Standard Test Method for Performance of Convection Ovens[1]

This standard is issued under the fixed designation F1496; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the energy consumption and cooking performance evaluation of convection ovens. The test method is also applicable to convection ovens with limited moisture injection. The results of applying it can be used by the food service operator to select a convection oven and to understand its energy consumption and performance.

1.2 This test method applies to general purpose, full-size, and half-size convection ovens and bakery ovens used primarily for baking food products. It is not applicable to ovens used primarily for slow cooking and holding food product, to large roll-in rack-type ovens, or to ovens that can operate in a steam-only mode (combination ovens).

1.3 This test method is intended to be applied to convection ovens that operate close to their rated input in the dry heating mode, with the circulating fan operating at its maximum speed.

NOTE 1—Ovens that can operate in steam-only mode should be evaluated using ASTM F2861.

1.4 The oven's energy consumption and cooking performance are evaluated in this test method specifically with respect to the following:

1.4.1 Thermostat calibration (10.2),

1.4.2 Energy input rate and preheat energy consumption and time (10.3),

1.4.3 Pilot energy rate (if applicable) (10.4),

1.4.4 Idle energy rate (10.5),

1.4.5 Cooking energy efficiency and production capacity (10.6),

1.4.6 Cooking uniformity (10.7),

1.4.7 White sheet cake browning (10.8), and

1.4.8 Bakery steam mode, if applicable (10.9).

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

1.6 *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

F2092 Specification for Convection Oven Gas or Electric

F2093 Test Method for Performance of Rack Ovens

F2861 Test Method for Enhanced Performance of Combination Oven in Various Modes

2.2 *ASHRAE Documents:*[3]

1989 ASHRAE Handbook of Fundamentals, Chapter 6, Table 2—Thermodynamic Properties of Water at Saturation

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

3. Terminology

3.1 *Definitions:*

3.1.1 *average preheat rate*—rate (°F/min) at which cavity temperature is heated from ambient temperature to the oven's thermostat set point.

3.1.2 *bakery steam mode*—a single injection of water/steam into the baking cavity at the start of a bake cycle. Injection time not to exceed 60 seconds per baking event.

3.1.3 *convection oven*—an appliance for cooking food by forcing hot air over the surface of the food using a fan in a closed cavity.

3.1.4 *cook time*—time required to cook potatoes during a cooking energy efficiency test.

3.1.5 *cooking energy*—energy consumed (kBtu or kWh) by the oven as it cooks potatoes during the cooking energy efficiency tests.

---

[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.

Current edition approved June 1, 2013. Published July 2013. Originally approved in 1993. Last previous edition approved in 2012 as F1496 – 12. DOI: 10.1520/F1496-13.

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

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. United States

3.1.6 *cooking energy efficiency*—the ratio of the quantity of energy absorbed by the food product to the quantity of energy input to the oven during a cooking energy efficiency test expressed as a percent.

3.1.7 *cooking energy rate*—average rate of the oven's energy consumption (kBtu/h or kW) during a cooking energy efficiency test.

3.1.8 *fan and control energy rate*—the rate of energy consumption (kW) by an oven's controls and fan motor.

3.1.9 *heavy load*—the testing capacity of the convection oven based on a minimum spacing of 2.75-in. (70mm) between adjacent racks.

3.1.10 *idle energy rate*—oven's rate of energy consumption (kBtu/h or kW), when empty, to maintain its cavity temperature at the thermostat set point.

3.1.11 *measured energy input rate*—peak rate (kBtu/h or kW) at which an oven will consume energy, measured during a period (typically, its preheat period) when it is known that the oven is operating at full input, including the fan at high speed.

3.1.12 *pilot energy rate*—rate of energy consumption (kBtu/h) by a gas oven's standing pilot during non-cooking periods, if applicable.

3.1.13 *preheat energy*—amount of energy consumed (kBtu or kWh) by the oven while preheating its cavity from ambient temperature to the oven's thermostat set point.

3.1.14 *preheat time*—time (min) required for the oven cavity to preheat from ambient temperature to the thermostat set point.

3.1.15 *production capacity*—maximum rate (lb/h (kg/h)) at which a convection oven can bring the specified food product to a specified "cooked" condition. May also be referred to as throughput.

3.1.16 *steam injection cycle*—a period whereby steam/water is introduced into the baking cavity during baking.

3.1.17 *uncertainty*—a measure of the combination of the bias and precision error in specified instrumentation or the measure of the repeatability of a reported test result.

4. Summary of Test Methods

4.1 *Thermostat Calibration*—The accuracy of the oven thermostat is checked at 350°F (177°C), the set point for all but the browning test, which is 300°F (149°C). This is accomplished by comparing the oven's temperature control setting with the temperature at the center of the oven's cavity. If necessary, the control is adjusted so that the maximum difference between its reading and the temperature at the center of the cavity is no more than ±5°F (±2.8°C).

4.2 *Preheat Energy Consumption and Time*—The time and energy required to preheat the oven from room temperature (75 ± 5°F) to 340°F is determined.

4.3 *Energy Input Rate*—The input rate of the oven is determined to check whether the oven is operating properly. If the measured input rate is not within 5 % of the rated input, all further testing ceases until the appliance can be made to operate within this specification. For gas ovens, the pilot energy rate and the fan and control energy rate are also determined.

4.4 *Idle Energy Rate*—The idle energy rate (kBtu/h or kW) is determined with the oven set to maintain 350 ± 5°F (177 ± 2.8°C).

4.5 *Cooking Energy Efficiency and Production Capacity*—The cooking energy efficiency and production rate are determined during heavy-load cooking tests.

4.6 *Cooking Uniformity*—The uniformity of heating within the oven's cavity is determined and reported based on the average temperature on each rack during cooking tests.

4.7 *White Sheet Cake Browning*—The uniformity of browning from rack to rack is documented using white sheet cakes.

4.8 *Bakery Steam Mode*—The recovery performance convection oven's baking steam delivery system is characterized by assessing the amount of steam produced on repeated bake cycles.

5. Significance and Use

5.1 *Thermostat Calibration*—This test is conducted to ensure that all test results are determined at the same bulk oven cavity air temperature.

5.1.1 The results of the following tests can be used by an operator to select a convection oven based on its energy consumption performance or its cooking performance. Also, the results allow an operator to understand an oven's energy consumption.

5.2 *Energy Input Rate*—This test is used to confirm the test oven's rated input and to ensure its proper operation during all testing.

5.3 *Fan and Control Energy Rate*—Information from this test can be used to estimate the cost of electricity required to operate a gas oven. This cost can be added to the cost of gas consumed to estimate the total cost of energy necessary to operate the oven.

5.4 *Pilot Energy Rate*—This test provides a measure of a gas oven's energy consumption rate during periods when its burner is not on.

5.5 *Preheat Energy Consumption and Time*—This test provides a measure of time and energy required to preheat the oven cavity from ambient temperature to the thermostat set point temperature.

5.6 *Idle Energy Rate*—This test provides a measure of an empty oven's energy consumption at a typical cooking temperature setting. It also provides an indicator of the combined effectiveness of components of the oven's design (for example, insulation, door seals, and combustion efficiency) that influence its energy consumption.

5.7 *Cooking Energy Efficiency*—This test provides a measure of the oven's energy efficiency while heavy loads of a standard food product are being cooked.

5.8 *Production Capacity*—This test provides information that allows an operator to select an oven that matches food output requirements.

5.9 *Cooking Uniformity*—This test provides information regarding the oven's ability to cook food at the same rate throughout the oven's cavity.

5.10 *White Sheet Cake Browning*—This test provides information regarding the oven's ability to brown white sheet cakes uniformly through its cavity.

5.11 *Bakery Steam Performance*—This test provides information on a bakery convection oven's ability to consistently create steam for a baking cycle.

6. Apparatus

6.1 *Watt-Hour Meter,* for measuring the electrical energy consumption of an oven or oven fan motor/controls, having 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 equal to or less than 100 W, the meter shall have a resolution of at least 1 Wh and a maximum uncertainty no greater than 10 %.

6.2 *Gas Meter,* for measuring the gas consumption of an oven, which 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 light, it shall have a resolution of at least 0.01 ft^3 and a maximum uncertainty no greater than 2 % of the measured value.

6.3 *Calibrated Exposed Junction Thermocouples,* 20-24 GA wire Type K with a range from –20 to 400°F (–30 to 200°C), with a resolution of 2°F (1°C) and an uncertainty of 1°F (0.5°C), for measuring temperature of potatoes.

6.4 *Shielded Air Thermocouple Probe,* 20-24 GA wire, Type K with a range from –20 to 400°F (–30 to 200°C), with a resolution of 2°F (0.1°C) and an uncertainty of 1°F (0.5°C), for measuring temperature of the oven cavity.

6.5 *Temperature Readout Device,* for reading thermocouples, shall be capable of displaying required average temperature(s) during cooking energy efficiency and cooking uniformity tests (minimum of 20 thermocouples needed).

6.6 *Counter Scale,* with a capacity of 20.0 lb (9.1 kg), a resolution of 0.01 lb (0.005 kg), and an uncertainty of ±0.01 lb (0.005 kg) to measure the weight of potatoes for the cooking energy efficiency tests, water for the cooking uniformity tests, and cake batter for the browning test.

6.7 *Canopy Exhaust Hood,* 4 ft (1.2 m) in depth, wall mounted with the lower edge of the hood 6 ft, 6 in. (1.98 m) from the floor, with the capacity to operate at a nominal exhaust ventilation rate of 300 cfm per linear foot of active hood length. This hood shall extend a minimum of 6 in. (152 mm) past both sides of the cooking appliance and shall not incorporate side curtains or partitions. Makeup air shall be delivered through face registers or from the space, or both.

6.8 *Stopwatch,* for measuring time to the nearest 1 s.

6.9 *Gas Temperature Probe,* for measuring the temperature of natural gas supplied to an oven with a range from 50 to 100°F (10 to 37.8°C), resolution of 1.0°F (0.6°C), and uncertainty of ±1.0°F (±0.6°C).

6.10 *Gas Pressure Gage,* for measuring the pressure of natural gas supplied to an oven, with a range from 0 to 15 in. H_2O, resolution of 0.1 in. H_2O, and uncertainty of ±0.1 in. H_2O.

6.11 *Barometer,* for measuring atmospheric pressure, with a range from 28 to 32 in. Hg, resolution of 0.2 in. Hg, and uncertainty of ±0.2 in. Hg.

6.12 *Flow Meter,* for measuring total water consumption of the oven during the optional bakery steam mode tests, having a resolution of 0.005 gal and an uncertainty of 0.005 gal for flows of 0.1 gpm and higher.

7. Reagents and Materials

7.1 Potatoes shall be fresh, whole, prewashed, U.S. No. 1 Russets. Size shall be 100 count. The potatoes shall be weighed and grouped such that the weight of 15 potatoes is 7.25 ± 0.3 lb.

NOTE 2—Additional cases of larger (e.g., 80 Count) and smaller (e.g., 120 Count) sizes may be required to meet the 7.25 ± 0.3 lb for 15 potatoes weight and count requirements for the heavy-load cooking test.

7.2 *Macaroni and Cheese,* a sufficient quantity of frozen, commercial-grade, ready-to-cook macaroni and cheese entrees, with a nominal weight between 4.5 and 4.75 lb per unit, shall be obtained from a food distributor. The frozen macaroni and cheese shall have an initial moisture content of 68 ± 2 %, by weight. The moisture content shall be verified using the procedure in Annex A2.

NOTE 3—Stouffer's Traditional macaroni and cheese has been shown to be an acceptable product for testing by PG&E.

7.3 *Aluminum Sheet Pans*—A sufficient number for three replicate heavy-load cooking tests on the test oven. Sizes required: 18 by 26 by 1 in. (457 by 660 by 25 mm) for full-size ovens and 18 by 13 by 1 in. (457 by 330 by 25 mm) for half-size ovens.

7.4 *Mixer,* commercial, for mixing cake batter (browning test).

7.5 *White Cake Mix,* 5 lb (2.3 kg) per box. A minimum of 20 lb (9.1 kg) is required for full-size oven browning tests and a minimum of 10 lb (4.5 kg) is required for half-size oven browning tests.

NOTE 4—Pillsbury Deluxe White cake mix has been shown to be an acceptable product for testing by PG&E.

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

7.7 *Hotel Pan,* to be used to collect water runoff during bakery steam performance testing.

7.8 *Water,* supplied to the rack oven shall be 65 ± 5°F (18 ± 2.8°C). If outside this range, hot and cold water supplies may be mixed to achieve the required inlet temperature.

8. Sampling, Test Units

8.1 *Oven*—A representative production model shall be selected for performance testing.

9. Preparation of Apparatus

9.1 Install the appliance according to the manufacturer's instructions under a 4-ft (1.2-m) deep canopy exhaust hood mounted against the wall, with the lower edge of the hood 6 ft, 6 in. (1.98 m) from the floor. Position the oven with the front edge of the oven door inset 6 in. (152 mm) from the vertical plane of the front edge of the hood, at the manufacturer's recommended working height. The length of the exhaust hood and active filter area shall extend a minimum of 6 in. (152 mm) past both sides of the oven. In addition, both sides of the oven shall be a minimum of 3 ft (0.9 m) from any side wall, side partition, or other appliance. The exhaust ventilation rate shall be based on 300 cfm per linear ft of hood length (for example, a 3-ft (0.9-m) wide oven shall be ventilated, at a minimum, by a hood 4 by 4 ft (1.2 by 1.2 m), with a nominal air flow rate of 1200 cfm. The application of a longer hood is acceptable, provided the ventilation rate is maintained at 300 cfm per linear foot over the entire length of the active hood.) The associated heating or cooling system shall be capable of maintaining an ambient temperature of 75 ± 5°F (21 ± 2.8°C) within the testing environment when the exhaust ventilation system is working. The ambient air temperature shall be measured during each test at a location that is approximately 2 ft (0.6 m) horizontally from either side of the oven at a vertical height equal to the distance from the floor to the center of the oven cooking cavity.

9.2 Connect the oven to a calibrated energy test meter. For gas oven installations, a pressure regulator shall be installed downstream from the meter to maintain a constant pressure of gas during all tests. Install instrumentation to record both the pressure and temperature of the gas supplied to an oven, as well as the barometric pressure, during each test so that the measured gas flow (ft^3) can be corrected to standard conditions. For electric oven installations, a voltage regulator may be required to maintain constant name plate voltage during tests if the voltage supply is not within 2.5 % of the manufacturer's nameplate voltage.

9.3 For a gas oven, adjust (while the oven is preheating) the gas supply pressure downstream from the oven's pressure regulator to within 2.5 % of the operating manifold pressure specified by the manufacturer. For gas ovens, make adjustments to the oven following the manufacturer's recommendations for optimizing combustion.

9.4 For an electric oven, adjust (while the oven is preheating) the supply voltage to within 2.5 % of the operating voltage specified by the manufacturer.

NOTE 5—If an electric oven is rated for dual voltage (for example, 208/240 V), the voltage selected by the manufacturer or tester, or both, shall be reported. If an oven is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the oven (for example, preheat time) may differ at the two voltages.

NOTE 6—It is the intent of the testing procedure herein to evaluate the performance of an oven at rated gas pressure or electrical voltage.

9.5 Make the oven ready for use in accordance with the manufacturer's instructions.

9.6 The average temperature must be monitored using thermocouples and a readout device in the cooking energy efficiency test (10.6) and the cooking uniformity tests (10.7). The average temperature can be measured using two basic approaches during these tests. In one, the thermocouples are wired in parallel, so that the voltage each generates is averaged with that of other thermocouples. The resistance of all thermocouple circuits connected in parallel must be equal to obtain a true average temperature. If one or more thermocouples circuits are open-circuited, the indicated read will no longer be the true average. The second method is to do the averaging of the appropriate thermocouples in a data logger and display it with the data readout. This is also susceptible to open-circuited thermocouples.

9.7 If applicable, install a flow meter to the 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.

10. Procedure

NOTE 7—Prior to commencement of testing, the tester should read the operating manual to understand thoroughly the operation of the oven being tested.

10.1 *General:*

10.1.1 For gas convection ovens, the following shall be recorded for each test run:

10.1.1.1 Gas higher heating value;

10.1.1.2 Gas temperature (measured at energy meter);

10.1.1.3 Gas pressure (measured at energy meter);

10.1.1.4 Barometric pressure;

10.1.1.5 Gas volume consumed, where applicable; and

10.1.1.6 Measured energy input rate during test run.

NOTE 8—The preferred method of determining the higher heating value of gas supplied to the oven under test is with a calorimeter or gas chromatograph used in accordance with accepted laboratory procedures. It is recommended that all testing be performed with gas having a higher heating value (HV) of between 1000 and 1075 Btu/SCF.

10.1.2 For a gas oven, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (see 10.3).

10.1.3 For electric ovens, the following shall be recorded for each test run:

(1) Voltage while elements are energized;

(2) Electricity consumed, where applicable; and

(3) Measured energy input rate during test run.

10.1.4 For an electric oven, adjust the voltage (while heating elements are energized) to the rated voltage ±2.5 % at the beginning of each test run. Ensure that the voltage is within 2.5% of the rated appliance voltage during each test run. throughout the test.

10.1.5 For each test run, confirm that the measured energy input rate (kBtu/h for a gas oven and kW for an electric oven) is within 5 % of the rated name plate input. If the difference is greater than 5 %, testing shall be terminated and the manufacturer contacted. The manufacturer may make appropriate changes or adjustments to the oven or choose to supply an alternative oven for testing.

10.1.6 Control options may allow the oven to be operated at different input rates, fan modes, moisture injection options, and moisture vent settings. For all tests, the oven shall be operated at the control setting that corresponds to its rated input. The fan shall be operated in the continuous mode at its highest speed setting. Lights that can be controlled by the operator shall be turned on for all tests. No moisture shall be injected into the oven, and manually-operated moisture vents shall be in the fully opened position for all tests. An automatically-controlled vent shall be operated per manufacturer's design specifications.

10.1.7 During all testing, the ambient air temperature shall be maintained at 75 ± 5°F (21 ± 2.8°C). No tests are to be conducted without operating the exhaust ventilation system.

10.2 *Energy Input Rate and Thermostat Calibration:*

10.2.1 Install a thermocouple at the geometric center of the oven cooking cavity to record the center of the oven temperature. The vertical location of the oven's geometric center is on a rack placed in the center rack position. If the test oven has an even number of rack positions, the vertical location is half the distance between the two middle rack positions. The horizontal location of the geometric center is half the distance between the rear wall of the cavity and the oven door and half the distance between the left and right cavity wall.

10.2.2 Set the temperature control to 350°F (177°C) and preheat the oven.

10.2.3 Calculate and record the oven's energy input rate and compare the result to the rated nameplate input. For gas ovens, only the burner energy consumption is used to compare the calculated energy input rate with the rated gas input; any electrical energy use shall be calculated and recorded separately as the fan/control energy rate.

10.2.4 Allow the oven to idle for 60 min after the burners or elements commence cycling at the thermostat set point.

NOTE 9—Heater cycling can be observed by noting when the heaters turn on and off. Some ovens are equipped with an oven ready light or heat on light to exhibit heater cycles.

10.2.5 After the 60-min idle period, record the center of oven temperature at 30-s intervals for 15 min. Calculate the average of the 30 temperatures recorded, and record the resulting average center of oven temperature as described in 11.4.1. If this recorded temperature is 350 ± 5°F (177 ± 2.8°C), the oven's thermostat is calibrated.

10.2.6 If the average center of oven temperature is not 350 ± 5°F (177 ± 2.8°C), repeat the step given in 10.2.5, and adjust the oven's temperature control following the manufacturer's instructions until it is within this range. Record the oven temperature control setting corresponding to 350 ± 5°F (177 ± 2.8°C) as described in 11.4.2. If calibration is not recommended or not easily accomplished, mark (on the dial) the exact position of the temperature control that corresponds to an average center of oven temperature of 350 ± 5°F (177 ± 2.8°C).

10.3 *Preheat Energy Consumption and Time:*

10.3.1 The preheat test shall be run as the first test of the day after allowing the oven to cool down for a minimum of 12 hours.

NOTE 10—It is the intent of the preheat test to determine the amount of time for the oven to reach a ready-to-cook state after it has been off for an extended period (e.g., overnight). The preheat tests should be conducted as the first appliance operation on the day of tests.

10.3.2 Verify that the oven cavity temperature is 75 ± 5°F (24 ± 3°F). Set the calibrated temperature control to 350°F, set the fan set to operate in the maximum speed, and turn the oven on.

10.3.3 For a gas oven, monitor and record the electricity consumed by the oven's fan and controls. Connect its electrical supply cord to an electrical meter capable of recording the electricity consumed to the nearest watt hour. Start recording this consumption when the burners actually ignite (not when the oven ready light comes on), and stop at the end of the preheat.

10.3.4 With the temperature controls set to maintain the average cavity air temperature at 350 ± 5°F (177 ± 2.8°C) (as determined in 10.2), turn the oven on.

10.3.5 Record the oven cavity temperature at a minimum of 5-s intervals during the course of preheat.

10.3.6 Record the time and energy consumption required to preheat the oven cavity air temperature from 75 ± 5°F to 340°F (21 ± 2.8°C to 177 °C).

10.3.7 Continue recording oven cavity temperature at a minimum of 5-s intervals until the temperature has exceeded, then returned to 350°F to characterize any possible temperature overshoot.

10.3.8 In accordance with 11.6, calculate and report the preheat energy consumption and time, and generate a preheat temperature versus time graph.

10.4 *Pilot Energy Rate:*

10.4.1 For a gas oven with a standing pilot, set the gas valve controlling gas supply to the oven at the pilot position. Also set the oven's temperature control to the off position.

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

10.4.3 Monitor gas consumption for a minimum of 8 h of pilot operation. Calculate and report the pilot energy rate (11.7).

10.5 *Idle Energy Rate:*

10.5.1 With the temperature controls set to maintain the average cavity air temperature at 350 ± 5°F (177 ± 2.8°C) (10.2), turn the oven on. Allow it to idle at 350°F (177°C) for at least 60 min after the cavity has reached 340°F before beginning to monitor its energy consumption. For the gas oven, monitor only the gas consumed by the burner(s). Allow the burners or elements to cycle on, then off again before beginning to record idle energy consumption.

10.5.2 Record the oven's energy consumption while it is idling at 350°F (177°C) for a minimum of 3 h. Record the length of the idle period (11.8.1).

10.5.3 Calculate and record the oven's idle energy rate (kBtu/h or kW) for an average cavity air temperature of 350 ± 5°F (177 ± 2.8°C) (11.8.1).

10.6 *Cooking Energy Efficiency and Production Capacity:*

NOTE 11—Cooking energy efficiency tests are run using potatoes as the food product. Potatoes are used since their composition makes it relatively easy to calculate the amount of energy they absorb during cooking.

10.6.1 The convection mode cooking energy efficiency test shall be repeated a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (Annex A1). The reported values of cooking energy efficiency, production capacity, and cooking energy rate shall be the average of the replications (runs).

10.6.2 Determine the number of pans to be used for the heavy-load cooking-energy efficiency test:

10.6.2.1 Place the top oven rack so that it is a minimum of 2.75 in. (70mm) from the top of the cavity.

10.6.2.2 Place the bottom oven rack so that it is a minimum of 1-in. (25mm) from the bottom of the cavity.

10.6.2.3 Place the remaining oven racks in the oven such that adjacent racks are no closer than 2.75 in. (70 mm) from each other. Racks should be spaced as evenly as possible throughout the cavity.

10.6.2.4 Count the number of racks. This is the maximum pan load for the heavy-load cooking tests.

10.6.2.5 For testing a full-size oven, use full-size (18 by 26 by 1-in. (457 by 660 by 25-mm)) sheet pans. For a half-size oven, use half-size (18 by 13 by 1-in. (457 by 330 by 25-mm)) sheet pans. Identify each sheet pan with an individual number. Three times the capacity determined in 10.6.2.4 will be required for the three replicate test runs. For each test run, record the dry weight of each sheet pan to the nearest 0.01 lb (0.005 kg). For heavy-load tests, use the number of pans determined in 10.6.2.

10.6.3 Prepare a minimum number of loads for three test runs using the number of pans required for the loading scenario (see 10.6.2). For testing a full-size oven, place 30 potatoes (three rows of ten potatoes per row) on each pan. The weight of the potatoes on each pan shall be 14.50 ± 0.30 lb (6.6 ± 0.14 kg). For a half-size oven, place 15 potatoes (three rows of five potatoes per row) on each pan. The weight of the potatoes on these pans shall be 7.25 ± 0.30 lb (3.3 ± 0.14 kg). Ensure that all potatoes are dry and at 75 ± 5°F (21 ± 2.8°C) prior to weighing out. Record the weight of the potatoes on each pan. For each test run, record the total weight of all of the potatoes as the initial potato weight. Record all weights to the nearest 0.01 lb (0.005 kg).

NOTE 12—If the weight of the potatoes on a pan is outside the 14.50 ± 0.30-lb (6.6 ± 0.14-kg) or 7.25 ± 0.30-lb (3.3 ± 0.14-kg) weight range specified above, substitute smaller or larger potatoes, as necessary, until the weight of the potatoes on each pan is within one of the appropriate required weight ranges.

10.6.4 Once the pans of potatoes have been prepared, mark selected potatoes to be monitored for temperature. Mark randomly selected potatoes on each pan (three for heavy-load runs). For each test run, record the position of the marked potatoes on each pan according to the positions shown in Fig. 1 for Full-Size ovens and Fig. 2 for Half-Size ovens.

NOTE 13—For a given pan, monitor potatoes at different combinations of locations for each test run. For example, if for Run No. 1, potatoes on Pan No. 5 are monitored at Location Nos. 5, 17, and 29, potatoes on this pan are not to be monitored at this same combination of locations during subsequent test runs.

10.6.5 Shortly before each test run, position the bead of a bare junction thermocouple into the center of the marked potatoes being cooked. Secure each thermocouple lead wire in such a manner that its junction will remain at the center of the potato throughout the cooking period. Ensure that the temperature readout device displays the average temperature of all of the monitored potatoes (see 9.6). The temperature of the potatoes at the start of each test shall be 75 ± 5°F (21 ± 2.8°C).

10.6.6 Preheat the oven to 350°F (177°C), and allow it to idle for 1 h prior to the start of the first test run. Once this time period has elapsed, wait for the oven elements or burners to cycle one additional time before starting the test run to ensure that the oven cavity air temperature is at 350°F (177°C).

10.6.7 When the heaters cycle off, begin recording the oven energy consumption. Open the oven door immediately, and allow it to remain open for the entire loading period, as indicated in 10.6.7.1. Do not close the door, even if the pan loading is completed in less than the allotted time. Load the pans of potatoes by centering them on the oven racks during this period. At the end of the load period, close the oven door and record the initial average potato temperature to the nearest 0.1°F (0.06°C). Record the time as the beginning of the cooking period.

10.6.7.1 The total loading time (the time from opening the door to closing the door) shall be the total of 10 s per pan for each load used (for example, the total loading time for a heavy-load test of a five-pan capacity, full-size oven would be: 10 s/pan × 5 pans = 50 s).

10.6.8 Monitor the average potato temperature during cooking. When it reaches 205°F (99°C), shut the oven off immediately, and record the amount of energy consumed and elapsed cook time to the nearest 0.1 min. (Cook time is the time from when the oven door is closed until the oven is shut off.) Remove the thermocouples from the potatoes, and quickly remove all of the pans from the oven prior to weighing them. Record the final weight of each pan of potatoes within 5 min as measured from the time at which the oven was shut off. Calculate and record the final weight of the potatoes in each pan. Record the sum of these five weights as the final potato weight. Record all weights to the nearest 0.01 lb (0.005 kg). Calculate the oven's cooking energy efficiency, production rate, and cooking energy rate (see 11.9). Once the pans have been removed from the oven, close the door and restart the oven. Idling the oven for 1 h between test runs is not necessary.

10.6.9 Perform Run Nos. 2 and 3 by repeating the steps given in 10.6.4 – 10.6.8. Follow the procedure in Annex A1 to determine whether more than three test runs are required. Report the results for the cooking energy efficiency, production rate, cooking energy rate, and cook time as described in Annex A1.

10.7 *Cooking Uniformity Test:*

NOTE 14—The objective of this test is to evaluate the cooking uniformity of the oven under heavy food loading conditions such as heating pans of frozen food. The results of this test describe the oven's cooking uniformity by a comparison of the average temperature of food on each rack. Each rack's reported average temperature is obtained by averaging the results of three test runs. This test is to be performed so that the variation in the average temperature among the racks is minimized.

10.7.1 Obtain the required number of pans of frozen macaroni and cheese entrees. Use four times the number of test pans

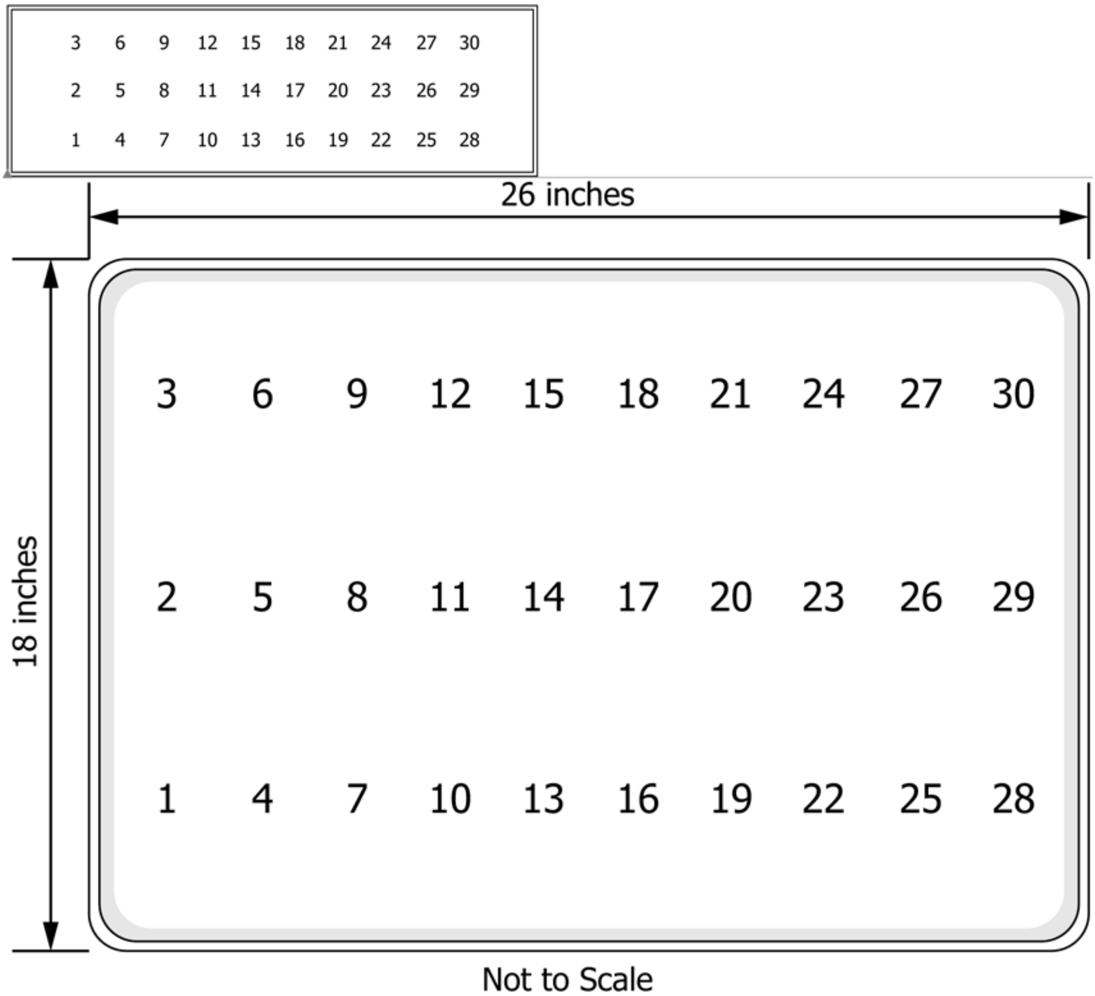


FIG. 1 Position of Potatoes on Full-Size Sheet Pans

as determined in 10.6.2 for a full-size oven test or two times the number of test pans as determined in 10.6.2 for a half-size oven test. Install one thermocouple in the center of each pan by drilling a small hole in the frozen mass and running the thermocouple underneath the foil cover (see Fig. 3). Secure the thermocouple to the pan with a small binder clip to prevent it from coming loose during the test.

10.7.2 Install stops on oven racks to ensure that pan placement on each rack is the same from test run to test run. This is accomplished by positioning the pans on the racks so that the four- or two-pan group is as close to the center of the rack as possible, with 0.5 in. (12.7 mm) of space left between pans, left to right and back to front (see Fig. 4).

10.7.3 Perform three test runs as indicated in 10.7.4 – 10.7.8, using the correct loading sequence as determined in 10.7.7. Average the temperatures obtained from the three test runs for each rack. Report the average temperature for each rack as indicated in 11.10.

10.7.4 Weigh and record the initial weight of each macaroni and cheese pan. Stabilize the instrumented pans of macaroni and cheese in a freezer at –5 ± 5°F.

10.7.5 Preheat the oven to 350°F (177°C), and allow its cavity to stabilize for 1 h.

10.7.6 Allow the oven to cycle one additional time, and then open the oven door when the oven ready or heat on light shuts off. Leave the oven door open for the entire allowable loading period: 5 seconds per pan (see 10.6.7.1). Do not close the door, even if the pan loading is completed in less than the allotted time.

10.7.7 Load the pans of macaroni and cheese into the oven from back to front. Place each pan into the oven with its longest side parallel to the back of the oven. Place four pans on each rack when testing a full-size oven and two pans on each rack when testing a half-size oven. Follow the manufacturer's recommendation for loading the pans from the top to bottom rack or vice versa. If a recommended loading sequence is not provided, follow the steps given in 10.7.7. Otherwise, perform each test run as described in 10.7.8 – 10.7.10.

NOTE 15—The intent of this test procedure is to load the oven (that is, top down or bottom up) so that the variation in average temperature among the racks is minimized.

10.7.8 Close the oven door at the end of the loading period, and begin to monitor the elapsed time, oven energy consumption, and the average temperature of the macaroni and cheese. Terminate the test run when the average macaroni and

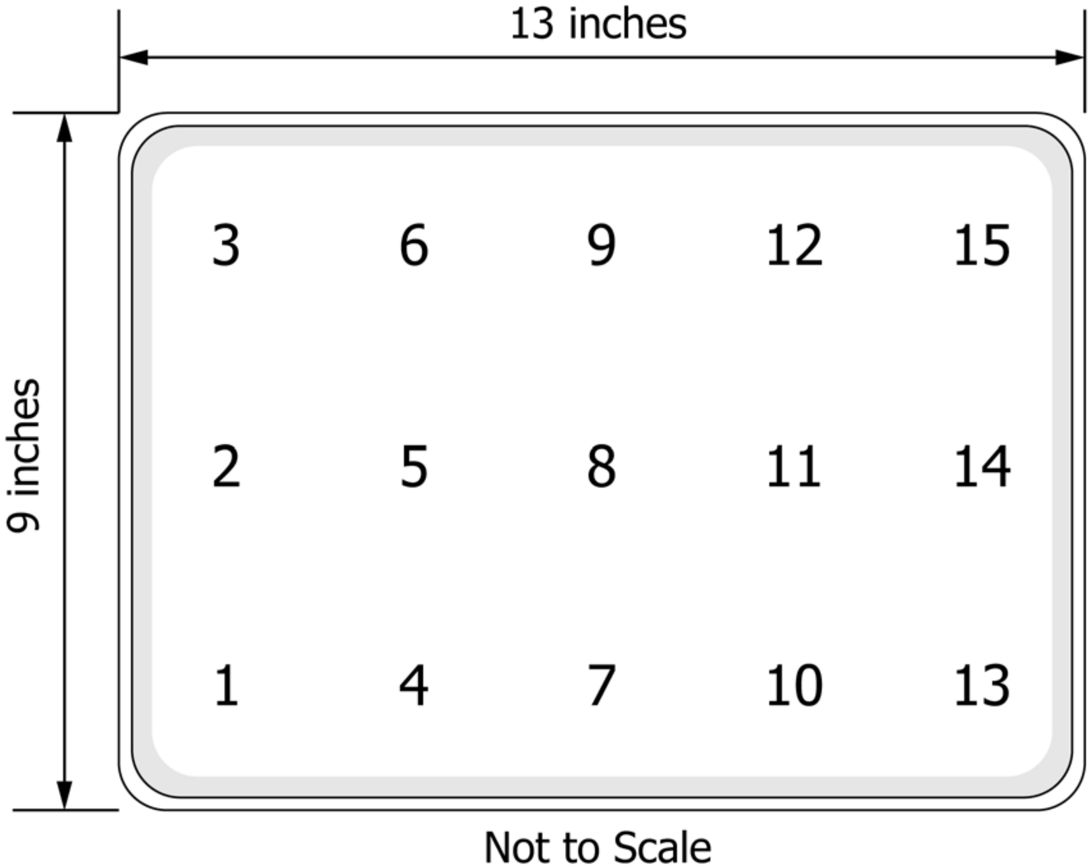


FIG. 2 Position of Potatoes on Half-Size Sheet Pans

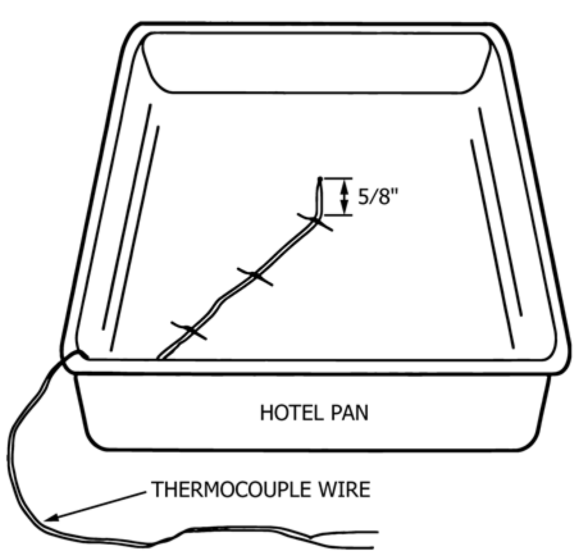


FIG. 3 Thermocouple Probe Placement in Hotel Pan

cheese temperature reaches 170°F (71°C). Record the elapsed time from when the oven door was closed as the cook time.

10.7.9 Weigh and record the weight of the cooked pans of macaroni and cheese.

10.7.10 Identify which rack had the highest average macaroni and cheese temperature. Record this rack as the fastest cooking rack. Record the average temperature on each of the other racks. Identify the slowest cooking rack.

10.8 *Browning Test (White Sheet Cakes):*

NOTE 16—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. As with the cooking uniformity test, this test is to be performed so that the variation in browning from rack to rack is minimized.

10.8.1 Place racks in the oven as described in 10.6.2.

10.8.2 Preheat the oven to 300°F (149°C), and allow its cavity temperature to stabilize for 1 h.

10.8.3 Use the same number of sheet pans for the browning uniformity test as determined in 10.6.2. Prepare the 18 by 26 by 1-in. (457 by 660 by 25-mm) sheet pans for testing a full-size oven or five 18 by 13 by 1-in. (457 by 330 by 25-mm) sheet pans for testing a half-size oven by lining each sheet pan with a paper liner.

10.8.4 Scale 5.0 ± 0.1 lb (2.3 ± 0.05 kg) of cake batter into each 18 by 26 by 1-in. (457 by 660 by 25-mm) sheet pan or 3.0 ± 0.1 lb (1.4 ± 0.05 kg) of batter into each 18 by 13 by 1-in. (457 by 330 by 25-mm) sheet pan. Level the batter in each pan with a spatula. Lightly drop each pan several times to reduce the number of air bubbles in the batter.

10.8.5 If more than one pan orientation on the racks is possible, obtain and follow the manufacturer's recommendations for orienting the pans. If a recommendation is not provided, load each pan with the longest side of the pan parallel to the back of the oven and centered on the rack. Record by rack which pan orientation is used for the test.

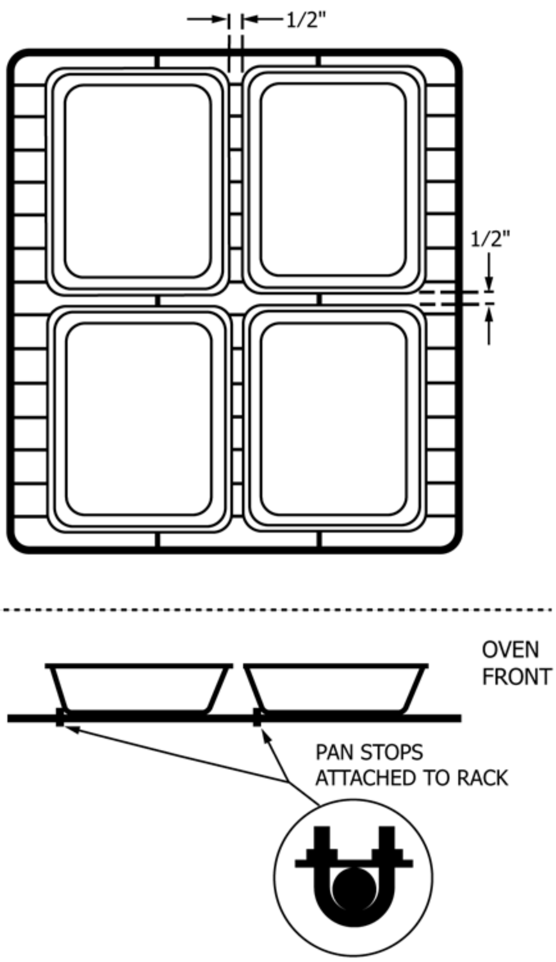


FIG. 4 Hotel Pan Placement on Oven Racks

10.8.6 In performing the test, obtain and follow the manufacturer's recommendations for the pan loading sequence (that is, from top rack down or from bottom rack up). If this loading sequence is not provided, follow the steps given in 10.8.7 to determine the correct loading sequence. Otherwise, proceed to 10.8.8.

10.8.7 To determine the correct pan loading sequence, perform at least two test runs following the procedure given in 10.8.8 and 10.8.9. The objective of these runs is to determine which loading sequence (top-down or bottom-up) has the least effect on the browning uniformity from rack to rack. This occurs when the first cake loaded is no darker than another cake at the end of the test. For the first run(s), load the first pan onto the top rack and work down. If the cakes are found to be overdone or underdone, run additional tests using this loading sequence until the cake doneness criteria given in 10.8.9 are satisfied. Once these criteria have been satisfied, record whether the cake on the top or on the bottom rack is darker. Next, reverse the loading sequence by loading the first pan onto the bottom rack and working up. Again, if the cake doneness criteria are not satisfied, repeat the test with this loading sequence until they are satisfied. Then report which cake is darker, the one on the top rack or the one on the bottom rack. Finally, determine which type of run, top-down or bottom-up, resulted in the minimum variation in browning uniformity. Use the results of that test run in reporting the test results as described in 11.11.

10.8.8 When the oven ready or heat on light shuts off, open the oven door and load the five sheet pans into the oven following the loading sequence and orientation, if applicable, as determined in 10.8.5 and 10.8.6. Allow 5 seconds per pan (see 10.6.7.1) to load the oven, and then close the door. Bake the cakes according to the instructions on the cake mix box.

NOTE 17—For example, research at PG&E's Food Service Technology Center has found that with the oven thermostat set at 300°F (149°C), the cook time for the cakes in a tested full-size oven is 18.5 min, while the cook time in a tested half-size oven is 16.0 min.

10.8.9 Determine whether the sheet cakes are done by first inserting a skewer into the center of each cake. The individual cake is considered done if no moist particles cling to it when it is withdrawn. Whether the cake load is done properly, overdone, or underdone is determined by the color of the cakes. If less than three of the cakes are golden or darker in color (Fig. 4), the cakes are considered underdone, and the cook time should be lengthened. If three or more cakes are dark brown, the cakes are overdone, and the cook time should be shortened. If underdone or overdone, browning uniformity cannot be determined. When cakes are cooked too long, browning will tend to become uniformly dark. If a cook time adjustment is required, repeat the steps given in 10.8.2 – 10.8.7 until an acceptable level of doneness is attained. Record the cook time required to achieve proper doneness.

10.8.10 Report the results of the test run as described in 11.11.

10.9 *Bakery Steam Performance (Optional for bakery ovens with steam injection):*

NOTE 18—The bakery steam performance test was based on a the steam performance test procedure in ASTM F2093. The objective of this test is to evaluate a bakery convection oven's steam generation capability on repeated bake cycles. Usage expectation is that a bakery oven is ready for immediate use after removal of prior product. For simplicity, the test is performed with an empty oven.

10.9.1 Preheat oven to 400°F (204°C) 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.

10.9.2 Record the initial weight of the empty runoff pan.

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

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

10.9.5 Repeat 10.9.2 through 10.9.4 a total of five times at 15 ± 0.1-min intervals.

11. Calculation and Report

NOTE 19—The results of each test are calculated, recorded, and reported as described in this section. A summary of the reported results is given in Annex A2.

11.1 *Test Oven*—Using Specification F2092 classifications, summarize the physical and operating characteristics of the convection oven. Use additional text to describe any design characteristics that may facilitate the audience's interpretation of the test results. Include all manufacturer's specifications and deviations therefrom.

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 convection ovens, report the voltage for each test.

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

11.3 *Gas Energy Calculations:*

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

11.3.2 Calculate the energy consumed based on the following:

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

where:

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

where:

V_{meas} = measured volume of gas, ft^3,
T_{cf} = temperature correction factor,
= $\frac{\text{absolute standard gas temperature, °R (°K)}}{\text{absolute actual gas temperature, °R (°K)}}$

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

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

NOTE 20—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Standard conditions using Practice D3588 are 14.696 psia (101.33 kPA) and 60°F (519.67 °R, (288.71 °K)).

11.4 *Thermostat Accuracy:*

11.4.1 For the as-received condition, report the center of oven temperatures that correspond to the 350°F (177°C) settings on the oven's temperature control (10.2.3).

11.4.2 If the oven's temperature control is adjusted to bring it within 5°F (2.8°C) of the center of the oven temperature, for the as-adjusted condition, report the oven temperature control setting that corresponds to 350 ± 5°F (177 ± 2.8°C) at the center of the oven as determined in 10.2.4.

11.5 *Energy Input Rate:*

11.5.1 Report the manufacturer's rated energy input (nameplate) in kBtu/h for a gas oven and kW for an electric oven.

11.5.2 Calculate and report the maximum energy input rate (Btu/h or kW) based on the energy consumed by the oven during the preheat period using the following:

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

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.

The conversion factor is 60 min/h.

11.5.3 For a gas oven, calculate and report the oven's fan/control energy rate (kW) using the following:

$$q_{fan} = \frac{E_{fan} \times 60}{t_{preheat}} \tag{3}$$

where:

q_{fan} = measured peak energy input rate, Btu/h or kW,
E_{fan} = fan energy consumed during the preheat period, Wh, and
$t_{preheat}$ = measured preheat time, min.

The conversion factors are 60 min/h and 1000 Wh/kWh.

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

11.6 *Preheat Energy and Time:*

11.6.1 Report the preheat energy consumption (kBtu or kWh, or both), and the preheat time (min), as determined in 10.3.

11.6.2 For a gas oven, report the preheat energy due to fan and control energy consumption (kWh) separately from the burner energy consumption (kBtu).

11.6.3 Calculate and report the average preheat rate (°F/min) based on the preheat period.

$$p_{oven} = \frac{T_f - T_i}{t_{preheat}} \tag{4}$$

where:

p_{oven} = oven preheat rate, °F/min (°C/min),
T_f = final oven temperature at the end of the preheat test, °F (°C),
= 340°F (171°C),
T_I = initial oven temperature at the beginning of the preheat test, °F (°C), and
$t_{preheat}$ = measured preheat time, min.

11.6.4 Generate a graph showing oven cavity temperature versus time for the preheat period including temperature overshoot, if any.

11.7 *Pilot Energy Rate:*

11.7.1 Calculate and report the pilot energy rate (Btu/h (kJ/h)) based on the following:

$$q_{pilot} = \frac{E \times 60}{t} \tag{5}$$

where:

q_{pilot} = pilot energy rate, Btu/h (kJ/h),

E = energy consumed during the test period, Btu (kJ), and
t = test period, min.

11.8 *Idle Energy Rate:*

11.8.1 Calculate and report the oven's idle energy rate (kBtu/h or kW) based on the idle energy consumption determined in 10.5 using the following:

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

where:

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

11.9 *Cooking Energy Efficiency and Production Capacity:*

NOTE 21—The following paragraphs describe how the cooking energy rate, cooking energy efficiency, and production capacity are calculated. The average values of these parameters, along with the average cook times, are to be calculated based on a minimum of three test runs and then reported as described in A1.1 of Annex A1.

11.9.1 Report a minimum of three run average value of the convection mode cooking-energy efficiency, production capacity and cooking energy rate.

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

$$q_{potato} = \frac{E \times 60}{t} \quad (7)$$

where:

q_{potato} = cooking energy rate, Btu/h (kJ/h) or kW,
E = energy consumed during cooking test, Btu (kJ) or kWh, and
t = cooking test period, min.

For gas ovens, report separately a gas cooking energy rate and an electric cooking energy rate.

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

$$q_{per\ pound} = \frac{E}{W} \quad (8)$$

where:

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

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

$$\eta_{potato} = \frac{E_{potato} + E_{pan}}{E_{oven}} \quad (9)$$

where:

η_{potato} = cooking energy efficiency, %,
E_{potato} = energy into the potatoes, Btu (kJ), and

E_{potato} = $E_{sens,potato} + E_{evap,potato}$.

where:

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

where:

$W_{i,potato}$ = initial weight of potatoes, lb (kg),
$C_{p,potato}$ = specific heat of potatoes, Btu/lb, °F (kJ/kg, °C),
= 0.84.

NOTE 22—For this analysis, the specific heat (C_p) of a load of potatoes is considered to be the weighted average of the specific heat of its components (for example, water and nonfat protein). Research conducted by PG&E determined that the weighted average of the specific heat for potatoes cooked in accordance with this test method was approximately 0.84 Btu/lb* °F.

$T_{f,potato}$ = average temperature of all of the potatoes at the end of the cooking test, °F,
$T_{i,potato}$ = average temperature of all of the potatoes at the beginning of the cooking test, °F,
$E_{evap,potato}$ = 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 how much moisture was lost during baking.
= $(W_{i,potato} - W_{f,potato}) \times H_v$

where:

$W_{f,potato}$ = final weight of the baked potatoes, lb (kg),
$W_{i,potato}$ = initial weight of the raw potatoes, lb (kg),
H_v = heat of vaporization, Btu/lb (kJ/kg),
= 970 Btu/lb (2256 kJ/kg), and

$$E_{pan} = W_{pan} \times Cp_{pan} \times \Delta T_{pan} \quad (10)$$

where:

W_{pan} = weight of sheet pan(s) used in cooking-energy efficiency test, lb,
Cp_{pan} = specific heat of aluminum, Btu/lb°F,
= 0.22 Btu/lb°F, and
ΔT_{pan} = useful temperature rise in sheet pan(s), °F, defined as the temperature rise of the potatoes
= $Tf_{potato} - Ti_{potato}$
E_{oven} = total energy consumed by the oven during the cooking-energy efficiency test, Btu (kJ). Includes sum of all fuel types used (for example, gas energy for heating plus electric energy used by circulating fans and/or controls).

11.9.5 Calculate and report the production rate (PR) (lb/h) for the oven as follows:

$$PR_{potato} = \frac{W_{i,potato} \times 60}{t_{cook,potato}} \quad (11)$$

where:

$W_{i,potato}$ = initial weight of the potatoes on all pans (lb) during the cooking-energy efficiency test, and
$t_{cook,potato}$ = cook time for the heavy-load cooking test (min).

11.9.6 Report the average cook time for the heavy-load tests.

11.10 *Cooking Uniformity Test:*

11.10.1 For each rack, calculate the average temperature of the macaroni and cheese in the pans at the end of the test using the corresponding average temperatures for the three test runs. Report these average temperatures for each of the five racks.

11.11 *Browning Test (White Sheet Cakes):*

11.11.1 Note and record the color at the center and 1 in. from each corner of each cake according the color chart (Fig. 4).

11.11.2 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. Photograph each cake showing its browning pattern and any irregularities may accompany the description.

11.11.3 If the orientation of the sheet pan on each rack was an option, report the orientation of the pan on each rack used during the test. Report the cake load cook time.

11.12 *Bakery Steam Performance (bakery ovens with steam injection):*

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

$$V_{steam} = V_{water} - V_{runoff} \quad (12)$$

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.

11.12.2 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 11.12.1.

12. Precision and Bias

12.1 *Precision:*

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

12.1.1.1 For each cooking energy efficiency result and for the heavy-load production rate (production capacity) result, the percent uncertainty in each result, based on at least three test runs, has been specified to be no greater than ±10 %.

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

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

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

13. Keywords

13.1 browning; convection ovens; cooking energy efficiency; cooking uniformity; energy efficiency; energy inputs; energy performances; preheat energy; preheat times; production capacity; productivity

ANNEXES

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

NOTE A1.1—The procedure described below is based on the procedure for determining the confidence interval for the average of several test results discussed in 6.4.3, ASHRAE Guideline 2-1986(RA90). It should be applied only to test results that have been obtained within the tolerances prescribed in this test method (for example, with the thermocouples calibrated, and the oven operating within 5 % of rated input during the test run).

A1.1 For the cooking energy efficiency and production capacity procedure, results are reported for the cooking energy efficiency, cooking energy rate, production rate, and cook time. The reporting requirements are summarized in Table A1.1. Each reported result is the average of results from at least three test runs. In addition, the uncertainty in these averages is reported. For each loading scenario, the uncertainty of the cooking energy efficiency and production rate must be no greater than ±10 % before any of the parameters for that scenario can be reported. These parameters are marked with an asterisk (*) in Table A1.1. Therefore, for the heavy load

TABLE A1.1 Reporting and Uncertainty Requirements for Cooking Energy Efficiency Tests

NOTE 1—An asterisk (*) indicates result must have uncertainty less than or equal to ±10 % for reporting.

Loading Scenario	CEE	CER	PR	tc
Heavy	X*	X	X*	X
Light	X*	X	X	X

scenario, the uncertainty in both the cooking energy efficiency and production rate must be no greater than ±10 % before any parameter can be reported.

A1.2 The uncertainty in a reported result is a measure of its precision. For example, if the heavy-load production rate for the oven is 60 lb/h, the uncertainty must not be greater than ±6 lb/h. This means that the true production rate is within the interval between 54 lb/h and 66 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 rate could be outside of this interval.

A1.3 Calculating the uncertainty not only guarantees the maximum uncertainty in the reported results, but also is used to determine how many test runs are necessary to satisfy this requirement. The uncertainty is calculated from the standard deviation of three or more test results and a factor from Table A1.2 which depends on 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—See A1.5 for an example of applying this procedure.

A1.4.1 *Step 1*—Calculate the average and the standard deviation for the test result (cooking energy efficiency or production rate) using the results of the first three test runs.

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

A1.4.1.1 The formula for the average (three test runs) is as follows:

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

where:

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

TABLE A1.2 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

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

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

where:

S_3 = standard deviation of the 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 A1.4—The "A" quantity is the sum of the squares of each test result, while 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 A1.2.

A1.4.2.1 The formula for the absolute uncertainty (three test runs) is as follows:

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

$$U_3 = 2.48 \times S_3$$

where:

U_3 = absolute uncertainty in the average for three test runs, and
C_3 = uncertainty factor for three test runs (Table A1.2).

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

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

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

where:

$\%\, U_3$ = percent uncertainty in the average for three test runs,
U_3 = absolute uncertainty in the 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 (all load scenarios) and production rate (heavy-load scenario only), report the average for all parameters, along with their corresponding absolute uncertainty, U_3, in the following format:

$$Xa_3 \pm U_3$$

If the percent uncertainty is greater than ±10 % for the cooking energy efficiency or heavy-load production rate, proceed to Step 5.

A1.4.5 *Step 5*—Run a fourth test for each loading scenario that resulted in the percent uncertainty being greater than ±10 %.

A1.4.6 *Step 6*—When a fourth test is run for a given load scenario, calculate the average and standard deviation for the 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 the results for four test runs, and

X_1, X_2, X_3, and X_4 = results for each test run.

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

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

where:

S_4 = standard deviation of the 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 A1.2.

A1.4.7.1 The formula for the absolute uncertainty (four test runs) is as follows:

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

$$U_4 = 1.59 \times S_4$$

where:

U_4 = absolute uncertainty in the average for four test runs, and
C_4 = uncertainty factor for four test runs (Table A1.2).

A1.4.8 *Step 8*—Calculate the percent uncertainty in the parameter averages using the averages from Step 6 and absolute uncertainties from Step 7.

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

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

where:

$\%\ U_4$ = percent uncertainty in the average for four test runs,
U_4 = absolute uncertainty in the 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 no greater than ±10 % for the cooking energy efficiency (all load scenarios) and production rate (heavy-load scenario only), report the average for all parameters, along with their corresponding absolute uncertainty, U_4, in the following format:

$$Xa_4 \pm U_4$$

If the percent uncertainty is greater than ±10 % for the cooking energy efficiency or heavy-load production rate, 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:

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

where:

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

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

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

where:

S_n = standard deviation of the 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:

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

where:

U_n = absolute uncertainty in the average for n test runs, and
C_n = uncertainty factor for n test runs (Table A1.2).

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

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

where:

$\%\ U_n$ = percent uncertainty in the average for n test runs.

When the percent uncertainty, $\%\ U_n$, is less than or equal to ±10 %, report the average for all parameters, along with their corresponding absolute uncertainty, U_n, in the following format:

$$Xa_n \pm U_n$$

NOTE A1.5—During the course of running these tests, the tester may compute a test result that deviates significantly from the other test results. It may be tempting to discard such a result in an attempt to meet the ±10 % uncertainty requirement. This should be done only if there is some physical evidence that the test run from which that particular result was obtained was not performed according to the conditions specified in this test method (for example, if a thermocouple was out of calibration, the oven's input rate was not within 5 % of the rated input, or a thermocouple slipped out of a potato). To be sure all results were obtained under approximately the same conditions, it is good practice to monitor those test conditions specified in this test method.

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

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

Test	PR
Run No. 1	69.8 lb/h
Run No. 2	75.9 lb/h
Run No. 3	70.3 lb/h

A1.5.2 *Step 1*—Calculate the average and standard deviation of the three test results for the production rate.

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

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

$$Xa_3 = \left(\frac{1}{3}\right) \times (69.8 + 75.9 + 70.3),$$

$$Xa_3 = 72.0 \text{ lb/h}$$

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

$$A_3 = (X_1)^2 + (X_2)^2 + (X_3)^2, \tag{A1.14}$$

$$A_3 = (69.8)^2 + (75.9)^2 + (70.3)^2,$$

$$A_3 = 15\,575$$

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

$$B_3 = \left(\frac{1}{3}\right) \times [(69.8 + 75.9 + 70.3)^2],$$

$$B_3 = 15\,552$$

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

$$S_3 = \left(1/\sqrt{2}\right) \times \sqrt{(15\,575 - 15\,552)}, \tag{A1.15}$$

$$S_3 = 3.39 \text{ lb/h}$$

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

$$U_3 = 2.48 \times S_3, \tag{A1.16}$$

$$U_3 = 2.48 \times 3.39,$$

$$U_3 = 8.41 \text{ lb/h}$$

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

$$\%\ U_3 = (U_3/Xa_3) \times 100\,\%, \tag{A1.17}$$

$$\%\ U_3 = (8.41/72.0) \times 100\,\%,$$

$$\%\ U_3 = 11.7\,\%$$

A1.5.5 *Step 4*—Run a fourth test. Since the percent uncertainty for the production rate is greater than ±10 %, the precision requirement has not been satisfied, and an additional test is run in an attempt to reduce the uncertainty. The production rate from the fourth test run was 72.8 lb/h.

A1.5.6 *Step 5*—Recalculate the average and standard deviation for the production rate using the fourth test result.

A1.5.6.1 The new average production rate is as follows:

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

$$Xa_4 = \left(\frac{1}{4}\right) \times (69.8 + 75.9 + 70.3 + 72.8),$$

$$Xa_4 = 72.0 \text{ lb/h}$$

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

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

$$A_4 = (69.8)^2 + (75.9)^2 + (70.3)^2 + (72.8),$$

$$A_4 = 20\,875$$

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

$$B_4 = \left(\frac{1}{4}\right) \times [(69.8 + 75.9 + 70.3 + 72.8)^2],$$

$$B_4 = 20\,851$$

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

$$S_4 = \left(1/\sqrt{3}\right) \times \sqrt{(20\,875 - 20\,851)}, \tag{A1.20}$$

$$S_4 = 2.83 \text{ lb/h}$$

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

$$U_4 = 1.59 \times S_4, \tag{A1.21}$$

$$U_4 = 1.59 \times 2.83,$$

$$U_4 = 4.50 \text{ lb/h}$$

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

$$\%\ U_4 = (U_4/Xa_4) \times 100\,\%, \tag{A1.22}$$

$$\%\ U_4 = (4.50/72.2) \times 100\,\%,$$

$$\%\ U_4 = 6.2\,\%$$

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

$$\text{PR} = 72.2 \pm 4.50 \text{ lb/h} \tag{A1.23}$$

The production rate can be reported assuming that the ±10 % precision requirement has been met for the corresponding cooking energy efficiency. The cooking energy efficiency and its production rate 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 Document:*[4]

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. 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 Place the food sample onto the sheet pan. Weigh and record the weight of the 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, one-half pound or more) 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 the following:

M = moisture content (by weight) of the sample food product, %,

W_i = initial weight of the food sample, lb, and

W_f = final dried weight of the food sample, lb.

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

APPENDIXES

(Nonmandatory Information)

X1. RESULTS REPORTING SHEETS

Manufacturer
Model
Date
Test Reference Number (optional)

1. Test Rack Oven

Fuel type:
Half-size or full-size:
Test capacity (number of pans):
Rated input:
Oven cavity volume (in. ^{3}):
Controls:
(Lists and discusses control settings, including input rate, fan speed, fan mode, and moisture injection options.)

Description of operational characteristics:
____
____
____
____
____
____
____

2. Apparatus

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

3. Thermostat Calibration

As-Received:

Oven temperature control setting (°F)	350
Oven cavity temperature (°F)	. . .
Oven temperature control setting (°F)	300
Oven cavity temperature (°F)	. . .

As-Adjusted:

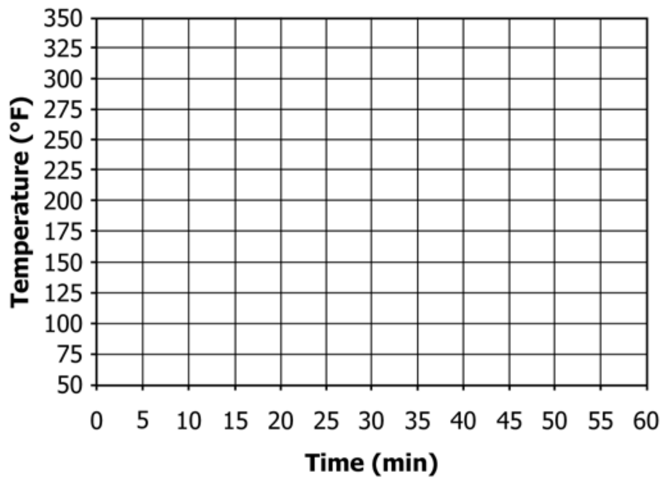
Oven temperature control setting (°F)	. . .
Oven cavity temperature (°F)	350 ± 5
Oven temperature control setting (°F)	. . .
Oven cavity temperature (°F)	300 ± 5

4. 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 (%)
Gas oven-fan and control energy rate (kW)

5. Preheat Energy and Time

Test voltage (V)
Gas heating value (Btu/ft^3)
Starting temperature (°F)
Energy consumption (Btu or kWh)
Electric energy consumption (kW, gas ovens only)
Duration (min)
Preheat rate (°F/min)



Preheat Curve

6. Pilot Energy Rate (if applicable)

Gas heating value (Btu/ft^3)
Pilot energy rate (Btu/h or kW)

7. Idle Energy Rate

Test Voltage (V)
Gas heating value (Btu/ft^3)
Idle energy rate at 350°F (Btu/h or kW)
Electric energy rate at 350°F (kW, gas ovens only)

8. Cooking Energy Efficiency, Cooking Energy Rate, and Production Capacity

Heavy-Load:
Test voltage (V)
Gas heating value (Btu/ft^3)
Cooking time (min)
Production rate (lb/h)
Energy to food (Btu/lb)
Energy to pans (Btu)
Cooking energy rate (Btu/h or kW)
Electric energy rate (kW, gas ovens only)
Energy per pound of food cooked (Btu/lb or kWh/lb)
Cooking energy efficiency (%)

9. Cooking Uniformity (Frozen Macaroni and Cheese)

Test voltage (V)
Gas heating value (Btu/ft^3)

Rack	Average Rack Temperature (°F)
1 (Top)	
2	
3	
4	
5 (Bottom)	

10. 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 cook time (min)
Sheet cake cooking energy (Btu or kWh)
Electric energy (kWh, gas ovens only)

11. Steam Performance (Optional, Bakery Ovens with Steam Injection)

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

X2. PROCEDURE FOR CALCULATING THE ENERGY CONSUMPTION OF A CONVECTION OVEN BASED ON REPORTED TEST RESULTS

X2.1 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 convection oven energy consumption based on data obtained from applying the appropriate test method.

X2.2 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 food cooked)

X2.3 The appropriate oven performance parameters are obtained from Section 11 in this test method.

X2.4 *Procedure*:

X2.4.1 The calculation will proceed as follows: First, determine the appliance operating time and total number of preheats. Then estimate the quantity of food. For example, an oven operating for 12 h a day with one preheat cooked 100 lb of food. Calculate the energy due to cooking, 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. Table X2.1 summarizes typical default operating assumptions for a steamer.

X2.4.2 *Step 1*—Determine the oven operating time, number of preheats, and amount of food cooked under heavy-, medium-, and light-load conditions.

X2.4.3 *Step 2*—Calculate the time and energy involved in cooking heavy (full) loads. Heavy loads are the equivalent of loading every rack in the oven with food to be cooked.

X2.4.3.1 Determine the total time cooking heavy loads as follows:

$$th = \frac{W}{PC} \quad \text{(X2.1)}$$

TABLE X2.1 Oven Operation Assumptions

Operating time	12 h
Number of preheats	1 preheat
Total amount of food cooked	100 lb

where:

t_h = total time cooking heavy-loads, h
W = total weight of food cooked per day, lb, and
PC = oven's production capacity as determined in 11.9.5, lb/h.

X2.4.3.2 Calculate the cooking energy consumption using the following set of equations. For gas ovens, determine separately any electric energy using the electric equations:

$$E_{gas,h} = q_{gas,h} \times t_h \quad \text{(X2.2)}$$

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

where:

$E_{gas,h}$ = total gas cooking energy consumption, Btu,
$q_{gas,h}$ = gas heavy-load cooking energy rate as determined in 11.9.2, Btu/h,
$E_{elec,h}$ = total electric cooking energy consumption, kWh, and
$q_{elec,h}$ = electric heavy-load cooking energy rate as determined in 11.9.2, kW.

X2.4.4 *Step 3*—Calculate the total idle time and energy consumption.

X2.4.4.1 Determine the total idle time as follows:

$$t_i = t_{on} - t_h - \frac{\eta_p \times t_p}{60} \quad \text{(X2.3)}$$

where:

t_i = total idle time, h,
t_{on} = total daily on-time, h,
η_p = number of preheats, and
t_p = preheat time, as determined in 11.6.1, min.

X2.4.4.2 Calculate the idle energy consumption using the following set of equations. For gas ovens, determine separately any electric energy using the electric equations.

$$E_{gas,i} = q_{gas,i} \times t_i \quad \text{(X2.4)}$$

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

where:

$E_{gas,i}$ = total gas idle energy consumption, Btu,
$q_{gas,i}$ = gas idle energy rate as determined in 11.7.1, Btu/h,
$E_{elec,i}$ = total electric idle energy consumption, kWh, and
$q_{elec,i}$ = electric idle energy rate as determined in 11.7.1, kW.

X2.4.5 *Step 4*—Calculate the total daily energy consumption as follows:

$$E_{gas,daily} = E_{gas,h} + E_{gas,i} + \eta_p \times E_{gas,p} \quad (X2.5)$$

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

where:

$E_{gas,daily}$ = total daily gas energy consumption, Btu/day,
η_p = total number of preheats per day,
$E_{gas,p}$ = gas preheat energy consumption as determined in 11.6.1, Btu,
$E_{elec,daily}$ = total daily electric energy consumption, kWh/day, and
$E_{elec,p}$ = electric preheat energy consumption as determined in 11.6.1, Btu.

$$E_{gas,daily} = \frac{W}{PC} \times q_{gas,h} + \left(t_{on} - \frac{W}{PC} - \frac{\eta_p \times t_p}{60} \right) \times q_{gas,i} + \eta_p \times E_{gas,p} \quad (X2.6)$$

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

X2.4.6 *Step 5*—Calculate the average electric demand for ovens in accordance with the following equation:

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}} \quad (X2.7)$$

where:

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

NOTE X2.1—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.

X2.4.7 *Step 6*—Determine the estimated monthly appliance energy cost as follows:

$$C_{gas,monthly} = r_{gas} \times \frac{E_{gas,daily}}{100\,000 \frac{\text{Btu}}{\text{therm}}} \times d_{op} \quad (X2.8)$$

$$C_{elec,monthly} = r_{elec} \times E_{elec,daily} \times d_{op} + r_{demand} \times q_{avg} \quad (X2.9)$$

where:

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

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, Tel: (978) 646-2600; http://www.copyright.com/