Designation: F1817 – 09 An American National Standard

Standard Test Method for Performance of Conveyor Ovens[1]

This standard is issued under the fixed designation F1817; 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 an evaluation of the energy consumption and cooking performance of conveyor ovens. The food service operator can use this evaluation to select a conveyor oven and understand its energy consumption.

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

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

1.3.1 Energy input rate and thermostat calibration (see 10.2),

1.3.2 Preheat energy consumption and time (see 10.3),

1.3.3 Idle energy rate (see 10.4),

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

1.3.5 Cooking energy efficiency and production capacity (see 10.6).

1.4 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

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 *ASHRAE Documents:*

ASHRAE Handbook of Fundamentals, "Thermal and Related Properties of Food and Food Materials," Chapter 30, Table 1, 1989[2]

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

3. Terminology

3.1 *Definitions:*

3.1.1 *conveyor oven, n*—an appliance that carries the food product on a moving conveyor into and through a heated chamber. The chamber may be heated by gas or electric forced convection, radiants, or quartz tubes. Top and bottom heat may be independently controlled.

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

3.1.3 *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).

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

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

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

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

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

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

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

3.1.11 *production rate, n*—rate (lb/h) at which a conveyor 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.

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

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

4. Summary of Test Method

4.1 Accuracy of the conveyor oven thermostat is checked at a setting of 475°F and the thermostat is adjusted as necessary.

4.2 Energy input rate is determined to confirm that the conveyor oven is operating within 5 % of the nameplate energy input rate. For gas conveyor 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 475°F.

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

5. Significance and Use

5.1 The energy input rate test and thermostat calibration are used to confirm that the conveyor oven is operating properly prior to further testing and to insure 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 conveyor 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 conveyor oven energy performance while cooking 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 conveyor oven.

5.5 Production capacity information can help an end user to better understand the production capabilities of a conveyor 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.

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 *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 *Convection Drying Oven,* with temperature controlled at 220 ± 5°F, to be used to determine moisture content of pizza crust, pizza sauce and pizza cheese.

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

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

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

6.9 *Thermocouple,* fiberglass insulated, 24 gage, Type K thermocouple wire, connected at the exposed ends by tightly twisting or soldering the two wires together.

6.10 *Thermocouple Probe,* type K, micro needle, product probe with a response time from ambient to 200°F of less than 20 s.

6.11 *Watt-Hour Meter,* for measuring the electrical energy consumption of a conveyor 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 *Pizza Crust* shall be a 12 in. diameter, prebaked or parbaked crust, weighing 0.9 ± 0.2 lb and having a moisture content of 36 ± 3 % by weight, based on a gravimetric moisture analysis. Refrigerate to 39 ± 1°F.

7.2 *Pizza Sauce* shall be a simple, tomato based sauce with a moisture content of 90 ± 2 % by weight, based on a gravimetric moisture analysis. Refrigerate to 39 ± 1°F.

7.3 *Pizza Cheese* shall be a part skim, low moisture, shredded mozzarella cheese with a moisture content of 50 ± 2 % by weight, based on a gravimetric moisture analysis. Refrigerate to 39 ± 1°F.

7.4 *Pizza* shall be comprised of a pizza crust, pizza sauce and pizza cheese according to the following: uniformly spread 0.25 lb of pizza sauce on top of a pizza crust to within 0.5 in. of the edge of the crust and cover the pizza sauce with 0.375 lb of pizza cheese.

7.5 Gravimetric moisture analysis shall be performed as follows: to determine moisture content, place a 1 lb sample of the test food on a dry, aluminum sheet pan and place the pan in a convection drying oven at a temperature of 220 ± 5°F for a period of 24 h. Weigh the sample before it is placed in the oven and after it is removed and determine the percent moisture content based on the percent weight loss of the sample. The sample must be thoroughly chopped (⅛ in. or smaller squares) and spread evenly over the surface of the sheet pan in order for all of the moisture to evaporate during drying and it is permissible to spread the sample on top of baking paper in order to protect the sheet pan and simplify cleanup.

NOTE 1—The moisture content of pizza crust, pizza sauce, and pizza cheese can be determined by a qualified chemistry lab using the AOAC Procedure 984.25 Moisture (Loss of Mass on Drying) in Frozen French Fried Potatoes.

8. Sampling, Test Units

8.1 *Conveyor Oven*—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 conveyor 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 conveyor 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 active 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.

NOTE 2—The ambient temperature requirements are designed to simulate real world kitchen temperatures and are meant to provide a reasonable guideline for the temperature requirements during testing. If a facility is not able to maintain the required temperatures, then it is reasonable to expect that the application of the procedure may deviate from the specified requirements (if it cannot be avoided) as long as those deviations are noted on the Results Reporting Sheets.

9.2 Connect the conveyor 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 conveyor 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 conveyor oven, confirm (while the conveyor 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 3—If an electric conveyor oven is rated for dual voltage (for example, 208/240 V), the conveyor oven shall be evaluated as two separate appliances in accordance with this test method.

9.4 For a gas conveyor 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.

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,

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

10.1.1.7 Ambient temperature.

NOTE 4—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 conveyor 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 conveyor 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 conveyor ovens, record the following for each test run:

10.1.3.1 Voltage while elements are energized,

10.1.3.2 Energy input rate during or immediately prior to test (for example, during the preheat for that days testing), and

10.1.3.3 Ambient temperature.

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 conveyor oven.

10.2 *Energy Input Rate and Thermostat Calibration:*

10.2.1 Install a thermocouple 2 in. above the conveyor, at the center of the oven cavity (side to side and front to back).

10.2.2 Set the temperature control to 475°F and turn the conveyor 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 conveyor oven's energy input rate and compare the result to the rated nameplate input. For gas conveyor 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 conveyor 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 conveyor oven cavity temperature and record the average temperature over a 30 min period. If this recorded temperature is 475 ± 5°F, then the conveyor oven's thermostat is calibrated.

10.2.6 If the average temperature is not 475 ± 5°F, adjust the conveyor 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 conveyor 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 conveyor oven cavity temperature is 75 ± 5°F. Set the calibrated temperature control to 475°F and turn the conveyor oven on.

10.3.2 Record the time, temperature and energy consumption required to preheat the conveyor oven, from the time when the unit is turned on until the time when the conveyor oven cavity reaches a temperature of 465°F. Recording should occur at intervals of 5 seconds or less in order to accurately document the temperature rise of the oven cavity.

NOTE 5—Research at PG&E's Food Service Technology Center indicates that a conveyor oven is sufficiently preheated and ready to cook when the oven cavity temperature is within 10°F of the oven set point (that is, 465°F when the thermostat is set to maintain 475°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 calibrated temperature control to 475°F and preheat the conveyor oven.

10.4.2 Allow the conveyor 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 conveyor oven's idle energy consumption, at 475°F, for a minimum of 2 h. Record the length of the idle period.

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

10.5 *Pilot Energy Rate:*

10.5.1 For a gas conveyor oven with a standing pilot, set the gas valve at the "pilot" position and set the conveyor 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 *Pizza Preparation:*

10.6.1 Prepare enough pizzas for a minimum of three runs each of the heavy-load and light-load pizza tests. The number of pizzas for each test is determined by the size of the oven to be tested. Measure the width of the oven conveyor and the length of the oven cavity to determine the nominal number of pizzas that will fit within the oven chamber at one time.

10.6.1.1 For the heavy-load tests, the number of pizzas per test is determined by the number of 12-in. pizzas that can be accommodated within the oven cavity at one time. Each run will require an equivalent of four cavity-loads of pizzas. The pizzas will be loaded at an angel between 0° and 45°, to maximize belt coverage. Table 1 lists how many pizzas are required for each run of a heavy load test.

10.6.1.2 For the light-laod tests, the number of pizzas shall be equivalent to four single rows of pizzas. Table 2 lists how many pizzas are required for each run of a light load test.

TABLE 1 Total Number of Pizzas Required for Each Run of a Heavy Load Test[A]

Cavity Length (inches)	Conveyor Width (inches)						
	12	18	24	32	36	40	48
12	4	8	8	12	12	16	16
16	4	8	8	12	12	16	16
18	4	8	8	12	12	16	16
20	4	8	8	12	12	16	16
24	8	16	16	24	24	32	32
28	8	16	16	24	24	32	32
32	8	16	16	24	24	32	32
36	12	24	24	36	36	48	48
40	12	24	24	36	36	48	48
55	16	32	32	48	48	64	64
70	20	40	40	60	60	80	80

[A]Includes both the stabilization pizzas and the test pizzas.

TABLE 2 Total Number of Pizzas Required for Each Run of a Light Load Test[A]

Cavity Length (inches)	Conveyor Width (inches)						
	12	18	24	32	36	40	48
12	4	4	8	8	12	12	16
16	4	4	8	8	12	12	16
18	4	4	8	8	12	12	16
20	4	4	8	8	12	12	16
24	4	4	8	8	12	12	16
28	4	4	8	8	12	12	16
32	4	4	8	8	12	12	16
36	4	4	8	8	12	12	16
40	4	4	8	8	12	12	16
55	4	4	8	8	12	12	16
70	4	4	8	8	12	12	16

[A]Includes both the stabilization pizzas and the test pizzas.

10.6.2 Cover the pizzas with cellophane (to inhibit moisture loss), and then place in a refrigerator to chill until they stabilize at 39 ± 1°F. Do not test with pizzas that have been in the refrigerator more than 48 h.

NOTE 6—The test pizzas should not be stored in the refrigerator for long periods, more than 48 h, because the pizza crust may absorb excessive moisture from the sauce and evaporation may reduce the moisture content of the sauce, changing the thermal characteristics of the pizza. The 48-h period is a practical "time" specification that allows the preparation of test pizzas on day one, overnight chilling and stabilization and application of the procedure within two days.

NOTE 7—In order to easily handle and store the pizzas, it is recommended that the prepared pizzas be placed on full size (18 by 26 in.) sheet pans, two pizzas per pan. The entire pan can then be covered with food grade plastic wrap. When stacking multiple pans in the refrigerator, spacers are necessary between the pans in order to protect the pizzas from damage. Researchers at PG&E's Food Service Technology Center have found that sauce cups can be used as spacers.

NOTE 8—A minimum of three test runs is specified, however, more test runs may be necessary if the results do not meet the uncertainty criteria specified in Annex A1.

NOTE 9—Table 1 and Table 2 are meant to help the tester prepare the right number of total pizzas needed to perform the cooking energy efficiency and production capacity (10.8) test procedure. As part of that procedure, the pizzas required for each run of a light load test and each run of a heavy load test are divided into two equal groups and referred to as "stabilization" pizzas and "test" pizzas. The quantities specified in Table 1 and Table 2 include the total number of required pizzas, that is, "stabilization" plus "test".

10.6.3 Prepare a minimum of four additional pizzas for use in cook time determination. The actual number of pizzas needed for the cook time determination will vary with the number of trials needed to establish a cooking time that demonstrates a 195 ± 3°F final pizza temperature after cooking.

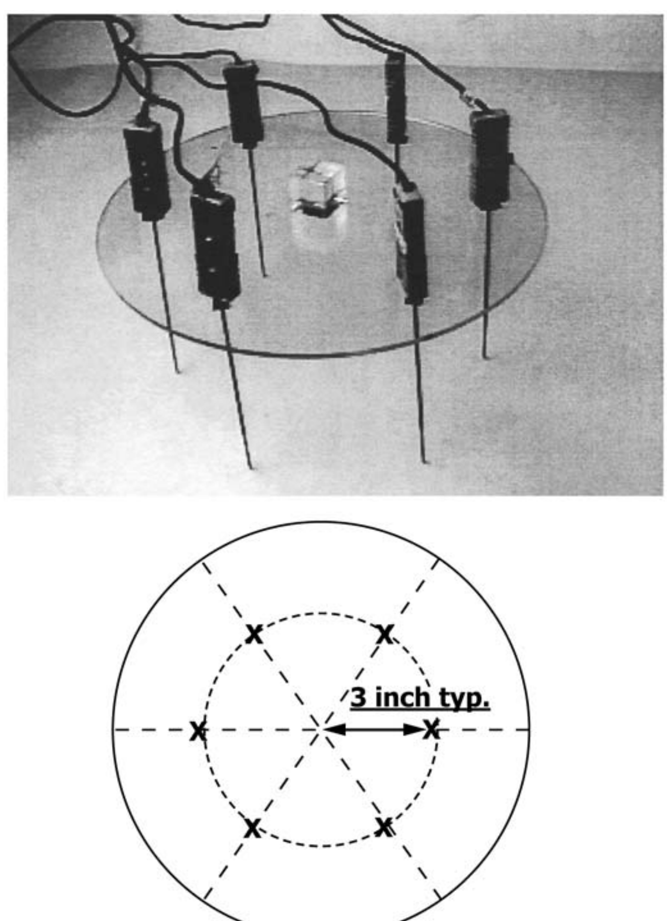
10.7 *Cook Time Determination:*

10.7.1 Set the calibrated temperature control to 475°F, preheat the conveyor oven and allow it to idle for 60 min. Estimate a cook time for pizza and set the conveyor in motion. The cook time is the time that it takes the entire pizza to pass completely through the oven cavity, starting from the point where the leading edge of the pizza enters the oven cavity until the point where the trailing edge of the pizza exits the oven cavity. The cook time will be different from the conveyor speed, which is the time it takes for a single point on the conveyor to pass through the oven cavity. The oven controls will most likely be based on the conveyor speed.

10.7.2 Remove a pizza from the refrigerator and place the pizza directly on the conveyor (do not use a pizza screen or pan) so that the leading edge of the pizza is adjacent to the entrance to the oven cavity. Do not allow more than 1 min to elapse from the time a pizza is removed from the refrigerator until it is placed on the conveyor.

10.7.3 Allow the pizza to pass through the oven cavity and cook. As soon as the entire pizza has passed through the oven cavity, remove the pizza from the conveyor and place the pizza on an insulated, nonmetallic surface such as corrugated cardboard. A standard cardboard pizza box is acceptable.

10.7.4 Determine the final temperature of the pizza by placing six thermocouple probes on the surface of the pizza. Locate the probes 3 in. from the center of the pizza and spaced equidistant from each other as shown in Fig. 1. The probes should penetrate the cheese and rest on the sauce-crust interface directly beneath the cheese. Allow no more than 10 s from the time the pizza is removed from the conveyor to the time the probes are placed on the pizza. Wait 30 s after the probes are placed on the pizza, which allows time for the probes to stabilize, record the temperatures of all six probes and average them together. Leave the probes in place and record and average the temperatures again at 40 s, 50 s and 60 s. Fig. 2 details the timing of the temperature measurement. The final pizza temperature is the highest of these four averaged temperature readings. If the final pizza temperature is not 195 ± 3°F, adjust the cook time and repeat the cook time determination test as necessary to produce a 195 ± 3°F final temperature.



NOTE 1—The structure shown in the above photograph can be gently set on top of the pizza during cook-time determination with just enough force to penetrate the cheese but not enough to push the probes beyond the sauce-crust interface. Because the sauce migrates into the crust during cooking, it is relatively easy to remain in the sauce-crust interface during temperature measurement.

FIG. 1 Location of Thermocouple Probes on Pizza Surface

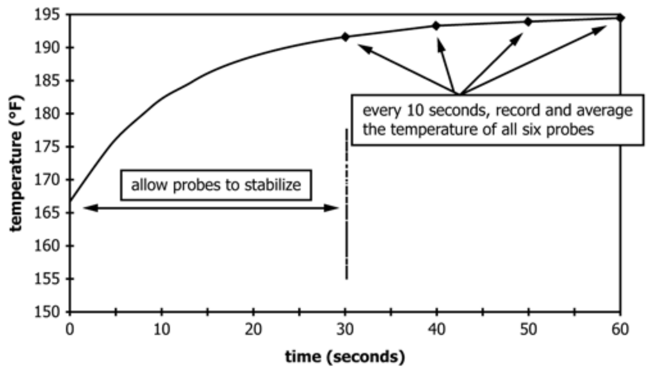


FIG. 2 Timing of Temperature Measurement After Probes are Placed on Cooked Pizza

NOTE 10—It is recommended that the six thermocouple probes be attached to a simple, lightweight, rigid structure that will maintain the proper spacing and upright position of the probes and will therefore help maintain the consistency of the temperature readings. The following photograph shows a thermocouple structure that is made of Plexiglas and includes a simple handle for easy placement of the structure on the pizza. This structure can be gently set on top of the pizza during cook time determination with just enough force to penetrate the cheese but not enough to push the probes beyond the sauce-crust interface. Because the sauce migrates into the crust during cooking, it is relatively easy to remain in the sauce-crust interface during temperature measurement.

10.7.5 Record the determined cook time for use during the cooking energy efficiency and production capacity tests.

10.8 *Cooking Energy Efficiency and Production Capacity:*

10.8.1 Set the calibrated temperature control to 475°F, preheat the conveyor oven and allow it to idle for 60 min. Set the conveyor speed to achieve the cook time for pizza determined in 10.7 and set the conveyor in motion.

10.8.2 The cooking energy efficiency and production capacity 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 cooking energy efficiency tests shall be performed in the following sequence, starting with the light loads and progressing to the heavy loads:

10.8.3 Divide the total number of pizzas required for each test run (as detailed in Table 2 and Table 1) into two equal parts. The pizzas included in the first half of the test run are used to stabilize the oven and are referred to as the "stabilization" pizzas and the pizzas included in the second half of the test run are used for efficiency determination and are referred to as the "test" pizzas. For example, an oven with a 32-in. conveyor width and a 40-in. cavity length will require 18 pizzas for a single heavy load test—9 stabilization pizzas and 9 test pizzas.

NOTE 11—During each test run, the pizzas are divided into two groups, stabilization pizzas and test pizzas. The stabilization pizzas will go into the oven first and are included to ensure that the oven is operating under steady state conditions. The stabilization pizzas are not a part of the energy equation and do not impact the energy efficiency. When the test pizzas go into the oven the tester begins recording the time and energy and the energy efficiency is based on these numbers. The classifications of "stabilization" and "test" within the test run are there to help differentiate between these two phases of the test.

10.8.4 Remove the first row of pizzas from the refrigerator. Place the pizza(s) on the conveyor so that the leading edge of the pizza(s) is adjacent to the entrance to the oven cavity. For a light load, place the second row of pizza on the conveyor as soon as the first row of pizza has passed completely through the oven cavity and continue this loading pattern for subsequent rows. For a heavy load, place the subsequent pizzas at an angel between 0 and 45° from the pizzas that have been placed along the inside edge of the conveyor belt, to maximize belt coverage. Place subsequent rows on the conveyor as soon as each row of pizza has passed completely into the oven cavity (that is, the leading edge of the second row will be immediately adjacent to the trailing edge of the first row) and continue this loading pattern for the remainder of the pizza test. Do not allow more than 1 min to elapse from the time a pizza is removed from the refrigerator until it is placed on the conveyor. The examples in Fig. 3 and Fig. 4 detail the heavy and light loading scenarios for an oven with a 32-in. conveyor width and a 40-in. cavity length.

10.8.5 As soon as the first row of test pizzas, the second half of the test run, is removed from the refrigerator, weigh each uncooked pizza and record the weight before placing the row of pizzas on the conveyor. Be sure the test pizzas are removed from the refrigerator, weighed and placed on the conveyor within the 1 min time allotted.

10.8.6 Start monitoring time and energy as soon as the leading edge of the test group of pizzas reaches the edge of the oven cavity (Fig. 3 and Fig. 4). Continue to weigh each test pizza as it is removed from the refrigerator and record the weights. Allow the pizza(s) to pass through the oven cavity and cook.

10.8.7 As soon as each row of test pizza has passed completely through the oven cavity, immediately remove the pizza(s) from the conveyor and determine the final pizza temperature (as detailed in the cook time determination) of one pizza from each row. The final temperature of each pizza shall be 195 ± 5°F. Remove any cheese that may stick to the thermocouple probes during temperature measurement and

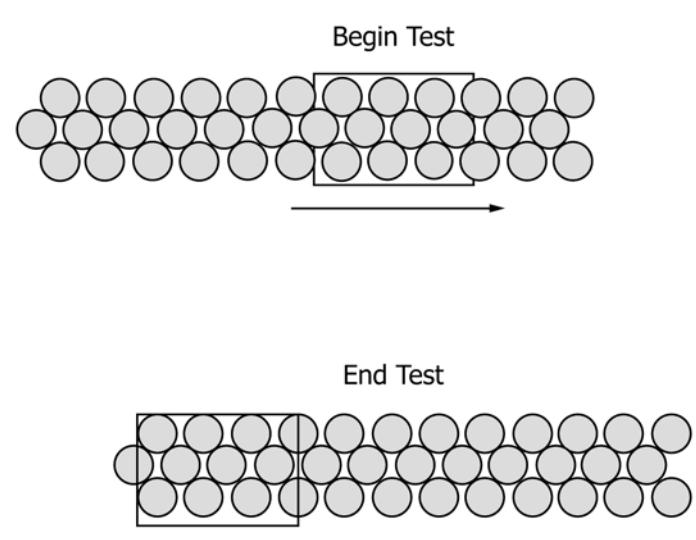


FIG. 3 Example of Heavy Load Test Scenario for an Oven with a 32-in. Conveyor Width and a 40-in. Cavity Length

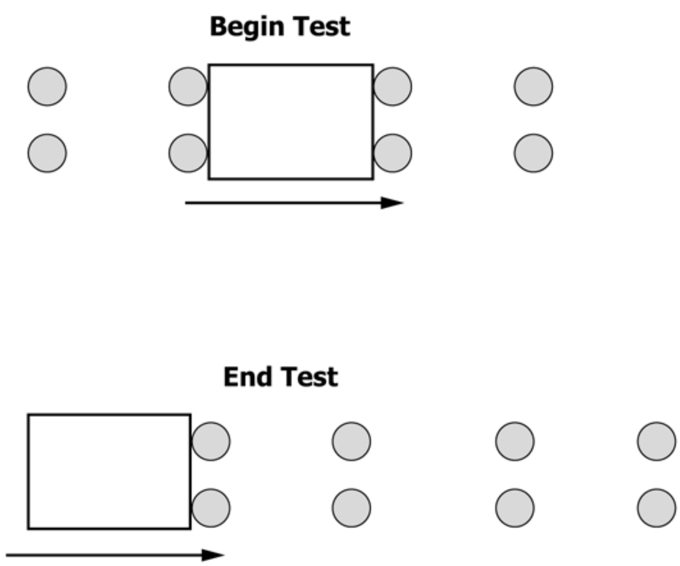


FIG. 4 Example of Light Load Test Scenario for an Oven with a 32-in. Conveyor Width and a 40-in. Cavity Length

place the cheese back on the pizza. Weigh each cooked test pizza and record the weight.

10.8.8 For a light load test, stop monitoring time and energy as soon as the last row of test pizza has moved completely out of the oven cavity. For a heavy load test, stop monitoring time and energy as soon as the last full row of test pizzas has moved completely within the oven cavity, that is, the trailing edge of the last full row of test pizzas is directly beneath the entrance to the oven cavity. The example in Fig. 3 details the start and stop timing for monitoring time and energy during light and heavy load testing of an oven with a 32-in. conveyor width and a 40-in. cavity length. Continue the test until all of the test pizzas have moved completely through the oven, making sure to weigh each test pizza and measuring the final temperature of one pizza from each row. Record the test time and the energy.

10.8.9 For heavy loads, calculate the average of the final pizza temperatures and verify that it is 195 ± 3°F. Record the average final pizza temperature. If the average final pizza temperature is less than 195 ± 3°F, then repeat 10.8.3 – 10.8.8, increasing the distance on the conveyor between the leading pizza(s) and the following pizza(s) until the specified final temperature is achieved. Record the increased distance.

NOTE 12—The final specified pizza temperature could also be achieved by reducing the speed of the oven conveyor and the overall effect on the oven efficiency and productivity would be the same as adding space between the pizzas.

10.8.10 In accordance with 11.8, calculate and report the cooking energy efficiency, cooking energy rate, electric energy rate (if applicable for gas conveyor ovens), and production capacity. Follow the procedure in Annex A1 to determine whether more than three tests runs are required.

11. Calculation and Report

11.1 *Test Conveyor Oven:*

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

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

11.3 *Gas Energy Calculations:*

11.3.1 For gas conveyor 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:

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

where:

E_{gas} = energy consumed by the appliance,
HV = higher heating value,
= energy content of gas measured at standard conditions, Btu/ft^3, and
V = actual volume of gas corrected for temperature and pressure at standard conditions, ft^3:

$$= V_{meas} \times T_{cf} \times P_{cf}$$

where:

$$= \frac{\textit{absolute standard gas temperature} \ ^\circ\text{R}}{\textit{absolute actual gas temperature} \ ^\circ\text{R}}$$

$$= \frac{\textit{absolute standard gas temperature} \ ^\circ\text{R}}{[\textit{gas temp} \ ^\circ F + 459.67] \ ^\circ\text{R}}$$

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

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

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

NOTE 13—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. PG&E standard conditions are 519.67 °R and 14.73 psia.

11.4 *Energy Input Rate:*

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

11.4.2 For gas or electric conveyor ovens, calculate and report the measured energy input rate (Btu/h or kW) based on the energy consumed by the conveyor 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 conveyor oven cavity temperature versus time for the preheat period.

11.6 *Idle Energy Rate:*

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

$$E_{idle\ rate} = \frac{E \times 60}{t} \tag{3}$$

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:*

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

$$E_{pilot\ rate} = \frac{E \times 60}{t} \tag{4}$$

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 Energy Rate and Production Capacity:*

11.8.1 Calculate the cooking energy efficiency, ηcook, for heavy- and light-load cooking tests based on:

$$\eta_{cook} = \frac{E_{food}}{E_{appliance}} \times 100 \tag{5}$$

where:

$$= (W_{uncooked} \times Cp(P) \times (T_2 - T_1)) + ((W_{uncooked} - W_{cooked}) * H_{fgt2})$$

η_{cook} = cooking energy efficiency, %, and
E_{food} = energy into food, Btu:
$W_{uncooked}$ = total weight of test pizzas before they are cooked,
W_{cooked} = total weight of cooked test pizzas,
$Cp\ (P)$ = the specific heat of pizzas based on the average specified pizza:
= 0.593 Btu/lb•°F

H_{fgt2} = the heat of vaporization of water (Btu/lb) based on T2 as found from a table of thermodynamic properties of water at saturation (see *1993 ASHRAE Handbook of Fundamentals*, Chapter 6, Table 3):
= 982 Btu/lb

T_2 = the average final temperature of the pizza,
T_1 = the initial temperature of the pizza, and
$E_{appliance}$ = energy into the appliance, Btu.

The conversion factor for electric energy is 3413 Btu/kWh.

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

$$E_{cook\ rate} = \frac{E \times 60}{t} \tag{6}$$

where:

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

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

11.8.3 Calculate production capacity (pizzas/h) based on:

$$PC = P_{num} \times \frac{60}{t} \tag{7}$$

where:

PC = production capacity of the conveyor oven, pizzas/h,
P_{num} = number of test pizzas in the heavy load, and
t = test time of heavy load cooking test, min.

11.8.4 Report the conveyor speed, the cook time and the three run average value of the cooking energy efficiency, cooking energy rate, and production capacity.

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.

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 conveyor oven; conveyor pizza oven; cooking energy efficiency; efficiency; energy; performance; production capacity; throughput

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS (SEE FIG A1.1)

A1. Procedure for Determining the Uncertainty in Reported Test Results

Note A1: 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. (e.g. thermocouples calibrated, range was operating within 5% of rated input during the test run).

A1.1 For the Cooking Energy Efficiency and Production Capacity procedures, results are reported for the cooking energy efficiency η_{cook} and the production capacity (*PC*). 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 (light, medium and heavy), the uncertainty of η_{cook} must be no greater than ± 10% before η_{cook} for that test can be reported. For the heavy load test, 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 η_{cook} is 40%, the uncertainty must not be larger than ± 4%. This means that the true η_{cook} 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 η_{cook} 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 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 A2: See A1.5 for example of applying this procedure

A1.4.1 *Step 1* - Calculate the average and the standard deviation for the η_{cook} and *PC* using the results of the first three test runs:

Note A3: 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 <u>sample</u> 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:

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

where:

Xa_3 - average of results for $\eta cook$, *PC*

FIG. A1.1 Procedure for Determining the Uncertainty in Reported Test Results

X_1, X_2, X_3 - results for η_{cook}, *PC*

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

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

where:

S_3 - standard deviation of results for η_{cook}, *PC*

$A_3 = (X_1)^2 + (X_2)^2 + (X_3)^2$

$B_3 = (1/3) \times (X_1 + X_2 + X_3)^2$

Note A4: 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.

The formula for the absolute uncertainty (3 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 η_{cook}, *PC*

C_3 - uncertainty factor for 3 test runs (Table A1)

Table A1

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

A 1.4.3 *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:

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

where:

FIG. A1.1 Procedure for Determining the Uncertainty in Reported Test Results *(continued)*

$\%U_3$ - percent uncertainty in average for η_{cook}, *PC*

U_3 - absolute uncertainty in average for η_{cook}, *PC*

Xa_3 - average η_{cook}, *PC*

A1.4.4 *Step 4* - If the percent uncertainty, $\%U_3$, is not greater than ± 10% for η_{cook} then report the average for η_{cook} and *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 η_{cook} then proceed to Step 5.

A1.4.5 *Step 5* - Run a fourth test for each η_{cook} which resulted in the percent uncertainty being greater than ± 10%

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

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

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

where:

Xa_4 - average of results for η_{cook}, *PC*

X_1, X_2, X_3, X_4 - results for η_{cook}, *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 η_{cook}, *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.

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

$$U_4 = C_4 \times S_4$$

$$U_4 = 1.59 \times S_4$$

FIG. A1.1 Procedure for Determining the Uncertainty in Reported Test Results *(continued)*

where:

U_4 - absolute uncertainty in average for η_{cook}, *PC*

C_4 - the uncertainty factor for 4 test runs (Table A1).

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:

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

where:

$\%U_4$ - percent uncertainty in average for η_{cook}, *PC*

U_4 - absolute uncertainty in average for η_{cook}, *PC*

Xa_4 - average η_{cook}, *PC*

A1.4.9 *Step 9* - If the percent uncertainty, $\%U_4$, is no greater than ± 10% for η_{cook} then report the average for η_{cook} and *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 η_{cook} 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:

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

where:

n - number of test runs

Xa_n - average of results for η_{cook}, *PC*

$X_1, X_2, X_3, X_4, \ldots X_n$ - results for η_{cook}, *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 η_{cook}, *PC* (n test runs)

$$A_n = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2 + \ldots + (X_n)^2$$

FIG. A1.1 Procedure for Determining the Uncertainty in Reported Test Results *(continued)*

$B_n = (1/n) \times (X_1 + X_2 + X_3 + X_4 + \ldots + X_n)^2$

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 η_{cook}, *PC*

C_n - uncertainty factor for n test runs (Table A1).

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 η_{cook}, *PC*

When the specified uncertainty, $\%U_{n,}$ is less than or equal to ± 10%; report the average for η_{cook} and *PC* along with their corresponding absolute uncertainty, U_n in the following format:

$Xa_n \pm U_n$

Note A5: In the course of running these tests, the tester may compute a test result that deviates significantly from the other test results. It may be tempting to discard such a result in an attempt to meet the ± 10% uncertainty requirement. This should be done only if there is some physical evidence that the test run from which that particular result was obtained was not performed according to the conditions specified in this method. For example, a thermocouple was out of calibration or the oven's input rate was not within 5% of the rated input. To be sure all results were obtained under approximately the same conditions, it is good practice to monitor those test conditions specified in this method.

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

A1.5.1 Three test runs for the full-energy input rate cooking efficiency test yielded the following η_{cook} results:

Test	η_{cook}
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 η_{cook}.

The average of the three test results:

FIG. A1.1 Procedure for Determining the Uncertainty in Reported Test Results *(continued)*

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

$Xa_3 = (1/3) \times (33.8 + 31.3 + 30.5)$

$Xa_3 = 31.9\%$

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 η_{cook} 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 η_{cook} is greater than ± 10%, the precision requirement has not been satisfied. An additional test is run in an attempt to reduce the uncertainty. The η_{cook} from the fourth test run was 31.8%.

A1.5.6 Recalculate the average and standard deviation for the η_{cook} using the fourth test result:

The new average η_{cook} is:

FIG. A1.1 Procedure for Determining the Uncertainty in Reported Test Results *(continued)*

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

$Xa_4 = (1/4) \times (33.8 + 31.3 + 30.5 + 31.8)$

$Xa_4 = 31.9\%$

The new standard deviation:

First calculate "A_4" and "B_4".

$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$

$A_4 = (33.8)^2 + (31.3)^2 + (30.5)^2 + (31.8)$

$A_4 = 4{,}064$

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

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

$B_4 = 4{,}058$

The new standard deviation for the η_{cook} 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 η_{cook} is reported along with its corresponding absolute uncertainty, U_4 as follows:

η_{cook}: 31.9 ± 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 η_{cook}.

FIG. A1.1 Procedure for Determining the Uncertainty in Reported Test Results *(continued)*

APPENDIXES

(Nonmandatory Information)

X1. RESULTS REPORTING SHEETS (SEE FIG X1.1)

Results Reporting Sheets

Manufacturer ________________

Model ________________

Serial # ________________

Date ________________

Test Reference Number (optional) ____________________________

Section 11.1 Test Oven

Description of operational characteristics :

____

____

____

____

Physical Dimensions

Size of oven:	_________	H x	_______	W x	_______	D inches
Conveyor width:	_________	inches				
Oven cavity length:	_________	inches				
Nominal conveyor width:	_________	feet				
Nominal oven cavity length:	_________	feet				

Section 11.2 Apparatus

____ Check if testing apparatus conformed to specifications in section 6.

Deviations :

____

____

____

FIG. X1.1 Results Reporting Sheets

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) ________________

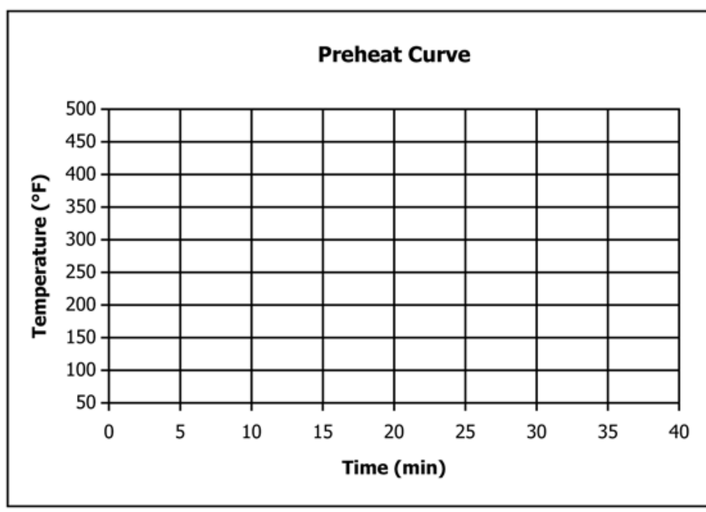
Section 11.5 Preheat Energy and Time

Test Voltage (V) ______________

Gas Heating Value (Btu/ft^3) ______________

Energy Consumption (Btu or kWh) ________________

Time from _______ °F to 475 °F (min) ________________



Section 11.6 Idle Energy Rate

Test Voltage (V) ______________

Gas Heating Value (Btu/ft^3) ______________

Idle Energy Rate (Btu/h or kW) ________________

FIG. X1.1 Results Reporting Sheets *(continued)*

Section 11.7 Pilot Energy Rate

Gas Heating Value (Btu/ft^3) ______________

Pilot Energy Rate (Btu/h) ________________

Section 11.8 Cooking Energy Efficiency and Cooking Energy Rate

Cook Time Determination:

Cook time: __________ min

Conveyor speed: __________ min

Light Load:

Test Voltage (V) ______________

Gas Heating Value (Btu/ft^3) ______________

Cooking Energy Efficiency (%) ________________

Cooking Energy Rate (Btu/h or kW) ________________

Electric Energy Rate (kW, gas ovens only) ________________

Heavy Load:

Test Voltage (V) ______________

Gas Heating Value (Btu/ft^3) ______________

Cooking Energy Efficiency (%) ________________

Cooking Energy Rate (Btu/h or kW) ________________

Electric Energy Rate (kW, gas ovens only) ________________

Production Capacity (pizzas/h) ________________

FIG. X1.1 Results Reporting Sheets *(continued)*

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

X2.1 Appliance test results are useful not only for benchmarking appliance performance, but also for estimating appliance energy consumption. The following procedure is a guideline for estimating conveyor oven energy consumption based on data obtained from applying the appropriate test method.

X2.2 The intent of this appendix is to present a standard method for estimating conveyor oven energy consumption based on ASTM performance test results. The examples contained herein are for information only and should not be considered an absolute. To obtain an accurate estimate of energy consumption for a particular operation, parameters specific to that operation should be used (for example, operating time and amount of food cooked under heavy and light loads).

X2.3 The appropriate conveyor oven performance parameters are obtained from Section 11.

X2.4 Procedure

NOTE X2.1—Sections X2.5 and X2.6 show how to apply this procedure.

X2.4.1 The calculation will proceed as follows. First, determine the appliance operating time and total number of preheats. Then estimate the typical quantity of food cooked per day. For example, a conveyor oven operating for 12 h a day with one preheat cooked 300 lb of food. Calculate the energy due to cooking, and then calculate the idle energy consumption. The total daily energy is the sum of these components plus the preheat energy. For simplicity, it is assumed that subsequent preheats require the same time and energy as the first preheat of the day.

X2.4.2 *Step 1*—Determine the conveyor oven operating time, number of preheats, and amount of food cooked per day (see Table X2.1).

X2.4.3 *Step 2*—Calculate the time and energy associated with the oven cooking.

TABLE X2.1 Conveyor Ovens Operation Assumptions

Operating Time	Number of Preheats	Total Amount of Food Cooked
12 h	1	300 lb

X2.4.3.1 Determine the total time cooking as follows:

$$t_h = \frac{\%h \times W}{PC} \quad (X2.1)$$

where:

t_h = total time cooking, h,
$\%h$ = percentage of food cooked during the day,
W = total weight of food cooked per day, lb, and
PC = conveyor oven's production capacity, lb/h.

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

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

where:

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

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

X2.4.4.1 Determine the total idle time as follows:

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

where:

t_i = total idle time, h,
t_{on} = total daily on-time, h,
n_p = number of preheats, and
t_p = preheat time, min.

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

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

where:

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

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

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

where:

$E_{gas,daily}$ = total daily gas energy consumption, Btu,
n_p = total number of preheats per day,
$E_{gas,p}$ = gas preheat energy consumption, Btu,
$E_{elec,daily}$ = total daily electric energy consumption, Btu, and
$E_{elec,p}$ = electric preheat energy consumption, Btu.

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

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}} \quad (X2.6)$$

where:

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

NOTE X2.2—It has been assumed that the appliance's contribution to the building's probable demand is the average demand for the appliance. This is useful because the probability of an appliance drawing its average rate during the period that the building peak is set is significantly higher than for any other input rate for that appliance. If data exists otherwise for a given operation, the probable contribution to demand can be other than the average demand.