INTERNATIONAL

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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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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.

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[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.

3.1.2 *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.

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~~0.1 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~~0.1 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 %~~3 % 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.

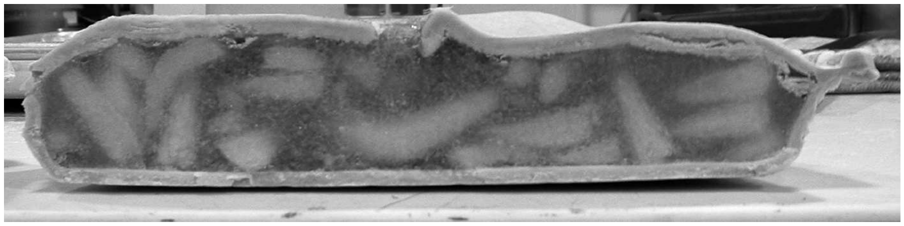

FIG. 1 Cross Section of a Frozen Apple Pie

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 %~~ ±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 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,

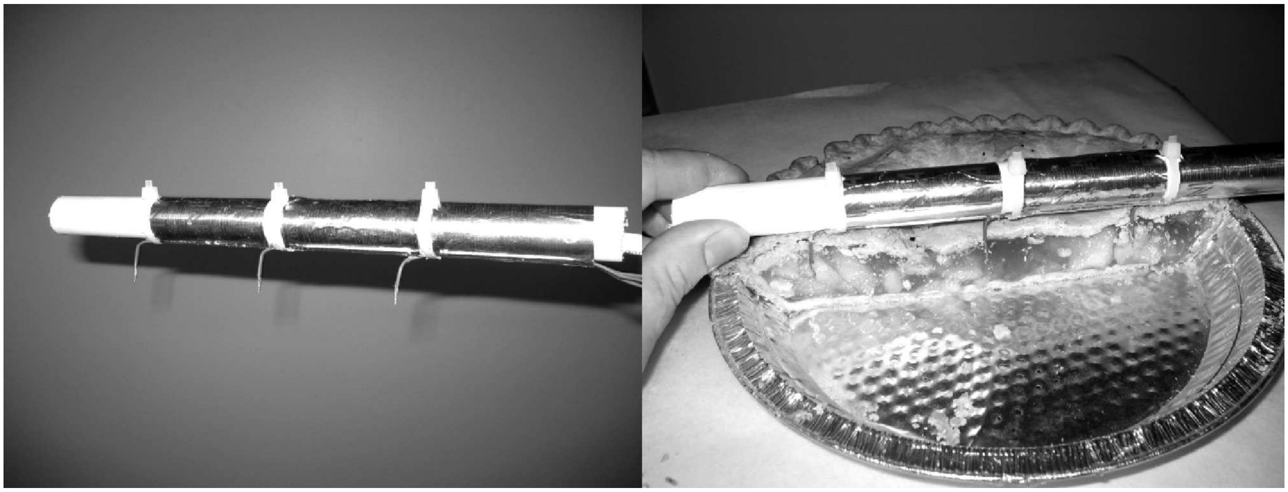

FIG. 2 Example Thermocouple Fixture for Measuring Pie Temperatures

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~~1000 to ~~1,075~~1075 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 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. If the oven has a setback mode, it must be disabled for the 3 h idle.

10.5.3 If the oven has an automatic setback mode, record the amount of time in idle operation to trigger setback mode.

10.5.4 Wait for the oven cavity temperature to drop and record the amount of time for the burner or heating element to start cycling in setback mode.

10.5.5 Start recording time, temperature and energy once the oven starts to cycle in setback mode for 3 h.

10.5.6 At the end of the setback idle, preheat the oven back to 400°F and record time, energy, and starting and final temperatures until the burners or elements cycle off.

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.

FIG. 3 Color Browning Chart

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.

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:

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

where:

E_{gas} = energy consumed by the appliance,
HV = higher heating value,
= energy content of gas measured at standard conditions, Btu/ft^3,
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:

$$q_{input} = \frac{E \times 60}{t} \tag{2}$$

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:

$$q_{idle} = \frac{E \times 60}{t} \tag{3}$$

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:

$$q_{pilot} = \frac{E \times 60}{t} \tag{4}$$

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:

$$V_{steam} = V_{water} - V_{runoff} \tag{5}$$

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:

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

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:

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