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An American National Standard

Standard Test Method for Performance of Rack Ovens[1]

This standard is issued under the fixed designation F2093; 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 baking performance of rack ovens. The food service operator can use this evaluation to select a rack oven and understand its energy performance.

1.2 This test method is applicable to thermostatically controlled, gas and electric rack ovens.

1.3 The rack oven can be evaluated with respect to the following (where applicable):

1.3.1 Energy input rate (10.2),

1.3.2 Thermostat calibration (10.3),

1.3.3 Preheat energy and time (10.4),

1.3.4 Idle energy rate (10.5),

1.3.5 Pilot energy rate, if applicable (10.6),

1.3.6 White sheet cake browning (10.7), and

1.3.7 Steam performance (10.8), and

1.3.8 Baking energy efficiency and production capacity (10.9).

1.4 The values stated in inch-pound units are to be regarded as 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

F1496 Test Method for Performance of Convection Ovens

2.2 *ANSI Document:*[3]

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

2.3 *ASHRAE Documents:*[4]

ASHRAE Fundamentals 1997

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bake time, n*—time required to bake the frozen pies specified in 7.3.

3.1.2 *baking cavity, n*—that portion of the appliance in which food products are heated or cooked.

3.1.3 *baking energy, n*—energy consumed by the rack oven as it is used to bake frozen pies under full-load conditions.

3.1.4 *baking energy efficiency, n*—quantity of energy imparted to the pies, expressed as a percentage of energy consumed by the rack oven during the baking event.

3.1.5 *baking energy rate, n*—average rate of energy consumption (Btu/h or kW) during the baking energy efficiency tests.

3.1.6 *duty cycle, n*—defined as percent (%) of burner time on divided by a complete on/off cycle during idle energy mode at 400°F.

3.1.7 *idle energy rate, n*—the rate of energy consumed (Btu/h or kW) by the rack oven while "holding" or "idling" the baking cavity at the thermostat set point.

3.1.8 *measured energy input rate, n*—peak rate at which a rack oven consumes energy (Btu/h or kW), typically reflected during preheat.

3.1.9 *mini-rack oven, n*—an appliance that bakes by forcing air within a closed cavity, either fitted with a mechanism for rotating an internal rack which accomodates 8 pans at 4 in. spacing or a fixed 8 pans at 4 in. spacing within the cavity.

[1] This test method is under the jurisdiction of ASTM Committee F26 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* 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, http://www.ansi.org.

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

3.1.10 *nameplate energy input rate, n*—the maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the nameplate.

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

3.1.12 *preheat energy, n*—amount of energy consumed by the rack oven while preheating the baking cavity from ambient room temperature (75 ± 5°F) to the thermostat set point.

3.1.13 *preheat rate, n*—average rate (°F/min) at which the rack oven's baking cavity is heated from ambient temperature (75 ± 5°F) to the thermostat set point: defined as the set temperature minus ambient temperature divided by the preheat time.

3.1.14 *preheat time, n*—time required for the rack oven to preheat from ambient room temperature (75 ± 5°F) to the thermostat set point.

3.1.15 *production capacity, n*—maximum rate (lb/h) at which the rack oven can bake frozen pies as specified in 7.3.

3.1.16 *rack, n*—a device which is used to hold pans within a rack oven.

3.1.17 *rack oven, n*—an appliance that bakes by forcing hot air over the food within a closed cavity, either fitted with a mechanism for rotating one or more racks, or one or more non-rotating racks within the cavity.

3.1.18 *steam injection cycle, n*—a period whereby steam is introduced into the baking cavity during baking.

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

4. Summary of Test Method

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

4.2 The accuracy of the oven's thermostat is checked at 400°F and adjusted as necessary.

4.3 The amount of energy and time required to preheat the rack oven to 400°F is determined.

4.4 The idle energy rate is determined with the rack oven set to maintain 400°F in the baking cavity.

4.5 Pilot energy rate is determined, when applicable, for gas rack ovens.

4.6 The rack oven is used to bake a full-load of white sheet cakes (8 cakes in a mini-rack, 15 cakes in a single-rack oven, and 30 cakes in a double-rack oven, for example) to assess the browning uniformity of the oven.

4.7 The rack oven's steam performance is characterized by assessing the amount of steam produced on repeated bake cycles.

4.8 The rack oven is used to bake a full-load of frozen pies. Baking energy efficiency, baking energy rate, and production rate are determined from these tests.

5. Significance and Use

5.1 The energy input rate and thermostat calibration tests are used to confirm that the rack oven is operating properly prior to further testing.

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

5.3 Idle energy rate and pilot energy rate can be used by the food service operator to estimate energy consumption during non-baking periods.

5.4 The oven's browning and baking uniformity can be used by an operator to select an oven that bakes a variety of products evenly.

5.5 Steam performance can be useful for a food service operator interested in the oven's ability to consistently create steam during a baking cycle.

5.6 Baking energy efficiency is a precise indicator of rack oven energy performance under various loading conditions. This information enables the food service operator to consider energy performance when selecting a rack oven.

5.7 Production capacity is used by food service operators to choose a rack oven that matches their food output requirements.

6. Apparatus

6.1 *Analytical Balance Scale,* for measuring weights up to 25 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 gas volume to standard conditions. Shall have a resolution of 0.2 in. Hg and an uncertainty of 0.2 in. Hg.

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

6.4 *Freezer,* sized large enough to hold a full-load of frozen pies (24 pies for a mini-rack oven, 45 pies for a single rack oven, and 90 pies for a double rack oven) and capable of maintaining the frozen product at 0 ± 5°F.

6.5 *Flow Meter,* for measuring total water consumption of the oven, having a resolution of 0.01 gal and an uncertainty of 0.01 gal for flows of 0.2 gpm and higher.

6.6 *Gas Meter,* for measuring the gas consumption of a rack oven, 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 *Heavy-Duty Chef's Thermometers,* capable of withstanding 400°F temperatures for monitoring food temperature while baking. A 2-in. or larger dial is recommended for enhanced visibility.

6.8 *Platform Balance Scale,* or appropriate load cells, for measuring weights up to 500 lb with a resolution of 0.2 lb and an uncertainty of 0.2 lb.

6.9 *Pressure Gauge,* for monitoring gas pressure. Shall have a range of zero to 15 in. H_2O, a resolution of 0.5 in. H_2O, and a maximum uncertainty of 1 % of the measured value.

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

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

6.12 *Thermocouple(s),* industry standard type K thermocouple wire with a range of 0 to 600°F and an uncertainty of ±1°F.

6.13 *Thermocouple Probe,* "fast response" type T or type K thermocouple probe, 1⁄16 in. or smaller diameter, with a 3 s or faster response time, capable of immersion with a range of 30 to 300°F and an uncertainty of ±1°F. The thermocouple probe's active zone shall be at the tip of the probe.

6.14 *Watt-Hour Meter,* for measuring the electrical energy consumption of a rack oven, 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 *Aluminum Sheet Pans,* measuring 18 by 26 by 1 in. for the baking energy efficiency and sheet cake browning tests.

7.2 *Cake Mix,* generic white cake mix, 5 lb per box. A minimum of 30 lb is required for mini-rack ovens, 50 lb for single-rack ovens, and 100 lb for double-rack ovens.

7.3 *Frozen Pies,* 10-in. frozen, commercial-grade, ready-to-bake apple pies, weighing 3.00 ± 0.15 lb, with a moisture content of 54 ± 2 %, by weight for baking energy efficiency and production capacity tests. The pie crust shall be made with 100 % vegetable shortening and the filling shall be a pre-cooked apple based filling (see Fig. 1).

NOTE 1—Sysco Classic fruit pies have been shown to be an acceptable product for testing by Pacific Gas and Electric Company.

7.4 *Hotel Pan,* to be used to collect water runoff during testing.

7.5 *Paper Baking Liners,* to line sheet pans for browning uniformity tests.

7.6 *Plastic Wrap,* commercial grade, 18-in. wide.

7.7 *Rack,* supplied by the oven manufacturer shall have a nominal 4-in. spacing between pan positions, with a minimum of 4-in. between the top pan and the top of the top of the rack and a minimum of 4-in. between the bottom pan and the floor.

7.8 *Water,* supplied to the rack oven shall be 65 ± 5°F. If outside this range, hot and cold water supplies may be mixed to achieve the required inlet temperature.

8. Sampling, Test Units

8.1 *Rack Oven*—Select a representative production model for performance testing.

9. Preparation of Apparatus

9.1 Install the oven according to the manufacturer's instructions in an appropriate space. All sides of the oven shall be a minimum of 6-in. from any side wall, side partition, or other operating appliance. The oven, moisture vent, and hood assembly, as furnished, shall be vented to the exterior of the testing space, using the manufacturer's specified ventilation rate(s). The associated heating or cooling system for the space shall be capable of maintaining an ambient temperature of 75 ± 5°F within the testing environment (outside the vertical area of the rack oven) when the combined oven exhaust ventilation system is operating.

9.2 Install a thermocouple at the vertical center of the oven's pressure panel in the air outlet, with the sensing tip 1.0 ± 0.25-in. away from the vertical plane of the panel to record the oven cavity temperature. Make certain that the thermocouple sensing tip is not touching the pressure panel or any of its components.

9.3 Adjust the air baffles inside the oven cavity to the manufacturer's recommended gap settings. Follow the manufacturer's recommendation for fine adjustments.

9.4 Connect the rack oven 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 rack oven 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.

9.5 For a gas rack oven, adjust (during maximum energy input) the gas supply pressure downstream from the appliance's pressure regulator to within ±2.5 % of the operating

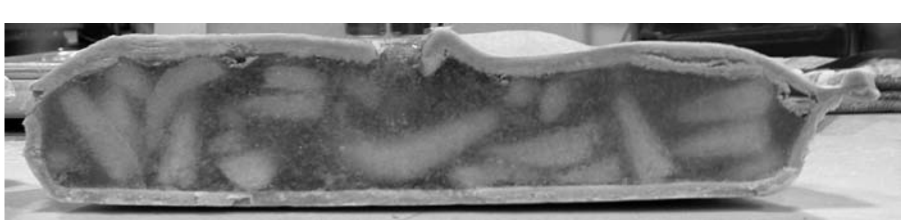

FIG. 1 Cross Section of a Frozen Apple Pie

manifold pressure specified by the manufacturer. Make adjustments to the appliance following the manufacturer's recommendations for optimizing combustion. Proper combustion shall be verified by measuring air-free CO in accordance with ANSI Z83.11.

9.6 For an electric rack oven, 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 2—It is the intent of the testing procedure herein to evaluate the performance of a rack oven at its rated gas pressure or electric voltage. If an electric unit is rated dual voltage (this is, designed to operate at either 240 or 480 V with no change in components), the voltage selected by the manufacturer and/or tester shall be reported. If a rack oven 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.

9.7 Install a flow meter to the rack oven water inlet such that total water flow to the appliance is measured and a pressure regulator downstream from the meter to maintain a constant pressure of water for the steam performance tests. Also install a thermocouple probe in the inlet water line to the rack oven for monitoring inlet water temperature.

9.8 Adjust the water pressure to the manufacturer's recommended operating water pressure.

9.9 Assure that the oven cavity vent is closed for all tests—except as instructed by this procedure.

9.10 To facilitate quickly measuring baked pie temperatures, fix three thermocouple probes along a straight line, located 3 ± 0.2 in. apart and configured with a mechanism for ensuring that they are inserted to 1 ± 0.1-in. depth as shown in Fig. 2.

NOTE 3—A small length of PVC pipe has been found an effective tool for fixing the probes and inserting them into the baked pies.

10. Procedure

10.1 *General:*

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

10.1.1.1 Higher heating value,

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

10.1.1.3 Measured gas temperature,

10.1.1.4 Measured gas pressure,

10.1.1.5 Barometric pressure,

10.1.1.6 Ambient temperature, and

10.1.1.7 Energy input rate during or immediately prior to test.

NOTE 4—Using a calorimeter or gas chromatograph in accordance with accepted laboratory procedures is the preferred method for determining the higher heating value of gas supplied to the rack oven under test. It is recommended that all testing be performed with natural gas having a higher heating value of 1,000 to 1,075 Btu/ft^3.

10.1.2 For gas rack ovens, record any electric energy consumption, in addition to gas energy for all tests.

10.1.3 For electric rack ovens, 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.

10.1.4 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 rack oven.

10.2 *Energy Input Rate:*

10.2.1 Set the temperature controls 400°F and turn on the oven.

10.2.2 Start recording time and energy consumption when the burners actually ignite or when the elements are energized (not when the oven ready light comes on) and stop recording when the burners or elements commence cycling.

10.2.3 Confirm that the measured input rate or power, (Btu/h for a gas rack oven and kW for an electric rack oven) is within 5 % of the rated nameplate input or power (it is the intent of the testing procedures herein to evaluate the performance of a rack oven at its rated energy input rate). If the

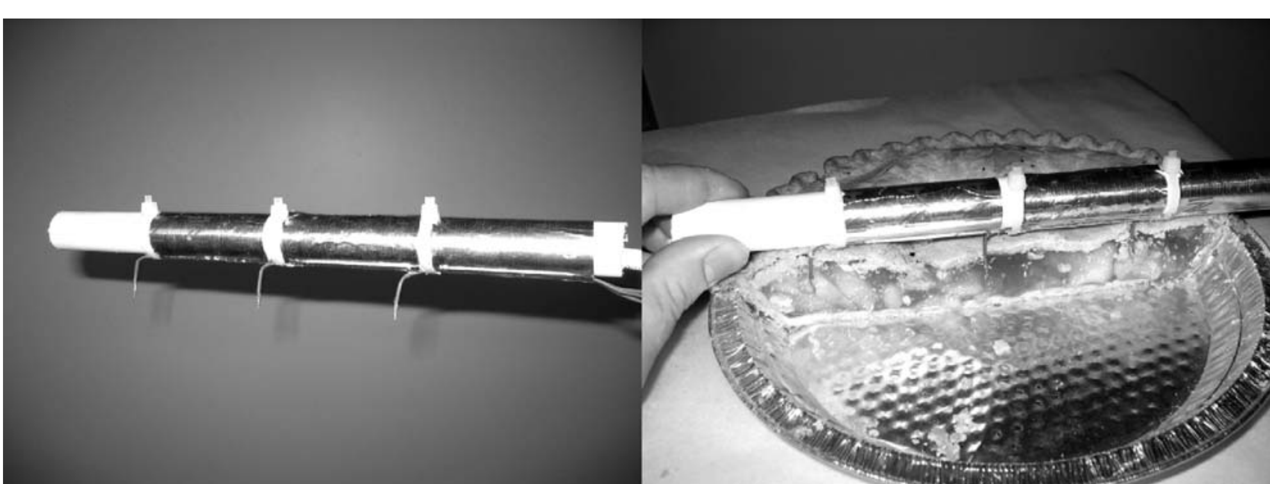

FIG. 2 Example Thermocouple Fixture for Measuring Pie Temperatures

difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the rack oven or supply another rack oven for testing.

10.3 *Thermostat Calibration:*

10.3.1 Preheat the baking cavity to a temperature of 400°F as indicated by the temperature control. Stabilize for 2 h after the burners or elements commence cycling at the thermostat set point.

10.3.2 Monitor and record the cavity temperature every 30 s for a minimum of 1 h.

10.3.3 As required (as indicated by the average temperature), calibrate or otherwise adjust the temperature control(s) to attain an actual baking cavity temperature of 400 ± 5°F. Repeat 10.3.2 to confirm that the cavity temperature is 400 ± 5°F.

10.4 *Preheat Energy Consumption and Time:*

NOTE 5—The preheat test should be conducted as the first appliance operation on the day of the test, starting with the baking cavity at room temperature (75 ± 5°F).

10.4.1 Record oven cavity temperature and ambient temperature at the start of the test. The cavity temperature shall be 75 ± 5°F at the start of the test.

10.4.2 Turn the unit on with controls set to maintain an average cavity temperature of 400°F, as determined in 10.3.3.

10.4.3 Record the cavity temperature at least once every 5 s during the course of preheat.

10.4.4 Record the energy and time to preheat the rack oven. Preheat is judged complete when the temperature at the pressure panel reaches 390°F, as indicated by the thermocouple.

10.5 *Idle Energy Rate:*

NOTE 6—The idle test may be conducted immediately following the preheat test (10.4).

10.5.1 Preheat the rack oven to 400°F and allow to stabilize for 2 h.

10.5.2 Monitor baking cavity temperature and rack oven energy consumption for an additional 3 h while the rack oven is operated in this condition.

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

10.6.1 Where applicable, set the gas valve that controls gas supply to the appliance at the "pilot" position. Otherwise, set the rack oven temperature controls to the "off" position.

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

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

10.7 *Browning Uniformity (White Sheet Cakes):*

NOTE 7—The objective of this test is to evaluate the browning uniformity of the oven using white sheet cakes. The oven's browning uniformity is reported by describing the browning pattern of the sheet cake baked on each rack. This test is to be performed so that the variation in browning from rack to rack is minimized.

10.7.1 Preheat oven to 325°F and allow to stabilize for 2 h.

10.7.2 Mix cake batter per purveyor's instructions. For mini-rack ovens, prepare a minimum of 45 lb of batter; for single-rack ovens, prepare a minimum of 75 lb of batter; and for double-rack ovens, prepare a minimum of 150 lb of batter.

10.7.3 Scale 5.0 ± 0.01 lb of cake batter into each lined, pre-weighed sheet pan. Level the batter in each pan with a spatula. Lightly drop each pan two to three times to reduce the number of air bubbles in the batter.

10.7.4 Load the filled sheet pans onto the rack(s). Use every pan position available (15 for single-racks and 30 for double-racks; for mini-rack ovens a simple holding rack is required).

10.7.5 Record the starting temperature of every other cake.

10.7.6 When the oven cycles off, for mini-rack ovens load the pans (8 required) into the allotted location on the internal rack into the hot oven; for rack ovens, load the rack(s) into the hot oven. Loading time shall be 45 ± 15 s. Begin monitoring time, temperature, and energy consumption when the door is shut.

10.7.7 Test is complete when cakes have turned uniformly golden brown. Open door and remove the rack(s) within 45 ± 15 s.

10.7.8 Determine whether the sheet cakes are done by first inserting a skewer into the center of several cakes. The individual cake is considered done if no moist particles cling to the skewer when it is withdrawn. Whether the cake load is done properly, overdone, or underdone is determined by the color of the cakes. Refer to Fig. 3. If less than 60 % of the cakes are golden or darker in color, the cakes are underdone and the bake time should be lengthened. If 60 % or more of the cakes are dark brown, the cakes are overdone and the bake time should be shortened. If underdone or overdone, the browning uniformity cannot be determined.

10.7.9 If a bake time adjustment is required, repeat 10.7.2 – 10.7.8 until an acceptable level of doneness is achieved. Record the final bake time.

10.7.10 Record the final temperature of every other cake within 3 min ± 15 s of removing them from the oven.

10.7.11 Record the final weight of each pan.

10.8 *Steam Performance:*

NOTE 8—The objective of this test is to evaluate steam generation capability on repeated bake cycles. Usage expectation is that a rack oven is ready for immediate use after removal of prior product. For simplicity, the test is performed with an empty oven.

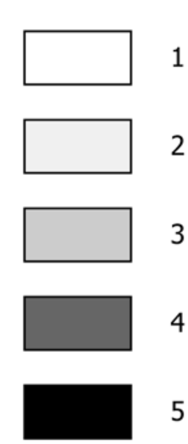

FIG. 3 Color Browning Chart

10.8.1 Preheat oven to 400°F and allow to stabilize for 2 h. Set the steam induction timer to the manufacturer's recommended interval. If the manufacturer does not specify a steam injection time, then set the timer to 10 s.

10.8.2 Record the initial weight of the empty runoff pan.

10.8.3 Run the steam cycle, measuring the input water volume.

10.8.4 Collect all runoff in the runoff pan and weigh the pan and accumulated runoff.

10.8.5 Repeat 10.8.2 through 10.8.4 a total of five times at 15 ± 0.1-min intervals.

10.9 *Baking Energy Efficiency and Production Capacity:*

10.9.1 Conduct the baking energy efficiency test a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (Annex A1).

10.9.2 Determine the number of pans required, use fifteen pans for single-racks and thirty pans for double-racks.

10.9.3 Weigh and record the weight of each sheet pan to be used in the mini-rack ovens and the empty rack(s) and the lined sheet pans for rack ovens.

10.9.4 Set aside at least two pies for determining moisture content. Place sample pies in a freezer inside self-sealing plastic bags unless the moisture content determination test (Annex A2) is conducted immediately.

10.9.5 Return the loaded pans to the freezer and allow the pies to stabilize at 0 ± 5°F.

10.9.6 Preheat the oven to 400°F and allow to stabilize for a minimum of 2 h.

10.9.7 Remove the frozen pies from their boxes and place three frozen pies per sheet pan.

10.9.8 Load the rack(s) with the pie-filled sheet pans.

10.9.9 To facilitate determining when the pies are baked, randomly select four pies on different pans for monitoring and insert a heavy-duty chef's thermometer into the center of the chosen pies, making certain that the dials rest along the edge of each pie tin and are fully visible from the oven window during baking.

10.9.10 Measure and record the temperature of at least one pie per pan by inserting a thermocouple probe into the geometric center of the pie. This is best accomplished by inserting the probe perpendicularly through the top of the pie. Record the total weight of the rack(s), pies, and pans.

10.9.11 When the oven cycles off, for mini-rack ovens load the pans into the appropriate location (8 pans) into the hot oven; for rack ovens, load the rack(s) into the hot oven. Loading time shall be 45 ± 15 s. Begin monitoring time, temperature, and energy consumption when the door is shut.

10.9.12 When the chef's thermometers indicate that the pies have reached an average temperature of 180°F, open the oven door and measure the internal temperature of a randomly chosen pie by inserting the 3-point thermocouple fixture into the center of the pie, along the pie's diameter.

10.9.12.1 If the average of the three temperatures is 185 ± 5°F, the pies are done and may be removed.

10.9.12.2 If the temperature is below 180°F, close the door and resume baking until the temperature of a randomly selected pie is 185 ± 5°F.

10.9.12.3 If the temperature is above 190°F, then the pies are overcooked and the test is invalid. Adjust the bake time as appropriate and repeat 10.9.2 – 10.9.11.

10.9.13 When the pies reach an average internal temperature of 185 ± 5°F, open the oven door and remove the rack(s). Unloading time shall be 45 ± 15 s. Record the total elapsed time and energy consumption.

10.9.14 After removing the racks, shut the oven door and record the time and energy required to return the cavity to 400 ± 5°F.

10.9.15 Record the temperature of at least one pie per every pan by inserting the 3-point thermocouple rig into the center of the pie, along the pie's diameter, within 3 min ± 15 s from the time the pies were removed from the oven. If the average of these temperatures is not 185 ± 5°F, then the test is invalid and must be repeated.

10.9.16 Record the final weight of the rack, pies, and pans.

10.9.17 Perform runs #2 and #3 by repeating 10.9.2 – 10.9.16. Follow the procedure in Annex A1 to determine whether more than three test runs are required.

11. Calculation and Report

11.1 *Test Rack Oven:*

11.1.1 Summarize the physical and operating characteristics of the rack oven, reporting all manufacturer's specifications and deviations therefrom. Include design characteristics, such as integrated hoods, automatic steam vents, steam generation, etc. Also report the ventilation rate used for the testing. Also include the type of material and weight of the steam generator.

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 rack ovens, report the voltage for each test.

11.2.3 For gas rack ovens, report the higher heating value of the gas supplied to the rack oven during each test.

11.3 *Gas Energy Calculations:*

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

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

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

where:

E_{gas} = energy consumed by the appliance,
HV = higher heating value,
= energy content of gas measured at standard conditions, Btu/ft^3,
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 temp °F + 459.67] °R

P_{cf} = pressure correction factor
= absolute actual gas pressure psia / absolute standard pressure psia
= gas gage pressure psig + barometric pressure psia / absolute standard pressure psia

NOTE 9—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 ASTM D3588-89 Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density (Specific Gravity) of Gaseous Fuels are 14.696 psia (101.33 kPA) and 60°F (519.67 °R, (288.71 °K)).

11.4 *Energy Input Rate:*

11.4.1 Report the manufacturer's nameplate energy input rate in Btu/h for a gas rack oven and kW for an electric rack oven.

11.4.2 For gas or electric rack ovens, calculate and report the measured energy input rate (Btu/h or kW) based on the energy consumed by the rack oven 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 Calculate and report the percent difference between the manufacturer's nameplate energy input rate and the measured energy input rate.

11.5 *Thermostat Calibration:*

11.5.1 For the as-received condition, report the oven cavity temperature (at the pressure panel) that corresponds to the 400°F setting on the oven's thermostat control.

11.5.2 Report any discrepancies greater than 5°F between the temperature indicated by the oven's control and the 400°F oven cavity temperature.

11.6 *Preheat Energy and Time:*

11.6.1 Report the preheat energy consumption (Btu or kWh) and air preheat time (min) to reach 390°F at the oven's pressure panel with the controls set to a calibrated 400°F setting.

11.6.2 Calculate and report the average air preheat rate (°F/min) based on the preheat period. Also report the starting temperature of the baking cavity. This rate is:

$$(T_{set} - T_{room})/(preheat\ time\ (mins))$$

11.6.3 Generate a graph showing the baking cavity temperature versus time based on the preheat period.

11.7 *Idle Energy Rate:*

11.7.1 Calculate and report the idle energy rate (Btu/h or kW) at 400°F 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 kWh, and
t = test period, min.

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 or kW,
E = energy consumed during the test period, Btu, and
t = test period, min.

11.9 *Browning Uniformity (White Sheet Cakes):*

11.9.1 Provide a written description of the browning pattern and any irregularities for each sheet cake. Also, note any differences in browning patterns and irregularities from cake to cake. A sketch or photograph of each cake showing its browning pattern and any irregularities shall accompany the description. Use a scale of 1 to 5 (Fig. 3 Color Chart) with 3 being the ideal color.

11.9.2 Report the cake load bake time and energy consumption. Also report the initial and final weights and temperatures of the sheet cakes.

11.10 *Steam Performance:*

11.10.1 For each steam injection cycle, calculate and report the amount of steam produced based on:

$$V_{steam} = V_{water} - V_{runoff} \quad (5)$$

where:

V_{steam} = volume of steam produced, gal,
V_{water} = volume of water consumed during the steam cycle, gal,
V_{runoff} = volume of water collected in the runoff pan, gal,
= $W_{runoff,\ i} - W_{runoff,\ f} / \rho_{water}$

where:

$W_{runoff,\ i}$ = initial weight of runoff pan, lb,
$W_{runoff,\ f}$ = final weight of runoff pan, including any accumulated water, lb, and
ρ_{water} = density of water, lb/gal,
= 8.334 lb/gal.

11.10.2 For each of the five successive steam injection cycles, report the volume of water consumed by the oven and the volume of the runoff and the volume converted to steam as determined in 11.10.1.

11.11 *Baking Energy Efficiency, Baking Energy Rate, and Production Capacity:*

11.11.1 Calculate and report the baking energy efficiency based on:

$$\eta_{cook} = \frac{E_{food} + E_{pans}}{E_{appliance}} \times 100 \quad (6)$$

where:

η_{cook} = baking energy efficiency, %,

E_{food} = energy into the food, Btu,
= $E_{sens} + E_{thaw} + E_{evap}$

where:

E_{sens} = the quantity of heat added to the food, which causes its temperature to increase from the starting temperature to the final cooked temperature, Btu,
= $W_i \times C_{p,\ pie} \times (T_f - T_i)$

where:

W_i = initial weight of the frozen pies, lb,
$C_{p,\ pie}$ = specific heat of the apple pies, Btu/lb,°F
= 0.63

NOTE 10—For this analysis, the specific heat ($C_{p,\ pie}$) of an apple pie 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 Company determined that the weighted average of the specific heat for frozen apple pies specified as in section 7.3 was approximately 0.63 Btu/lb °F.

T_f = final average internal temperature of the baked pies, °F,
T_i = initial average internal temperature of the frozen pies, °F,
E_{thaw} = latent heat (of fusion) added to the food, which causes the moisture (in the form of ice) contained in the food to melt when the temperature of the food reaches 32°F (the additional heat required to melt the ice is not reflected by a change in the temperature of the food), Btu,
= $W_{iw} \times H_f$

where:

W_{iw} = initial weight of water in the pies, lb,
= $M_i \times W_i$

where:

M_i = the average initial moisture of the pies (Annex A2), %,
W_i = the initial weight of the frozen pies, lb,
H_f = heat of fusion, Btu/lb,
E_{evap} = the latent heat (of vaporization) added to the food, which causes some of the moisture contained in the food to evaporate. The heat of vaporization cannot be perceived by a change in temperature and must be calculated after determining the amount of moisture lost from a fully baked pie,
= $(W_i - W_f) \times H_v$

where:

W_i = the initial weight of the frozen pies, lb,
W_f = the final weight of the baked pies, lb,
H_v = heat of vaporization, Btu/lb,
= 970 Btu/lb at 212°F,
E_{pans} = energy into the sheet pans, Btu,
= $W_{pans} \times C_{p,\ pans} \times (T_f - T_i)$

where:

W_{pans} = weight of sheet pans, lb,
$C_{p,\ pans}$ = specific heat of the sheet pans, Btu/lb,°F,
= 0.20
T_f = final average internal temperature of the baked pies, °F
T_i = initial average internal temperature of the frozen pies, °F, and
$E_{appliance}$ = energy into the appliance, Btu.

NOTE 11—The energy into the appliance includes electric energy consumed by fans, motors, and controls.

11.11.2 Calculate and report the baking energy rate based on:

$$E_{bake\ rate} = \frac{E \times 60}{t} \quad (7)$$

where:

$E_{bake\ rate}$ = baking energy rate, Btu/h or kW,
E = energy consumed during the pie baking test, Btu or kWh, and
t = pie baking test period, min.

For gas appliances, report separately a gas baking energy rate and an electric baking energy rate.

11.11.3 Calculate and report the energy consumption per pound of food cooked for the baking tests based on:

$$E_{per\ pound} = \frac{E_{appliance}}{W} \quad (8)$$

where:

$E_{per\ pound}$ = energy per pound, Btu/lb or kWh/lb,
$E_{appliance}$ = energy consumed during the baking test, Btu or kWh, and
W = initial weight of the frozen pies, lb.

11.11.4 Calculate and report the production capacity (lb/h) based on:

$$PC = \frac{W \times 60}{t} \quad (9)$$

where:

PC = production capacity of the rack oven, lb/h,
W = total weight of frozen pies (excluding pan weights) cooked during heavy-load baking test, lb, and
t = total bake time for the heavy-load test, min.

11.11.5 Report the average bake time for the full-load baking tests.

12. Precision and Bias

12.1 *Precision:*

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

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

12.1.1.2 The repeatability of each remaining reported parameter, with the exception of browning uniformity, is being determined. The repeatability of browning uniformity cannot be determined because of the descriptive nature of the test result.

12.1.2 *Reproducibility* (multiple laboratories)

12.1.2.1 The inter-laboratory precision of the procedure in this test method for measuring each reported parameter, with the exception of browning uniformity, is being determined. The reproducibility of browning uniformity cannot be determined because of the descriptive nature of the test result.

12.2 *Bias:*

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

13. Keywords

13.1 bake time; energy efficiency; performance; production capacity; rack oven; test method

ANNEXES

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

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

A1.1 For the baking 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 baking 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 100 lb/h, the uncertainty must not be greater than ±10 lb/h. Thus, the true production capacity is between 90 and 110 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.

A1.4 *Procedure:*

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

TABLE A1.1 Uncertainty Factors

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

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:

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

where:

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

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

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

where:

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

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

NOTE A1.4—The "A" quantity is the sum of the squares of each test result, and the "B" quantity is the square of the sum of all test results multiplied by a constant (⅓ 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 (3 test runs) is as follows:

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

$$U_3 = 2.48 \times S_3$$

where:

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

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

A1.4.3.1 The formula for the percent uncertainty (3 test runs) is as follows:

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

where:

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

A1.4.4 *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 baking 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:

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

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:

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

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:

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

$$U_4 = 1.59 \times S_4$$

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:

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

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 baking 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 baking 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:

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

where:

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

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

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

where:

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

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

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

where:

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

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

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

where:

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

When the percent uncertainty, $\%U_n$, is less than or equal to ± 10 % for the baking 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 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 baking scenario yielded the following production capacity (PC) results:

Test	PC
Run #1	110 lb/h
Run #2	104 lb/h
Run #3	101 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:

$$Xa_3 = \left(\frac{1}{3}\right) \times (X_1 + X_2 + X_3),$$
$$Xa_3 = \left(\frac{1}{3}\right) \times (110 + 104 + 101),$$
$$Xa_3 = 105\ lb/h$$

A1.5.2.2 The standard deviation of the three test results is as follows. First calculate "A3" and "B3":

$$A_3 = (X_1)^2 + (X_2)^2 + (X_3)^2,$$
$$A_3 = (110)^2 + (104)^2 + (101)^2,$$
$$A_3 = 33{,}117$$
$$B_3 = \left(\frac{1}{3}\right) \times [(X_1 + X_2 + X_3)^2],$$
$$B_3 = \left(\frac{1}{3}\right) \times [(110 + 104 + 101)^2],$$
$$B_3 = 33{,}075$$

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

$$S_3 = (1/\sqrt{2}) \times \sqrt{(33{,}117 - 33{,}075)},$$
$$S_3 = 4.58\ lb/h$$

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

$$U_3 = 2.48 \times S_3,$$
$$U_3 = 2.48 \times 4.58,$$
$$U_3 = 11.4\ lb/h$$

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

$$\%U_3 = (U_3/Xa_3) \times 100\,\%,$$
$$\%U_3 = (11.4/105) \times 100\,\%,$$
$$\%U_3 = 10.9\,\%$$

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 106 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:

$$Xa_4 = \left(\frac{1}{4}\right) \times (X_1 + X_2 + X_3 + X_4),$$
$$Xa_4 = \left(\frac{1}{4}\right) \times (110 + 104 + 101 + 106),$$
$$Xa_4 = 105\ lb/h$$

A1.5.6.2 The new standard deviation is. First calculate "A4" and "B4":

$$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2,$$
$$A_4 = (110)^2 + (104)^2 + (101)^2 + (106)^2,$$
$$A_4 = 44{,}353$$
$$B_4 = \left(\frac{1}{4}\right) \times [(X_1 + X_2 + X_3 + X_4)^2],$$
$$B_4 = \left(\frac{1}{4}\right) \times [(110 + 104 + 101 + 106)^2],$$
$$B_4 = 44{,}310$$

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

$$S_4 = (1/\sqrt{3}) \times \sqrt{(44{,}353 - 44{,}310)},$$
$$S_4 = 3.79\ lb/h$$

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

$$U_4 = 1.59 \times S_4,$$
$$U_4 = 1.59 \times 3.79,$$
$$U_4 = 6.03\ lb/h$$

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

$$\%U_4 = (U_4/Xa_4) \times 100\,\%,$$
$$\%U_4 = (6.03/105) \times 100\,\%,$$
$$\%U_4 = 5.74\,\%$$

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

$$PC{:}\,105 \pm 6\ lb/h$$

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

A2. PROCEDURE FOR DETERMINING THE MOISTURE CONTENT OF FOOD PRODUCTS USING GRAVIMETRIC WEIGHT LOSS

INTRODUCTION

Moisture content of food products can have a significant effect on the amount of energy required for cooking. It was imperative for researchers to be able to quickly and accurately determine whether a food product was within specifications before commencing testing. Moisture contents are also used in energy-to-food calculations. The moisture content of raw and cooked food can be determined using an air drying method and determining the gravimetric weight loss.

A2.1 Scope

A2.1.1 The test procedure in this annex determines the moisture content of raw and cooked food products using gravimetric weight loss on air drying.

A2.2 Referenced Documents

A2.2.1 *AOAC Documents:*[5]

AOAC Official Action 984.25 Moisture (Loss of Mass on Drying) in Frozen French Fried Potatoes

A2.3 Apparatus

A2.3.1 *Convection Drying Oven,* with temperature controlled at 215 to 220°F, used to determine moisture content of both the raw and cooked food product.

A2.4 Reagents and Materials

A2.4.1 *Half-Size Aluminum Sheet Pans,* measuring 9 by 13 by 1 in. for holding the sample food product.

A2.5 Procedure

NOTE A2.1—This procedure has been adapted from AOAC Official Action 984.25 Moisture (Loss of Mass on Drying) in Frozen French Fried Potatoes. A larger sample is used to reduce the uncertainty in the results.

A2.5.1 Weigh and record the weight of a dry, lined half-size sheet pan.

A2.5.2 Remove the sample pie from its pan (or pie tin) and place the whole pie onto the sheet pan. Weigh and record the weight of the pie sample.

NOTE A2.2—To obtain an accurate determination of the moisture content in the test food product, a representative sample of the food product (for example, accurate proportion of crust to filling) must be used for air drying.

A2.5.3 Thoroughly chop, grind, or otherwise break apart the food sample into ⅛-in. or smaller cubes. Evenly spread the sample over the area of the pan.

A2.5.4 Place into a preheated convection drying oven set at 220 ± 5°F for a period of 18 h.

A2.5.5 After 18 h have elapsed, weigh and record the weight of the dried sample.

A2.5.6 Return the sample to the oven and dry for an additional 2 h.

A2.5.7 Weigh and record the weight of the sample.

A2.5.8 Compare this weight to the previously recorded weight of the dried sample. Repeat A2.5.6 and A2.5.7 until the difference between successive weighings does not exceed 0.01 lb.

A2.6 Calculation

A2.6.1 Calculate the moisture content of the sample food product based on:

$$M = \frac{(W_i - W_f)}{W_i} \times 100 \quad \text{(A2.1)}$$

where:

M = the moisture content (by weight) of the sample food product, %,
W_i = the initial weight of the food sample, lb, and
W_f = the final dried weight of the food sample, lb.

[5] AOAC Official Methods of Analysis, 1990 available from the Association of Analytical Chemists.

APPENDIXES

(Nonmandatory Information)

X1. BAKING ENERGY EFFICIENCY AND PRODUCTION CAPACITY USING POTATOES

INTRODUCTION

The following procedure evaluates the rack oven's baking energy efficiency and production capacity when baking potatoes. The results from applying this potato test will be valuable to operators intending to use a rack oven for heavy food loads not characteristic of typical baking scenarios (for example, potatoes, meats, and meat products).

The performance indices generated from applying this potato test are not comparable to oven performance while baking baked goods (for example, cakes, cookies, bread, pies) and shall not be implied as such. Accordingly, the potato test is referenced in an appendix to this test method.

X1.1 Scope

X1.1.1 The test procedure in this appendix determines the baking energy efficiency and production capacity of the rack oven, using potatoes as a test product.

X1.2 Referenced Documents

X1.2.1 *ASTM Standards:*

F1496 Test Method for the Performance of Convection Ovens

X1.3 Summary of Test Method

X1.3.1 The rack oven is used to bake heavy-, medium-, and light-loads of potatoes. Potato baking energy efficiency, potato baking energy rate, and potato production rate are determined from these tests.

X1.4 Significance and Use

X1.4.1 The potato test may be used as an indicator of oven performance under heavy product loading, not characteristic of typical baking scenarios. The test results are comparable to results obtained for convection ovens using the procedure detailed in Test Method F1496.

X1.5 Reagents and Materials

X1.5.1 *Potatoes*—A sufficient quantity of fresh, whole, pre-washed, U.S. No. 1 Russet potatoes shall be obtained for the baking energy efficiency tests.

X1.6 Procedure

X1.6.1 Conduct the baking 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).

X1.6.2 Determine the number of pans required for the loading scenario. For heavy-load tests, use fifteen pans for single-racks and thirty pans for double-racks. For medium-load tests, use half the number of pans required for a heavy-load test (8 pans for a single-rack and 16 for a double-rack). For light-load tests, use one pan for single-racks and two pans for double-racks. See Table X1.1.

TABLE X1.1 Number of Pans per Load

Loading Scenario	6-pan Mini Rack Oven	8-Pan Mini Rack Oven	Single-Rack Oven	Double-Rack Oven
Heavy	6	8	15	30
Medium	3	4	8	16
Light	1	1	1	2

X1.6.3 Weigh and record the weight of the empty rack(s) and the sheet pans.

X1.6.4 Place 30 potatoes (3 rows of 10 potatoes per row) on each pan. The weight of the potatoes on each pan shall be 14.50 ± 0.30 lb. Record the weight of the potatoes on each pan.

NOTE X1.1—If the weight of the potatoes on a pan is outside the 14.50 ± 0.30 lb weight range specified above, substitute smaller or larger potatoes, as necessary, until the weight of the potatoes on each pan is within the appropriate required weight range.

X1.6.5 Load the rack(s) with the potato-filled sheet pans. Randomly select five potatoes on different pans for monitoring. Insert a heavy-duty chef's thermometer lengthwise into the center of the chosen potatoes, making certain that the dials are fully visible from the oven window during baking.

X1.6.6 Preheat the oven to 350 °F and allow it to idle for a minimum of 1 h.

X1.6.7 Measure and record the temperature of at least one potato per pan. The temperature of the potatoes at the start of each test shall be 75 ± 5°F.

X1.6.8 When the oven cycles off, load the rack(s) into the hot oven. Loading time shall be 45 ± 15 s. Begin monitoring time and energy consumption when the door is shut.

X1.6.9 When the thermometers reach an average temperature of 205°F, open the oven door and measure the internal temperature of a randomly chosen potato. If the potato is 205 ± 5°F, the potatoes are done and may be removed. If the temperature is below 200°F, close the door and resume baking until the average potato temperature is 205 ± 5°F.

X1.6.10 When the potatoes reach an internal temperature of 205 ± 5°F, open the oven door and remove the rack. Unloading time shall be 45 ± 15 s. Record the total elapsed time and energy consumption.

X1.6.11 Record the temperature of at least one potato per every pan within 3 min ± 15 s from the time the potatoes were removed from the oven.

X1.6.12 Weigh and record the final weight of the potatoes and pans.

X1.6.13 Perform runs #2 and #3 by repeating X1.6.2 – X1.6.12. Follow the procedure in Annex A1 to determine whether more than three test runs are required.

X1.6.14 Repeat X1.6.1 – X1.6.13 for the medium- and light-load scenarios.

X1.7 Calculation and Report

NOTE X1.2—The reported potato baking energy efficiency and production capacity parameters are the average values from the three test replicates.

X1.7.1 Calculate and report the potato baking energy efficiency for heavy-, medium-, and light-load baking tests based on:

$$\eta_{pot} = \frac{E_{pot} + E_{pans}}{E_{appliance}} \times 100 \quad (X1.1)$$

where:

η_{pot} = baking energy efficiency, %
E_{pot} = energy into the potatoes, Btu
= $E_{sens,\ pot} + E_{evap,\ pot}$

where:

$E_{sens,\ pot}$ = the quantity of heat added to the potatoes, which causes their temperature to increase from the starting temperature to the final cooked temperature, Btu
= $W_{i,\ pot} \times C_{p,\ pot} \times (T_{f,\ pot} - T_{i,\ pot})$

where:

$W_{i,\ pot}$ = initial weight of the raw potatoes, lb,
$C_{p,\ pot}$ = specific heat of the potatoes, Btu/lb,°F,
= 0.84
$T_{f,\ pot}$ = final average internal temperature of the baked potatoes, °F,
$T_{i,\ pot}$ = initial average internal temperature of the raw potatoes, °F,
$E_{evap,\ pot}$ = the latent heat (of vaporization) added to the potatoes, which causes some of the moisture contained in the potatoes to evaporate. The heat of vaporization cannot be perceived by a change in temperature and must be calculated after determining the amount of moisture lost from a fully baked potato.
= $(W_{i,\ pot} - W_{f,\ pot}) \times H_v$

where:

$W_{i,\ pot}$ = initial weight of the raw potatoes, lb,
$W_{f,\ pot}$ = final weight of the baked potatoes, lb,
H_v = heat of vaporization, Btu/lb,
= 970 Btu/lb at 212°F,
E_{pans} = energy into the sheet pans, Btu,
= $W_{pans} \times C_{p,\ pan} \times (T_{f,\ pot} - T_{i,\ pot})$

where:

W_{pans} = weight of the sheet pans, lb,
$C_{p,\ pan}$ = specific heat of the sheet pans, Btu/lb,°F,
= 0.20
$T_{f,\ pot}$ = final average internal temperature of the baked potatoes, °F,
$T_{i,\ pot}$ = initial average internal temperature of the raw potatoes, °F,
$E_{appliance}$ = energy into the appliance, Btu.

NOTE X1.3—The energy into the appliance includes electric energy consumed by fans, motors, and controls.

X1.7.2 Calculate and report the baking energy rate for heavy-, medium-, and light-load baking tests based on:

$$E_{pot\ cook\ rate} = \frac{E \times 60}{t} \quad (X1.2)$$

where:

$E_{pot\ cook\ rate}$ = baking energy rate, Btu/h or kW,
E = energy consumed during baking test, Btu or kWh,
t = baking test period, min.

For gas appliances, report separately a gas baking energy rate and an electric baking energy rate.

X1.7.3 Calculate and report the energy consumption per pound of food cooked for heavy-, medium-, and light-load baking tests based on:

$$E_{per\ pound\ pot} = \frac{E_{appliance}}{W} \quad (X1.3)$$

where:

$E_{per\ pound\ pot}$ = energy per pound of potatoes, Btu/lb or kWh/lb,
$E_{appliance}$ = energy consumed during the baking test, Btu or kWh,
W = initial weight of the raw potatoes, lb.

X1.7.4 Calculate and report the production capacity (lb/h) based on:

$$PC_{pot} = \frac{W_{i,\ pot} \times 60}{t} \quad (X1.4)$$

where:

PC_{pot} = production capacity of the rack oven, lb/h,
$W_{i,\ pot}$ = initial weight of the raw potatoes cooked during heavy-load baking test, lb,
t = total bake time for the heavy-load test, min

X1.7.5 Calculate and report the production rate (lb/h) for the medium- and light-load tests based on:

$$PR_{pot} = \frac{W_{i,\ pot} \times 60}{t} \quad (X1.5)$$

where:

PR_{pot} = production rate of the rack oven, lb/h,
$W_{i,\ pot}$ = total weight of the raw potatoes (excluding pan weights) cooked during the medium- and light-load baking tests, lb,
t = total bake time for the medium- and light-load tests, min.

X1.7.6 Report the average bake time for the heavy-, medium-, and light-load baking tests.

X2. RESULTS REPORTING SHEETS

Manufacturer ___________________________________
Model ___________________________________
Date ___________________________________
Test Reference Number (optional) ________________________

Section 11.1 Test Rack Oven
Description of operational characteristics:
____
____
____
____
____
____
____

Description of steam generator:
____
____
____

Ventilation rate: ___________________________________

Section 11.2 Apparatus
_______ Check if testing apparatus conformed to specifications in Section 6.

Deviations:
____
____
____
____

Energy Input Rate
Test Voltage (V) _______
Gas Heating Value (Btu/ft^3) _______
Measured (Btu/h or kW) _______
Rated (Btu/h or kW) _______
Percent Difference between Measured and Rated (%) _______

Thermostat Calibration
As-Received:
Oven Temperature Control Setting (°F) ______
Oven Cavity Temperature (°F) _______
As-Adjusted:
Oven Temperature Control Setting (°F) _______
Oven Cavity Temperature (°F) ______

Preheat Energy and Time
Preheat to 400°F:
Test Voltage (V) _______
Gas Heating Value (Btu/ft^3) _______
Starting Temperature (°F) _______
Energy Consumption (Btu or kWh) _______
Electric Energy Consumption (kW, gas rack ovens only) _______
Duration (min) _______
Preheat Rate (°F/min) _______

Idle Energy Rate
Idle @ 400°F:
Test Voltage (V) _______
Gas Heating Value (Btu/ft^3) _______
Idle Energy Rate (Btu/h or kW) _______
Electric Energy Rate (kW, gas rack ovens only) _______

Pilot Energy Rate (if applicable)
Gas Heating Value (Btu/ft^3) _______
Pilot Energy Rate (Btu/h or kW) _______

Browning Uniformity (White Sheet Cakes)
Description of sheet cake browning and surface irregularities. Includes a sketch or photograph of the browning pattern and a discussion of the differences of the results from cake to cake.
Test Voltage (V) ______
Gas Heating Value (Btu/ft^3) ______
Initial Cake Temperature (°F) ______

Final Cake Temperature (°F) ______
Initial Cake Weight (lb) ______
Final Cake Weight (lb) ______
Sheet Cake Bake Time (min) ______
Sheet Cake Baking Energy (Btu or kWh) ______
Electric Energy (kWh, gas rack ovens only) ______

Steam Performance

	Cycle #1	Cycle #2	Cycle #3	Cycle #4	Cycle #5
Volume of water delivered per cycle (gal)	______	______	______	______	______
Volume of Runoff per Cycle (gal)	______	______	______	______	______
Volume of steam delivered each cycle (gal)	______	______	______	______	______

Baking Energy Efficiency, Baking Energy Rate, and Production Capacity
Test Voltage (V) ______
Gas Heating Value (Btu/ft^3) ______
Baking Time (min) ______
Production Capacity (lb/h) ______
Energy to Food (Btu/lb) ______
Baking Energy Rate (Btu/h or kW) ______
Electric Energy Rate (kW, gas rack ovens only) ______
Energy per Pound of Food Cooked (Btu/lb or kWh/lb) ______
Baking Energy Efficiency (%) ______

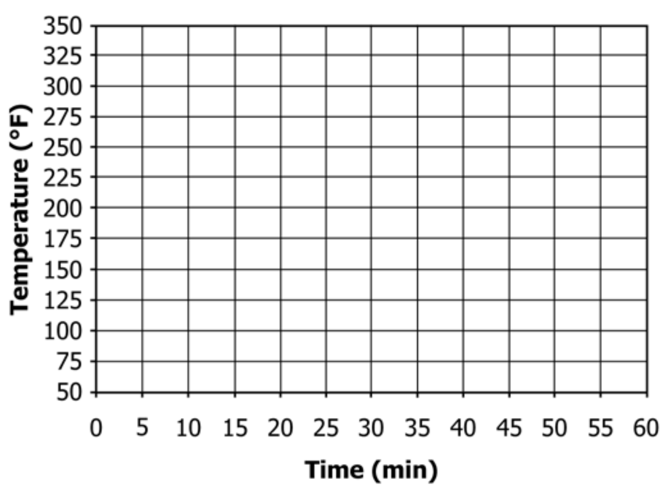

FIG. X2.1 Preheat Curve

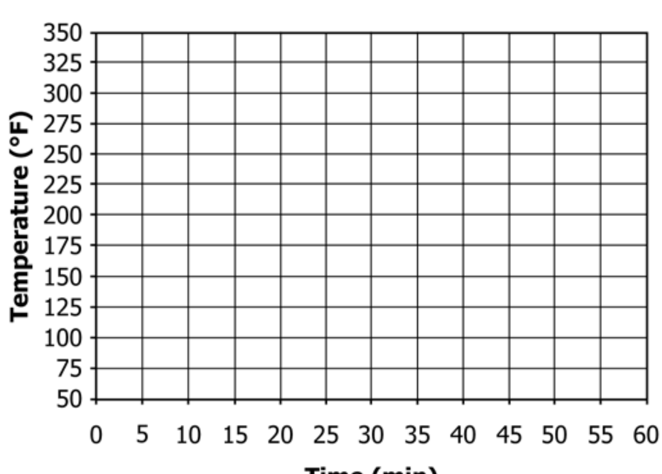

FIG. X2.2 Steam Performance Curve

X3. PROCEDURE FOR CALCULATING THE ENERGY CONSUMPTION OF A RACK OVEN BASED ON REPORTED TEST RESULTS

X3.1 Appliance test results are useful not only for benchmarking appliance performance, but also for estimating appliance energy consumption. The following procedure is a guideline for estimating rack oven energy consumption based on data obtained from applying the appropriate test method.

X3.2 The intent of this Appendix is to present a standard method for estimating oven energy consumption based on ASTM performance test results. The examples contained herein are for information only and should not be considered an absolute. To obtain an accurate estimate of energy consumption for a particular operation, parameters specific to that operation should be used (for example, operating time and amount of product baked).

X3.3 The appropriate rack oven performance parameters are obtained from Section 11 in the test method.

X3.4 *Procedure*:

NOTE X3.1—Sections X3.5 and X3.6 show how to apply this procedure.

X3.4.1 The calculation will proceed as follows: First, determine the appliance operating time and total number of preheats. Then estimate the quantity of product baked during an average day. For example a rack oven operating for 12 h a day with two preheats baked 1200 lbs of food. Calculate the energy due to baking and then calculate the idle energy consumption. The total daily energy is the sum of these components plus the preheat energy. For simplicity, it is assumed that subsequent preheats require the same time and energy as the first preheat of the day.

X3.4.2 *Step 1*—Determine the oven operating time, number of preheats, and amount of food baked.

X3.4.3 *Step 2*—Calculate the time and energy involved in baking. It is assumed for simplicity that all food is baked under full-load conditions.

X3.4.3.1 The total time baking is determined as follows:

$$t_h = \frac{W}{PC} \tag{X3.1}$$

where:

t_h = total time baking, h,
W = total weight of food baked per day, lb, and
PC = the oven's production capacity as determined in 11.11.4, lb/h.

X3.4.3.2 The baking energy consumption is calculated using the following set of equations. For gas ovens, any electric energy shall be determined separately using the electric equations.

$$E_{gas,h} = q_{gas,h} \times t_h \tag{X3.2}$$

$$E_{elec,h} = q_{elec,h} \times t_h$$

where:

$E_{gas,h}$ = total gas baking energy consumption, Btu,
$q_{gas,h}$ = gas baking energy rate as determined in 11.11.2, Btu/h,
$E_{elec,h}$ = total electric baking energy consumption, kWh,
$q_{elec,h}$ = electric baking energy rate as determined in 11.11.2, kW.

X3.4.4 *Step 3*—Calculate the total idle time and energy consumption.

X3.4.4.1 The total idle time is determined as follows:

$$t_i = t_{on} - t_h - \frac{n_p \times t_p}{60} \tag{X3.3}$$

where:

t_i = the total idle time, h,
t_{on} = the total daily on-time, h,
n_p = the number of preheats, and
t_p = preheat time, as determined in 11.6, min.

X3.4.4.2 The idle energy consumption is calculated using the following set of equations. For gas ovens, any electric energy shall be determined separately using the electric equations.

$$E_{gas,i} = q_{gas,i} \times t_i \tag{X3.4}$$

$$E_{elec,i} = q_{elec,i} \times t_i$$

where:

$E_{gas,i}$ = total gas idle energy consumption, Btu,
$q_{gas,i}$ = gas idle energy rate as determined in 11.7, Btu/h,
$E_{elec,i}$ = total electric idle energy consumption, kWh, and
$q_{elec,i}$ = electric idle energy rate as determined in 11.7, kW.

X3.4.5 *Step 4*—The total daily energy consumption is calculated as follows:

$$E_{gas,daily} = E_{gas,h} + E_{gas,i} + n_p \times E_{gas,p} \tag{X3.5}$$

$$E_{elec,daily} = E_{elec,h} + E_{elec,i} + n_p \times E_{elec,p}$$

where:

$E_{gas,daily}$ = the total daily gas energy consumption, Btu/d,
n_p = the total number of preheats per day,
$E_{gas,p}$ = gas preheat energy consumption as determined in 11.6, Btu,
$E_{elec,daily}$ = the total daily electric energy consumption, kWh/d, and
$E_{elec,p}$ = electric preheat energy consumption as determined in 11.6, kWh.

X3.4.5.1 The complete formulae for calculating daily energy consumption are as follows:

$$E_{gas,daily} = \frac{W}{PC} \times q_{gas,h} + \left(t_{on} - \frac{W}{PC} - \frac{n_p \times t_p}{60} \right) \times q_{gas,i} + n_p \times E_{gas,p} \tag{X3.6}$$

$$E_{elec,daily} = \frac{W}{PC} \times q_{elec,h} + \left(t_{on} - \frac{W}{PC} - \frac{n_p \times t_p}{60} \right) \times q_{elec,i} + n_p \times E_{elec,p}$$

X3.4.6 *Step 5*—The average electric demand for ovens may be calculated according to the following equation:

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}} \quad (X3.7)$$

NOTE X3.2—It has been assumed that the appliance's probable contribution to the building's peak demand is the average demand for the appliance. This is useful because the probability of an appliance drawing its average rate during the period that the building peak is set is significantly higher than for any other input rate for that appliance. If data exists otherwise for a given operation, the probable contribution to demand can be other than the average demand.

where:

q_{avg} = the average demand for the oven, kW,
$E_{elec,daily}$ = the total daily electric energy consumption, kWh/d, and
t_{on} = the total daily on-time, h.

X3.4.7 *Step 6*—The estimated monthly appliance energy cost may be determined as follows:

$$C_{gas,monthly} = r_{gas} \times \frac{E_{gas,daily}}{100{,}000\,\frac{Btu}{therm}} \times d_{op} \quad (X3.8)$$

$$C_{elec,monthly} = r_{elec} \times E_{elec,daily} \times d_{op} + r_{demand} \times q_{avg} \quad (X3.9)$$

where:

$C_{gas,monthly}$ = the monthly appliance gas cost, \$/mo,
r_{gas} = the appropriate utility gas rate, \$/therm,
$E_{gas,daily}$ = the total daily gas energy consumption, Btu/d,
d_{op} = the average number of operating days per month,
$C_{elec,monthly}$ = the monthly appliance electric cost, \$/mo,
r_{elec} = the appropriate utility electric rate, \$/kWh,
$E_{elec,daily}$ = the total daily electric energy consumption, kWh/d,
r_{demand} = the appropriate utility demand charge, \$/kW, and
q_{avg} = the average demand for the griddle, kW.

X3.5 *Example of Calculating the Daily Energy Consumption for an Electric Rack Oven*:

X3.5.1 Application of the test method to an electric oven yielded the following results:

Electric Oven Test Results—Example

Test	Result
Preheat Time	30.0 min
Preheat Energy	15.0 kWh
Idle Energy Rate	7.5 kW
Baking Energy Rate	25.0 kW
Production Capacity	200 lb/h

X3.5.2 *Step 1*—The following appliance operation is assumed:

Oven Operation Assumptions

Operating Time	12 h
Number of Preheats	2 preheats
Total Amount of Food Baked	1200 lb

X3.5.3 *Step 2*—Calculate the total baking energy.

X3.5.3.1 The total time baking is determined as follows:

$$t_h = \frac{W}{PC}, \quad (X3.10)$$

$$t_h = \frac{1200\ lb}{200\ lb/h},$$

$$t_h = 6.00\ h$$

X3.5.3.2 The total baking energy consumption is then calculated as follows:

$$E_{elec,h} = q_{elec,h} \times t_h, \quad (X3.11)$$

$$E_{elec,h} = 25.0\ kW \times 6.0\ h,$$

$$E_{elec,h} = 150\ kWh$$

X3.5.4 *Step 3*—Calculate the total idle time and energy consumption.

X3.5.4.1 The total idle time is determined as follows:

$$t_i = t_{on} - t_h - \frac{n_p \times t_p}{60}, \quad (X3.12)$$

$$t_i = 12.0\ h - 6.0\ h - \frac{2\ preheats \times 30.0 min}{60 min/h},$$

$$t_i = 5.0\ h$$

X3.5.4.2 The idle energy consumption is then calculated as follows:

$$E_{elec,i} = q_{elec,i} \times t_i, \quad (X3.13)$$

$$E_{elec,i} = 7.5\ kW \times 5.0\ h,$$

$$E_{elec,i} = 37.5\ kWh$$

X3.5.5 *Step 4*—The total daily energy consumption is calculated as follows:

$$E_{elec,daily} = E_{elec,h} + E_{elec,i} + n_p \times E_{elec,p}, \quad (X3.14)$$

$$E_{elec,daily} = 150\ kWh + 37.5\ kWh + 2 \times 15.0\ kWh,$$

$$E_{elec,daily} = 217.5\ kWh/day$$

X3.5.6 *Step 5*—Calculate the average demand as follows:

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}}, \quad (X3.15)$$

$$q_{avg} = \frac{217.5\ kWh}{12.0\ h},$$

$$q_{avg} = 18.2\ kW$$

X3.6 *Example of Calculating the Daily Energy Consumption for a Gas Combination Oven*:

X3.6.1 Application of the test method to a gas oven yielded the following results:

Gas Oven Test Results—Example

Test	Result
Preheat Time	30.0 min
Preheat Energy[A]	100,000 Btu + 3.5 kWh
Idle Energy Rate[A]	50,000 Btu/h + 2.0 kW
Cooking Energy Rate[A]	150,000 Btu/h + 2.5 kW
Production Capacity	200 lb/h

[A] Includes electric energy consumed by the fan and controls.

X3.6.2 *Step 1*—The following appliance operation is assumed:

Oven Operation Assumptions

Operating Time	12 h
Number of Preheats	2 preheats
Total Amount of Food Baked	1200 lb

X3.6.3 *Step 2*—Calculate the total baking energy.

X3.6.3.1 The total time baking is as follows:

$$t_h = \frac{W}{PC}, \tag{X3.16}$$

$$t_h = \frac{1200\ lb}{200\ lb/h},$$

$$t_h = 6.0\ h$$

X3.6.3.2 The total baking energy consumption is then calculated as follows:

$$E_{gas,h} = q_{gas,h} \times t_h, \tag{X3.17}$$

$$E_{gas,h} = 150{,}000\ Btu/h \times 6.0\ h,$$

$$E_{gas,h} = 900{,}000\ Btu$$

$$E_{elec,h} = q_{elec,h} \times t_h,$$

$$E_{elec,h} = 2.5\ kW \times 6.0\ h,$$

$$E_{elec,h} = 15.0\ kWh$$

X3.6.4 *Step 3*—Calculate the total idle time and energy consumption.

X3.6.4.1 The total idle time is determined as follows:

$$t_i = t_{on} - t_h - \frac{n_p \times t_p}{60}, \tag{X3.18}$$

$$t_i = 12.0\ h - 6.0\ h - \frac{2\ preheats \times 30.0 min}{60 min/h},$$

$$t_i = 5.0\ h$$

X3.6.4.2 The idle energy consumption is then calculated as follows:

$$E_{gas,i} = q_{gas,i} \times t_i, \tag{X3.19}$$

$$E_{gas,i} = 50{,}000\ Btu/h \times 5.0\ h,$$

$$E_{gas,i} = 250{,}000\ Btu$$

$$E_{elec,i} = q_{elec,i} \times t_i,$$

$$E_{elec,i} = 2.0\ kW \times 5.0\ h,$$

$$E_{elec,i} = 10.0\ kWh$$

X3.6.5 *Step 4*—The total daily energy consumption is calculated as follows:

$$E_{gas,daily} = E_{gas,h} + E_{gas,i} + n_p \times E_{gas,p}, \tag{X3.20}$$

$$E_{gas,daily} = 900{,}000\ Btu + 250{,}000\ Btu + 2 \times 100{,}000\ Btu,$$

$$E_{gas,daily} = 1{,}350{,}000\ Btu/day = 13.5\ therms/day$$

$$E_{elec,daily} = E_{elec,h} + E_{elec,i} + n_p \times E_{elec,p},$$

$$E_{elec,daily} = 15.0\ kWh + 10.0\ kWh + 2 \times 3.5\ kWh,$$

$$E_{elec,daily} = 32.0\ kWh/day$$

X3.6.6 *Step 5*—Calculate the average demand as follows:

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}}, \tag{X3.21}$$

$$q_{avg} = \frac{32.0\ kWh}{12.0\ h},$$

$$q_{avg} = 2.67\ kW$$