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Standard Test Method for Performance of Retherm Ovens¹

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1. Scope

1.1 This test method evaluates the energy consumption and cooking performance of retherm ovens. The food service operator can use this evaluation to select a retherm oven and understand its energy consumption.

1.2 This test method is applicable to gas and electric retherm ovens.

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

1.3.1 Energy input rate (10.2),

1.3.2 Preheat energy consumption and time (10.3),

1.3.3 Idle energy rate (10.4),

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

1.3.5 Cooking Energy Rate, Production Capacity, Cooking Energy Efficiency (10.7).

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

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and 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

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 the Annual Book of ASTM standards volume information, refer the standard's Document Summary page on the ASTM website.

D3588 Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels

2.2 *ASHRAE Documents:*³

ASHRAE Handbook of Refrigeration “Thermal Properties of Food,” Chapter 19, Table 3, 2014.

3. Terminology

3.1 *Definitions:*

3.1.1 *cooking energy efficiency, n*—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.

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

3.1.3 *energy input rate, n*—the peak rate at which a retherm oven consumes energy (Btu/h or kW).

3.1.4 *idle energy rate* (ready-to-cook condition), *n*—the retherm oven's rate of energy consumption (Btu/h or kW), when empty, required to maintain its cavity temperature at the specified thermostat set point or to otherwise maintain the oven in a ready-to-cook condition.

3.1.5 *oven cavity, n*—the portion of the retherm oven in which food products are heated.

3.1.6 *pilot energy rate, n*—the rate of energy consumed (Btu/h) by a retherm oven's continuous pilot (if applicable).

3.1.7 *preheat energy, n*—the amount of energy consumed (Btu or kWh), by the retherm oven while preheating its cavity from ambient temperature to the specified thermostat set point or while preheating any other component of the oven, for example an integral heat exchanger, to a ready-to-cook condition.

3.1.8 *preheat time, n*—the time (min) required for the retherm oven cavity to preheat from ambient temperature to the specified thermostat set point or for the retherm oven to achieve a ready-to-cook condition.

³ Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329.

3.1.9 *production capacity, n*—the maximum rate (lb/h or kg/h) at which a retherm oven can bring the specified food product to a specified “cooked” condition.

3.1.10 *retherm oven, n*—an appliance with a closed, heated cavity, designed specifically for low-temperature reheating.

3.1.11 *uncertainty, n*—the 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 *Thermostat Calibration*—Accuracy of the retherm oven thermostat is checked at a setting of 250°F (121°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 $\pm 5^\circ\text{F}$ (3°C).

4.2 *Energy Input Rate*—The input rate of the oven is determined to check whether the retherm oven is operating within 5 % of its nameplate energy input rate. For gas combination ovens, the pilot energy rate and the fan and control energy rates are also determined.

4.3 *Preheat Energy Consumption and Time*—The time and energy required to preheat the oven from room temperature ($75 \pm 5^\circ\text{F}$ or $24 \pm 3^\circ\text{C}$) to a ready-to-cook condition (for example, $250 \pm 5^\circ\text{F}$ or $121 \pm 3^\circ\text{C}$).

4.4 *Idle Energy Rate*—Idle energy rate is determined with the retherm oven set to maintain a ready-to-cook condition (for example, $250 \pm 5^\circ\text{F}$ or $121 \pm 3^\circ\text{C}$).

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

5. Significance and Use

5.1 *Energy Input Rate*—Energy input rate is used to confirm that the retherm oven is operating properly prior to further testing.

5.2 *Preheat Energy Consumption and Time*—Preheat energy and time can be useful to food service operators to manage power demands and to know how quickly the retherm oven can be ready for operation.

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

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

5.5 *Cooking Energy Efficiency*—This test provides a measure of the oven’s energy efficiency while heavy loads are being cooked.

6. Apparatus

6.1 *Analytical Balance Scale*, for measuring weights up to 20 lb (9.1 kg), with a resolution of 0.01 lb (4 g) and an uncertainty of 0.01 lb (4 g).

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

6.3 *Flow Meter*, for measuring total water consumption of the appliance (if applicable). The meter shall have a resolution of 0.01 gal (0.03 L), and an uncertainty of 0.01 gal (0.03 L), at flow rate as low as 0.2 gpm (0.76 L/min).

6.4 *Gas Meter*, for measuring the gas consumption of a retherm oven, shall be a positive displacement type with a resolution of at least 0.01 ft³ and a maximum uncertainty no greater than 1 % of the measured value for any demand greater than 2.2 ft³/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 ft³ and a maximum uncertainty no greater than 2 % of the measured value.

6.5 *Pressure Gauge*, for monitoring natural gas pressure. Shall have a range of zero to 10 in. H₂O, a resolution of 0.5 in. H₂O, and a maximum uncertainty of 1 % of the measured value.

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

6.7 *Temperature Sensor*, for measuring natural gas temperature in the range from 50 to 100°F (10 to 38°C), with an uncertainty of $\pm 1^\circ\text{F}$ (0.6°C).

6.8 *Thermocouple Probes*, Type K stainless steel-sheathed exposed junction with a range from -20 to 400°F (-29 to 204°C), with a resolution of 0.2°F (0.1°C), and an uncertainty of 0.5°F (0.3°C), for measuring oven cavity and food product temperatures.

NOTE 1—To facilitate monitoring food temperatures, it is recommended that only stainless-steel sheathed thermocouple probes be used.

6.9 *Watt-Hour Meter*, for measuring the electrical energy consumption of a retherm oven, shall have a resolution of 10 Wh or better 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 *Mashed Potato Packages*, for the cooking energy efficiency test, mashed potatoes shall be lightly seasoned, pre-cooked, unfrozen ($37 \pm 3^\circ\text{F}$ or $3 \pm 1^\circ\text{C}$), in sealed packages, and 4 ± 0.1 lb (1.8 ± 0.05 kg) per package. The mashed potatoes shall be stabilized in a refrigerator at $37 \pm 3^\circ\text{F}$ ($2.8 \pm 1.7^\circ\text{C}$).

7.2 *Steam Pans*, for cooking energy efficiency test, pans shall be perforated 12 by 20 by $2\frac{1}{2}$ in. (305 by 508 by 64 mm) stainless steel weighing 2.5 ± 0.5 lb (1.1 ± 0.2 kg).

7.3 *Baskets*, for cooking energy efficiency test, baskets shall be open-wired $13\frac{3}{8}$ by $25\frac{7}{8}$ by $2\frac{5}{8}$ in. (340 by 657 by 67 mm) stainless steel weighing 3.4 ± 0.3 lb (1.5 ± 0.1 kg).

8. Sampling, Test Units

8.1 *Retherm Oven*—Select one representative production model for performance testing.

9. Preparation of Apparatus

9.1 Install the retherm oven according to the manufacturer's instructions in an appropriate space. All sides of the hot food retherm cabinets shall be a minimum of 3 ft (91 cm) from any side wall, side partition, or other operating appliance and add 2 in. (51 mm) clearance from back wall or manufacture's listed requirement whichever is largest in length. The associated heating or cooling system for the space shall be capable of maintaining an ambient temperature of $75 \pm 5^\circ\text{F}$ ($24 \pm 3^\circ\text{C}$) within the testing environment.

9.2 Connect the retherm 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 retherm 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 $\pm 2.5\%$ of the manufacturer's nameplate voltage.

9.3 For an electric retherm oven, confirm (while the retherm oven's heating elements are energized) that the supply voltage is within $\pm 2.5\%$ of the manufacturer's nameplate voltage.

Record the test voltage for each test.

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

9.4 For a gas retherm oven, adjust (during maximum energy input) the gas supply pressure downstream from the appliance's pressure regulator to within $\pm 2.5\%$ of the operating manifold pressure specified by the manufacturer. Make adjustments to the appliance following the manufacturer's recommendations for optimizing combustion.

9.5 If the retherm oven has manually controlled vents, then adjust the vents to remain 100 % open during all tests.

10. Procedure

10.1 General:

10.1.1 For gas appliances, record the following for each test run: 1) Higher heating value, 2) Standard gas pressure and temperature used to correct measured gas volume to standard conditions, 3) Measured gas temperature, 4) Measured gas pressure, 5) Barometric pressure, and 6) Energy input rate during or immediately prior to test (for example, during the preheat for that days testing).

NOTE 3—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 retherm oven under test. It is recommended that all testing be performed with gas having a higher

heating value of 1000 to 1075 Btu/ft³.

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

10.1.3 For electric retherm ovens, record the following for each test run: 1) Voltage while elements are energized, and 2) Energy input rate during or immediately prior to test (for example, during the preheat for that days testing).

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 retherm oven.

10.2 Energy Input Rate and Thermostat Calibration:

10.2.1 Install a thermocouple at the geometric center (top to bottom, side to side, and front to back) of the retherm oven cooking cavity.

10.2.2 Set the temperature control to 250°F (121°C) and turn the retherm oven on. Record the time and energy consumption from the time when the unit is turned on until the time when any of the burners or elements first cycle off.

10.2.3 Calculate and record the retherm oven's energy input rate and compare the result to the rated nameplate input. For gas appliances, 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 retherm oven to idle for 60 min after the burners or elements commence cycling at the thermostat set point.

10.2.5 After the 60-min idle period, start monitoring the oven cavity temperature, and record the average temperature over a 15-min period. If this recorded temperature is $250 \pm 5^\circ\text{F}$ ($121 \pm 3^\circ\text{C}$), then the retherm oven's thermostat is calibrated.

10.2.6 If the average temperature is not $250 \pm 5^\circ\text{F}$ ($121 \pm 3^\circ\text{C}$), adjust the temperature control following the manufacturer's instructions and repeat 10.2.5 until it is within this range. Record the corrections made to the controls during calibration.

10.2.7 In accordance with 11.4, calculate and report the retherm oven energy input rate, fan/control energy rate where applicable, and rated nameplate input.

10.3 Preheat Energy Consumption and Time:

10.3.1 Verify that the retherm oven cavity temperature is $75 \pm 5^\circ\text{F}$ ($24 \pm 3^\circ\text{C}$). Set the calibrated temperature control to 250°F (121°C) and turn the oven on.

10.3.2 Record the time, temperature, and energy consumption required to preheat the retherm oven, from the time when the unit is turned on until the time when the oven cavity reaches a temperature of $250 \pm 5^\circ\text{F}$ ($121 \pm 3^\circ\text{C}$).

10.3.3 In accordance with 11.5, calculate and report the preheat energy consumption and time, and generate a preheat temperature versus time graph.

10.4 Idle Energy Rate:

10.4.1 Turn the retherm oven on and allow it to achieve a ready-to-cook state. Allow the oven to idle for 60 min after it is fully preheated.

10.4.2 After the 60 min stabilization period, the run idle energy rate test shall be run for a minimum of 3 h and include a minimum of ten complete thermal cycles or heater cycles. After the test period (either 3 h or 10 thermal/heater cycles, whichever is longer), end the test. If the test unit does not exhibit clear thermal cycles, then the test shall be run for 3 h. Record data in 5 s intervals.

NOTE 4—Models with proportional controls may not exhibit distinct heater cycles. The intent of the test is to accurately represent the average energy consumption of the retherm oven, while minimizing any error that may be introduced as a result of capturing partial thermal cycles.

10.4.3 In accordance with 11.6, calculate and report the retherm oven’s idle energy rate.

10.5 Pilot Energy Rate:

10.5.1 For a gas retherm oven with a standing pilot, set the gas valve at the “pilot” position and set the retherm oven’s temperature control to the “off” position.

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

10.5.3 Monitor gas consumption for a minimum of 3 h of pilot operation.

10.5.4 In accordance with 11.7, calculate and report the pilot energy rate.

10.6 Test Product Preparation:

10.6.1 Determine the roasting capacity of the retherm oven by measuring the internal height and depth of the oven cavity. Place the oven racks between 6 to 7 in. (15 to 18 cm) apart, starting from the bottom rack position, and leaving a minimum of 6 in. (15 cm) from the top rack to the cavity ceiling. Count the number of racks. Each rack will hold a two packages of mashed potatoes for every 13 in. (33 cm) of rack depth. For example, an oven with an internal cavity height of 25 in. (64 cm), and a rack depth of 15 in. (38 cm) will have a load size of six packages.

10.6.2 Remove the mashed potatoes from the refrigerator. While keeping the outside packaging, weigh the packages. Note the weight of the individual packages. Each package shall be 4.1 ± 0.1 lb (1.9 ± 0.05 kg).

10.6.3 The total load weight shall be the number of mashed potato packages times 4.1 lb (1.9 kg) and the tolerance of the total load weight shall reference Table 1. For example, a retherm oven with five full-size racks can accommodate ten total packages. The total test weight for the example oven is $10 \times 4.1 \pm 0.1$ lb (10×1.9 kg), or 41.0 ± 1.0 lb (19 ± 0.5 kg). For total load weight of <41 lb (<19 kg), the tolerance shall be ± 1.0 lb (0.5 kg), the tolerance shall increase by an additional ± 1.0 lb (0.5) for every additional 41 lb (19 kg). Refer to Table 1.

10.6.4 The packages shall have an average load weight of 4.1 ± 0.1 lb (1.9 ± 0.05 kg). If the total weight is greater than the number of packages, $n \times 4.1 \pm 0.1$ lb (1.9 ± 0.05 kg), then substitute heaviest packages for smaller packages to bring the weight to within the tolerance specified in Table 1. If the total weight is less than the number of packages, $n \times 4.1 \pm 0.1$ lb (1.9 ± 0.05 kg), then substitute the smallest packages for larger packages until the total load weight is within the tolerance specified in Table 1. For basket loading, refer to Table 2.

10.6.5 There should be one monitored package per shelf. For hotel pan loading, alternate placement of monitored package front to back. For basket loading, rotate placement of monitored package front to back and right to left in counter-clockwise direction. Refer to Fig. 1. Place thermocouple probes into the geometric center of each package to facilitate monitoring of internal package temperatures. For basket loading, place a thermocouple into only one package per basket. This shall be done by taking a frozen package, drilling a small hole in the center of a face, and inserting a thermocouple probe into the drilled hole. The probe shall be secured on the package using heat-resistant tape, and by flipping the bag upside-down. Refer to Fig. 2.

10.6.6 Place each package into individual hotel pans or baskets and cover with plastic wrap. For basket, place two packages in each basket. Return the packages to the refrigerator until they stabilize at $37 \pm 3^\circ\text{F}$ ($3 \pm 2^\circ\text{C}$).

10.6.7 Monitor the internal temperature of each package with a thermocouple probe. Its internal temperature must be $37 \pm 3^\circ\text{F}$ ($3 \pm 2^\circ\text{C}$) before the package can be removed from the refrigerator and loaded into the retherm oven. If necessary, adjust the refrigerator temperature to achieve this required internal temperature.

10.7 Cooking Energy Rate, Production Capacity, and Cooking Energy Efficiency:

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

10.7.2 Fill water pan if required by manufacture’s recommendations. Turn the retherm oven on and allow it to achieve a ready-to-cook state and reach a temperature of 250°F (121°C). Allow the oven to idle for a minimum of 60 min after it is fully preheated.

10.7.3 Remove the packages from the refrigerator. Open the door(s) of the retherm oven and commence loading the

TABLE 1 Oven Retherm Capacity and Cooking Test Load Weight for Hotel Pan Loading

Retherming Capacity	Cooking Test Weight
5 racks	41.0 ± 1.0 lb
8 racks	65.6 ± 2.0 lb
10 racks	82.0 ± 2.0 lb
12 racks	98.4 ± 3.0 lb
16 racks	131 ± 3.0 lb
18 racks	147.6 ± 4.0 lb

TABLE 2 Oven Retherm Capacity and Cooking Test Load Weight for Basket Loading

Retherming Capacity	Cooking Test Weight
5 racks	82.0 ± 2.0 lb
8 racks	122 ± 3.0 lb
10 racks	164.0 ± 4.0 lb
12 racks	196.8 ± 4.0 lb
16 racks	262 ± 5.0 lb
18 racks	295.2 ± 5.0 lb

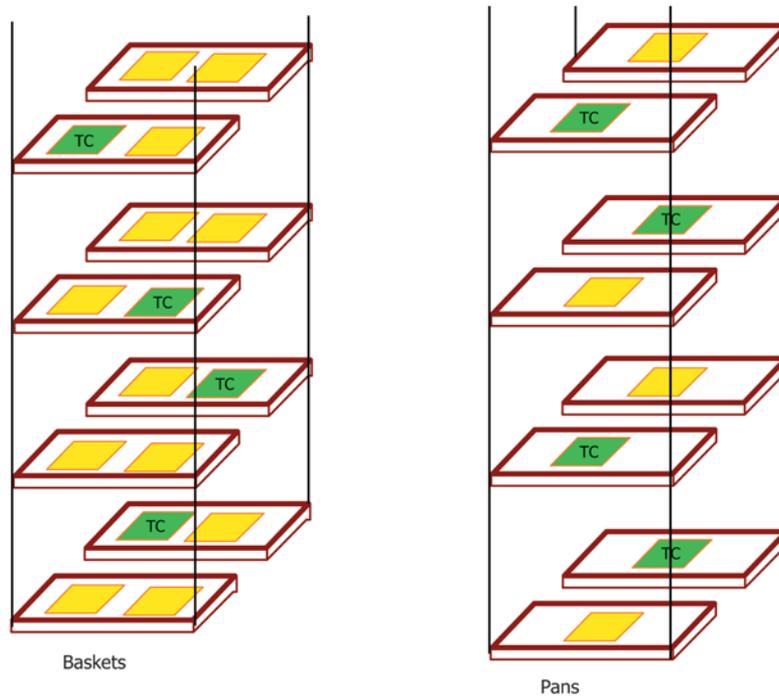


FIG. 1 Placement Pattern of Monitored Package per Shelf

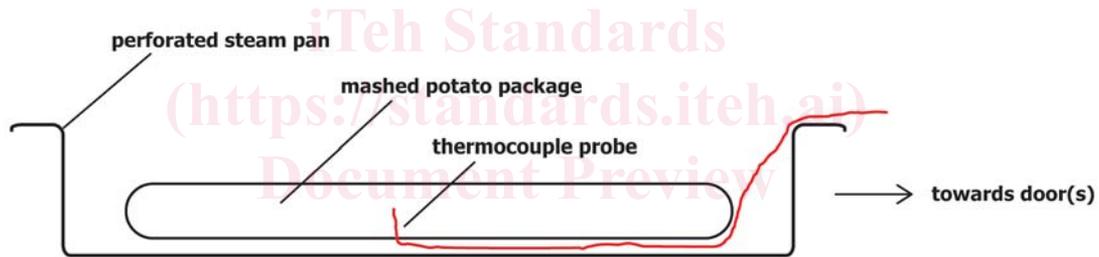


FIG. 2 Diagram of Package of Mashed Potatoes in Hotel Pan with Installed Thermocouple

packages into the oven, starting from the bottom and proceeding to the top. Allow 7 s for each pan/basket (for example, a heavy load of 12 packages \times 7 s = 84 s maximum loading time). The initial average temperature of the packages (all packages together) when the test is started (the retherm oven door is closed) shall be $37 \pm 3^\circ\text{F}$ ($3 \pm 2^\circ\text{C}$). Keep the door(s) open for the maximum load time, even if the loading is accomplished in less time. If the retherm oven has more than one cavity door (in other words, a top door and a bottom door), fully open all doors at the start of loading.

10.7.4 Shut the door(s) and start the oven cooking cycle to begin the test. Start monitoring time, temperature, energy consumption, and water consumption (if applicable).

10.7.5 When the average temperature of the mashed potato packages reaches 140°F (60°C), note the total elapsed time and even energy (and water, if applicable) consumption.

10.7.6 Remove the packages from the oven and close the oven door(s). Remove the thermocouples from the packages, and immediately weigh them. Allow 30 s per package for weighing once removed from oven.

10.7.7 Record the final package temperature, the total test time, the cooked weight of the packages, and the energy (and water, if applicable) consumed by the retherm oven during the test.

10.7.8 Perform runs No. 2 and No. 3 by repeating 10.7.2 – 10.7.7.

Follow the procedure in Annex A1 to determine whether more than three test runs are required.

10.7.9 In accordance with 11.8, calculate and report the cooking energy rate, cooking energy efficiency, electric energy rate (if applicable for gas retherm ovens), production capacity, and water consumption (if applicable).

11. Calculation and Report

11.1 *Test Retherm Oven*—Summarize the physical and operating characteristics of the retherm oven. If needed, describe other design or operating characteristics that may facilitate interpretation of the test results.

11.2 *Apparatus and Procedure:*

11.2.1 Confirm that the testing apparatus conformed to all of the specifications in Section 6. Describe any deviations from those specifications.

11.2.2 For electric retherm ovens, report the voltage for each test.

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

11.3 Gas Energy Calculations:

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

11.3.2 Calculate the energy consumed based on:

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

where:

E_{gas} = energy consumed by the appliance, Btu,
 HV = higher heating value,
 = volumetric energy content of gas measured at standard conditions, Btu/ft³,
 V = actual volume of gas corrected for temperature and pressure at standard conditions, ft³, and
 = $V_{meas} \times T_{cf} \times P_{cf}$

where:

V_{meas} = measured volume of gas, ft³,
 T_{cf} = temperature correction factor,
 = $\frac{\text{absolute standard gas temperature}^{\circ}\text{R}}{\text{absolute actual gas temperature}^{\circ}\text{R}}$,
 = $\frac{\text{absolute standard gas temperature}^{\circ}\text{R}}{\text{gas temp}^{\circ}\text{F} + 459.67^{\circ}\text{R}}$,

P_{cf} = pressure correction factor,

= $\frac{\text{absolute actual gas pressure psia}}{\text{absolute standard pressure psia}}$, and
 = $\frac{\text{gas gauge pressure psig} + \text{barometric pressure psia}}{\text{absolute standard pressure psia}}$.

NOTE 5—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 (“Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels”) are 14.696 psia (101.33 kPa) and 60°F (519.67°R, (288.71°K)) for pressure and temperature, respectively.

11.4 Energy Input Rate:

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

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

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

where:

q_{input} = measured peak energy input rate, Btu/h or kW,

E = energy consumed during period of peak energy input, Btu or kWh, and

t = period of peak energy input, min.

11.5 Preheat Energy and Time—Report the preheat energy consumption (Btu or kWh) and preheat time (min).

11.6 Idle Energy Rate—Calculate and report the idle energy rate (Btu/h or kW) based on:

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

where:

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

11.7 Pilot Energy Rate—Calculate and report the pilot energy rate (Btu/h) based on:

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

where:

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

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

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

$$q_{cook} = \frac{E \times 60}{t} \quad (5)$$

where:

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

NOTE 6—The cooking test period includes the actual cooking time and recovery time. For gas retherm ovens, report separately a gas cooking energy rate and an electric cooking energy rate.

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

$$E_{per\ pound} = \frac{E_{appliance}}{W} \quad (6)$$

where:

$E_{per\ pound}$ = energy per pound, Btu/lb or kWh/lb,
 $E_{appliance}$ = energy consumed during the cooking test, Btu or kWh, and
 W = total initial weight of the packages, lb or kg.

11.8.3 Calculate and report the cooking-energy efficiency for heavy-load cooking tests based on:

$$\eta_{potato} = \frac{E_{potato} + E_{pan/basket}}{E_{oven}} \quad (7)$$

where:

η_{cook} = cooking-energy efficiency, %,

E_{potato} = energy into food, Btu, and

$$E_{potato} = E_{sens} + E_{vap}$$

where:

E_{sens} = quantity of the heat added to the packages, which causes its temperature to increase from the starting temperature to the average bulk temperature of a done load of mashed potatoes (that is, $140 \pm 5^\circ\text{F}$), Btu (Wh), and
 $= (W_i) (C_p) (T_f - T_i)$.

where:

W_i = initial weight of the packages, lb (kg),
 C_p = specific heat of mashed potatoes, Btu/lb $^\circ\text{F}$ (kJ/kg $^\circ\text{K}$), and
 $= 0.89$.

NOTE 7—For this analysis, the specific heat of a load of mashed potatoes is considered to be the weighted average of the specific heat of its components (for example, water, potatoes, seasoning, and so forth). Research conducted by SCE determined that the weighted average of the specific heat for mashed potatoes in accordance with this test was approximately 0.899 Btu/lb $^\circ\text{F}$.

T_f = final internal temperature of the cooked mashed potatoes, $^\circ\text{F}$ ($^\circ\text{C}$),

T_i = initial temperature of the mashed potatoes, $^\circ\text{F}$ ($^\circ\text{C}$),

E_{vap} = latent heat (of vaporization) added to the mashed potatoes, which causes some of the moisture contained in it 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 from a done load of mashed potatoes, and
 $= W_{loss} \times H_v$.

where:

W_{loss} = weight loss of water during cooking, lb (kg), and
 $= W_{w,i} - W_{w,f}$

where:

$W_{w,i}$ = initial weight of the water in the mashed potatoes, lb (kg),

$W_{w,f}$ = final weight of the water in the cooked mashed potatoes, lb (kg),

H_v = heat of vaporization, Btu/lb (kWh/kg),
 $= 970$ Btu/lb at 212°F ,

W_{pan} = weight of sheet pan(s) used in cooking-energy efficiency test, lb,

Cp_{pan} = specific heat of stainless steel, Btu/lb $^\circ\text{F}$,
 $= 0.11$ Btu/lb $^\circ\text{F}$ (see 2.4),

W_{basket} = weight of basket(s) used in cooking-energy efficiency test, lb,

Cp_{basket} = specific heat of stainless steel, Btu/lb $^\circ\text{F}$,
 $= 0.11$ Btu/lb $^\circ\text{F}$ (see 2.4),

ΔT_{pan} = useful temperature rise in basket(s), $^\circ\text{F}$, defined as the temperature rise of the potatoes,

$$= T_{f,potato} - T_{i,potato}, \text{ and}$$

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 or controls, or both).

11.8.4 Calculate the production capacity, lb/h (kg/h) based on:

$$PC = \frac{w \times 60}{t} \quad (8)$$

where:

PC = production capacity of the retherm oven, lb/h (kg/h),

W = total weight of food cooked during heavy-load cooking test, lb (kg), and

t = total time of heavy-load cooking test, (min).

11.8.5 Report the cook time for the heavy-load tests.

12. Precision and Bias

12.1 *Precision:*

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

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

12.1.1.2 The repeatability of each reported parameter is being determined.

12.1.2 *Reproducibility* (multiple laboratories)—The inter-laboratory precision of the procedure in this test method for measuring each reported parameter is being determined.

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

13. Keywords

13.1 retherm oven; throughput