Standard Test Method for Performance of Cook-and-Hold Ovens[1]

This standard is issued under the fixed designation F3051; 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 cook-and-hold ovens. The food service operator can use this evaluation to select a cook-and-hold oven and understand its energy consumption.

1.2 This test method is applicable to gas and electric cook-and-hold ovens.

1.3 The cook-and-hold 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).

1.3.5 Cooking energy rate, and production capacity (10.7).

1.3.6 Holding energy rate, energy utilization factor, and product yield (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 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

2.2 *ASHRAE Documents:*[3]

ASHRAE Handbook of Fundamentals, "Thermal and Related Properties of Food and Food Materials," Chapter 30, Table 1, 1989

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

3. Terminology

3.1 *Definitions:*

3.1.1 *cook-and-hold oven, n*—an appliance with a closed heated cavity designed specifically for low-temperature cooking, followed by a holding period at a specified temperature.

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

3.1.3 *energy input rate, n*—peak rate at which a cook-and-hold oven consumes energy (Btu/h or kW).

3.1.4 *energy utilization factor, n*—the ratio of the energy consumed per pound yield (Wh/lbs) of food product during the cook-and-hold test.

3.1.5 *holding energy rate, n*—the rate of energy consumed (Btu/h or kW) by the cook-and-hold oven while maintaining the temperature of the cooked food product for a specified period.

3.1.6 *idle energy rate* (ready-to-cook condition), *n*—the cook-and-hold 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.

3.1.7 *oven cavity, n*—that portion of the cook-and-hold oven in which food products are heated or cooked.

3.1.8 *pilot energy rate, n*—rate of energy consumed (Btu/h) by a cook-and-hold oven's continuous pilot (if applicable).

3.1.9 *preheat energy, n*—amount of energy consumed (Btu or kWh), by the cook-and-hold oven while preheating its cavity from ambient temperature to the specified thermostat set point

[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 Jan. 1, 2014. Published September 2014. DOI: 10.1520/F3051-14.

[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, http://www.ashrae.org.

or while preheating any other component of the oven, for example an integral heat exchanger, to a ready-to-cook condition.

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

3.1.11 *production capacity, n*—maximum rate (lb/h) at which a cook-and-hold oven can bring the specified food product to a specified "cooked" condition.

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

4. Summary of Test Method

4.1 Accuracy of the cook-and-hold oven thermostat is checked at a setting of 225°F. 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.

4.2 Energy input rate is determined to confirm that the cook-and-hold oven is operating within 5 % of the nameplate energy input rate. For gas combination ovens, the pilot energy rate and the fan and control energy rates are also determined.

4.3 The time and energy required to preheat the oven from room temperature (75 ± 5°F) to a ready-to-cook condition (for example, 225 ± 5°F).

4.4 Idle energy rate is determined with the cook-and-hold oven set to maintain a ready-to-cook condition (for example, 225 ± 5°F).

4.5 Cooking energy rate and production capacity are determined during heavy-load conditions using beef round roasts.

4.6 Holding energy rate, energy utilization factor, and average product yield are determined immediately following the cooking cycle.

5. Significance and Use

5.1 The energy input rate test is used to confirm that the cook-and-hold oven is operating properly prior to further testing.

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

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

5.4 Energy utilization factor is a precise indicator of a cook-and-hold oven's energy performance while cooking and holding a typical food product under various loading conditions. If energy performance information is desired using a food product other than the specified test food, the test method could be adapted and applied. Energy performance information allows an end user to better understand the operating characteristics of a cook-and-hold oven.

5.5 Production capacity information can help an end user to better understand the production capabilities of a cook-and-hold 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.

5.6 Holding energy rate may be used to determine the cost of holding cooked product in the cook-and-hold oven.

5.7 Product yield may be used by the food service operator to compare relative product output from one cook-and-hold oven to another. Additionally, product shrinkage during holding may be used by the food service operator to evaluate the cook-and-hold oven's performance when holding cooked product.

6. Apparatus

6.1 *Analytical Balance Scale,* for measuring weights up to 20 lb, with a resolution of 0.01 lb and an uncertainty of 0.01 lb.

6.2 *Barometer,* for measuring absolute atmospheric pressure, to be used for adjustment of measured 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, and an uncertainty of 0.01 gal, at flow rate as low as 0.2 gpm.

6.4 *Gas Meter,* for measuring the gas consumption of a cook-and-hold 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 Gage,* 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-sec resolution.

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

6.8 *Thermocouple Probes,* Type K stainless-steel sheathed exposed junction with a range from –20 to 400°F, with a resolution of 0.2°F, and an uncertainty of 0.5°F, 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 cook-and-hold oven, shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 1.5% of the measured value for any demand greater than 100 W. For any demand less than 100 W, the meter shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 10%.

7. Reagents and Materials

7.1 *Roast,* for the cooking energy efficiency test. Roasts shall be raw, unfrozen, 100% Choice beef top (inside) round with a ¼-inch trim, 12 ± 0.25 lb per roast. The raw roasts shall be stabilized in a refrigerator at 37 ± 2°F.

7.2 *Hotel Pan,* solid 12 by 20 by 2½ in. (300 by 500 by 65 mm) stainless steel weighing 2.8 ± 0.5 lb (1.3 ± 0.2 kg).

8. Sampling, Test Units

8.1 *Cook-and-Hold Oven*—Select one representative production model for performance testing.

9. Preparation of Apparatus

9.1 Install the cook and hold oven according to the manufacturer's instructions in an appropriate space. All sides of the hot food holding cabinets shall be a minimum of 3 ft from any side wall, side partition, or other operating appliance and add 2 in. 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 within the testing environment.

9.2 Connect the cook-and-hold 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 cook-and-hold 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 cook-and-hold oven, confirm (while the cook-and-hold oven 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 cook-and-hold oven at its rated gas pressure or electric voltage. If an electric unit is rated dual voltage (that is, designed to operate at either 208 or 240 V with no change in components), the voltage selected by the manufacturer or tester, or both, shall be reported. If a cook-and-hold 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 cook-and-hold 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 cook-and-hold 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 cook-and-hold 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 cook-and-hold ovens, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (section 10.3).

10.1.3 For electric cook-and-hold 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 cook-and-hold 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 cook-and-hold oven cooking cavity.

10.2.2 Set the temperature control to 150°F and turn the cook-and-hold 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 cook-and-hold 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 cook-and-hold 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 150 ± 5°F, then the cook-and-hold oven's thermostat is calibrated.

10.2.6 If the average temperature is not 150 ± 5°F, 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 cook-and-hold 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 cook-and-hold oven cavity temperature is 75 ± 5°F. Set the calibrated temperature control to 225°F and turn the oven on.

10.3.2 Record the time, temperature, and energy consumption required to preheat the cook-and-hold oven, from the time when the unit is turned on until the time when the oven cavity reaches a temperature of 225 ± 5°F.

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 cook-and-hold 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, then run idle energy rate test shall be run for a minimum of 3 h and include a minimum of 10 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.

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 holding cabinet, while minimizing any error that may be introduced as a result of capturing partial thermal cycles.

10.4.3 In accordance with section 11.6, calculate and report the cook-and-hold oven's idle energy rate.

10.5 *Pilot Energy Rate:*

10.5.1 For a gas cook-and-hold oven with a standing pilot, set the gas valve at the "pilot" position and set the cook-and-hold 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 hr of pilot operation.

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

10.6 *Test Product Preparation:*

10.6.1 Determine the roasting capacity of the cook-and-hold oven by measuring the internal height and depth of the oven cavity. Place the oven racks between 6 and 7-in. apart, starting from the bottom rack position, and leaving a minimum of 6-in. from the top rack to the cavity ceiling. Count the number of racks. Each rack will hold a single roast for every 13-in. of rack depth. For example, an oven with an internal cavity height of 25-in., and a rack depth of 15-in. will have a load size of 3 roasts.

10.6.2 Remove the roasts from the refrigerator, remove any packaging and weigh the roasts, not including any juice that may accompany the roast. Note the weight of the individual roasts. Each roast shall be 12 ± 0.25 lb.

10.6.3 The total load weight shall be the number of roasts times 12 lb and the tolerance of the total load weight shall reference Table 1. For example, a cook-and-hold oven with four full-size racks can accommodate 8 total roasts. The total test weight for the example oven is 8 × 12 ± 1.0 lb, or 96.0 ± 1.0 lb. For total load weight of <100 lbs, the tolerance shall be ± 1.0 lb, for total load weight ≥ 100 lbs, the tolerance shall be ± 2.0 lb. Refer to Table 1.

10.6.4 The roasts shall have an average load weight of 12.0 ± 0.25 lb. If the total weight is greater than the number of roasts, $n \times 12 + 0.25$ lb, then trim the ends of the largest roasts to bring the total load weight to within the tolerance specified in Table 1. If the total weight is less than the number of roasts, $n \times 12 \pm 0.25$ lb, then substitute the smallest roasts for larger roasts until the total load weight is within the tolerance specified in Table 1.

10.6.5 Place thermocouple probes into the geometric center of each roast to facilitate monitoring internal roast temperatures.

10.6.6 Place each roast into individual hotel pans and cover with plastic wrap. Return the roasts to the refrigerator until they stabilize at 37 ± 2°F.

10.6.7 Monitor the internal temperature of each roast with a thermocouple probe. Its internal temperature must be 37 ± 2°F before the roasts can be removed from the refrigerator and loaded into the cook-and-hold oven. If necessary, adjust the refrigerator temperature to achieve this required internal temperature.

10.7 *Cooking Energy Rate, Production Capacity, Holding Energy Rate, and Energy Utilization Factor:*

10.7.1 The cooking energy rate, production capacity, holding energy rate, and energy utilization factor, 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, holding energy rate, energy utilization factor, and product yield shall be the average of the replications (runs).

10.7.2 Fill water pan if required by manufacture's recommendations. Turn the cook-and-hold oven on and allow it to achieve a ready-to-cook state reach temperature of 225°F. Allow the oven to idle for a minimum of 60 min after it is fully preheated.

10.7.3 Remove the roasts from the refrigerator and remove the plastic wrap. Open the door of the cook-and-hold oven and commence loading the roasts into the oven, starting from the bottom and preceding to the top. Allow 10 s for each rack position (for example, a heavy load of 3 racks times 10 s = 30 sec maximum loading time). The initial average temperature of the roasts (all roasts together) when the test is started (the cook-and-hold oven door is closed) shall be 40 ± 2°F (4 ± 1°C). Keep the door open for the maximum load time, even if the loading is accomplished in less time.

10.7.4 Shut the door 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 temperature of the last roast reaches a minimum of 90–110°F, note the total elapsed time and oven energy (and water, if applicable) consumption and then switch the controls to hold mode. Hold the cavity temperature at 150°F until last roast internal temperature is 130°F for a minimum of 112 minutes.

TABLE 1 Oven Roasting Capacity and Cooking Test Load Weight

Roasting Capacity	Cooking Test Weight
2 Roasts	24.0 ± 1.0 lb
3 Roasts	36.0 ± 1.0 lb
4 Roasts	48.0 ± 1.0 lb
8 Roasts	96.0 ± 1.0 lb
12 Roasts	144.0 ± 2.0 lb
16 Roasts	192.0 ± 2.0 lb
20 Roasts	240.0 ± 2.0 lb

10.7.6 Remove the roasts from the oven and close the oven door. Remove the thermocouples from the roasts, and immediately weigh the roasts. Allow 30 seconds per roast for weighing once removed from oven. Do not include the weight of any collected juices in the final roast weight.

10.7.7 Record the final roast temperature, the total test time, the cooked weight of the roasts, and the energy (and water, if applicable) consumed by the cook-and-hold oven during the test.

10.7.8 Perform runs No. 2 and No. 3 by repeating 10.7.2 – 10.7.7. Allow a minimum of 24 h between subsequent tests. 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, holding energy rate, energy utilization factor, electric energy rate (if applicable for gas cook-and-hold ovens), production capacity, product yield, and water consumption (if applicable).

11. Calculation and Report

11.1 *Test Cook-and-Hold Oven:*

11.1.1 Summarize the physical and operating characteristics of the cook-and-hold 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 cook-and-hold ovens, report the voltage for each test.

11.2.3 For gas cook-and-hold ovens, report the higher heating value of the gas supplied to the cook-and-hold oven during *each* test.

11.3 *Gas Energy Calculations:*

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

11.3.2 Calculate the energy consumed based on:

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

where:

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

where:

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

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

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

P_{cf} = pressure correction factor,

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

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

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

11.4 *Energy Input Rate:*

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

11.4.2 For gas or electric cook-and-hold ovens, calculate and report the measured energy input rate (Btu/h or kW) based on the energy consumed by the cook-and-hold 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:*

11.5.1 Report the preheat energy consumption (Btu or kWh) and preheat time (min).

11.6 *Idle Energy Rate:*

11.6.1 Calculate and report the idle energy rate (Btu/h or kW) based on:

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

where:

$q_{idle\ rate}$ = 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:*

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

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

where:

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

11.8 *Cooking Energy Rate, Holding Energy Rate, Energy Utilization Factor, Production Capacity and Product Yield:*

11.8.1 Calculate the cooking energy rate 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 the cooking portion of the cook-and-hold test, Btu or kWh, and
t = cooking test period, min.

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

11.8.2 Calculate the holding energy rate based on:

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

where:

q_{hold} = holding energy rate, Btu/h or kW,
E = energy consumed during the holding portion of the cook-and-hold test, Btu or kWh, and
t = holding test period, min.

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

11.8.3 Calculate the energy utilization factor, E_{factor}, based on:

$$k_u = \frac{E_{cook} + E_{hold}}{W_{final}} \quad (7)$$

where:

k_{fu} = energy utilization factor (Wh/lbs),
E_{cook} = energy consumed during the cooking portion of the cook-and-hold test, kWh,
E_{hold} = energy consumed during the holding portion of the cook-and-hold test, kWh, and
W_{final} = final weight of the cooked roasts, lbs.

The conversion factor for electric energy is 3,413 Btu / kWh.

11.8.4 Calculate production capacity based on:

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

where:

PC = production capacity of the cook-and-hold oven, lb/h,
W = total raw weight of the roasts, lb, and
t = cooking test period, min.

11.8.5 Calculate product yield (%) based on:

$$Y = \frac{W_{cooked}}{W_{raw}} \times 100 \quad (9)$$

where:

Y = product yield, %,
W_{raw} = total weight of the uncooked roasts, and
W_{cooked} = final weight of the cooked roasts.

11.8.6 Report the cook time and the three run average value of the energy utilization factor, cooking energy rate, holding energy rate, production capacity and product yield for the cook-and-hold tests. Also report the three run average value of the total water consumption (if applicable) for the cook-and-hold tests.

12. Precision and Bias

12.1 *Precision:*

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

12.1.1.1 For energy utilization factor 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):

12.1.2.1 The interlaboratory precision of the procedure in this test method for measuring each reported parameter is being determined.

12.2 *Bias:*

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

13. Keywords

13.1 cook-and-hold oven; energy utilization factor; production capacity of roast; product yield; slow roast 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 Energy Utilization Factor and Production Capacity procedures, results are reported for the energy utilization factor (E_{factor}) 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 ($q_{total\ rate\ reduction}$). 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 energy utilization factor test (roast test load), the uncertainty of E_{factor} must be no greater than ± 10% before E_{factor} 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_{factor} is 40%, the uncertainty must not be larger than ± 4%. This means that the true E_{factor} 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_{factor} 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_{factor} 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 (3 test runs) is:

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

where:

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

The formula for the sample standard deviation (3 test runs) is:

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

where:

S_3 = standard deviation of results for E_{factor}, *PC*,
A_3 = $(X_1)^2 + (X_2)^2 + (X_3)^2$
B_3 = $(1/3) \times (X_1 + X_2 + X_3)^2$

TABLE A1.1

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

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 (1/3 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 (3 test runs) is:

$$U_3 = C_3 \times S_3$$
$$U_3 = 2.48 \times S_3 \quad \text{(A1.3)}$$

where:

U_3 = absolute uncertainty in average for E_{factor}, *PC*, and
C_3 = uncertainty factor for 3 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 (3 test runs) is:

$$\%U_3 = (U_3 / Xa_3) \times 100\% \quad \text{(A1.4)}$$

where:

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

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

A1.4.5 *Step 5*—Run a fourth test for each E_{factor}, *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_{factor}, calculate the average and standard deviation for E_{factor} and *PC* using a calculator or the following formulas.

The formula for the average (4 test runs) is:

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

where:

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

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

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

where:

S_4 = standard deviation of results for E_{factor}, *PC*, (4 test runs),
A_4 = $(X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$
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:

$$U_4 = C_4 \times S_4$$
$$U_4 = 1.59 \times S_4 \quad (A1.7)$$

where:

U_4 = absolute uncertainty in average for E_{factor}, PC, and
C_4 = the uncertainty factor for 4 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.

The formula for the percent uncertainty (4 test runs) is:

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

where:

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

A1.4.9 *Step 9*—If the percent uncertainty, $\%U_4$, is no greater than ± 10% for E_{factor}, PC, then report the average for E_{factor}, 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_{factor}, 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:

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

where:

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

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

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

where:

S_n = standard deviation of results for E_{factor}, PC, (n test runs),
A_n = $(X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2 + ... + (X_n)^2$
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:

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

where:

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

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

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

where:

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

When the specified uncertainty, $\%U_n$, is less than or equal to ± 10%; report the average for E_{factor}, 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 full-energy utilization factor test yielded the following E_{factor} results:

Test	E_{factor}
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_{factor}.

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".

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

The new standard deviation for the E_{factor} is:

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

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_{factor} 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_{factor} from the fourth test run was 31.8%.

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

The new average E_{factor} 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".

$$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$$
$$A_4 = (33.8)^2 + (31.3)^2 + (30.5)^2 + (31.8)^2$$
$$A_4 = 4{,}064$$
$$B_4 = (1/4) \times [(X_1 + X_2 + X_3 + X_4)^2]$$
$$B_4 = (1/4) \times [(33.8 + 31.3 + 30.5 + 31.8)^2]$$
$$B_4 = 4{,}058$$

The new standard deviation for the E_{factor} is:

$$S_4 = \left(1/\sqrt{3}\right) \times \sqrt{(4064 - 4058)}$$
$$S_4 = 1.41\%$$

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_{factor} is reported along with its corresponding absolute uncertainty, U_4 as follows:

$$E_{factor} = 31.9 \pm 2.24\%$$

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_{factor}.

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 cook-and-hold oven: _______ H × _______ W × _______ D inches

Size of cook-and-hold oven cavity: _______ H × _______ W × _______ 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 Energy Utilization Factor , Cooking Energy Rate, Holding Energy Rate, Production Capacity, and Product Yield

Test Voltage (V) ____________________

Gas Heating Value (Btu/ft^3) ____________________

Cooking Energy Rate (Btu/h or kW) ____________________

Electric Cooking Energy Rate (kW, gas ovens only) ____________________

Holding Energy Rate (Btu/h or kW) ____________________

Electric Holding Energy Rate (kW, gas ovens only) ____________________

Energy Utilization Factor (Wh/lbs) ____________________

Energy into the appliance - $E_{appliance}$ (Btu, or kWh) ____________________

Production Capacity (lb/h) ____________________

Product Yield (%) ____________________

Water Consumption, if applicable (gal) ____________________