Standard Test Methods for Performance of Range Tops[1]

This standard is issued under the fixed designation F1521; 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 These test methods cover the energy consumption and cooking performance of range tops. The food service operator can use this evaluation to select a range top and understand its energy consumption.

1.2 These test methods are applicable to gas and electric range tops including both discreet burners and elements and hot tops.

1.3 The range top can be evaluated with respect to the following (where applicable):

1.3.1 Energy input rate (see 10.2), and

1.3.2 Pilot energy consumption (see 10.3).

1.3.3 Heat-up temperature response and temperature uniformity at minimum and maximum control settings (see 10.4), and

1.3.4 Cooking energy efficiency and production capacity (see 10.5).

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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 *ASTM Standards:*[2]

A36/A36M Specification for Carbon Structural Steel

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

2.2 *ASHRAE Standard:*

ASHRAE Guideline 2-1986 (RA90) Thermal and Related Properties of Food and Food Materials[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *cooking container*—a vessel used to hold the food product that is being heated by the cooking unit.

3.1.2 *cooking energy*—energy consumed by the cooking unit as it is used to raise the temperature of water in a cooking container under full-input rate.

3.1.3 *cooking energy efficiency*—quantity of energy input to the water expressed as a percentage of the quantity of energy input to the cooking unit during the full-input rate tests.

3.1.4 *cooking unit*—a heating device located on the range top that is powered by a single heat source comprised of either a gas burner or an electrical element that is independently controlled.

3.1.5 *energy input rate*—rate (Btu/h) at which an appliance consumes energy.

3.1.6 *heat-up temperature response*—temperature rise on the surface of a steel plate during the test period in accordance with the heat-up temperature-response test.

3.1.7 *production capacity*—maximum rate at which the cooking unit heats water in accordance with the cooking energy-efficiency test.

3.1.8 *production rate*—rate at which the cooking unit heats water in accordance with the cooking energy-efficiency test.

3.1.9 *range*—a device for cooking food by direct or indirect heat transfer from one or more cooking units to one or more cooking containers.

3.1.10 *temperature uniformity*—the comparison of individual temperatures measured on the surface of a steel plate at the end of the test period in accordance with the heat-up temperature-response test.

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

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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] See *ASHRAE Handbook of Fundamentals*, Chapter 30, Table I, 1989, available from American Society of Heating, Refrigeration, and Air-Conditioning Engineers, 1791 Tullie Circle NE, Atlanta, GA 30329.

4. Summary of Test Methods

4.1 The range to be tested is connected to the appropriate metered energy source. The energy input rate is determined for each type of cooking unit on the range top and for the entire range top (all cooking units operating at the same time) to confirm that the range top is operating within 5.0 % of the nameplate energy input rate. The pilot energy consumption is also determined when applicable to the range being tested.

4.2 Thermocouples are attached to a circular steel plate which is then placed on the cooking unit to be tested. The heat-up temperature response of the cooking unit at the minimum control setting and at the maximum control setting is determined as well as the temperature uniformity at each control setting.

4.3 Energy consumption and time are monitored as each different type of cooking unit on the range is used to heat water from 70 to 200°F (21 to 93°C) at the full-energy input rate. Cooking energy efficiency and production capacity are calculated from this data.

5. Significance and Use

5.1 The energy input rate test is used to confirm that the range under test is operating at the manufacturer's rated input. This test would also indicate any problems with the electric power supply or gas service pressure.

5.2 The heat transfer characteristics of a cooking unit can be simulated by measuring the temperature uniformity of a steel plate.

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

5.4 The cooking energy efficiency is a direct measurement of range efficiency at the full-energy input rate. This data can be used by food service operators in the selection of ranges, as well as for the management of a restaurant's energy demands.

NOTE 1—The PG&E Food Service Technology Center has determined that the cooking energy efficiency does not significantly change for different input rates. If precise efficiency calculations are desired at lower input rates, the full-input rate test procedure is valid for all input rates (that is, less than full-input).

5.5 Production rate and production capacity can be used to estimate the amount of time required for food preparation and as a measure of range capacity. This helps the food service operator match a range to particular food output requirements.

6. Apparatus

6.1 *Analytical Balance Scale,* for the determination of water and cooking container weight, with a resolution of 0.01 lb (5 g).

6.2 *Barometer,* for measuring absolute atmospheric pressure, to be used for adjustment of measured natural gas volume to standard conditions. The barometer shall have a resolution of 0.2 in. Hg (670 Pa).

6.3 *Cooking Container,* 13-in. (330-mm) diameter, 20-qt (19-L), sauce pot with matching lid. The bottom of the pot shall be flat to within 0.0625 in. (1.6 mm) over the diameter.

6.3.1 The recommended cooking container for all testing shall be a professional standard weight Wear Ever Model 4333[4] sauce pot with a Wear Ever Model 4193 lid.[4] If it is not possible to use the recommended cooking container for testing, then a cooking container with a similar capacity may be substituted. The cooking container capacity should be no less than 12-qt and no more than 24-qt. The cooking container may be aluminum or steel. The weight of the substituted cooking container and lid must be noted and included in 11.7.1.

NOTE 2—The recommended aluminum sauce pot may not always be a suitable cooking container. For example, an electric induction range top requires that the cooking container be magnetic, typically steel or stainless steel plated nickel. For this reason 6.3.1 is included for flexibility.

6.4 *Canopy Exhaust Hood,* 4 ft (1.2 m) in depth, wall-mounted with the lower edge of the hood 6½ ft (2.0 m) from the floor and with the capacity to operate at a nominal exhaust ventilation rate of 300 ft^3/min/linear foot (230 L/s/linear metre) of active hood length. This hood shall extend a minimum of 6 in. (150 mm) past both sides of the cooking appliance and shall not incorporate side curtains or partitions.

6.5 *Gas Meter,* for measuring the gas consumption of a range, shall be a positive displacement type with a resolution of at least 0.01 ft^3 (0.0003 m^3) and a maximum error no greater than 1 % of the measured value for any demand greater than 2.2 ft^3/h (0.06 m^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 (0.0003 m^3) and have a maximum error no greater than 2 % of the measured value.

6.6 *Pressure Gage,* for monitoring natural gas pressure, with a range from 0 to 10 in. H_2O (0 to 2.5 kPa), a resolution of 0.5 in. H_2O (125 Pa), and a maximum uncertainty of 1 % of the measured value.

6.7 *Steel Plate,* composed of structural-grade carbon steel in accordance with Specification A36/A36M, free of rust or corrosion, 12-in. (300-mm) diameter, and ¼ in. (6.4 mm) thick. The plate shall be flat to within 0.010 in. (3 mm) over the diameter.

6.8 *Strain Gage Welder,* capable of welding thermocouples to steel.[5]

6.9 *Thermocouple(s),* fiberglass-insulated, 24-gage, Type K thermocouple wire, peened flat at the exposed ends and spot welded to surfaces with a strain gage welder.

6.10 *Thermocouple Probe(s),* capable of immersion with a range from 50 to 200°F (10 to 93°C) and accuracy of ±2°F (±1°C), preferably industry standard Type T or Type K thermocouples.

6.11 *Temperature Sensor,* for measuring natural gas temperature in the range from 50 to 100°F (10 to 38°C), with a resolution of 0.1°F (0.05°C) and an accuracy of ±0.5°F (±0.3°C).

[4] Available from Lincoln Foodservice Products, Inc., P.O. Box 1229, Fort Wayne, IN 46801.

[5] Eaton Model W1200 Strain Gage Welder, available from Eaton Corp., 1728 Maplelawn Road, Troy, MI 48084, has been found satisfactory for this purpose.

6.12 *Watt-Hour Meter,* for measuring the electrical energy consumption of a range, shall have a resolution of at least 1 Wh and a maximum error no greater than 1.5 % of the measured value for any demand greater than 100 W.

7. Reagents and Materials

7.1 *Water,* having a maximum hardness of three grains per gallon. Distilled water may be used.

8. Sampling and Test Units

8.1 *Range*—A representative production model shall be selected for performance testing.

9. Preparation of Apparatus

9.1 Install the appliance in accordance with the manufacturer's instructions under a 4-ft (1.2-m) deep canopy exhaust hood mounted against a wall with the lower edge of the hood 6½ ft (2.0 m) from the floor. Position the range so that the front edge is 6 in. (150 mm) inside the front edge of the hood. The length of the exhaust hood and active filter area shall extend a minimum of 6 in. (150 mm) beyond both sides of the range. In addition, both sides of the range shall be 3 ft (1.1 m) from any side wall, side partition, or other operating appliance. The exhaust ventilation rate shall be 300 ft^3/min/ linear foot (460 L/s/linear metre) of hood length. 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 while the exhaust system is operating.

9.2 Connect the range to a calibrated energy-test meter. For gas installations, a pressure regulator shall be installed downstream from the meter to maintain a constant pressure of gas for all tests. Both the pressure and temperature of the gas supplied to a range, as well as the barometric pressure, shall be recorded during each test so that the measured gas flow can be corrected to standard conditions. For electric installations, a voltage regulatory may be required during tests if the voltage is not within ±2.5 % of the manufacturer's nameplate voltage.

9.3 For a gas range, adjust (while a cooking unit is operating) the gas pressure downstream from the appliance pressure regulator to within ±2.5 % of the operating manifold pressure specified by the manufacturer. Also make adjustments to the appliance following the manufacturer's recommendations for optimizing combustion.

9.4 For an electric range, confirm (while a cooking unit is operating) that the supply voltage is to within ±2.5 % of the operating voltage specified by the manufacturer. The test voltage shall be recorded for each test.

NOTE 3—If an electric range is rated for dual voltage (for example, 208/240), the range should be evaluated as two separate appliances in accordance with these test methods.

10. Procedure

10.1 *General:*

NOTE 4—Prior to starting these test methods, the tester should read the operating manual and fully understand the operation of the appliance.

10.1.1 For gas ranges, obtain and record the following for each run of every test:

10.1.1.1 Higher heating value,

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

10.1.1.3 Measured gas temperature,

10.1.1.4 Measured gas pressure,

10.1.1.5 Barometric pressure, and

10.1.1.6 Energy input rate during or immediately prior to test.

NOTE 5—The preferred method for determining the heating value of gas supplied to the range under test is by using a calorimeter or gas chromatograph in accordance with accepted laboratory procedures. It is recommended that all testing be performed with gas with a heating value between 1000 and 1075 Btu/ft^3 (37 300 to 40 000 kJ/m^3).

10.1.2 For gas ranges, measure and add any electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (see 10.2).

10.1.3 For electric ranges, obtain and record the following for each run of every test:

10.1.3.1 Voltage while elements are energized.

10.1.3.2 Energy input rate during or immediately prior to test run.

10.2 *Energy Input Rate:*

10.2.1 For gas ranges, operate one of the cooking units with the temperature control in the full "on" position. Allow the cooking unit to operate for 15 min.

10.2.2 At the end of the 15-min stabilization period, begin recording the energy consumption of the cooking unit for the next 15 min.

10.2.3 For electric ranges, operate one of the cooking units with the temperature control in the full "on" position, and record the energy consumption of the cooking unit for the next 15 min. If an electric cooking unit begins to cycle, see Note 6.

NOTE 6—If an electric unit cycles within the 15-min time period required for the test, record only the energy used during the noncycling period starting from the instant that the cooking unit was turned on. If more than one cooking unit is operating, stop recording the energy consumption when any unit begins to cycle.

10.2.4 Repeat the procedure in 10.2.1 – 10.2.3 for each cooking unit on the range top and record the energy consumption for the specified time period as well as the position of the cooking unit (for example, left front, left rear, center front, or right rear).

10.2.5 Repeat the procedure in 10.2.1 – 10.2.3, operating all of the range top cooking units at the same time, and record the energy consumption of the entire range top for the specified time period. If an electric cooking unit begins to cycle see Note 7.

10.2.6 In accordance with 11.4, report the measured energy input rate for each separate cooking unit tested and for the entire range (all cooking units operating at the same time). Report the nameplate ratings for each separate cooking unit tested and for the complete range top.

NOTE 7—The nameplate rated input of a range top is generally specified as the sum of the nameplate ratings of each of the individual cooking units located on the range top. For example, a range top with four 20 000-Btu/h burners has a nameplate rating of 80 000 Btu/h. Due to this fact, the measured input rate of the entire range top is sometimes different from the nameplate rating. Section 10.2.5 compares the nameplate rating against the measured rating for the entire range top. The remainder of the tests contained in this test method concentrate on individual cooking units; therefore, it is important that the measured input rates of the individual cooking units fall within the specified variance from their nameplate ratings.

10.2.7 Confirm that the measured input rate or power (British thermal units per hour for a gas range top and kilowatts for an electric range top) for each cooking unit tested is within ±5 % of the rated nameplate input or power for that cooking unit. If the difference is greater than ±5 %, terminate testing and contact the manufacture. The manufacturer may make appropriate changes or adjustments to the individual cooking units or the entire range top or choose to supply an alternative range for testing. It is the intent of the testing procedures herein to evaluate the performance of a range at rated gas pressure or electrical voltage.

10.3 *Pilot Energy Consumption (Gas Models with Standing Pilots):*

10.3.1 Where applicable, set the gas valve controlling the gas supply to the range top at the "pilot" position. Otherwise, set the range top temperature controls to the "off" position.

10.3.2 Light and adjust pilots in accordance with the manufacturer's instructions.

10.3.3 Record the gas reading after a minimum of 8 h of pilot operation.

10.3.4 Allow pilots to operate for the remainder of the tests listed in this procedure. Do not extinguish pilots until all testing is complete.

10.4 *Heat-Up Temperature Response and Temperature Uniformity at Minimum and Maximum Control Settings:*

10.4.1 Using a strain gage welder, attach seventeen thermocouples to a 12-in. (300-mm) diameter, ¼-in. (6.4-mm) thick steel plate as detailed in Fig. 1. Thermocouple locations shall be numbered, starting with 1in the center, 2 to 9 on the innermost circle of thermocouples, and 10 to 17 on the outermost circle of thermocouples. For a hot top see Note 8.

NOTE 8—Use one steel plate for each full 1 by 1 ft (305 by 305 mm) of cooking surface on the hot top cooking unit. For example, both a 1 by 2-ft (305 by 610-mm) and a 1½ by 2-ft (457 by 610-mm) cooking unit would require two plates; however, a 2 by 2-ft (610 by 610-mm) cooking surface would require four plates. Alternately, a surface requiring more than one plate can be tested using only one plate by moving the plate to each of the required positions and repeating the test for each position. Many hot tops are designed to have a temperature gradient from front to back; therefore, the temperature data gathered from every plate position should be reported separately.

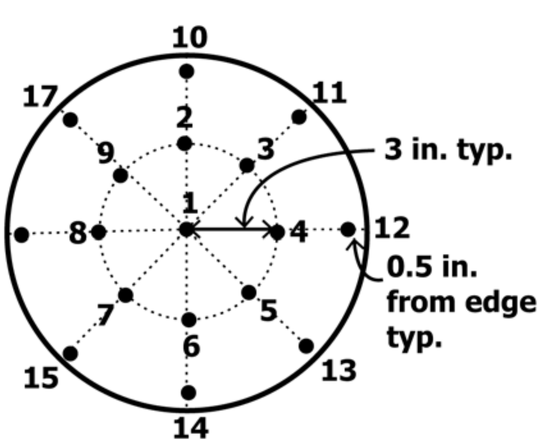

FIG. 1 Thermocouple Placement

10.4.2 Place and center the plate, thermocoupled side up, on the first cooking unit to be tested. The cooking unit to be tested shall be the one closest to front and left. Report the position of the tested cooking unit on a diagram of the range top (see Fig. 2). If the cooking unit is an open gas burner, ensure that the plate is situated so that the thermocouple locations on the top of the plate are over the open flame and not over the burner grates. Support the thermocouple wires so that their weight does not affect the contact between any part of the plate and the cooking unit.

10.4.3 Verify that the plate is at 75 ± 5°F (24 ± 3°C). The cooking unit shall not have been operated for at least the preceding 1 h.

10.4.4 Operate the cooking unit at its minimum control setting or lowest level (that is, for gas cooking units operate the cooking unit at the lowest sustainable flame level and for electric cooking units set the control at the lowest position at which the indicator light turns on or at the lowest setting of the control knob) and immediately start recording the temperatures and the time, simultaneously computing the average temperature of the plate (all of the thermocouples combined).

10.4.5 Allow the cooking unit to operate for 1 h. Record the energy consumption of the cooking unit.

NOTE 9—The length of the test is set at 1 h in order to be sure to include the temperature response for all types of ranges.

10.4.6 At the end of 1 h, note the average temperature of the plate (all of the thermocouples combined) and the temperature of each individual point on the plate.

10.4.7 Turn the cooking unit off and allow it to sit and cool for at least 1 h. Remove the plate from the cooking unit and allow it to cool to 75 ± 5°F (24 ± 3°C).

10.4.8 Replace the plate on the cooking unit. Set the cooking unit controls at the maximum control setting or full "on," and immediately start recording the temperatures and the time, simultaneously computing the average temperature of the plate (all of the thermocouples combined).

10.4.9 Allow the cooking unit to operate for 1 h. Record the energy consumption of the cooking unit.

10.4.10 At the end of 1 h, note the average temperature of the plate (all of the thermocouples combined) and the temperature of each individual point on the plate.

10.4.11 Repeat the test for each type of cooking unit on the range top.

10.5 *Cooking Energy Efficiency and Production Capacity:*

10.5.1 This procedure is comprised of one 30-min stabilization run, followed by a minimum of three separate test runs

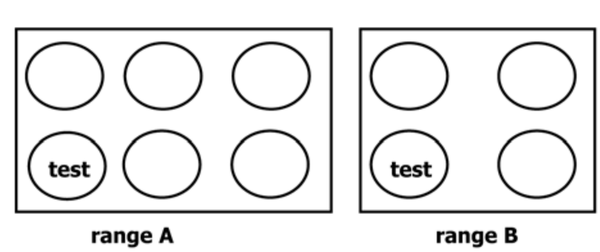

FIG. 2 Selection of Test Cooking Unit

(in accordance with A1.4.4) at the full-energy input rate. The reported values of cooking energy efficiency and production capacity shall be the average of the three test runs.

10.5.2 Prepare a minimum of three empty 13-in. (330-mm), 20-qt (19-L), sauce pots and lids (in accordance with 6.3). Verify that each sauce pot is at 75 ± 5°F (24 ± 3°C). For a hot top see Note 10.

NOTE 10—Use one sauce pot for each full 1 by 1 ft (305 by 305 mm) of cooking surface on the hot top cooking unit. For example, both a 1 by 2-ft (305 by 610-mm) and a 1½ by 2-ft (457 by 610-mm) cooking unit would require 6 sauce pots (two pots for three tests); however, a 2 by 2-ft (610 by 610-mm) cooking surface would require 12 sauce pots (4 pots for three tests).

10.5.3 Each sauce pot lid shall have a hole located within 2 in. (51 mm) of the center and no larger than 0.25 in. (6 mm) in diameter to allow for a thermocouple probe. The thermocouple shall extend 4 in. (102 mm) below the bottom of the lid.

10.5.4 Pour 20 lb (9091 g) of 70 ± 2°F (21 ± 1°C) water into each sauce pot and record the water temperature. Place a lid on each sauce pot. These are the test pots. Pour 20 lb of 70 ± 2°F water into a fourth similar sauce pot and center the pot on the first cooking unit to be tested (see 10.4.2). Place the lid on this sauce pot. This is the stabilization pot.

10.5.5 Set the cooking unit controls at 50 ± 5 % of the full-energy input rate (including any pilot energy) and allow the unit to operate for 30 min. At the end of 30 min, remove the stabilization pot.

10.5.6 If the cooking unit is a hot top, repeat the stabilization procedure detailed in 10.5.4 and 10.5.5 for two 30-min stabilization periods, totaling 1 h.

10.5.7 Center a test pot on the cooking unit, allowing no more than 15 min between the removal of the previous pot and the placement of this pot.

10.5.8 Record the time and energy (including any electric energy used by a gas range) required to raise the water temperature to 200°F (93°C). If more than one sauce pot is required, end the test when the water temperature of all the sauce pots combined averages 200°F.

10.5.9 Repeat 10.5.7 and 10.5.8 for the two remaining test runs.

10.5.10 Calculate the cooking energy efficiency and production capacity for the cooking unit in accordance with 11.7 and 11.8.

10.5.11 Repeat the procedures detailed in 10.5 until each type of cooking unit has been tested.

11. Calculation and Report

11.1 *Test Range*—Summarize the physical and operating characteristics of the range.

11.2 *Apparatus and Procedure*—Confirm that the testing apparatus conformed to all of the specifications in Section 9. Describe any deviations from those specifications.

11.3 *Gas Calculations:*

11.3.1 For gas range tops, 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 range top,
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,
T_{cf} = temperature correction factor

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

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

P_{cf} = pressure correction factor

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

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

NOTE 11—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Standard conditions using Practice D3588 are 519.67°R and 14.73 psia.

11.4 *Energy Input Rate:*

11.4.1 Report the manufacturer's nameplate rated energy input in British thermal units per hour for a gas range and kilowatts for an electric range for each cooking unit on the range and for the complete range top (see Note 7).

11.4.2 Calculate and report the measured energy input (British thermal units per hour or kilowatts) based on the energy consumed by each cooking unit and by the entire range top while the cooking units are operating at their maximum control setting in accordance with the following relationship:

$$\textit{input rate} \text{ (Btu/h or kW)} =$$

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

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 *Pilot Energy Consumption*—Calculate and report an energy input rate (British thermal units per hour or kilowatts) based on the energy consumed by the range during the pilot test period in the following relationship:

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

where:

E_{pilot} = pilot energy consumption, Btu/h or kW,
E = energy consumed during the test period, Btu or kWh, and
t = test period, min.

11.6 *Heat-Up Temperature Response and Temperature Uniformity at Minimum and Maximum Control Settings:*

11.6.1 For each test that is run, plot the rise of the average temperature of the plate (all of the thermocouples combined) over the test period and report the average temperature of the plate and the temperature of each individual point on the plate at the end of the test.

11.6.2 Report the energy input rate for the cooking unit during the test period.

11.7 *Cooking Energy Efficiency:*

NOTE 12—Sections 11.7 and 11.8 describe how the cooking energy efficiency and production capacity are calculated. The average values of these parameters are to be calculated based on a minimum of three test runs, then reported as described in A1.1.

11.7.1 Calculate the cooking energy efficiency (η_{cook}) for the full-energy input rate cooking tests using the following equation:

$$\eta_{cook} = \frac{E_{water} + E_{pot}}{E_{input}} \times 100\,\%$$

where:

$$E_{water} + E_{pot} = \left(\left(W_{water} \times Cp_{water} \right) + \left(W_{pot} \times Cp_{pot} \right) \right) \times \left(T_2 - T_1 \right)$$

where:

W_{water} = weight of water in the sauce pot, that is specified as 20 lb (9091 g) of water,
Cp_{water} = specific heat of water = 1.0 Btu/lb·°F (418.7 J/kg·°K),
W_{pot} = weight of cooking container, as specified in 6.3,
Cp_{pot} = specific heat of cooking container, specified as either: aluminum = 0.22 Btu/lb·°F, or steel = 0.11 Btu/lb·°F,
T_2 = ending temperature of the water, that is specified as 200°F (93°C),
T_1 = beginning temperature of the water, that is specified as 70 ± 2°F (21 ± 1°C), and
E_{input} = energy consumed by the cooking unit during the test, Btu, including any electric energy consumed by a gas range top.

11.8 *Production Capacity:*

11.8.1 Calculate the production rate (*PC*) for the full-energy input rate cooking tests using the following equation;

$$PC = \frac{\text{lb(g)}}{\text{h}} = \frac{60\text{min/h}}{T_{test}} \times W_w$$

where:

T_{test} = length of test, min, and
W_w = weight of water in the sauce pot, that is specified as 20 lb (9091 g) of water.

11.8.2 Report the input rate at both the full-energy input rate and plot the production capacity against the input rate on the same *x-y* graph with the production capacity on the *x* axis and the input rate on the *y* axis (see Fig. 3 for example).

12. Precision and Bias

12.1 *Precision:*

12.1.1 *Repeatability (Within Laboratory, Same Operator and Equipment):*

12.1.1.1 For each cooking energy result, the percent uncertainty in each result, based on at least three test runs, has been specified to be no greater than ±10.0 %.

12.1.1.2 The repeatability of each remaining parameter is being determined.

12.1.2 *Reproducibility (Multiple Laboratories)*—The interlaboratory precision of the procedures in these test methods for measuring each reported parameter is being determined.

12.2 *Bias*—No statement can be made concerning the bias of the procedures in these test methods because there are no accepted reference values for the parameters reported.

13. Keywords

13.1 efficiency; energy; performance; production capacity; production rate; range; range top; throughput; uniform test procedure

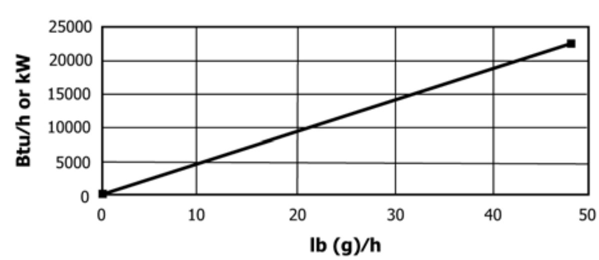

FIG. 3 Example of Input versus Production

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

NOTE A1.1—The procedure described as follows is based on the method for determining the confidence interval for the average of several test results discussed in Section 6.4.3 of ASHRAE Guideline 2-1986(RA90). It should only be applied to test results that have been obtained within the tolerances prescribed in these test methods (for example, 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 rate (*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 the full-energy input rate test, the uncertainty of η_{cook} must be no greater than ±10.0 % before either η_{cook} or *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 EEF_{cook} is 40 %, the uncertainty must not be larger than ±4 %. This means that the true EEF_{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 EEF_{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 A1.1 which depends on the number of test results used to calculate the average. The percent uncertainty is the ratio of the uncertainty to the average expressed as a percent.

A1.4 *Procedure:*

NOTE A1.2—See A1.5 for example of applying this procedure.

A1.4.1 *Step 1*—Calculate the average and the standard deviation for the EEF_{cook} and *PR* using the results of the first three test runs.

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

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

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

where:

Xa_3 = average of results for EEF_{cook}, *PR*, and
X_1, X_2, X_3 = results for EEF_{cook}, *PR*.

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

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

where:

S_3 = standard deviation of results for EEF_{cook}, *PR*,
A_3 = $(X_1)^2 + (X_2)^2 + (X_3)^2$, and
B_3 = $\left(\frac{1}{3}\right) \times (X_1 + X_2 + X_3)^2$.

NOTE A1.4—The *A* quantity is the sum of the squares of each test result, while the *B* quantity is the square of the sum of all test results multiplied by a constant (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. The formula for the absolute uncertainty (3 test runs) is as follows:

$$U_3 = C_3 \times S_3$$
$$U_3 = 2.48 \times S_3$$

where:

U_3 = absolute uncertainty in average for EEF_{cook}, *PR*, and
C_3 = uncertainty factor for three test runs (see Table A1.1).

A1.4.3 *Step 3*—Calculate the percent uncertainty in each parameter average using the averages from Step 1 and the absolute uncertainties from Step 2. The formula for the percent uncertainty (3 test runs) is as follows:

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

where:

$\%\ U_3$ = percent uncertainty in average for EEF_{cook}, *PR*,
U_3 = absolute uncertainty in average for EEF_{cook}, *PR*, and
Xa_3 = average EEF_{cook}, *PR*.

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

A1.4.5 *Step 5*—Run a fourth test for each EEF_{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 EEF_{cook}, calculate the average and standard deviation for

TABLE A1.1 Uncertainty Factor

Number of Test Results	Uncertainty Factor
3	2.48
4	1.59
5	1.24
6	1.05
7	0.92
8	0.84
9	0.77
10	0.72

EEF_{cook} and PR using a calculator or the following formulas: The formula for the average (four test runs) is as follows:

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

where:

Xa_4	=	average of results for EEF_{cook}, PR, and
X_1, X_2, X_3, X_4	=	results for EEF_{cook}, PR.

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

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

where:

S_4	=	standard deviation of results for EEF_{cook}, PR (four test runs),
A_4	=	$(X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$, and
B_4	=	$\left(\frac{1}{4}\right) \times (X_1 + X_2 + X_3 + X_4)^2$.

A1.4.7 *Step 7*—Calculate the absolute uncertainty in the average for each parameter listed in Step 1. Multiply the standard deviation calculated in Step 6 by the uncertainty factor for four test results from Table A1.1. The formula for the absolute uncertainty (four test runs) is as follows:

$$U_4 = C_4 \times S_4$$
$$U_4 = 1.59 \times S_4$$

where:

U_4	=	absolute uncertainty in average for EEF_{cook}, PR, and
C_4	=	uncertainty factor for four test runs (see Table A1.1).

A1.4.8 *Step 8*—Calculate the percent uncertainty in the parameter averages using the averages from Step 6 and the absolute uncertainties from Step 7. The formula from the percent uncertainty (four test runs) is as follows:

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

where:

% U_4	=	percent uncertainty in average for EEF_{cook}, PR,
U_4	=	absolute uncertainty in average for EEF_{cook}, PR, and
Xa_4	=	average EEF_{cook}, PR.

A1.4.9 *Step 9*—If the percent uncertainty, % U_4, is no greater than ±10 % for EEF_{cook} then report the average for EEF_{cook} and PR 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 EEF_{cook} proceed to Step 10.

A1.4.10 *Step 10*—The steps required for five or more test runs are the same as those described in A1.4.1 – A1.4.9. More general formulas for calculating the average, standard deviation, absolute uncertainty, and percent uncertainty are as follows: The formula for the average (n test runs) is as follows:

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

where:

n	=	number of test runs,
Xa_n	=	average of results for EEF_{cook}, PR, and
X_1, X_2, X_3, X_4, ... X_n	=	results for EEF_{cook}, PR.

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

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

where:

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

The formula for the absolute uncertainty (n test runs) is as follows:

$$U_n = C_n \times S_n$$

where:

U_n	=	absolute uncertainty in average for EEF_{cook}, PR, and
C_n	=	uncertainty factor for n test runs (see Table A1.1).

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

$$\%\,U_n = (U_n/Xa_n) \times 100\ \%$$

where:

% U_n	=	percent uncertainty in average for EEF_{cook}, PR.

When the specified uncertainty % U_n, is less than or equal to ±10 %, report the average for EEF_{cook} and PR along with their corresponding absolute uncertainty, U_n, in the following format:

$$Xa_n + U_n$$

NOTE A1.5—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, the range's input rate was not within 5 % of the rated input, or a thermocouple slipped out of a pot. 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 EEF_{cook} results:

Test	EEF_{cook}
Run No. 1	33.8 %
Run No. 2	31.3 %
Run No. 3	30.5 %

A1.5.2 *Step 1*—Calculate the average and standard deviation of the three test results for the EEF_{cook}. The average of the three test results is as follows:

$$Xa_3 = (1/3) \times (X_1 + X_2 + X_3)$$
$$Xa_3 = (1/3) \times (33.8 + 31.3 + 30.5)$$
$$Xa_3 = 31.9\ \%$$

The standard deviation of the three test results is as follows:

First calculate A_3 and B_3:

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

$$A_3 = (33.8)^2 + (31.3)^2 + (30.5)^2$$
$$A_3 = 3052$$
$$B_3 = (1/3) \times [(X_1 + X_2 + X_3)^2]$$
$$B_3 = (1/3) \times [(33.8 + 31.3 + 30.5)^2]$$
$$B_3 = 3046$$

The new standard deviation for the EEF_{cook} is as follows:

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

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

$$U_3 = 2.48 \times S_3$$
$$U_3 = 2.48 \times 1.73$$
$$U_3 = 4.29\,\%$$

A1.5.4 *Step 3*—Calculate percent uncertainty as follows:

$$\%\ U_3 = (U_3/Xa_3) \times 100\,\%$$
$$\%\ U_3 = (4.29/31.9) \times 100\,\%$$
$$\%\ U_3 = 13.5\,\%$$

A1.5.5 *Step 4*—Run a fourth test. Since the percent uncertainty for the EEF_{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 EEF_{cook} from the fourth test run was 31.8 %.

A1.5.6 *Step 5*—Recalculate the average and standard deviation for the EEF_{cook} using the fourth test result. The new average EEF_{cook} is as follows:

$$Xa_4 = (1/4) \times (X_1 + X_2 + X_3 + X_4)$$
$$Xa_4 = (1/4) \times (33.8 + 31.3 + 30.5 + 31.8)$$
$$Xa_4 = 31.9\,\%$$

The new standard deviation is as follows:

First calculate A_4 and B_4

$$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$$
$$A_4 = (33.8)^2 + (31.3)^2 + (30.5)^2 + (31.8)^2$$
$$A_4 = 4064$$
$$B_4 = (1/4) \times [(X_1 + X_2 + X_3 + X_4)^2]$$
$$B_4 = (1/4) \times [(33.8 + 31.3 + 30.5 + 31.8)^2]$$
$$B_4 = 4058$$

The new standard deviation for the EEF_{cook} is as follows:

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

A1.5.7 *Step 6*—Recalculate the absolute uncertainty using the new average and standard deviation as follows:

$$U_4 = 1.59 \times S_4$$
$$U_4 = 1.59 \times 1.41$$
$$U_4 = 2.24\,\%$$

A1.5.8 *Step 7*—Recalculate the percent uncertainty as follows:

$$\%\ U_4 = (U_4/Xa_4) \times 100\,\%$$
$$\%\ U_4 = (2.24/31.9) \times 100\,\%$$
$$\%\ U_4 = 7\,\%$$

A1.5.9 *Step 8*—Since the percent uncertainty, % U_4, is less than ±10 %, the average for the EEF_{cook} is reported along with its corresponding absolute uncertainty, U_4, as follows:

$$EEF_{cook} = 31.9 \pm 2.24\,\%$$

The *PR* and its absolute uncertainty can be calculated and reported following the same steps, assuming the ±10 % precision requirement has been met for the corresponding EEF_{cook}.