Standard Test Method for Performance of Conveyor Toasters[1]

This standard is issued under the fixed designation F2380; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method evaluates the energy consumption and cooking performance of conveyor toasters. The food service operator can use this evaluation to select a conveyor toaster and understand its energy consumption.

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

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

1.3.1 Energy input rate and preheat temperature profile (10.2),

1.3.2 Preheat energy consumption and time (10.3),

1.3.3 Idle energy rate (10.4),

1.3.4 Pilot energy rate (if applicable, 10.5),

1.3.5 Cooking energy rate (10.8), and

1.3.6 Production capacity (10.8).

1.4 The values stated in inch-pound units are to be regarded as standard. The SI units given in parentheses are for information only.

1.5 *This test method may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

2.2 *ASHRAE Document:*

ASHRAE Guideline 2 (RA90) Engineering Analysis of Experimental Data[3]

2.3 *UL Document:*

UL 1026 Electric Household Cooking and Food Service Appliances[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *conveyor toaster, n*—an appliance for caramelizing bread products that carries the bread product on a belt or chain 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 rate, n*—average rate of energy consumption (Btu/h or kW) during the production capacity tests.

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

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

3.1.5 *toaster cavity, n*—that portion of the conveyor toaster in which bread products are heated or toasted.

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

3.1.7 *preheat energy, n*—amount of energy consumed (Btu or kWh), by the conveyor toaster while preheating its cavity from ambient temperature to the determined steady state temperature.

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

3.1.9 *production capacity, n*—maximum rate (slices/h) at which a conveyor toaster can bring the specified bread product to a specified "toasted" condition.

[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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

[4] Available from Underwriters Laboratories (UL), 333 Pfingsten Rd., Northbrook, IL 60062-2096, http://www.ul.com.

3.1.10 *production rate, n*—rate (slices/h) at which a conveyor toaster brings the specified food product to a specified "toasted" condition. This does not necessarily refer to maximum rate. Production rate varies with the amount of food being toasted.

3.1.11 *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 Energy input rate is determined to confirm that the conveyor toaster is operating within 5 % of the nameplate energy input rate. For gas conveyor toaster, the pilot energy rate and the fan and control energy rates are also determined.

4.2 Preheat energy and time are determined.

4.3 Idle energy rate is determined.

4.4 Production rate is determined using sliced bread as a food product.

5. Significance and Use

5.1 The energy input rate test is used to confirm that the conveyor toaster is operating properly prior to further testing.

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

5.3 Idle energy rate and pilot energy rate can be used to estimate energy consumption during non-cooking periods. In addition, a power saving mode (if applicable) will demonstrate energy savings during idle periods.

5.4 Production capacity information can help an end user to better understand the production capabilities of a conveyor toaster 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. It shall have a resolution of 0.2 in. Hg and an uncertainty of 0.2 in. Hg.

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

6.4 *Pressure Gage,* for monitoring natural gas pressure. It shall have a range of zero to 10 in. water, a resolution of 0.5 in. water, and a maximum uncertainty of 1 % of the measured value.

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

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

6.7 *Thermocouple,* high temperature glass insulated, 24 gage, type K thermocouple wire, connected at the exposed ends by tightly twisting or soldering the two wires together.

6.8 *Watt-Hour Meter,* for measuring the electrical energy consumption of a conveyor toaster, 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 *Bread for Toasting,* shall be a generic grocery store brand, 1.5 ± 0.1 lb white loaf with a crown, consisting of 20 slices (not including the ends) measuring approximately 4.5 by 4.5 by 0.5 in. per slice. Each slice must weigh 0.065 ± 0.01 lb. The bread shall be stored at room temperature 75 ± 5°F.

NOTE 1—The bread is not to have any type of topping such as a butter top, flour top, or any seed/nut topping. Sandwich type bread is not to be used because it does not have a crown. In addition, loaves of bread that only have 19 slices (not including the heals) typically have too high of individual slice weight. The 1.5 lb of generic store brand white bread that has 20 slices (not including the heals) more often than not consists of individual slices that weigh approximately 0.065 lb which is specified for this test method.

8. Sampling and Test Units

8.1 *Conveyor Toaster*—Select a representative production model for performance testing.

9. Preparation of Apparatus

9.1 Install the appliance according to the manufacturer's instructions. The associated heating or cooling system shall be capable of maintaining an ambient temperature of 75 ± 5°F (24 ± 3°C) 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 toaster 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 toaster 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 toaster, confirm (while the conveyor toaster 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—It is the intent of the testing procedure herein to evaluate the performance of a conveyor toaster at its rated gas pressure or electric voltage. If an electric unit is rated dual voltage (that is, designed to operate at either 240 or 480 V with no change in components), the voltage selected by the manufacturer or tester, or both, shall be reported. If a conveyor toaster is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the unit (for example, preheat time) may differ at the two voltages.

9.4 For a gas conveyor toaster, 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 day's 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 toaster 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 toasters, 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 toasters, 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 day's 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 toaster.

10.2 *Energy Input Rate and Preheat Temperature Profile:*

10.2.1 Install a thermocouple ¼ in. above the conveyor, at the center of the toaster cavity (side to side and front to back).

NOTE 5—When placing the thermocouple wire in the toaster cavity above the conveyor belt, it is highly suggested to feed the thermocouple wire in from the front of the unit, in the same direction as the belt travels. This will prevent the toast from fouling the thermocouple wire, which could get tangled in the conveyor belt. In addition, having the thermocouple wire visible will serve as a reminder as not to place the bread over the thermocouple when loading the toaster during the testing.

10.2.2 Turn the conveyor toaster on, and set the temperature controls to their maximum settings (if applicable). Record the time, temperature, and energy consumption for one hour. At this time the conveyor toaster should have reached a steady state temperature as described in Section 10.2.3.

10.2.3 At the end of that hour, create a temperature plot (see Fig. 1). On that plot, when the temperature reaches a steady state (a steady state temperature is when the cavity temperature is neither rising nor falling, but instead holding a consistent temperature). This consistent temperature or "steady state" temperature idle will be used to determine when the unit is preheated. The toaster is considered preheated when the temperature reaches 95 % of its steady state temperature. If the unit has not reached a steady state temperature within an hour,

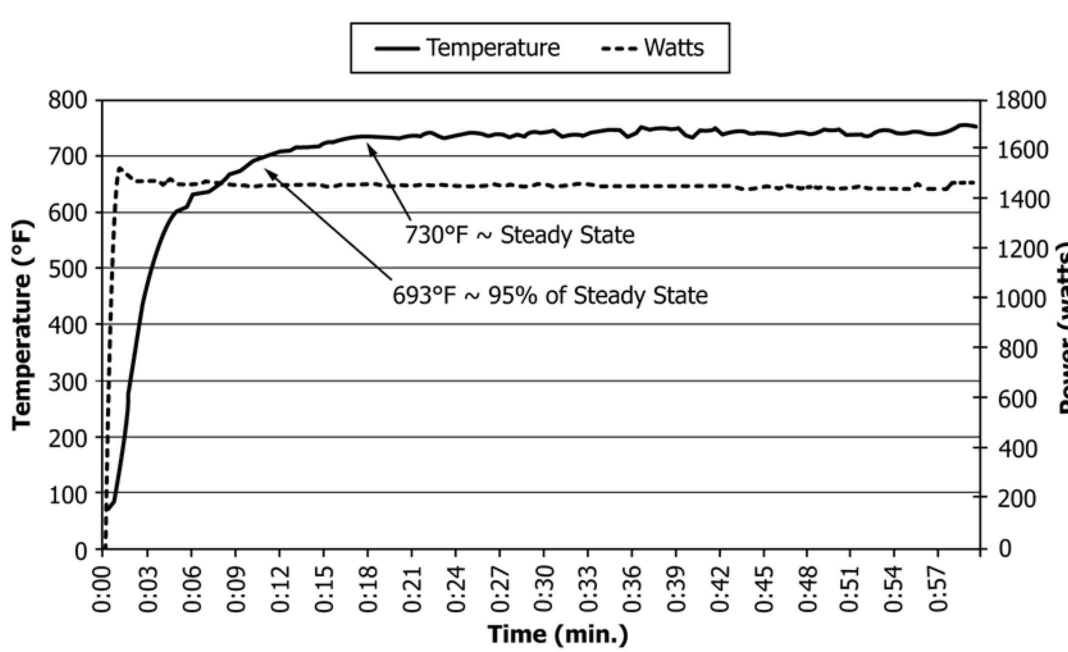

FIG. 1 Conveyor Toaster Preheat Profile

repeat 10.2.2 and increase the monitoring time from 1 h to 2 h, or until a steady state temperature is reached.

NOTE 6—Research at the Food Service Technology Center indicates that a conveyor toaster is sufficiently preheated and ready to cook/toast when the toaster's cavity temperature reaches 95 % of the toaster's steady state temperature. In Fig. 1, the steady state temperature is 730°F, and 95 % of that steady state temperature is 693°F. The unit then can be considered preheated when it reaches 693°F and ready to toast.

10.2.4 In accordance with 11.4, calculate and record the conveyor toaster's energy input rate and compare the result to the rated nameplate input. For gas conveyor toasters, 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 control energy rate.

10.3 *Preheat Energy Consumption and Time:*

10.3.1 Verify that the conveyor toaster cavity temperature is 75 ± 5°F (24 ± 3°C) and turn the conveyor toaster on.

10.3.2 Record the time, temperature, and energy consumption required to preheat the conveyor toaster, from the time when the unit is turned on until the time when the conveyor toaster cavity reaches a steady state temperature as determined in 10.2.3. Recording shall occur at intervals of 5 s or less in order to accurately document the temperature rise of the toaster cavity. The toaster is considered preheated when the temperature reaches 95 % of its steady state temperature.

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 and Power Saving Mode/Control:*

10.4.1 Turn on the controls (to the highest setting if applicable) and preheat the conveyor toaster.

10.4.2 Allow the conveyor toaster to idle for 60 min. If the appliance features a standby or power saving mode, then this mode shall be enabled for the 60-min stabilization period.

10.4.3 At the end of 60 min, begin recording the conveyor toaster's idle energy consumption (with all the controls at their highest settings, if applicable, and standby mode enabled, if applicable) for 2 h. Record elapsed time, energy consumption, and conveyor toaster temperature for the 2 h test period.

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

10.5 *Pilot Energy Rate:*

10.5.1 For a gas conveyor toaster with a standing pilot, set the gas valve at the "pilot" position and set the conveyor toaster'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 *Bread Preparation:*

10.6.1 Measure the width of the toaster conveyor and determine the nominal width by rounding down to the nearest 5 in. (127 mm) to see how many slices of bread can fit across the conveyor at one time. For example, a conveyor that is 10½-in. (267-mm) wide can be divided into two sections, allowing two standard slices of bread to fit side-by-side on the conveyor.

10.6.2 Based on the conveyor toaster belt width (two slice, three slice toaster, and so forth) prepare enough loaves (in accordance with Section 7) for a test. Each test will consist of a minimum of three runs. Each 5-in. (127-mm) wide lane of the conveyor shall toast a minimum of sixty slices. For example, a 2-slice toaster will require a minimum of 120 slices of bread; a three-lane toaster will require a minimum of 180 slices of bread. The loaves are to be kept sealed in their package at room temperature (to inhibit moisture loss), until they are loaded into the conveyor toaster, and be no more than three-day-old bread. Heals are not to be used in either the stabilization test period or the production test period.

10.6.3 The loaves included in the first portion of the test run are used to stabilize the toaster and are referred to as the "stabilization" loaves and the loaves included in the second half of the test run are used for production capacity and are referred to as the "test" loaves.

10.6.4 Prepare an additional ten loaves of bread for determination of the cook time. The actual number of loaves needed for the cook time determination will vary with the number of trials needed to establish a cooking time/conveyor belt speed which consistently yields a #5 color on the Food Color Chart in Appendix B of UL 1026.

10.7 *Cook Time Determination:*

10.7.1 Turn the conveyor toaster on, and set the temperature controls to the maximum settings (if applicable). Preheat the conveyor toaster and allow it to idle for 60 min (with the power saving mode disabled, if applicable).

10.7.2 Estimate a cook time for the test and set the conveyor in motion. The cook time is the time that it takes the entire slice of bread to pass completely though the toaster cavity, starting from the point where the leading edge of the slice enters the toaster cavity until the point where the trailing edge of the slice exits the toaster cavity falling into the exit tray.

NOTE 7—The cook time of a single slice of bread will be different to that of maximum capacity of the toaster (production capacity) when the unit has been preheated. Therefore, a test period is necessary for determining the proper conveyor speed in order to obtain acceptable toast brownness (color) while examining the toaster's production capacity.

10.7.3 Begin loading the toaster, (usually two or three slices at a time) with no space between the bread on the loader (reminder, keep the bread off the thermocouple wire while testing).

10.7.4 Allow the bread slice to pass through the toaster cavity and toast. As soon as the slice falls off the conveyor chain on to the unload zone, place the toast on a full size sheet pan to check for proper toast color.

10.7.5 Once the toast reaches #5 on the UL Food Color Chart, continue toasting an additional 40 slices of bread to assure the conveyor toaster is maintaining a consistent UL Food Color Chart #5 toast color. If the toast color changes (darker or lighter), adjust the conveyor belt speed and continue toasting additional bread slices until 40 slices of bread per toaster section can be toasted without any color deviation.

NOTE 8—The adjustment of the conveyor speed will require some trial and error, largely due to the fact that the toaster will burn the first few slices of bread as the toasting chamber stabilizes at a lower temperature under full load conditions, thus requiring a slower conveyor speed to obtain a #5 type toast from the UL Food Color Chart.

10.7.6 Once the correct conveyor speed is determined for the production capacity test, mark the position of the conveyor belt control with a piece of tape or a permanent maker. This will be the conveyor speed for the production capacity test. Note how many slices of bread it takes to stabilize the toaster and round up to the nearest ten slices. This will be the amount used for the stabilization period of the production capacity test.

10.8 *Production Capacity:*

10.8.1 The production capacity test is 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).

10.8.2 Set the conveyor speed as determined in 10.7, preheat the conveyor toaster, and allow it to stabilize for 60 min. Do not activate the power saving mode (if applicable).

10.8.3 Separate the total number of loaves required for each test run into stabilization loaves and test loaves. For example, a two-slice toaster with a nominal 10-in. (254-mm) wide conveyor will require a minimum of 20 slices per lane (two loaves) for the stabilization period, and 40 slices per lane (four loaves) for the production capacity test for a total of 120 slices of bread. At no time are heals of the bread to be used for any portion of the testing. The actual amount needed for the stabilization period is determined in 10.7.

NOTE 9—During each test run, the loaves are divided into two groups, stabilization loaves and test loaves. The stabilization loaves will go into the toaster first and are included to ensure that the toaster is operating under steady state conditions. The stabilization loaves are not a part of the production capacity. When the test loaf slices go into the toaster, the tester begins recording the time and energy and the production capacity 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 bread from the package that has been stored at room temperature (75 ± 5°F (24 ± 3°C)). Place the stabilization loaves directly on the load-up tray feeding the conveyor (do not use the heals) so that the leading edge of the bread slice is in contact with the conveyor chain, and continue loading the bread slices onto the load-up tray as room becomes available. Continue loading the toaster until all the stabilization loaves have been fed into the toaster as determined in 10.7, followed by the 40 test slices per lane.

10.8.5 As soon as the first row of test slices is even with the leading edge of the toaster cavity, begin monitoring time, temperature, and energy immediately.

10.8.6 As the toast begins to fall on to the unloading zone, place the toast on a sheet pan.

10.8.7 During the testing phase of the production capacity test, pull every fifth slice of bread from the sheet pan and verify its color to the Toast Color Chart #5, alternating toaster sections, and sides of the toast. If the color of the toast begins to darken or becomes lighter, stop testing and start over at 10.7 to redetermine the toast cook time (conveyor belt speed) and the numbers of slice required to stabilize the toaster.

10.8.8 Stop monitoring time and energy as soon as the last row of test slices has fallen off the conveyor on to the unload zone.

10.8.9 In accordance with 11.8, calculate and report the cooking energy rate, electric energy rate (if applicable for gas conveyor toasters), final cook time 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 Toaster*—Summarize the physical and operating characteristics of the conveyor toaster. 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 toasters, report the voltage for each test.

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

11.3 *Gas Energy Calculations:*

11.3.1 For gas conveyor toasters, 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:

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

where:

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

where:

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

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

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

P_{cf} = pressure correction factor,

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

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

NOTE 10—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Standard conditions using Practice D3588 are 14.696 psia (101.33 kPA) and 60°F (519.67°R (288.71°K)).

11.4 *Energy Input Rate:*

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

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

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

where:

q_{input} = measured peak energy input rate, Btu/h or kW,
E = energy consumed during the period of peak energy input, Btu/h or kW, 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 toaster cavity temperature versus time for the preheat period.

11.5.3 Report the starting cavity temperature, final stabilized cavity temperature, and preheat rate (°F (°C)).

11.6 *Idle Energy Rate:*

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

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

where:

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

11.6.2 Report the average idle cavity temperature and whether a standby mode was enabled.

11.7 *Pilot Energy Rate*—Calculate and report the pilot energy rate (Btu/h) based on:

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

where:

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

11.8 *Cooking Energy Rate and Production Capacity:*

11.8.1 Calculate the cooking energy rate based on:

$$q_{cook} = \frac{E \times 60}{t} \quad (5)$$

where:

q_{cook} = cooking energy rate, Btu/h or kW,
E = energy consumed during 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.

11.8.2 Calculate production capacity (slices/h) based on:

$$PC = \frac{P_{num} \times 60}{t} \quad (6)$$

where:

PC = production capacity of the conveyor toaster, slices/h,
P_{num} = number of test slices, and
t = test time of cooking test, min.

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

12. Precision and Bias

12.1 *Precision:*

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

12.1.1.1 The repeatability of each reported parameter is being determined.

12.1.2 *Reproducibility* (multiple laboratories):

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

12.2 *Bias*—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 toaster; energy; performance; production capacity; test method; throughput

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

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

A1.1 For the cooking energy rate and production capacity results, the uncertainty in the averages of at least three test runs is reported. For each loading scenario, the uncertainty of the cooking energy rate and production capacity must be no greater than ±10 % before any of the parameters for that loading scenario can be reported.

A1.2 The uncertainty in a reported result is a measure of its precision. If, for example, the production capacity for the appliance is 30 lb/h, the uncertainty must not be greater than ±3 lb/h. Thus, the true production capacity is between 27 and 33 lb/h. This interval is determined at the 95 % confidence level, which means that there is only a 1 in 20 chance that the true production capacity could be outside of this interval.

A1.3 Calculating the uncertainty not only guarantees the maximum uncertainty in the reported results, but is also used to determine how many test runs are needed to satisfy this requirement. The uncertainty is calculated from the standard deviation of three or more test results and a factor from Table A1.1, which lists the number of test results used to calculate the average. The percent uncertainty is the ratio of the uncertainty to the average expressed as a percent.

A1.4 *Procedure* :

NOTE A1.2—Section A1.5 shows how to apply this procedure.

A1.4.1 *Step 1*—Calculate the average and the standard deviation for the test result (cooking-energy efficiency or production capacity) using the results of the first three test runs, as follows:

A1.4.1.1 The formula for the average (three test runs) is as follows:

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

where:

Xa_3 = average of results for three test runs, and
X_1, X_2, X_3 = results for each test run.

TABLE A1.1 Uncertainty Factors

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

A1.4.1.2 The formula for the sample standard deviation (three test runs) is as follows:

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

where:

S_3 = standard deviation of results for three test runs,
A_3 = $(X_1)^2 + (X_2)^2 + (X_3)^2$, and
B_3 = $(⅓) \times (X_1 + X_2 + X_3)^2$.

NOTE A1.3—The formulas may be used to calculate the average and sample standard deviation. However, a calculator with statistical function is recommended, in which case be sure to use the sample standard deviation function. The population standard deviation function will result in an error in the uncertainty.

NOTE A1.4—The "A" quantity is the sum of the squares of each test result, and the "B" quantity is the square of the sum of all test results multiplied by a constant (⅓ in this case).

A1.4.2 *Step 2*—Calculate the absolute uncertainty in the average for each parameter listed in Step 1. Multiply the standard deviation calculated in Step 1 by the uncertainty factor corresponding to three test results from Table A1.1.

A1.4.2.1 The formula for the absolute uncertainty (three test runs) is as follows:

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

$$U_3 = 2.48 \times S_3$$

where:

U_3 = absolute uncertainty in average for three test runs, and
C_3 = uncertainty factor for three test runs (Table A1.1).

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

A1.4.3.1 The formula for the percent uncertainty (three test runs) is as follows:

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

where:

$\%U_3$ = percent uncertainty in average for three test runs,
U_3 = absolute uncertainty in average for three test runs, and
Xa_3 = average of three test runs.

A1.4.4 *Step 4*—If the percent uncertainty, $\%U_3$, is not greater than ±10 % for the cooking energy rate and production capacity, report the average for these parameters 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 the cooking energy rate or production capacity, proceed to Step 5.

A1.4.5 *Step 5*—Run a fourth test for each loading scenario whose percent uncertainty was greater than ±10 %.

A1.4.6 *Step 6*—When a fourth test is run for a given loading scenario, calculate the average and standard deviation for test results using a calculator or the following formulas:

A1.4.6.1 The formula for the average (four test runs) is as follows:

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

where:

Xa_4 = average of results for four test runs, and
X_1, X_2, X_3, X_4 = results for each test run.

A1.4.6.2 The formula for the standard deviation (four test runs) is as follows:

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

where:

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

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

A1.4.7.1 The formula for the absolute uncertainty (four test runs) is as follows:

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

$$U_4 = 1.59 \times S_4$$

where:

U_4 = absolute uncertainty in average for four test runs, and
C_4 = the uncertainty factor for four test runs (Table A1.1).

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

A1.4.8.1 The formula for the percent uncertainty (four test runs) is as follows:

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

where:

$\%U_4$ = percent uncertainty in average for four test runs,
U_4 = absolute uncertainty in average for four test runs, and
Xa_4 = average of four test runs.

A1.4.9 *Step 9*—If the percent uncertainty, $\%U_4$, is not greater than ±10 % for the cooking energy rate and production capacity, report the average for these parameters 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 the cooking energy rate or production capacity, proceed to Step 10.

A1.4.10 *Step 10*—The steps 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.

A1.4.10.1 The formula for the average (*n* test runs) is as follows:

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

where:

n = number of test runs,
Xa_n = average of results *n* test runs, and
$X_1, X_2, X_3, X_4, \ldots, X_n$ = results for each test run.

A1.4.10.2 The formula for the standard deviation (*n* test runs) is as follows:

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

where:

S_n = standard deviation of results for *n* test runs,
A_n = $(X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2 + \ldots + (X_n)^2$, and
B_n = $(1/n) \times (X_1 + X_2 + X_3 + X_4 + \ldots + X_n)^2$.

A1.4.10.3 The formula for the absolute uncertainty (*n* test runs) is as follows:

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

where:

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

A1.4.10.4 The formula for the percent uncertainty (*n* test runs) is as follows:

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

where:

$\%U_n$ = percent uncertainty in average for *n* test runs,
U_n = absolute uncertainty in average for *n* test runs, and
Xa_n = average of *n* test runs.

When the percent uncertainty, $\%U_n$, is less than or equal to ±10 % for the cooking energy rate and production capacity, report the average for these parameters along with their corresponding absolute uncertainty, U_n, in the following format:

$$Xa_n \pm U_n$$

NOTE A1.5—The researcher may compute a test result that deviates significantly from the other test results. Such a result should be discarded only if there is some physical evidence that the test run was not performed according to the conditions specified in this method. For example, a thermocouple was out of calibration, the appliance's input capacity was not within 5 % of the rated input, or the food product was not within specification. To assure that all results are 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-load cooking scenario yielded the following production capacity (PC) results:

Test	PC
Run #1	33.8 lb/h
Run #2	34.1 lb/h
Run #3	31.0 lb/h

A1.5.2 *Step 1*—Calculate the average and standard deviation of the three test results for the PC.

A1.5.2.1 The average of the three test results is as follows:

$$Xa_3 = (1/3) \times (X_1 + X_2 + X_3) \quad (A1.13)$$

$$Xa_3 = (1/3) \times (33.8 + 34.1 + 31.0)$$

$$Xa_3 = 33.0 \text{ lb/h}$$

A1.5.2.2 The standard deviation of the three test results is as follows. First calculate "A_3" and "B_3":

$$A_3 = (X_1)^2 + (X_2)^2 + (X_3)^2 \quad (A1.14)$$

$$A_3 = (33.8)^2 + (34.1)^2 + (31.0)^2$$

$$A_3 = 3266$$

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

$$B_3 = (1/3) \times [(33.8 + 34.1 + 31.0)^2]$$

$$B_3 = 3260$$

A1.5.2.3 The new standard deviation for the PC is as follows:

$$S_3 = \left(1/\sqrt{2}\right) \times \sqrt{(3266 - 3260)} \quad (A1.15)$$

$$S_3 = 1.73 \, lb/h$$

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

$$U_3 = 2.48 \times S_3 \quad (A1.16)$$

$$U_3 = 2.48 \times 1.73$$

$$U_3 = 4.29 \text{ lb/h}$$

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

$$\% U_3 = (U_3/Xa_3) \times 100\,\% \quad (A1.17)$$

$$\% U_3 = (4.29/33.0) \times 100\,\%$$

$$\% U_3 = 13\,\%$$

A1.5.5 *Step 4*—Run a fourth test. Since the percent uncertainty for the production capacity is greater than ±10 %, the precision requirement has not been satisfied. An additional test is run in an attempt to reduce the uncertainty. The PC from the fourth test run was 32.5 lb/h.

A1.5.6 *Step 5*—Recalculate the average and standard deviation for the PC using the fourth test result:

A1.5.6.1 The new average PC is as follows:

$$Xa_4 = (1/4) \times (X_1 + X_2 + X_3 + X_4) \quad (A1.18)$$

$$Xa_4 = (1/4) \times (33.8 + 34.1 + 31.0 + 32.5)$$

$$Xa_4 = 32.9 \text{ lb/h}$$

A1.5.6.2 The new standard deviation is as follows. First calculate "A_4" and "B_4":

$$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2 \quad (A1.19)$$

$$A_4 = (33.8)^2 + (34.1)^2 + (31.0)^2 + (32.5)^2$$

$$A_4 = 4322$$

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

$$B_4 = (1/4) \times [(33.8 + 34.1 + 31.0 + 32.5)^2]$$

$$B_4 = 4316$$

A1.5.6.3 The new standard deviation for the PC is as follows:

$$S_4 = \left(1/\sqrt{3}\right) \times \sqrt{(4322 - 4316)} \quad (A1.20)$$

$$S_4 = 1.41 \text{ lb/h}$$

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

$$U_4 = 1.59 \times S_4 \quad (A1.21)$$

$$U_4 = 1.59 \times 1.41$$

$$U_4 = 2.24 \text{ lb/h}$$

A1.5.8 *Step 7*—Recalculate the percent uncertainty using the new average.

$$\% U_4 = (U_4/Xa_4) \times 100\,\% \quad (A1.22)$$

$$\% U_4 = (2.24/32.9) \times 100\,\%$$

$$\% U_4 = 6.8\,\%$$

A1.5.9 *Step 8*—Since the percent uncertainty, $\%U_4$, is less than ±10 %, the average for the production capacity is reported along with its corresponding absolute uncertainty, U_4, as follows:

$$\text{PC}: 32.9 \pm 2.24 \text{ lb/h} \quad (A1.23)$$

The production capacity can be reported assuming the ±10 % precision requirement has been met for the corresponding cooking energy rate value. The cooking energy rate and its absolute uncertainty can be calculated following the same steps.

APPENDIX

(Nonmandatory Information)

X1. RESULTS REPORTING SHEETS

Manufacturer ______________________________________
Model ______________________________________
Date _____________
Test Reference Number (optional) ______________

Test Conveyor Toaster
Description of operational characteristics ____
____
____
____
____

Apparatus
____ Check if testing apparatus conformed to specifications in Section 6.
Deviations
____
____
____
____

Energy Input Rate
Test Voltage (V) ________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ________
Measured (kW or Btu/h (kJ/h)) ________
Rated (kW or Btu/h (kJ/h)) ________
Percent Difference between Measured and Rated (%) ________

Preheat Energy and Time (see Fig. X1.1 for Preheat Curve)
Test Voltage (V) ________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ________
Starting Cavity Temperature (°F (°C)) ________
Stabilized Cavity Temperature (°F (°C)) ________
Energy Consumption (kWh or Btu (kJ)) ________
Duration (min) ________
Preheat Rate (°F/min (°C/min)) ________

Pilot Energy Rate (Gas Conveyor Toasters with Standing Pilots)
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ________
Pilot Energy Rate (kW or Btu/h (kJ/h)) ________

Energy Consumption (Idle Energy Rate)
Test Voltage (V) ________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ________
Stabilized Cavity Temperature (°F (°C)) ________
Standby Mode (yes/no) ________
Idle Energy Rate (kW or Btu/h (kJ/h)) ________

Production Capacity
Test Voltage (V) ________
Gas Heating Value (Btu/ft^3 (kJ/m^3)) ________
Cook Time (min) ________
Conveyor Speed (rpm) ________
Cooking Energy Rate (kW or Btu/h (kJ/h)) ________
Production Capacity (slices/h) ________

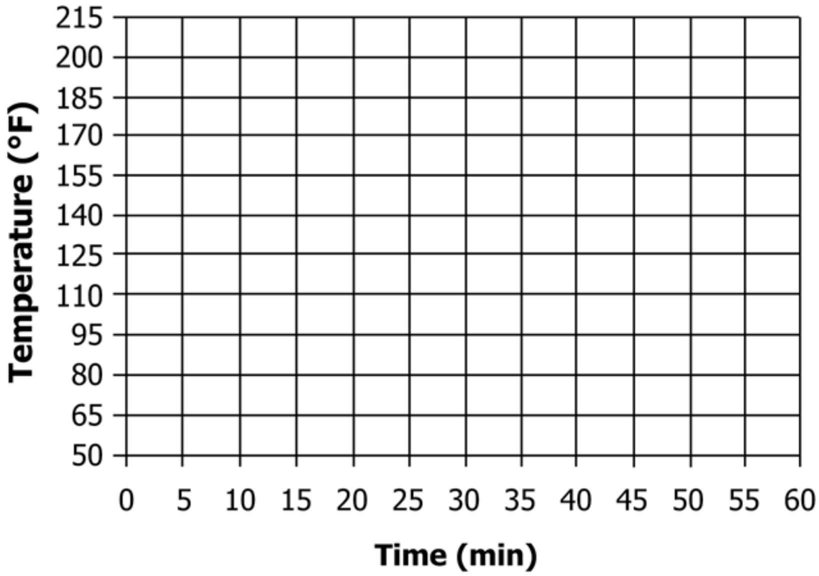

FIG. X1.1 Preheat Curve