INTERNATIONAL

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

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASHRAE Documents:*[2]

2013 ASHRAE Handbook of Fundamentals Chapter 1, Psychrometrics

2014 ASHRAE Handbook—Refrigeration Chapter 19 Thermal Conductivity of Foods, page 9 (R19.9); Diffusivity of foods, R19.17, and Enthalpy of foods R19.8

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

ASHRAE Guideline 2 2010 (RA 2014) Engineering Analysis of Experimental Data

2.2 *Other Document:*

AOAC Procedure 984.25 Moisture (Loss of Mass on Drying) in Frozen French Fried Potatoes[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *chamber stabilization pizzas, n*—full cooking cavity load of nominal 12 in. pizzas loaded at beginning of production capacity test.

3.1.2 *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, radiant, or quartz tubes. Top and bottom heat may be independently controlled.

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 conveyor oven during the cooking event.

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

3.1.5 *cooking stabilization pizzas, n*—full cooking chamber of nominal 12 in. pizzas continuously loaded directly following the test pizzas. Pizzas keep the cooking chamber consistent during the measured test pizzas.

[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.

[3] Available from AOAC International, 2275 Research Blvd., Suite 300, Rockville, MD 20850-3250, http://www.aoac.org.

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

3.1.7 *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.

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

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

3.1.10 *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.

3.1.11 *preheat time, n*—time (min.) required for the conveyor 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 conveyor oven can bring the specified food product to a specified "cooked" condition.

3.1.13 *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.

3.1.14 *test pizzas, n*—full cooking chamber of nominal 12 in. pizzas continuously loaded directly following the stabilization load. These are the pizzas measured for production capacity.

3.1.15 *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 conveyor oven thermostat is checked at a setting of 475°F (246°C) and the thermostat is adjusted as necessary.

4.2 *Energy Input Rate*—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. The input rate of the oven is determined to check whether the oven is operating properly. If the measured input rate is not within 5 % of the rated input, all further testing ceases until the appliance can be made to operate within this specification. For gas ovens, the pilot energy rate and the fan and control energy rate are also determined.

4.3 *Preheat Energy Consumption and Time*—The time and energy required to preheat the oven from room temperature 75 ± 5°F (24 ± 2.8°C) to 475 ± 5°F (246 ± 2.8°C) determined.

4.4 *Idle Energy Rate*—The idle energy rate (kBtu/h or kW) is determined with the oven set to maintain 475 ± 5°F (246 ± 2.8°C).

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

4.6 *Cooking Uniformity*—The uniformity of heating within the oven's cavity is determined and reported based on the product cooked temperature per cooking position and visual of product appearance top and bottom.

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*—This test provides a measure of an empty oven's energy consumption and pilot energy during noncooking periods, at a typical cooking temperature setting. It also provides an indicator of the combined effectiveness of components of the oven's design (for example, insulation, door seals, and combustion efficiency) that influence its energy consumption.

5.4 *Cooking Energy Efficiency*—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 (9.1 kg), with a resolution of 0.01 lb (0.005 kg) and an uncertainty of ±0.01 lb (±0.005 kg).

6.2 *Barometer,* for measuring absolute atmospheric pressure, with a range from 28 to 32 in. 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 (1.2 m) in depth, wall-mounted with the lower edge of the hood 6 ft , 6 in. (1.98 m) 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. (152 mm) past both sides and the front of the cooking appliance and shall not incorporate side curtains or partitions. Makeup air shall be delivered through face registers or from the space, or both.

6.4 *Convection Drying Oven,* with temperature controlled at 220 ± 5°F (104 ± –2.8°C), 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 0 to 15 in. H_2O, a resolution of 0.2 in. H_2O, and an uncertainty of ±0.1 in. H_2O.

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 (93.3°C) of less than 20 s.

6.11 *Temperature Readout Device,* connected to bare junction thermocouple probes, with a range from 0 to 450°F (−17.8 to 232°C), a resolution of 0.1°F (0.06°C), and an uncertainty of ±1.0°F (±0.6°C), used to measure the temperature of air (ambient and cavity), and ice/water mixture. The device readout shall be capable of displaying required average temperature(s) during cooking energy efficiency and cooking uniformity tests (minimum of 20 thermocouples needed).

6.12 *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 %.

6.13 *Pizza Cooking Screens,* for handling and cooking pizzas, 12 in. diameter aluminum (3003-H14 material) expanded metal 66 % open mesh. Weight 0.24± 0.02 Lps. New screens to be seasoned. (See Fig. 1.)

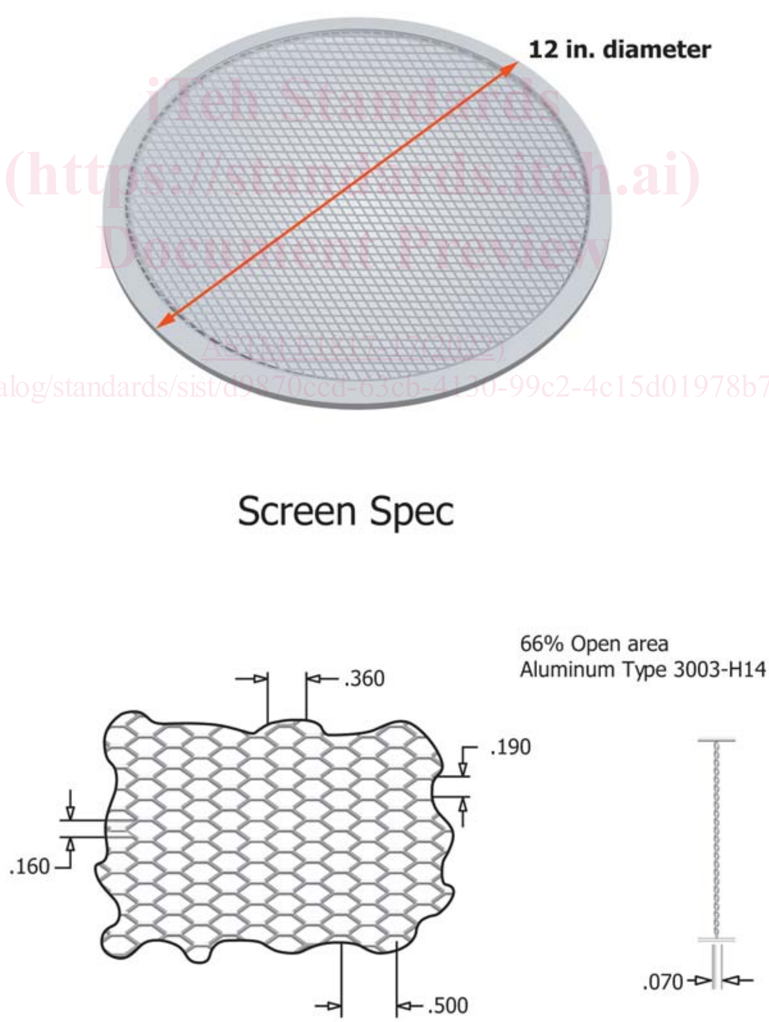

FIG. 1 Pizza Cooking Screen

FIG. 2 Discharge Gap Minimum 2.25 in. (57.2 mm); Load Minimum Gap 1.25 in. (31.8 mm)

NOTE 1—Minimum Discharge Opening 2.25 in.

FIG. 3 Pizza Exit Must Clear Discharge Opening Without Touching

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.[4]

7.5 Gravimetric moisture analysis shall be performed as follows: to determine moisture content, place a thawed, refrigerated 38 ± 2°F pizza on a dry, aluminum sheet pan and place the pan in a convection drying oven at a temperature of 220 ± 5°F (104 ± 2.8°C) for a period of 24 h. Weigh the sample

[4] The Food Service Technology Center has found that Villa Prima – Frozen (25.85 oz), 4 Cheese Pizza, Item # 73184 – complies with the pizza specification requirements for this test method. The sole source of supply of the pizza known to the committee at this time is Schwan's Food Company Inc., Marshall, MN, 56258. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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 (1⁄8 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. (152 mm) 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 (0.91 m) 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 (24 ± 2.8°C) within the testing environment when the exhaust ventilation system is operating.

9.1.1 Oven openings are to be set to minimum clearance openings for product entry and cooked discharge end. The load opening minimum 1.25 in. (31.8 mm). Discharged cooked minimum clearance of 2.25 in. (57.2 mm). See Fig. 2 and Fig. 3.

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 (246°C) 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 (246 ± 2.8°C), then the conveyor oven's thermostat is calibrated.

10.2.6 If the average temperature is not 475 ± 5°F (246 ± 2.8°C), 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 (24 ± 2.8°C). Set the calibrated temperature control to 475°F (246°C) 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 (241°C). 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 (±5.6°C) of the oven set point (that is, 465°F (241°C) when the thermostat is set to maintain 475°F (246°C)).

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

10.4 *Idle Energy Rate:*

10.4.1 Set the calibrated temperature control to 475°F (246°C) 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 (246°C), 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 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. Pizzas should be placed atop the approximate center of the pizza screens, to facilitate ease of handling and loading during tests.

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 angle between 0 and 45°, to maximize belt coverage (see Fig. 4). Table 1 lists how many pizzas are required for each run of a heavy load test.

NOTE 6—Ensure enough stabilization pizzas to follow test pizzas to maintain a full cooking compartment.

FIG. 4 Pizzas Loaded to Maximize Belt Coverage

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.

10.6.1.2 Pizza screens to be seasoned to avoid product sticking (method to season screens: coat screen with cooking oil and bake at 475°F until no visible smoke emitting).

10.6.2 Prepare frozen pizzas by placing two pizza screens on full size sheet pan. Place pizzas on center of screens. Cover the pizzas with cellophane (to inhibit moisture loss), and then place in a refrigerator to thaw until they stabilize at 38 ± 2°F (3.3 ± 1.1°C). (Minimum 12 h thaw in refrigeration.) Do not test with pizzas that have been in the refrigerator more than 48 h.

NOTE 7—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 8—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 9—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 10—Table 1 is 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 heavy load test are divided into two equal groups and referred to as "stabilization" pizzas and "test" pizzas. The quantities specified in Table 1 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 (91 ± 1.7°C) final pizza temperature after cooking.

10.7 *Cook Time Determination:*

10.7.1 Set the calibrated temperature control to 475°F (246°C), 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 (centered on the pizza screen) directly on the scale and record weight of pizza and screen.

10.7.3 Load conveyor cooking feed belt so that the leading edge of the two outer edge pizza screens are adjacent to the entrance to the oven cavity. Note that the screens are to be placed to the inter edge of belt knuckle (Fig. 5). 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.

10.7.4 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.

10.7.5 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. 6. 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. Allow time for the probes to stabilize, record the highest average temperature of all six probes. Fig. 7 details the timing of the temperature measurement. The final pizza temperature is the highest average temperature reading. If the final pizza temperature is not 195 ± 3°F (91 ± 1.7°C), adjust the cook time and repeat the cook time determination test (adjust cook time) as necessary to produce a 195 ± 3°F (91 ± 1.7°C) final temperature.

NOTE 11—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.

10.7.6 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 (246°C), 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).

10.8.3 Divide the total number of pizzas required for each test run (as detailed in Table 1) into four equal parts. The pizzas included in the first quarter of the test run are used to stabilize the oven and are referred to as the "stabilization" pizzas and the

FIG. 5 Pizza screen edge aligned with inside knuckle of belt, result pizza approx. 1 in. from O.D. of belt width

pizzas included in the second half are used for efficiency determination and are referred to as the "test" pizzas. The last quarter are "cooking stabilization" to keep the test pizza cooking chamber consistent while test pizzas exit chamber. For example, an oven with a 32-in. (812.8 mm) conveyor width and a 40-in. (1016 mm) cavity length will require 36 pizzas for a single heavy load test—9 cooking chamber stabilization pizzas, 18 test pizzas, followed by 9 cooking stabilization pizzas.

NOTE 12—During each test run, the pizzas are divided into three groups, cavity stabilization pizzas, test pizzas, and cooking stabilization. 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. Following the test pizzas are another full chamber load of stabilization pizzas. The classifications of "stabilization" and "test" within the test run are there to help differentiate between these three phases of the test.

10.8.4 Remove the first row of pizzas from the refrigerator, keeping it atop the screen. Place the pizza(s) on the scale and record the weight of the pizza on the screen. Place pizzas on conveyor so that the leading edge of the pizza(s) is adjacent to the entrance to the oven cavity. Heavy load, place two pizzas to the outer edge of belt width, extending all the way to the belt inner knuckle edges (see Fig. 8) and 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 coverage. The pizza screens should be touching, but should not overlap. 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 example in Fig. 8 details the heavy loading scenario for an oven with a 32-in. (812.8 mm) conveyor width and a 40-in. (1016 mm) cavity length.

10.8.5 As soon as the chamber stabilization rows of pizzas are loaded the "test pizzas" are weighed, each uncooked pizza on screen, 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. 8). 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 pizzas has passed completely through the oven cavity, immediately remove the pizza(s) from the conveyor, separate from the pizza screen and determine the final pizza temperature (as detailed in the cook time determination) of one pizza from each row. The final

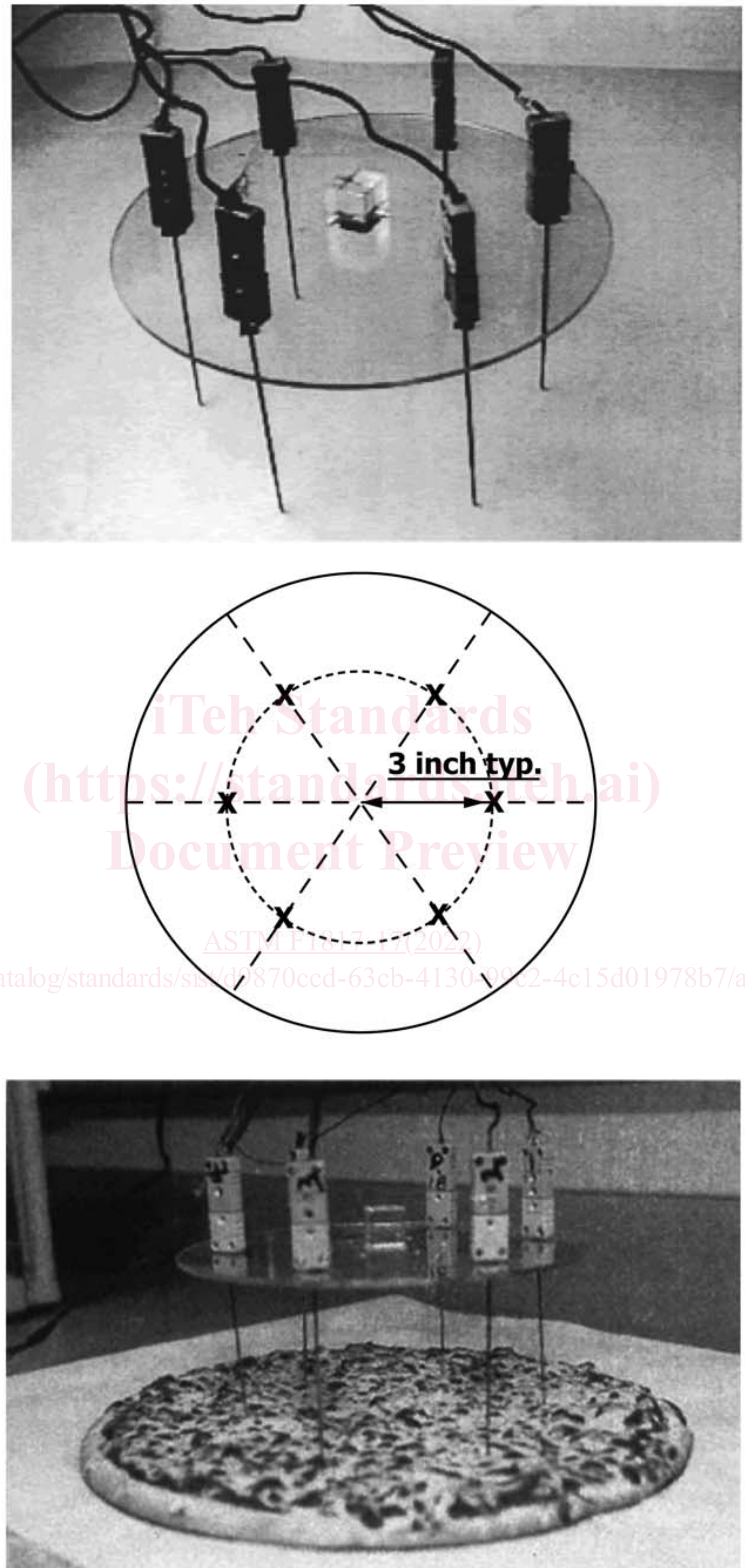

FIG. 6 Location of Thermocouple Probes on Pizza Surface

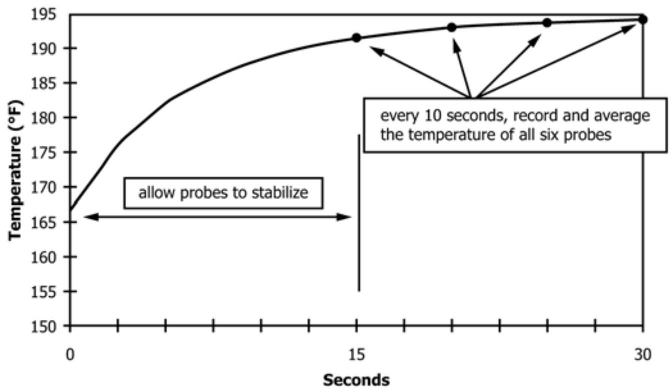

FIG. 7 Timing of Temperature Measurement After Probes are Placed on Cooked Pizza

temperature of each pizza shall be 195 ± 5°F. Remove any cheese that may stick to the thermocouple probes during temperature measurement and place the cheese back on the pizza. Weigh each cooked test pizza (no screen) and record the weight. Place the test pizza screens to the side until the end of the test. Do not include stabilization screens weight. Once the test has concluded, weigh all the test pizza screens and record their combined weight.

10.8.8 For a heavy load test, stop monitoring time and energy as soon as the cook stabilization first full row of pizzas has moved to the leading edge directly beneath the entrance to the oven cavity (see Fig. 9). The example in Fig. 8 details the start and stop timing for monitoring time and energy during heavy load testing of an oven with a 32-in. conveyor width and a 40-in. cavity length. Continue the test until the entire 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. Alternate pizza temperature measurements to measure each position across the width of the conveyor belt. Record the test time and the energy. Continue loading pizzas (cook stabilization) to maintain a full cavity load following the test pizzas.

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, decreasing belt speed until the specified final temperature is achieved. Record the increased time.

NOTE 13—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, cooking energy per square foot, 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 10.2.3).

11.3.2 Calculate the energy consumed based on:

$$E_{gas} = V \times HV \tag{1}$$

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:

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

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

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

P_{cf} = pressure correction factor

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

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

NOTE 14—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:

$$E_{input\ rate} = \frac{E \times 60}{t} \tag{2}$$

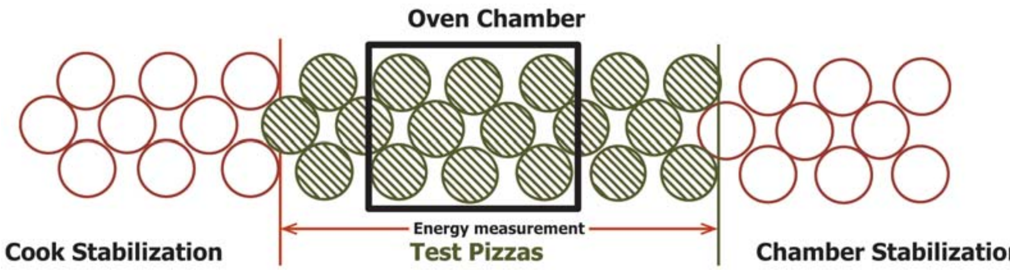

FIG. 8 Example of Heavy Load Test Scenario for an Oven with a 32-in. Conveyor Width and a 40-in. Cavity Length

FIG. 9 First Row of Pizzas Directly Beneath Entrance to Oven Cavity

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, including electric energy used for gas ovens, and
t = test period, min.

11.6.2 Idle energy rate per sq-ft of cooking chamber:

$$idle\ sq{\cdot}ft = \frac{E_{idle\ rate}}{\frac{(W \times L)}{144\ in.^2/sqft}} \tag{4}$$

where:

$E_{idle\ rate}$ = idle energy rate, Btu/h or kW,
W = width of cooking belt (inches), and
L = length of cooking chamber (inches).

11.7 *Pilot Energy Rate:*

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

$$E_{pilot\ rate} = \frac{E \times 60}{t} \tag{5}$$

where:

$E_{pilot\ rate}$ = pilot energy rate, Btu/h,
E = energy consumed during the test period, Btu, including electric energy used for gas ovens, and
t = test period, min.

NOTE 15—The conversion factor for electric energy is 3413 Btu/kWh.

11.8 *Cooking Energy Efficiency, Cooking Energy Rate and Production Capacity:*

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

$$\eta_{cook} = \frac{E_{food}}{E_{appliance}} \times 100 \tag{6}$$

where:

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