Designation: F3216 – 16

# Standard Test Method for Performance of Retherm Ovens[1]

This standard is issued under the fixed designation F3216; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method evaluates the energy consumption and cooking performance of 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 test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all of the potential safety problems associated with its use. It is the responsibility of the users of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to its use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

2.2 *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.

3.1.9 *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

[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 Oct. 1, 2016. Published December 2016. DOI: 10.1520/F3216-16.

[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.

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

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 (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 ± 5°F or 24 ± 3°C) to a ready-to-cook condition (for example, 250 ± 5°F or 121 ± 3°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 ± 5°F or 121 ± 3°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 $ft^3$ and a maximum uncertainty no greater than 1 % of the measured value for any demand greater than 2.2 $ft^3$/h. If the meter is used for measuring the gas consumed by the pilot lights, it shall have a resolution of at least 0.01 $ft^3$ and a maximum uncertainty no greater than 2 % of the measured value.

6.5 *Pressure Gauge,* for monitoring natural gas pressure. Shall have a range of zero to 10 in. $H_2O$, a resolution of 0.5 in. $H_2O$, 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 ±1°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, precooked, unfrozen (37 ± 3°F or 3 ± 1°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 ± 3°F (2.8 ± 1.7°C).

7.2 *Steam Pans,* for cooking energy efficiency test, pans shall be perforated 12 by 20 by 2½ 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 13⅜ by 25⅞ by 2⅝ 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 ± 5°F (24 ± 3°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 ±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 ±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 ±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/ft$^3$.

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 ± 5°F (121 ± 3°C), then the retherm oven's thermostat is calibrated.

10.2.6 If the average temperature is not 250 ± 5°F (121 ± 3°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 ± 5°F (24 ± 3°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 ± 5°F (121 ± 3°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 × 4.1 ± 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 × 4.1 ± 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 × 4.1 ± 0.1lb (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 counterclockwise 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.

**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 |

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 ± 3°F (3 ± 2°C).

10.6.7 Monitor the internal temperature of each package with a thermocouple probe. Its internal temperature must be 37 ± 3°F (3 ± 2°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 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 × 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 ± 3°F (3 ± 2°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.

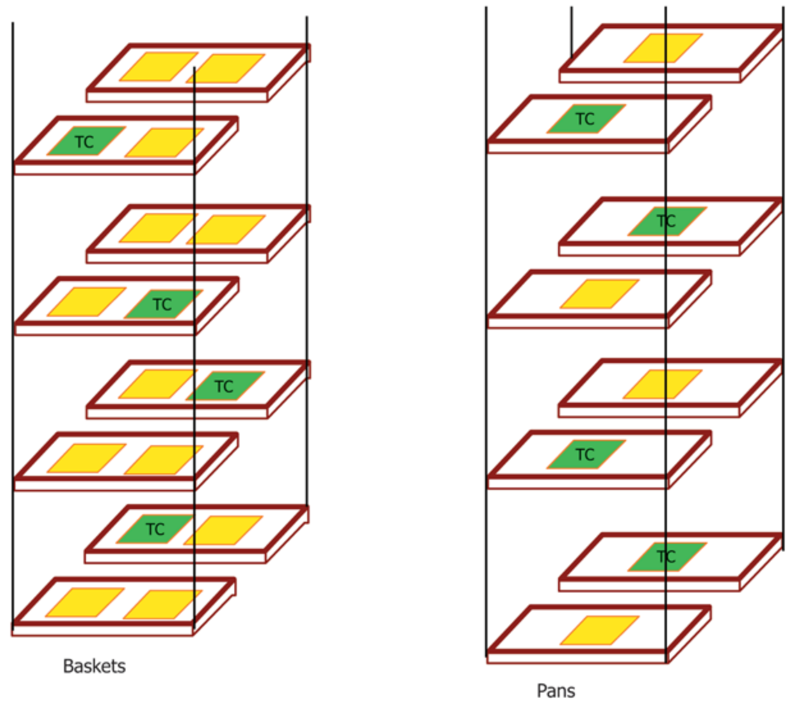


FIG. 1 Placement Pattern of Monitored Package per Shelf

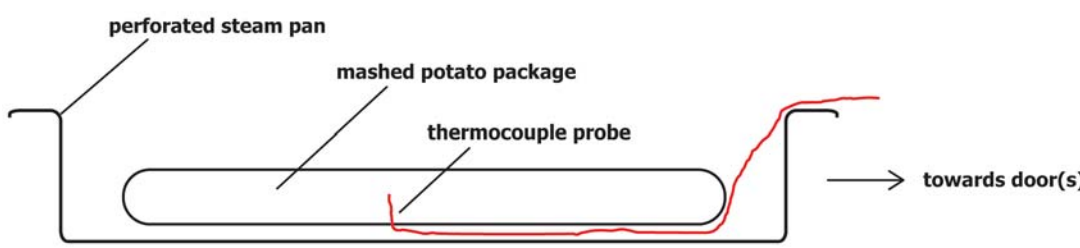


FIG. 2 Diagram of Package of Mashed Potatoes in Hotel Pan with Installed Thermocouple

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/ft$^3$,
$V$ = actual volume of gas corrected for temperature and pressure at standard conditions, ft$^3$, and
= $V_{meas} \times T_{cf} \times P_{cf}$.

where:

$V_{meas}$ = measured volume of gas, ft$^3$,
$T_{cf}$ = temperature correction factor,

$$= \frac{absolute\ standard\ gas\ temperature°\text{R}}{absolute\ actual\ gas\ temperature°\text{R}},$$

$$= \frac{absolute\ standard\ gas\ temperature°\text{R}}{gas\ temp°\text{F} + 459.67°\text{R}},$$

$P_{cf}$ = pressure correction factor,

$$= \frac{absolute\ actual\ gas\ pressure\ \text{psia}}{absolute\ standard\ pressure\ \text{psia}}, \text{ and}$$

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

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 overns, 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:

$\eta_{cook}$ = 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 ± 5°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°F (kJ/kg°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°F.

$T_f$ = final internal temperature of the cooked mashed potatoes, °F (°C),
$T_i$ = initial temperature of the mashed potatoes, °F (°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 (kh), 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°F,
= 0.11 Btu/lb°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°F,
= 0.11 Btu/lb°F (see 2.4),
$\Delta T_{pan}$ = useful temperature rise in basket(s), °F, defined as the temperature rise of the potatoes,
= $Tf_{\text{potato}} - Ti_{\text{potato}}$, 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 ±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 interlaboratory precision of the procedure in this test method for measuring each reported parameter is being determined.

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

## 13. Keywords

13.1 retherm oven; throughput

# ANNEX

### (Mandatory Information)

## A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

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

A1.1 For the Cooking Efficiency and Production Capacity procedures, results are reported for the cooking efficiency ($E_{eff}$) and the production capacity (*PC*). For the Barreling Energy Performance procedure, the total reduction in the cooking energy rate from the first barreling test run to the sixth is reported (qtotal rate reduction). 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 cooking energy efficiency test (heavy load test), the uncertainty of $E_{eff}$ must be no greater than ±10 % before $E_{eff}$ for that test can be reported and the uncertainty of *PC* must also be no greater than ±10 % before *PC* for that test can be reported.

A1.2 The uncertainty in a reported result is a measure of its precision. If, for example, the $E_{eff}$ is 40 %, the uncertainty must not be larger than ±4 %. This means that the true $E_{eff}$ is within the interval between 36 and 44 %. This interval is determined at the 95 % confidence level, which means that there is only a 1 in 20 chance that the true $E_{eff}$ 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 needed to satisfy this requirement. The uncertainty is calculated from the standard deviation of three or more test results and a factor from Table A1.1, which 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 example of applying this procedure

A1.4.1 *Step 1*—Calculate the average and the standard deviation for the $E_{eff}$ and *PC*, 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.

The formula for the average (three test runs) is:

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

where:

$Xa_3$ = average of results for $E_{eff}$, *PC*, and
$X_1, X_2, X_3$ = results for $E_{eff}$, *PC*.

The formula for the sample standard deviation (three test runs) is:

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

where:

$S_3$ = standard deviation of results for $E_{eff}$, *PC*,
$A_3$ = $(X_1)^2 + (X_2)^2 + (X_3)^2$, 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 A1.1.

The formula for the absolute uncertainty (three test runs) is:

$$U_3 = C_3 \times S_3$$
$$U_3 = 2.48 \times S_3$$

where:

$U_3$ = absolute uncertainty in average for $E_{eff}$, *PC*, and
$C_3$ = uncertainty factor for three test runs (Table A1.1),

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

The formula for the percent uncertainty (three test runs) is:

$$\% \ U_3 = (U_3 / Xa_3) \times 100 \ \%$$

where:

$\% \ U_3$ = percent uncertainty in average for $E_{eff}$, *PC*,
$U_3$ = absolute uncertainty in average for $E_{eff}$, *PC*, and
$Xa_3$ = average $E_{eff}$, *PC*.

A1.4.4 *Step 4*—If the percent uncertainty, % $U_3$, is not greater than ±10 % for $E_{eff}$, *PC*, then report the average for $E_{eff}$, *PC*, 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 $E_{eff}$, *PC*, then proceed to Step 5.

A1.4.5 *Step 5*—Run a fourth test for each $E_{eff}$, *PC*, which resulted in the percent uncertainty being greater than ±10 %.

A1.4.6 *Step 6*—When a fourth test is run for a given $E_{eff}$, calculate the average and standard deviation for $E_{eff}$ and *PC* using a calculator or the following formulas:

The formula for the average (four test runs) is:

$$Xa_4 = (1/4) \times (X_1 + X_2 + X_3 + X_4)$$

where:

$Xa_4$ = average of results for $E_{eff}$, *PC*, and
$X_1, X_2, X_3, X_4$ = results for $E_{eff}$, *PC*.

The formula for the standard deviation (four test runs) is:

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

where:

$S_4$ = standard deviation of results for $E_{eff}$, *PC*, (four test runs),
$A_4$ = $(X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$, and
$B_4$ = $(1/4) \times (X_1 + X_2 + X_3 + X_4)^2$.

A1.4.7 *Step 7*—Calculate the absolute uncertainty in the average for each parameter listed in Step 1. Multiply the standard deviation calculated in Step 6 by the Uncertainty Factor for four test results from Table A1.1.

The formula for the absolute uncertainty (four test runs) is:

$$U_4 = C_4 \times S_4$$
$$U_4 = 1.59 \times S_4$$

where:

$U_4$ = absolute uncertainty in average for $E_{eff}$, *PC*, and
$C_4$ = the uncertainty factor for four test runs (Table A1.1).

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

**TABLE A1.1**

| 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 |

The formula for the percent uncertainty (four test runs) is:

$$\% \ U_4 = (U_4 / Xa_4) \times 100 \ \%$$

where:

$\% \ U_4$ = percent uncertainty in average for $E_{eff}$, *PC*,
$U_4$ = absolute uncertainty in average for $E_{eff}$, *PC*, and
$Xa_4$ = average $E_{eff}$, *PC*.

A1.4.9 *Step 9*—If the percent uncertainty, % $U_4$, is no greater than ±10 % for $E_{eff}$, *PC*, then report the average for $E_{eff}$, *PC*, 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 $E_{eff}$, *PC*, or proceed to Step 10.

A1.4.10 *Step 10*—The step 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.

The formula for the average (*n* test runs) is:

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

where:

$n$ = number of test runs,
$Xa_n$ = average of results for $E_{eff}$, *PC*, and
$X_1, X_2, X_3, X_4, ..., X_n$ = results for $E_{eff}$, *PC*.

The formula for the standard deviation (*n* test runs) is:

$$S_n = (1/\sqrt{(n-1)}) \times (\sqrt{(A_n - B_n)})$$

where:

$S_n$ = standard deviation of results for $E_{eff}$, *PC*, (*n* test runs)
$A_n$ = $(x_1)^2 + (x_2)^2 + (x_3)^2 + (x_4)^2 + ... + (x_n)^2$ and
$B_n$ = $(1/n) \times (X_1 + X_2 + X_3 + X_4 + ... + X_n)^2$

The formula for the absolute uncertainty (*n* test runs) is:

$$U_n = C_n \times S_n$$

where:

$U_n$ = absolute uncertainty in average for $E_{eff}$, *PC*, and
$C_n$ = uncertainty factor for *n* test runs (Table A1.1).

The formula for the percent uncertainty (*n* test runs) is:

$$\% \ U_n = (U_n / Xa_n) \times 100 \ \%$$

where:

$\% \ U_n$ = percent uncertainty in average for $E_{eff}$, *PC*.

When the specified uncertainty, % Un, is less than or equal to ±10 %; report the average for $E_{eff}$, *PC*, along with their corresponding absolute uncertainty, $U_n$ in the following format:

$$Xa_n \pm U_n$$

## A1.5 Example of Determining Uncertainty in Average Test Result

A1.5.1 Three test runs for the cooking energy efficiency test yielded the following $E_{eff}$ results:

| Test | $E_{eff}$ |
|---|---|
| Run #1 | 33.8 % |
| Run #2 | 31.3 % |
| Run #3 | 30.5 % |

A1.5.2 *Step 1*—Calculate the average and standard deviation of the three test results for the $E_{eff}$.The average of the three test results:

$Xa_3$ = $(1/3) \times (X_1 + X_2 + X_3)$
$Xa_3$ = $(1/3) \times (33.8 + 31.3 + 30.5)$
$Xa_3$ = 31.9 %

The standard deviation of the three test results:
First calculate "$A_3$" and "$B_3$":

$A_3$ = $(X_1)^2 + (X_2)^2 + (X_3)^2$
$A_3$ = $(33.8)^2 + (31.3)^2 + (30.5)^2$
$A_3$ = 3,052
$B_3$ = $(1/3) \times [(X1 + X2 + X3)^2]$
$B_3$ = $(1/3) \times [(33.8 + 31.3 + 30.5)^2]$
$B_3$ = 3,046

The new standard deviation for the $E_{eff}$ is:

$S_3$ = $(1/\sqrt{2}) \times \sqrt{(3052 - 3046)}$
$S_3$ = 1.73 %

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

$U_3$ = $2.48 \times S_3$
$U_3$ = $2.48 \times 1.73$
$U_3$ = 4.29 %

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

$\% \ U_3$ = $(U_3/Xa_3) \times 100$ %
$\% \ U_3$ = $(4.29/31.9) \times 100$ %
$\% \ U_3$ = 13.5 %.

A1.5.5 *Step 4*—Run a fourth test. Since the percent uncertainty for the $E_{eff}$ is greater than ±10 %, the precision requirement has not been satisfied. An additional test is run in an attempt to reduce the uncertainty. The $E_{eff}$ from the fourth test run was 31.8 %.

A1.5.6 *Step 5*—Recalculate the average and standard deviation for the $E_{eff}$ using the fourth test result:

The new average $E_{eff}$ is:

$Xa_4$ = $(1/4) \times (X_1 + X_2 + X_3 + X_4)$
$Xa_4$ = $(1/4) \times (33.8 + 31.3 + 30.5 + 31.8)$
$Xa_4$ = 31.9 %

The new standard deviation:
First calculate "$A_4$" and "$B_4$".

$$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$$
$$A_4 = (33.8)^2 + (31.3)^2 + (30.5)^2 + (31.8)$$
$$A_4 = 4064$$

$B_4$ = $(1/4) \times [(X_1 + X_2 + X_3 + X_4)^2]$
$B_4$ = $(1/4) \times [(33.8 + 31.3 + 30.5 + 31.8)^2]$

$$B_4 = 4058$$

The new standard deviation for the $E_{eff}$ is:

$S_4$ = $(1/\sqrt{3}) \times \sqrt{(4\,064 - 4\,058)}$

$$S_4 = 1.41\%$$

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

$U_4 = 1.59 \times S_4$
$U_4 = 1.59 \times 1.41$
$U_4 = 2.24\ \%$

A1.5.8 *Step 7*—Recalculate the percent uncertainty.

$\%\ U_4 = (U_4/Xa_4) \times 100\ \%$
$\%\ U_4 = (2.24/31.9) \times 100\ \%$
$\%\ U_4 = 7\ \%$

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

$$E_{eff}: 31.9 \pm 2.24\ \%$$

The *PC* and its absolute uncertainty can be calculated and reported following the same steps, assuming the ±10 % precision requirement has been met for the corresponding $E_{eff}$.

## APPENDIX

**(Nonmandatory Information)**

### X1. Results Reporting Sheets

Manufacturer ____________________
Model ____________________
Serial # ____________________
Date ____________________
Test Reference Number (optional) ____________________

*Section 11.1 Test Oven*
Description of operational characteristics:
________________________________________
________________________________________
________________________________________
________________________________________

*Physical Dimensions*
Size of retherm oven : __________ Hx __________ Wx __________ D inches
Size of retherm oven cavity : __________ Hx __________ Wx __________ D inches

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

Deviations:
________________________________________
________________________________________
________________________________________

*Section 11.4 Energy Input Rate*
Test Voltage (V) ____________________
Gas Heating Value (Btu/ft$^3$) ____________________
Rated (Btu/h or kW) ____________________
Measured (Btu/h or kW) ____________________
Percent Difference Between Measured and Rated (%) ____________________
Fan / Control Energy Rate (kW, gas ovens only) ____________________

*Section 11.5 Preheat Energy and Time*
Test Voltage (V) ____________________
Gas Heating Value (Btu/ft$^3$) ____________________
Energy Consumption (Btu or kWh) ____________________
Time ____________________

*Section 11.6 Idle Energy Rate*
Test Voltage (V) ____________________
Gas Heating Value (Btu/ft$^3$) ____________________
Idle Energy Rate (Btu/h or kW) ____________________

*Section 11.7 Pilot Energy Rate*
Gas Heating Value (Btu/ft$^3$) ____________________
Pilot Energy Rate (Btu/h) ____________________

*Section 11.8 Cooking Energy Rate, Production Capacity, and Cooking Energy Efficiency*
Test Voltage (V) ____________________
Gas Heating Value (Btu/ft$^3$) ____________________
Test Voltage (V) ____________________
Gas Heating Value (Btu/ft$^3$) ____________________
Cooking Time (min)

| | |
|---|---|
| Production Capacity (lb/h) | ____________ |
| Energy to Food (Btu/lb) | ____________ |
| Energy to Pans/ Baskets (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 (%) | ____________ |
| Water Consumption, if Applicable (gal) | ____________ |