyor and nominal cavity length of the broiler under test. The nominal length of the broiler cavity, in conjunction with the nominal width of the conveyor(s), represents how many hamburger patties can fit completely within the broiler cavity(ies) at a spacing of one patty per 6 in. For instance, a broiler with a nominal conveyor width of 18 in. and a nominal cavity length of 30 in. can hold 15 hamburger patties at once (five patties in each of three lanes).

10.6.2 Based on the nominal conveyor width(s) and nominal cavity length, prepare enough hamburger patties for a light load test and a heavy load test. Each test will consist of a minimum of three runs. Table 1 lists how many hamburger patties are required for each run of a light load test, and Table 2 lists how many hamburger patties are required for each run of a heavy load test. Table 3 lists how many hamburger patties are

TABLE 1 Total Number of Hamburger Patties Required for Each Run of a Light Load Test

Nominal Width, in.	Nominal Length, in.			
	12	18	24	30
12	8	8	8	8
18	12	12	12	12
24	16	16	16	16
30	20	20	20	20

TABLE 2 Total Number of Hamburger Patties Required for Each Run of a Heavy Load Test

Nominal Width, in.	Nominal Length, in.			
	12	18	24	30
12	20	30	40	50
18	30	45	60	75
24	40	60	80	100
30	50	75	100	125

TABLE 3 Total Number of Hamburger Patties Required for a Complete Broiler Test

Nominal Width, in.	Nominal Length, in.			
	12	18	24	30
12	84	114	144	174
18	126	171	216	261
24	168	228	288	348
30	210	285	360	435

required for a complete broiler test—three runs of a light load test plus three runs of a heavy load test.

NOTE 9—A minimum of three test runs is specified, however, more test runs may be necessary if the results do not meet the uncertainty criteria specified in Annex A1.

NOTE 10—Tables 1-3 are meant to help the tester prepare the right number of total hamburger patties needed to perform the Cooking Energy Efficiency and Production Capacity (see 10.8 and 10.9) test procedure. As part of that procedure, the patties required for each run of a light load test and each run of a heavy load test are divided into two equal groups and referred to as "stabilization" patties and "test" patties. The quantities specified in Tables 1-3 include the total number of required patties, that is, "stabilization" plus "test."

10.6.3 Verify the fat and moisture content of the hamburger patties in accordance with recognized laboratory procedures (AOAC Official Action 960.39 and Official Action 950.46B). Select hamburger patties (1 for every 15) randomly, and weigh them. Record the average weight of these samples to enable later determination of the total raw weight of each load.

10.6.4 Prepare patties for the test by loading them onto half-size 18 by 13 by 1-in. (46 by 33 by 2.5-cm) sheet pans (Fig. 1). Package 24 patties per sheet pan (six patties per level by four levels), separating each level by a double sheet of waxed freezer paper (Fig. 2). To facilitate verification that the patties are at the required temperature for the beginning of the test, implant a thermocouple 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 freezer near the broiler test area until the temperature of the patties has stabilized at the freezer temperature.

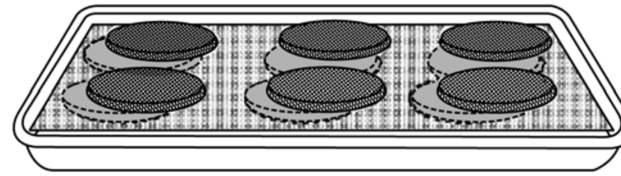

FIG. 1 Sample of Hamburger Patty Packaging

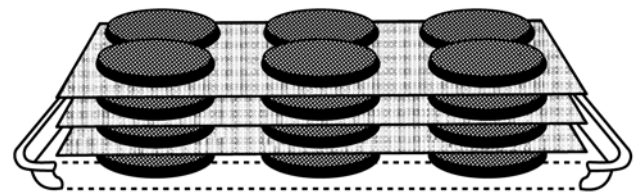

FIG. 2 Cutaway of Packaged Hamburger Patties

10.6.5 Monitor the temperature of the frozen patty with a thermocouple. Its internal temperature must reach 0 ± 5°F (-17.8 ± 2.8°C) before the hamburger patties can be removed from the freezer and loaded onto the broiler. Adjust the freezer temperature to achieve this required internal temperature (the typical freezer setting is -5°F) if necessary.

10.6.6 Prepare a minimum of 24 additional hamburger patties for use in cook time determination. The actual number of patties needed for the cook time determination will vary with the width of the conveyor and the number of trials needed to establish a cooking time that demonstrates a 165°F final patty temperature after cooking.

10.7 *Cook Time Determination:*

10.7.1 Set the calibrated temperature control for each cooking cavity to the manufacturer's recommended setting, preheat all cavities of the conveyor broiler and allow it to idle for 60 min. Estimate a cook time for a hamburger patty. For broilers with multiple conveyors, set the cook time to the same value for each conveyor. The cook time is the time that it takes the entire patty to pass completely though the broiler cavity, starting from the point where the leading edge of the patty enters the broiler cavity until the point where the trailing edge of the patty exits the broiler cavity. The cook time will be different from the conveyor speed, which is the time it takes for a single point on the conveyor to pass through the broiler cavity. The broiler controls will most likely be based on the conveyor speed.

NOTE 11—It is the intent of this test method to have all broiler cavities cook hamburger patties using the same conveyor speed to allow reasonable implementation of the test procedure. Any variation in cooked food product between the different cooking lanes will be averaged in the final weighing.

10.7.2 Remove enough frozen hamburger patties from the freezer to fill the width of the conveyor(s) with patties (three patties for a conveyor broiler with a nominal conveyor width of 18 in.). Place the patties directly onto the conveyor(s) so that the leading edge of each patty is adjacent to the entrance of the broiler cavity, and spaced with equal distance between each patty from side to side. Do not allow more than 30 s to elapse from the time the patties are removed from the freezer until they are placed on the conveyor(s).

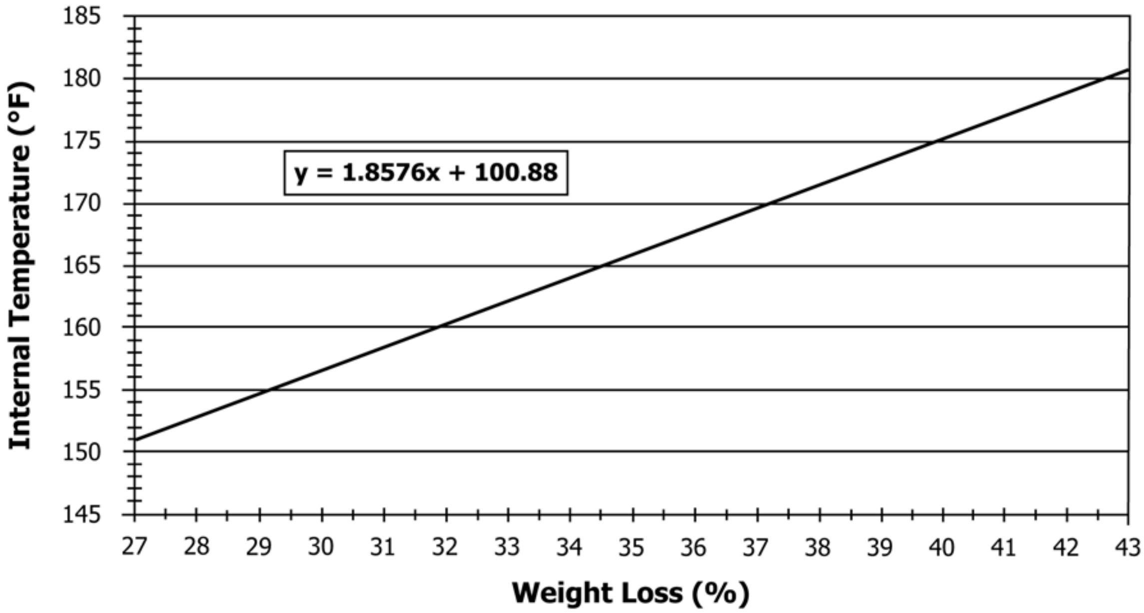

FIG. 3 Relationship Between Bulk Internal Temperature and the Weight Loss of Hamburger Patties Cooked on a Continuous Conveyor Broiler

10.7.3 Allow the patties to pass through the broiler cavity and cook.

10.7.4 Hamburger patties shall be cooked to an internal temperature of 165 ± 5°F (74°C) which results in a medium-done condition. For continuous conveyors, this can be accomplished by cooking the patties to a 35 ± 2 % weight loss. For intermittent conveyors, this can be accomplished by cooking the patties to a 30 ± 2 % weight loss (see Fig. 3 and Fig. 4).

NOTE 12—Research conducted by PG&E has 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. 3 and Fig. 4), as long as the hamburger patties are within the specifications described in 7.4.

10.7.5 After removing the patties from the broiler, place them on a wire drip rack, drip for 2 min (1 min per side) and then weigh. Calculate the weight loss using the average initial patty weight determined in 10.6.3. The percent weight loss shall be as specified in 10.7.4 for an internal patty temperature of 165 ± 5°F.

10.7.6 If the percent weight loss is not 35 ± 2 % for continuous conveyors or 30 ± 2 % for intermittent conveyors, repeat the steps given in 10.7.2 – 10.7.5, adjusting the cook time (for example, speed of the conveyor(s) on continuous conveyors) to attain the appropriate weight loss for a 165 ± 5°F internal temperature. Be sure to keep all conveyor speeds in all cavities equal when making changes.

10.7.7 Record the determined conveyor speed and cook time for use during the cooking energy efficiency and production tests.

10.8 *Light-Load Cooking Energy Efficiency:*

10.8.1 The light-load cooking energy efficiency test is to be run a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (see Annex A1).

10.8.2 Set the temperature control for each cooking cavity to the manufacturer's recommended operating temperature, preheat the broiler, and allow it to idle for 60 min. Set the cook times or conveyor speed to achieve the cook time for the hamburger patties determined in 10.7.7. Record the conveyor speed (continuous conveyors) and cook time (both continuous conveyors and intermittent conveyors).

10.8.3 Each light-load test run uses the number of hamburger patties detailed in Table 1, and is performed in two steps, or halves. The patties included in the first half of the test run are used to stabilize the broiler and are referred to as the "stabilization" patties. The patties included in the second half of the test run are used for energy efficiency determination and are referred to as the "test" patties. For example, a broiler with a nominal 18 in. conveyor width and a 24 in. nominal cavity length will require twelve patties for a light load—six stabilization patties and six test patties.

10.8.4 Remove the first row of patties from the freezer. Place the patties directly on the conveyor(s) so that the leading edge of each patty is adjacent to the entrance of the broiler cavity, and spaced with equal distance between each patty from side to side. Do not allow more than 30 s to elapse from the time the patties are removed from the freezer until they are placed on the conveyor(s). The example in Fig. 5 details the light loading scenario for a broiler with a 12 in. nominal conveyor width and an 18 in. nominal cavity length.

10.8.4.1 For continuous conveyors, place the second row of patties on the conveyor(s) as soon as the first row of patties has passed completely through the broiler cavity and continue this loading pattern for subsequent rows.

10.8.4.2 For intermittent conveyors, place the second row of patties onto the conveyor 30 s after the first load has passed outside the broiler cavity.

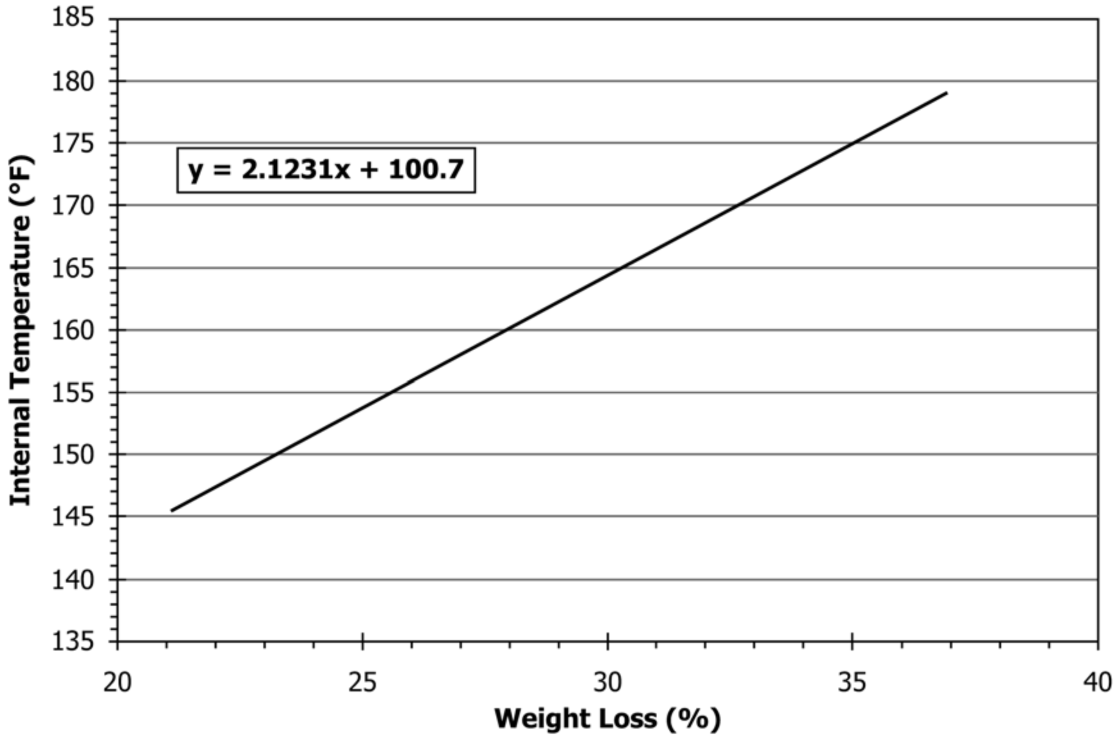

FIG. 4 Relationship Between Bulk Internal Temperature and the Weight Loss of Hamburger Patties Cooked on a Intermittent Conveyor Broiler

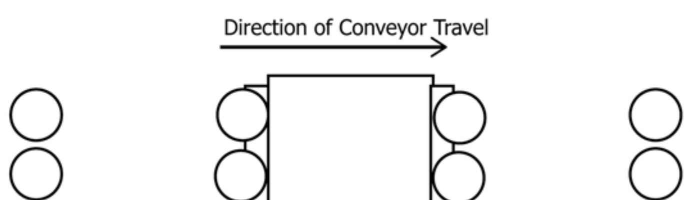

FIG. 5 Example of Light Loading Scenario for a Broiler With a 12 in. Conveyor Width and an 18 in. Cavity Length

10.8.5 After the second row of stabilization patties has passed through the broiler, load the first row of test patties on the conveyor(s). Start monitoring time and energy immediately upon placing the first row of test patties on the conveyor(s). Allow the patties to pass through the broiler cavity and cook.

10.8.6 As soon as each row of test patties has passed completely through the broiler, immediately remove the patties from each conveyor and place on a wire rack. Drip the patties for 2 min (1 min per side), then weigh.

10.8.7 Stop monitoring time and energy as soon as the second row of test patties has moved completely out of the broiler. The example in Fig. 6 details the start and stop timing for monitoring time and energy during light load testing of a broiler with a 12 in. nominal conveyor width and an 18 in. nominal cavity length. Drip and weigh the second row in the same manner as the first. Record the test time and energy.

10.8.8 Calculate the weight loss of the hamburger patties and verify that it meets the criteria in 10.7.4 for a 165 ± 5°F internal temperature. Record the final patty weight loss. If the weight loss is not within the range specified in 10.7.4, then repeat steps 10.8.3 – 10.8.7, adjusting the cook time until the specified weight loss is achieved. Record the adjusted conveyor speed and resulting cook time.

10.8.9 Perform run numbers 2 and 3 by repeating 10.8.3 – 10.8.8. Follow the procedure in Annex A1 to determine whether more than three test runs are required.

10.8.10 In accordance with 11.9, calculate and report the cooking energy efficiency, cooking energy rate, electric energy rate (if applicable for gas conveyor broilers), and production rate.

10.9 *Heavy-Load Cooking Energy Efficiency, Cooking Uniformity and Production Capacity:*

10.9.1 The heavy-load cooking energy efficiency test is to be run a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (see Annex A1).

10.9.2 Weigh ten of the plastic self-locking bags and calculate an average plastic bag weight.

10.9.3 Set the temperature control for each broiler cavity to the manufacturer's recommended operating temperature, preheat the broiler, and allow it to idle for 60 min. For continuous

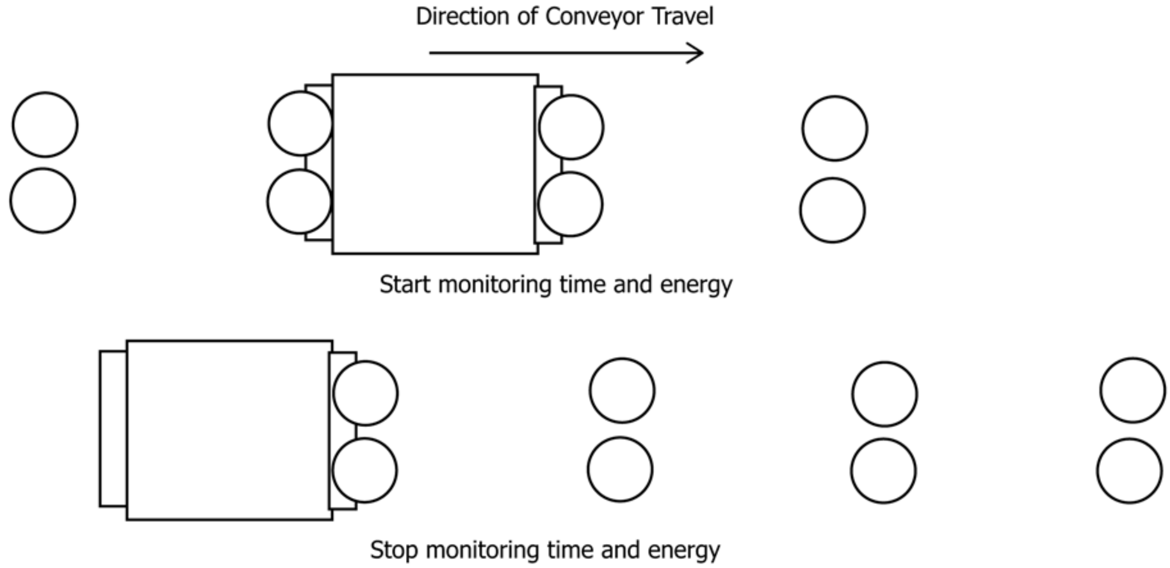

FIG. 6 Start and Stop Timing for Monitoring Test Time and Energy During Light Load Testing of a Broiler With a 12 in. Conveyor Width and an 18 in. Cavity Length

conveyors, set the conveyor speed to achieve the cook time for the hamburger patties determined in 10.7.7. Record the conveyor speed and cook time.

10.9.4 Each heavy-load test run uses the number of hamburger patties detailed in Table 2, and utilizes enough patties to fully load the conveyor broiler five times. For example, a broiler with a nominal 18 in. conveyor width and a 24 in. nominal cavity length will require 60 patties for a heavy load—24 stabilization patties and 36 test patties.

10.9.4.1 For continuous conveyors, the patties included in the first and last cavity loads are used to stabilize the broiler and are referred to as the "stabilization" patties. The patties included in the middle three cavity loads of the test run are used for energy efficiency, cooking uniformity and production capacity determination, and are referred to as the "test" patties.

10.9.4.2 For intermittent conveyors, the patties included in the first cavity load are used to stabilize the broiler and are referred to as the "stabilization" patties. The patties included in the remaining cavity loads of the test run are used for energy efficiency, cooking uniformity and production capacity determination, and are referred to as the "test" patties.

10.9.5 Remove the first row of stabilization patties from the freezer. Place the patties directly on each conveyor so that the leading edge of each patty is adjacent to the entrance of the broiler cavity, and spaced with equal distance between each patty from side to side. Do not allow more than 30 s to elapse from the time the patties are removed from the freezer until they are placed on the conveyor. The example in Fig. 7 details the heavy loading scenario for a broiler with a 12 in. nominal conveyor width and an 18 in. nominal cavity length.

10.9.5.1 For continuous conveyors, allow the first row of patties to pass completely into the broiler cavity and to travel an additional distance of 1 in. Remove the second row of patties from the freezer and place them on each conveyor with the leading edge of each patty adjacent to the entrance of the broiler cavity. Continue this loading pattern for subsequent rows.

10.9.5.2 For intermittent conveyors, allow the first load of patties to pass completely out of the broiler cavity. Thirty seconds (30 s) after the patties have passed through the broiler, then place the second load of patties on the conveyor with the leading edge of each patty adjacent to the entrance of the broiler cavity. Continue this loading pattern for subsequent loads.

10.9.6 Start monitoring time and energy immediately upon placing the first row of test patties on the conveyor. Allow the patties to pass through the broiler and cook.

10.9.7 As soon as a row of test patties has passed completely through the broiler, remove the patties from the conveyor(s) and place them on a wire rack. Arrange the patties so the position on the broiler from which the patties were removed can be easily determined. As more patties are cooked, place subsequent rows on the wire rack, making certain that the position of each patty on the wire rack is consistent with the position from which it was removed from the broiler. It is not necessary to turn the patties during the drip. One minute after the third row of patties is removed from the broiler, place the three patties from each lane into a separate self-sealing plastic bag. Clearly mark each bag with the conveyor position for later identification. Repeat this procedure until all test patties have been dripped and placed into sealed plastic bags.

NOTE 13—It is the intent of this procedure to have the cooked hamburger patties separated into distinct groups representing the different conveyor positions, or cooking lanes, of the broiler. The patties are placed in the bags in groups of three to maintain a consistent drip procedure.

10.9.8 The end of test is determined by the last load of patties:

10.9.8.1 For continuous conveyors, stop monitoring time and energy as soon as the last row of test patties has moved completely within the broiler cavity, that is, the trailing edge of the last row of test patties is directly beneath the entrance to the broiler cavity. The example in Fig. 8 details the start and stop timing for monitoring time and energy during light load testing

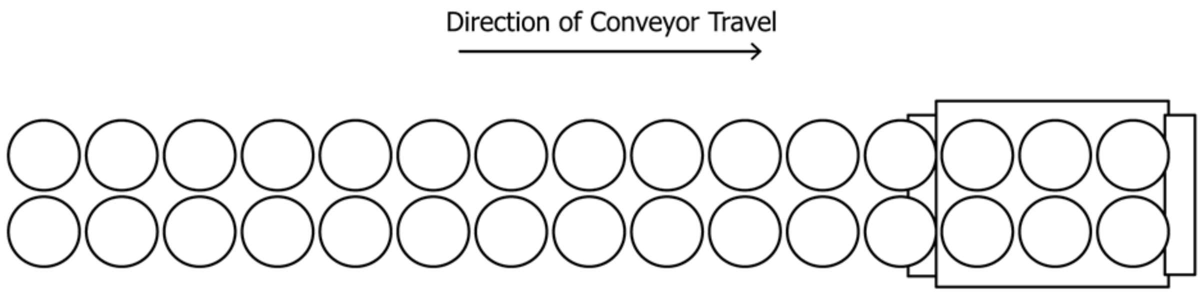

FIG. 7 Example of Heavy Loading Scenario for a Broiler With a 12 in. Conveyor Width and an 18 in. Cavity Length

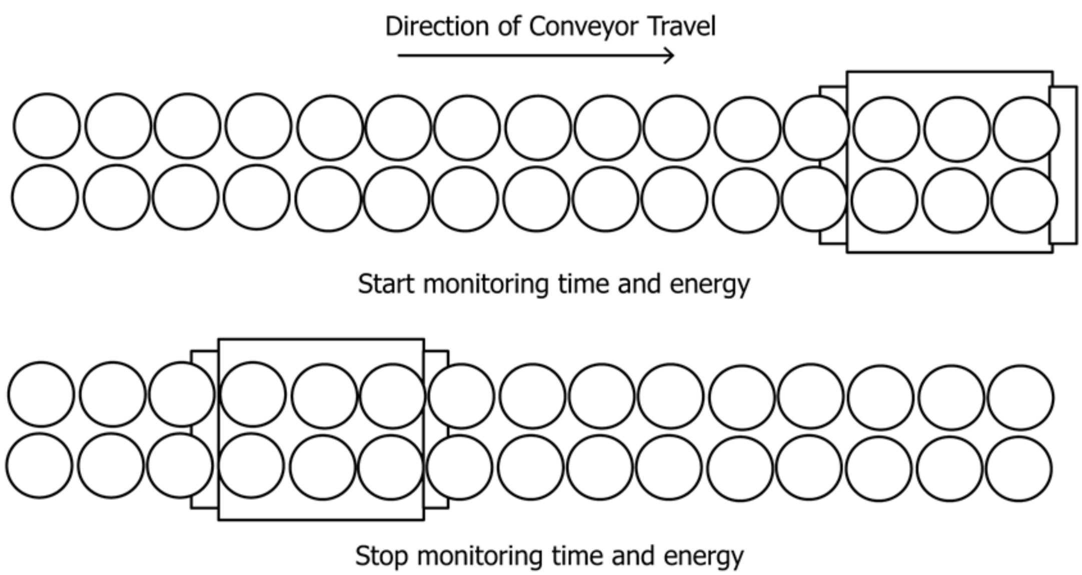

FIG. 8 Start and Stop Timing for Monitoring Test Time and Energy During Heavy Load Testing of a Broiler With a 12 in. Conveyor Width and an 18 in. Cavity Length

of a broiler with a 12 in. conveyor width and an 18 in. cavity length. Record the test time and energy.

10.9.8.2 For intermittent conveyors, stop monitoring time and energy as soon as the last load of test patties has moved completely out of the broiler cavity. Record the test time and energy.

10.9.9 At the conclusion of the test, weigh all sealed bags and cooked patties. Be sure to subtract the weights of the plastic bags determined in 10.9.2. Calculate the bulk weight loss of the entire set of hamburger patties and verify that it meets the criteria in 10.7.4 for a 165 ± 5°F internal temperature. Record the final patty weight loss. If the bulk weight loss is within the range specified in 10.7.4, then repeat steps 10.9.4 – 10.9.8, adjusting the cook time as necessary. Record the adjusted conveyor speed and resulting cook time.

10.9.10 Divide the bags into groups representing each conveyor position, or lane, in the broiler. Weigh each group separately and calculate the weight loss for each lane.

10.9.11 Perform run numbers 2 and 3 by repeating 10.9.4 – 10.9.10. Follow the procedure in Annex A1 to determine whether more than three test runs are required.

10.9.12 In accordance with 11.9, calculate and report the cooking energy efficiency, cooking energy rate, electric energy rate (if applicable for gas conveyor broilers), cooking uniformity and production capacity.

10.10 *Temperature Uniformity (Optional):*

10.10.1 Measure the width of the conveyor belt within each broiler cavity and determine the nominal conveyor width for each cavity by rounding down to the nearest 6 in. For example, a conveyor that is 22 in. wide has a nominal width of 18 in. Measure the length of the broiler cavity and determine the nominal cavity length by rounding down to the nearest 6 in. For example, a broiler cavity that is 31 in. long has a nominal cavity length of 30 in.

10.10.2 Divide each broiler cavity into a grid layout where each square of the grid represents an area 6 by 6 in. The width of the grid is equal to the nominal conveyor width and the length of the grid is equal to the nominal broiler cavity length. A thermocouple is then placed in the center of each square, 1 in. above the conveyor. Fig. 9 shows the thermocouple layout for a broiler cavity with a conveyor width of 22 in. (nominal 18 in.) and a cavity length of 31 in. (nominal 30 in.).

NOTE 14—The thermocouple layout grid is centered on the broiler cavity, such that any length of conveyor or broiler cavity rounded off for the nominal measurements is evenly spaced around the perimeter of the grid.

NOTE 15—It is the intent of this procedure to characterize the temperature of the broiler cavity along the center of each cooking lane. Each position along the width of the conveyor where a hamburger patty is placed represents a cooking lane. For example, a conveyor with a nominal width of 18 in. will have three cooking lanes.

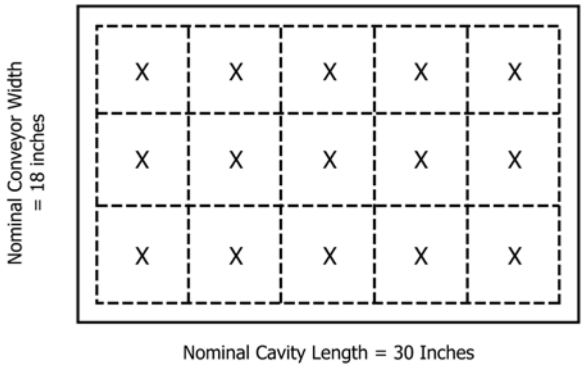

FIG. 9 Thermocouple Placement for a Broiler With a Nominal Conveyor Width of 18 in. and a Nominal Cavity Length of 30 in.

10.10.3 Set the temperature control(s) to the manufacturer's recommended temperature setting(s) and preheat the conveyor broiler. Allow the conveyor broiler to stabilize for 60 min after the last broiler cavity reaches its thermostat set point.

10.10.4 At the end of 60 min, begin recording the temperatures of the individual thermocouples for a minimum of 2 h. Determine the average temperature for each thermocouple location. Record the length of the test period.

10.10.5 In accordance with 11.7, report the average temperature and maximum temperature variation for each thermocouple location in the conveyor broiler.

11. Calculation and Report

11.1 *Test Conveyor Broiler:*

11.1.1 Summarize the physical and operating characteristics of the conveyor broiler. 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 For electric and hybrid gas/electric conveyor broilers, report the voltage for each test.

11.2.3 For gas and hybrid gas/electric conveyor broilers, report the higher heating value of the gas supplied to the conveyor broiler during each test.

11.3 *Gas Energy Calculations:*

11.3.1 For gas and hybrid gas/electric conveyor broilers, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (see 10.2). The conversion factor for electric energy is 3 413 Btu/kWh.

11.3.2 Calculate the energy consumed based on:

$$E_{gas} = V \times HV \quad (1)$$

where:

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

where:

V_{meas} = measured volume of gas, ft^3,
T_{cf} = temperature correction factor,
= *absolute standard gas temperature* °R / *absolute actual gas temperature* °R,
= *absolute standard gas temperature* °R / [*gas temperature* °F + 459.67] °R,
P_{cf} = pressure correction factor,
= *absolute actual gas pressure* (psia) / *absolute standard pressure* (psia), and
= *gas gage pressure* (psig) + *barometric pressure* (psia) / *absolute standard pressure* (psia).

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 519.67°R and 14.73 psia.

11.4 *Energy Input Rate:*

11.4.1 Report the manufacturer's nameplate energy input rate in Btu/h for gas conveyor broilers and in kW for an electric conveyor broiler.

NOTE 17—For hybrid gas/electric conveyor broilers, report the gas energy input rate in Btu/h and the electric energy input rate in kW.

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

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

where:

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

11.4.3 For gas conveyor broilers, report the control energy rate (where applicable).

11.5 *Preheat Energy and Time:*

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

11.5.2 Generate a graph showing the conveyor broiler cavity temperature(s) versus time for the preheat period. Show a separate curve for each broiler cavity.

11.6 *Idle Energy Rate:*

11.6.1 Calculate and report the idle energy rate (Btu/h or kWh) based on:

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

where:

q_{idle} = idle energy rate, Btu/h or kW,
E = energy consumed during the test period, Btu or kW, and
t = test period, min.

11.7 *Temperature Uniformity (optional):*

11.7.1 Report the average temperature at each measurement location on a plan drawing of the broiler cavity. Report the maximum variation from the average temperature at each measurement location.

11.8 *Pilot Energy Rate:*

11.8.1 Calculate and report the pilot energy rate (Btu/h) based on:

$$q_{pilot} = \frac{E \times 60}{t} \quad (4)$$

where:

q_{pilot} = pilot energy rate, Btu/h,
E = energy consumed during the test period, Btu, and
t = test period, min.

11.9 *Cooking Energy Efficiency, Cooking Energy Rate, Cooking Uniformity, and Production Capacity:*

11.9.1 Calculate the cooking energy efficiency, η_{cook}, for heavy- and light-load cooking tests based on:

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

where:

η_{cook} = energy efficiency, %, and
E_{food} = energy into food cooking, Btu,
= $E_{sens} + E_{thaw} + E_{evap}$.

where:

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

where:

W_i = initial weight of the frozen hamburger patties, lb, and
C_p = specific heat of the hamburger patties, Btu/lb, °F,
= 0.72.

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 Pacific Gas and Electric Co has determined that the weighted average of the specific heat for frozen hamburger patties cooked in accordance with this test method was approximately 0.72 Btu/lb, °F.

T_f = final internal temperature of the cooked hamburger patties, °F,
= $1.858 \times W_{tl} + 100.88$ for continuous conveyors, or
= $2.123 \times W_{tl} + 100.70$ for intermittent conveyors

NOTE 19—Research conducted by Pacific Gas and Electric Co has determined that the final internal temperature of hamburger patties cooked on a conveyor broiler and the percent weight loss are connected by the above relationship as long as the hamburger patties are within the specifications described in 7.1. Weight loss is expressed as a percentage, and the internal temperature is in °F.

where:

W_{tl} = percent weight loss of the hamburger patties, expressed as a whole number,
T_i = initial patty temperature, °F, and
E_{thaw} = latent heat (of fusion) added to the hamburger patties, which causes the moisture (in the form ofice) contained in the patties to melt when the temperature of the patties reaches 32°F (the additional heat required to melt the ice is not reflected by a change in the temperature of the patties), Btu,
= $W_{wi} \times H_f$.

where:

W_{wi} = initial weight of water in the patty, lb,
H_f = heat of fusion, Btu/lb,
= 144 Btu/lb at 32°F, and
E_{evap} = latent heat (of vaporization) added to the hamburger patties, which causes some of the moisture contained in the patties to evaporate; similar to the heat of fusion, 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 medium-done patty.
= $W_{loss} \times H_v$.

where:

W_{loss} = weight loss of water during cooking, lb,
= $W_{wi} - W_{wf}$.

where:

W_{wi} = initial weight of water in the raw hamburger patties, lb,
W_{wf} = final weight of water in the raw hamburger patties, lb,
H_v = heat of vaporization, Btu/lb,
= 970 Btu/lb at 212°F, and
$E_{appliance}$ = energy consumed by the broiler, Btu.

The conversion factor for electric energy is 3, 413 Btu / kWh.

11.9.2 Calculate the cooking energy rate for heavy- and light-load cooking tests based on:

$$q_{cook} = \frac{E \times 60}{t} \quad (6)$$

where:

q_{cook} = cooking energy rate, Btu/h or kW,
E = energy consumed during cooking test, Btu or kWh, and
t = test time of cooking test, min.

NOTE 20—For gas and hybrid gas/electric broilers, report separately a gas cooking energy rate and an electric cooking energy rate.

11.9.3 Calculate the average cooked patty temperature for each cooking lane, based on:

T_f = $1.858 \times W_{tl} + 100.88$ for continuous conveyors, or
= $2.123 \times W_{tl} + 100.70$ for intermittent conveyors

where:

T_f = average cooked patty temperature, °F, and
W_{tl} = percent weight loss of hamburger patties, expressed as a whole number.

NOTE 21—The average weight loss for all patties cooked in a lane are used for each calculation.

11.9.4 Calculate production capacity (lb/h) based on:

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

where:

PC = production capacity of the conveyor broiler, lb/h,
W = total weight of test patties in the heavy load, lb, and
t = test time of heavy load cooking test, min.

11.9.5 Calculate the production rate (lb/h) for the light load test using the equation for production capacity in 10.9.4, where W is the total weight of the test patties during the light-load test run and t is the test time of the light-load test.

11.9.6 Report the conveyor speed, the cook time and the three run average value of the cooking energy efficiency, cooking energy rate, and production rates for the heavy and light load tests.

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 reported parameter is being determined.

12.1.2 *Reproducibility (Multiple Laboratories):*

12.1.2.1 The interlaboratory precision of the procedure in this test method for measuring each reported parameter is being determined.

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.

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

NOTE A1.1—This procedure is based on the ASHRAE Handbook of Fundamentals 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 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 production capacity for the appliance is 30 lb/h, the uncertainty must not be greater than ±3 lb/h. Thus, the true production capacity is between 27 and 33 lb/h. This interval is determined at the 95 % confidence level, which means that there is only a 1 in 20 chance that the true production capacity 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.

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

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 (cooking-energy efficiency or production capacity) 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:

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

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 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 (see 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 (3 test runs) is as follows:

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

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 production capacity, report the average for these parameters along with their 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 or production capacity, 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:

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

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:

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

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 production capacity, report the average for these parameters along with their 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 or production capacity, 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:

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

where:

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

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 (see 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, $\%U_n$, is less than or equal to ±10 % for the cooking energy efficiency and production capacity, 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 test 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 production capacity (*PC*) results:

Test	*PC*
Run #1	33.8 lb/h
Run #2	34.1 lb/h
Run #3	31.0 lb/h

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:

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

$$Xa_3 = \left(\frac{1}{3}\right) \times (33.8 + 34.1 + 31.0)$$

$$Xa_3 = 33.0 \text{ lb/h}$$

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

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

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

$$A_3 = 3\,266$$

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

$$B_3 = \left(\frac{1}{3}\right) \times [(33.8 + 34.1 + 31.0)^2]$$

$$B_3 = 3\,260$$

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

$$S_3 = \left(1/\sqrt{2}\right) \times \sqrt{(3\,266 - 3\,260)}, \quad (A1.15)$$

$$S_3 = 1.71 \text{ lb/h}$$

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

$$U_3 = 2.48 \times S3 \quad (A1.16)$$

$$U_3 = 2.48 \times 1.71$$

$$U_3 = 4.24 \text{ lb/h}$$

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

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

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

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

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

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:

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

$$Xa_4 = \left(\frac{1}{4}\right) \times (33.8 + 34.1 + 31.0 + 32.5)$$

$$Xa_4 = 32.9\ lb/h$$

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

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

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

$$A_4 = 4\,323$$

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

$$B_4 = \left(\frac{1}{4}\right) \times [(33.8 + 34.1 + 31.0 + 32.5)^2]$$

$$B_4 = 4\,316$$

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

$$S_4 = \left(1/\sqrt{3}\right) \times \sqrt{(4\,323 - 4\,316)}, \quad \text{(A1.20)}$$

$$S_4 = 1.42\, lb/h$$

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

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

$$U_4 = 1.59 \times 1.42$$

$$U_4 = 2.25 \text{ lb/h}$$

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

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

$$\% U_4 = (2.25/32.9) \times 100\,\%$$

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

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

$$PC{:}32.9 \pm 2.25 \text{ lb/h} \quad \text{(A1.23)}$$

The production capacity can be reported assuming the ±10 % precision requirement has been met for the corresponding cooking energy efficiency value. The cooking energy efficiency and its absolute uncertainty can be calculated following the same steps.

APPENDIX

(Nonmandatory Information)

X1. RESULTS REPORTING SHEETS

Manufacturer ________________
Model ________________
Date ________________
Test Reference Number (optional) ________________

Section 11.1—Test Conveyor Broiler

Description of Broiler (operational characteristics, number of cooking cavities, nominal conveyor width(s), and nominal cavity length):

____
____
____
____
____

Section 11.2—Apparatus

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

Deviations (custom hood setup, catalyst, etc.):

____
____
____
____
____

Section 11.4—Energy Input Rate

Test Voltage (V) ________________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ________________
Rated Electric Energy Input Rate (kW) ________________
Measured Electric Energy Input Rate(kW) ________________
Percent Difference Between Measured and Rated Electric Energy Input Rate (%) ________________
Rated Gas Energy Input Rate (Btu/h) ________________
Measured Gas Energy Input Rate (Btu/h) ________________
Percent Difference Between Measured and Rated Gas Energy Input Rate (%) ________________
Control Energy Rate (kW, gas broilers only) ________________

Section 11.5—Preheat Energy and Time

Test Voltage (V) ________________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ________________
Thermostat Settings ____ Thermostat 1 ____ Thermostat 2 ____ Thermostat 3
Energy Consumption (Btu or kWh) ________________
Duration (min) ________________

Section 11.6—Idle Energy Rate

Test Voltage (V) ____________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ____________
Idle Energy Rate (Btu/h or kW) ____________

Section 11.7—Temperature Uniformity

Direction of Conveyor Travel ____________

Section 11.8—Pilot Energy Rate

Gas Heating Value (Btu/ft^3 (kJ/m^3)) ____________
Pilot Energy Rate (Btu/h or kW) ____________

Section 11.9—Energy Efficiency, Cooking Energy Rate, Cooking Uniformity, and Production Capacity

Heavy Load:

Test Voltage (V) ____________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ____________
Cook Time (min) ____________
Conveyor Speed (min) ____________
Energy to Food (Btu/lb) ____________
Cooking Energy Rate (Btu/h or kW) ____________
Electric Energy Rate (kW, gas broilers only) ____________
Energy per Pound of Food Cooked (Btu/lb or kWh/lb) ____________
Cooking Energy Efficiency (%) ____________
Production Capacity (lb/h) ____________
Average Patty Temperature by Lane (°F) ____________
____ Lane 1 ____ Lane 2 ____ Lane 3 ____ Lane 4 ____ Lane 5 ____ Lane 6
(lanes are numbered from left to right, when looking at the front of the broiler)

Light Load:

Test Voltage (V) ____________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ____________
Cook Time (min) ____________
Conveyor Speed (min) ____________
Energy to Food (Btu/lb) ____________
Cooking Energy Rate (Btu/h or kW) ____________
Electric Energy Rate (kW, gas broilers only) ____________
Energy per Pound of Food Cooked (Btu/lb or kWh/lb) ____________
Cooking Energy Efficiency (%) ____________
Production Rate (lb/h) ____________
Average Patty Temperature by Lane (°F)

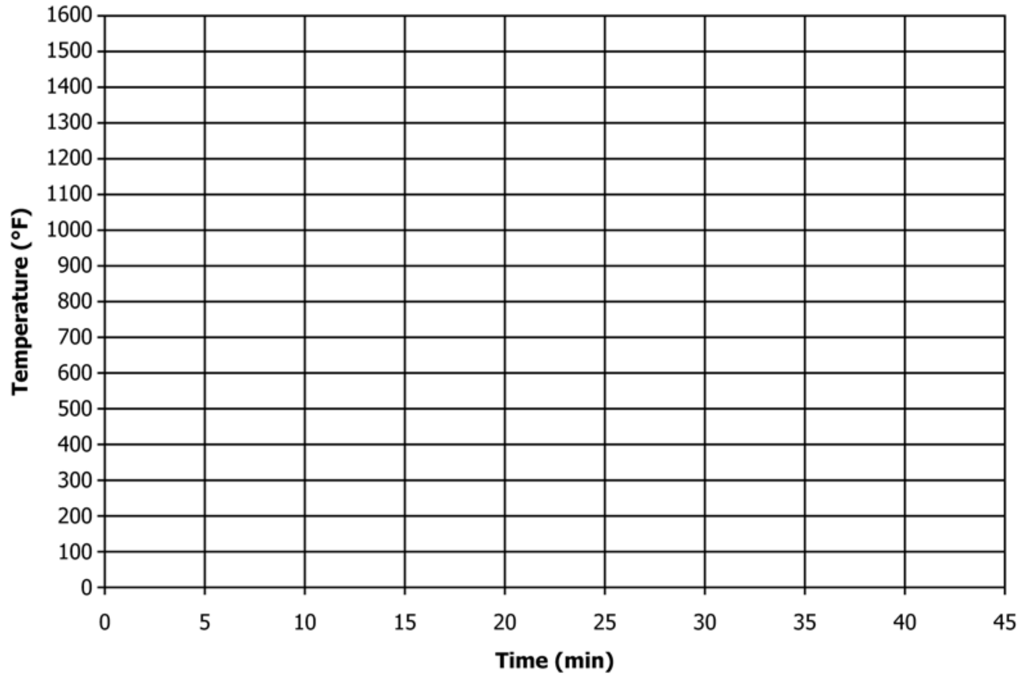

FIG. X1.1 Preheat Curve(s)

FIG. X1.2 Average Broiler Cavity Temperatures and Maximum Deviations