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An American National Standard

Standard Test Method for Performance of Combination Ovens[1]

This standard is issued under the fixed designation F 1639; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

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

1.2 This test method is applicable to gas and electric combination ovens that are operated in the combination mode. For evaluation of a combination oven operated in either convection oven mode or steam cooker mode, apply either Test Method F 1484 or Test Method F 1496.

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

1.3.1 Energy input rate and thermostat calibration (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 efficiency, cooking-load energy efficiency, and production capacity (10.6).

1.3.6 Water consumption (10.6).

1.3.7 Condensate temperature (10.6).

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

F 1484 Test Method for Performance of Steam Cookers[2]

F 1495 Specification for Ovens, Combination, Electric[2]

F 1496 Test Method for Performance of Convection Ovens[2]

2.2 *ASHRAE Documents:*[3]

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

ASHRAE Guideline 2-1986 (RA90) Thermal and Related Properties of Food and Food Materials

3. Terminology

3.1 *Definitions:*

3.1.1 *combination oven*, *n*—a device that combines the function of hot air convection or saturated and superheated steam heating, or both, to perform steaming, baking, roasting, rethermalizing, and proofing of various food products. In general, the term combination oven is used to describe this type of equipment, which is self contained. The combination oven is also referred to as a combination oven/steamer.

3.1.2 *condensate*, *n*—a mixture of condensed steam and cooling water, exiting the combination oven and directed to a drain.

3.1.3 *cooking energy efficiency*, *n*—quantity of energy imparted to the specified food product, expressed as a percentage of energy consumed by the combination oven during the cooking event.

3.1.4 *cooking-load energy efficiency*, *n*—quantity of energy imparted to the specified food product and the pot or pan containing the food product, expressed as a percentage of energy consumed by the combination oven during the cooking event.

3.1.5 *cooking energy rate*, *n*—average rate of energy consumption (Btu/h or kW) during the cooking energy efficiency tests. Refers to all loading scenarios (heavy, medium, light).

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

3.1.7 *idle energy rate*, *n*—the combination oven's rate of energy consumption (kW or Btu/h), when empty, required to maintain its cavity temperature at the specified thermostat set point.

3.1.8 *oven cavity*, *n*—that portion of the combination oven in which food products are heated or cooked.

[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] *Annual Book of ASTM Standards*, Vol 15.07.

[3] See the *ASHRAE Handbook of Fundamentals*, available from the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329.

3.1.9 *pilot energy rate*, *n*—rate of energy consumption (Btu/h) by a combination oven's continuous pilot (if applicable).

3.1.10 *preheat energy*, *n*—amount of energy consumed (Btu or kWh), by the combination oven while preheating its cavity from ambient temperature to the specified thermostat set point.

3.1.11 *preheat time*, *n*—time (in min) required for the combination oven cavity to preheat from ambient temperature to the specified thermostat set point.

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

3.1.13 *production rate*, *n*—rate (lb/h) at which a combination oven brings the specified food product to a specified" cooked" condition. Does not necessarily refer to maximum rate. Production rate varies with the amount of food being cooked.

3.1.14 *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 combination oven thermostat is checked at a setting of 350°F and the thermostat is adjusted as necessary.

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

4.3 Preheat energy and time are determined.

4.4 Idle energy rate is determined at a thermostat setting of 350°F.

4.5 Cooking energy efficiency, cooking-load energy efficiency and production rate are determined during light-, medium-, and heavy-load cooking tests using chicken breasts as a food product.

5. Significance and Use

5.1 The energy input rate test and thermostat calibration are used to confirm that the combination oven is operating properly prior to further testing and to ensure that all test results are determined at the same temperature.

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

5.3 Idle energy rate and pilot energy rate can be used to estimate energy consumption during noncooking periods.

5.4 Cooking energy efficiency is a precise indicator of combination oven energy performance under various loading conditions. This information enables the food service operator to consider energy performance when selecting a combination oven.

5.5 Production capacity can be used by food service operators to choose a combination oven that matches their food output requirements.

5.6 Water consumption characterization is useful for estimating water and sewage costs associated with combination oven operation.

5.7 Condensate temperature measurement is useful to verify that the condensate temperature does not violate applicable building codes.

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, having a resolution of 0.2 in. Hg and an uncertainty of 0.2 in. Hg.

6.3 *Canopy Exhaust Hood*, 4 ft in depth, wall-mounted with the lower edge of the hood 6 ft 6 in. from the floor and with the capacity to operate at a nominal exhaust ventilation rate of 300 cfm per linear foot of active hood length. This hood shall extend a minimum of 6 in. past both sides and the front of the cooking appliance and shall not incorporate side curtains or partitions.

6.4 *Flowmeter*, for measuring total water consumption of the appliance, having a resolution of 0.01 gal and an uncertainty of 0.01 gal at a flow rate as low as 0.2 gpm.

6.5 *Gas Meter*, for measuring the gas consumption of a combination 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.

6.6 *Pressure Gage*, for monitoring natural gas pressure, having a range from 0 to 10 in. H_2O, a resolution of 0.5 in. H_2O, and a maximum uncertainty of 1 % of the measured value.

6.7 *Stopwatch*, with a 1-s resolution.

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

6.9 *Thermocouple Probes*, with a range from 0 to 450°F, with a resolution of 0.2°F, and an uncertainty of 0.5°F, for measuring temperature of combination oven cavity, chicken breasts, and condensate. Calibrated Type T thermocouples (24 GA.) are recommended.

6.10 *Watt-hour Meter*, for measuring the electrical energy consumption of a combination oven, having a resolution of at least 10 Wh and a maximum uncertainty no greater than 1.5 % of the measured value for any demand greater than 100 W. For any demand 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 *Water*, shall have a maximum hardness of three grains per gallon. Distilled water may be used.

7.2 *Chicken Breasts*, shall be 5-oz frozen, boneless, skinless, butterfly cut, chicken breasts (whole meat, not fabricated).

7.3 *Aluminum Sheet Pans*, 18 by 26 by 1 in. for a full-size combination oven and 18 by 13 by 1 in. for a half-size combination oven.

8. Sampling, Test Units

8.1 *Combination Oven/Steamer*—Select a representative production model for performance testing.

9. Preparation of Apparatus

9.1 Install the appliance according to the manufacturer's instructions under a canopy exhaust hood. Position the combination oven so that a minimum of 6 in. is maintained between the edge of the hood and the vertical plane of the front and sides of the appliance. In addition, both sides of the combination oven shall be a minimum of 3 ft from any side wall, side partition, or other operating appliance. The exhaust ventilation rate shall be 300 cfm per linear foot of hood length. The associated heating or cooling system shall be capable of maintaining an ambient temperature of 75± 5°F within the testing environment when the exhaust ventilation system is operating.

9.2 Connect the combination 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 combination 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 combination oven, confirm (while the combination oven elements are energized) that the supply voltage is within± 2.5 % of the operating voltage specified by the manufacturer. Record the test voltage for each test.

NOTE 1—If an electric combination oven is rated for dual voltage (for example, 208/240 V), the combination oven shall be evaluated as two separate appliances in accordance with this standard test method.

9.4 For a gas combination 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 Install a flowmeter to the combination oven water inlet such that total water flow to the appliance is measured.

9.6 Install a temperature sensor such that it is immersed in the condensate water path just as it enters the drain.

10. Procedure

10.1 *General*:

10.1.1 For gas appliances, record the following for each test run:

10.1.1.1 Higher heating value,

10.1.1.2 Standard gas pressure and temperature used to correct measured gas volume to standard conditions,

10.1.1.3 Measured gas temperature,

10.1.1.4 Measured gas pressure,

10.1.1.5 Barometric pressure, and

10.1.1.6 Energy input rate during or immediately prior to test (for example, during the preheat for that days' testing).

NOTE 2—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 combination 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 combination ovens, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (see 10.3).

10.1.3 For electric combination ovens, record the following for each test run:

10.1.3.1 Voltage while elements are energized, and

10.1.3.2 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 combination 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 combination oven cooking cavity.

10.2.2 Set the temperature control to 350°F; set the controls to operate in the combination mode; and turn the combination 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 (in the steam generator or the convection oven) first cycle off.

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

10.2.4 Allow the combination 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 combination oven cavity temperature, and record the average temperature over a 15-min period. If this recorded temperature is 350 ± 5°F, then the combination oven's thermostat is calibrated.

10.2.6 If the average temperature is not 350 ± 5°F, adjust the combination oven's 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 combination 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 combination oven cavity temperature is 75 ± 5°F. Set the calibrated temperature control to 350°F; set the controls to operate in the combination mode; and turn the combination oven on.

10.3.2 Record the time, temperature, and energy consumption required to preheat the combination oven, from the time when the unit is turned on until the time when the combination oven cavity reaches a temperature of 350 ± 2°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 Set the temperature control to 350°F; set the controls to operate in the combination mode; and preheat the combination oven.

10.4.2 Allow the combination oven to idle for 60 min after the burners or elements commence cycling.

10.4.3 At the end of 60 min, begin recording the combination oven's idle energy consumption, at 350°F, for a minimum of 3 h. Record the length of the idle period.

10.4.4 In accordance with 11.6, calculate and report the combination oven's idle energy rate.

10.5 *Pilot Energy Rate*:

10.5.1 For a gas combination oven with a standing pilot, set the gas valve at the "pilot" position, and set the combination 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 8 h of pilot operation.

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

10.6 *Cooking Energy Efficiency and Production Capacity*:

10.6.1 Based on Table 1, determine the number of pans required for a heavy load (6, 8, or 16), and place an equal number of racks in the combination oven in accordance with the manufacturer's suggested rack placement.

NOTE 3—Some combination ovens are designed with extra rack spaces; however, they are not meant to be operated with a rack in every available space. The extra spaces are meant to give the user greater flexibility in rack placement. Once the proper number of racks is determined they should be placed in the oven based on the manufacturer's suggested rack spacing to ensure proper cooking.

10.6.2 Based on Table 1, thaw enough 5-oz, boneless, skinless, butterfly-cut chicken breasts for a minimum of 3 runs of each loading scenario (light, medium, and heavy load). Half-size sheet pans shall be used in a half-size combination oven, and full-size sheet pans shall be used in a full-size combination oven. There are eight chicken breasts for each half-size sheet pan and 16 for each full-size sheet pan. Drain the thawed chicken breasts in a refrigerator for 1 h.

NOTE 4—It is suggested that the frozen chicken breasts be thawed in cold running water.

TABLE 1 Loading Criteria

Combination Oven Type	Pans per Run			Chicken Breasts per Run		
Type I—Table Top	Light	Medium	Heavy	Light	Medium	Heavy
Class A—Half-size nominal 6 pan	1	3	6	8	24	48
Class A—Half-size nominal 10 pan	1	4	8	8	32	64
Class B—Full-size	1	3	6	16	48	96
Type II—Floor	Light	Medium	Heavy	Light	Medium	Heavy
Class A—Half-size	1	8	16	8	64	128
Class B—Full-size	1	8	16	16	128	256

NOTE 5—It is important that the raw chicken breasts be properly and consistently thawed and drained. Excess moisture on the pans will make it difficult to accurately determine the amount of product shrinkage.

10.6.3 Mark a sheet pan with a number for later identification. Weigh the sheet pan, and record the weight. Place the required number of chicken breasts on the sheet pan, either 8 or 16, making sure to spread the chicken breasts open with the smooth side up. Weigh the sheet pan with the chicken breasts to determine the weight of the chicken breasts. The weight of the uncooked chicken breasts shall be 2.4 ± 0.1 lb per each eight chicken breasts. If it is not possible to find eight chicken breasts that weigh 2.4± 0.1 lb, then add or remove no more than one chicken breast until the target weight is met. Repeat for each pan required for the test and record the total uncooked weight of the chicken breasts for each test load.

10.6.4 Insert two thermocouples into the thickest parts of two of the center chicken breasts on each of the pans. Insert the thermocouples into the chicken breasts from the side at an angle as close to horizontal as possible. Do not instrument more than four pans for any particular test run. For example, an oven with ten rack spaces would require eight pans for a heavy load, four of which would be instrumented.

NOTE 6—Because the purpose of the two thermocouples is to provide an average temperature of the chicken breasts on that pan, the thermocouples can be mechanically averaged by joining two equal lengths of thermocouple wire into one wire which is attached to the temperature measuring device. This method simplifies the procedure by reducing the number of thermocouple wires leaving the combination oven.

NOTE 7—It is recommended that the thermocouple wires be attached to the side of the pan with clips or some other form of strain relief to ensure that the thermocouples remain in the same spot in the chicken breasts during handling and loading of the pans.

NOTE 8—It was determined by the Food Service Technology Center[4] that four thermocouple pairs were sufficient to produce accurate and repeatable results for test loads consisting of more than four pans. Limiting the number of thermocouples simplifies the handling of the pans and reduces the chance that the wires will become tangled.

10.6.5 Cover the pans with cellophane (to inhibit moisture loss), place the pans in a refrigerator and chill the chicken breasts until they stabilize at 37 ± 2°F. Do not store the thawed chicken breasts in the refrigerator for more than one week.

10.6.6 Set the temperature control to 350°F; set the controls to operate in the combination mode; preheat the combination oven; and then allow the combination oven to idle for 60 min.

10.6.7 Remove the chicken breasts from the refrigerator. Open the door of the combination oven; slide out the appropriate racks; and load the pans of chicken breasts on the racks. Do not push the racks back into the combination oven until all the loading is complete. The light load pan shall be placed as close to the center of the combination oven as possible, and the medium load pans shall be loaded on every other rack starting from the top. The heavy load pans shall be loaded on every rack starting from the top. If a load is comprised of more than four pans, spread the four instrumented pans as evenly as possible throughout the combination oven cavity. Allow 10 s to

[4] See the *Development and Application of a Uniform Testing Procedure for Combination Ovens*, Publication Pending, available from Pacific Gas and Electric Company, 12949 Alcosta Blvd., San Ramon, CA 94583.

load each pan into the combination oven (for example, a heavy load is six pans times 10 s = 1-min maximum loading time). When all the racks are loaded, push the racks back into the combination oven; shut the door; and start the combination oven to begin the test. Start monitoring time, temperature, energy, water consumption, and condensate temperature. The initial average temperature of the chicken breasts (all the pans together) when the test is started (the combination oven door is closed) shall be 40± 2°F.

10.6.8 End the test when the average temperature of the chicken breasts (all the pans together) reaches 170°F. Stop monitoring time, temperature, energy, water consumption, and condensate temperature. Remove the pans of chicken breasts from the combination oven. Remove the thermocouples from the chicken breasts, and immediately weigh each pan of chicken breasts including any juice that might be on the pans. Subtract the weight of the pans to determine a total cooked weight of the chicken breasts. Record the final temperature, the test time, the total cooked weight of the chicken breasts, and the energy and water consumed during the test. Remove the chicken breasts from the pans, leaving any juice on the pan and shaking off any excess moisture that may have condensed on the chicken breast. Weigh and record the net weight of the chicken breasts.

NOTE 9—The total cooked weight of the chicken breasts will be subtracted from the total uncooked weight of the chicken breasts in order to determine the amount of moisture evaporated during the test. It is crucial to include all of the moisture that is remaining on the pans when determining the total cooked weight so that the evaporation will not be exaggerated.

NOTE 10—The net weight of the chicken breasts will be subtracted from the total uncooked weight of the chicken breasts in order to determine the product shrinkage. The net weight is representative of the final product or the quantity of product that would be available to be served.

10.6.9 Once the pans have been removed from the combination oven, close the door and restart the combination oven. Perform runs No. 2 and No. 3 by repeating 10.6.3-10.6.8. Idling the combination oven for 60 min between test runs is not necessary. Follow the procedure in Annex A1 to determine whether more than three test runs are required.

10.6.10 In accordance with 11.8, calculate and report the cooking energy efficiency, cooking-load energy efficiency, cooking energy rate, electric energy rate (if applicable for gas combination ovens), production capacity, product shrinkage, water consumption, and condensate temperature.

11. Calculation and Report

11.1 *Test Combination Oven*—Summarize the physical and operating characteristics of the combination 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 combination ovens, report the voltage for each test.

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

11.3 *Gas Energy Calculations*:

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

11.3.2 Calculate the energy consumed based on the following:

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

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,

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

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

P_{cf} = pressure correction factor

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

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

NOTE 11—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Pacific Gas and Electric Company (PG&E) standard conditions are 519.67°R and 14.73 psia.[4]

11.4 *Energy Input Rate*:

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

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

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

where:

$E_{input\ rate}$ = 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).

11.5.2 Generate a graph showing the combination oven cavity temperature versus time for the preheat period.

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

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

where:

$E_{idle\ rate}$ = 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*—Calculate and report the pilot energy rate (Btu/h) based on the following:

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

where:

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

11.8 *Cooking Energy Efficiency, Cooking-Load Energy Efficiency and Cooking Energy Rate, Production Capacity, Product Shrinkage, Water Consumption, and Condensate Temperature*:

11.8.1 Calculate the cooking energy efficiency, η_{cook}, and the cooking-load energy efficiency, η_{load}, for heavy-, medium-, and light-load cooking tests based on the following:

$$\eta_{cook} = \frac{E_{food}}{E_{appliance}} \times 100 \quad \eta_{load} = \frac{E_{food} + E_{pan}}{E_{appliance}} \times 100 \quad (5)$$

where:

η_{cook} = cooking energy efficiency, %,
η_{load} = cooking-load energy efficiency, %,
E_{food} = energy into food, Btu,
= $(Wraw \times Cp\ (C) \times (T_2 - T_1)) + ((Wraw - Wcooked) \times Hfgt2)$
E_{pan} = energy into pan(s), Btu,
= $Wp \times Cp\ (P) \times (T_2 - T_1)$
$Wraw$ = total weight of uncooked chicken breasts,
$Wcooked$ = total weight of cooked chicken breasts including juice,
Wp = weight of pan(s),
$Cp(C)$ = specific heat of chicken breasts based on an average moisture content of 75 %
= 0.800 Btu/lb·°F,
$Cp(P)$ = specific heat of aluminum pan(s),
= 0.22 Btu/lb·°F,
$Hfgt2$ = heat of vaporization of water (Btu/lb) based on T_2 as found from a table of thermodynamic properties of water at saturation[5]
= 996 Btu/lb
T_2 = ending temperature of the chicken breasts, which is specified as 170°F,
T_1 = beginning temperature of the chicken breasts, which is specified as 40 ± 2°F, and
$E_{appliance}$ = energy into the appliance, Btu.

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

11.8.2 Calculate the cooking energy rate for heavy-, medium-, and light-load cooking tests based on the following:

$$E_{cook\ rate} = \frac{E \times 60}{t} \quad (6)$$

where:

$E_{cook\ rate}$ = cooking energy rate, Btu/h or kW,
E = energy consumed during cooking test, Btu or kWh,
t = cooking test period, min.

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

11.8.3 Calculate production capacity (lb/h) based on the following:

$$PC = W \times \frac{60}{t} \quad (7)$$

where:

PC = production capacity of the combination oven, lb/h,
W = total weight of chicken breasts cooked during heavy-load cooking test, lb,
t = total time of heavy-load cooking test, min.

11.8.4 Calculate product shrinkage (%) based on the following:

$$S = \frac{W_{raw} - W_{net}}{W_{raw}} \times 100 \quad (8)$$

where:

S = product shrinkage, %,
W_{raw} = total weight of the uncooked chicken breasts, and
W_{net} = final net weight of the cooked chicken breasts.

11.8.5 Calculate the average water consumption rate during the test based on the following:

$$gal/h = gal \times \frac{60}{t} \quad (9)$$

where:

gal/h = average water consumption rate during the test,
gas = water consumed by the combination oven during the test, and
t = cooking test period, min.

11.8.6 Calculate the maximum temperature and the average temperature of the cooking condensate during the test, °F.

11.8.7 Report the three-run average value of cooking energy efficiency, cooking-load energy efficiency, cooking energy rate, production capacity, product shrinkage, water consumption, and condensate temperature.

12. Precision and Bias

12.1 *Precision*:

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

[5] See the *ASHRAE Handbook of Fundamentals*, "Thermal and Related Properties of Food and Food Materials," Chapter 30, Table 1, 1989.