Standard Test Methods for Performance of Steam Cookers[1]

This standard is issued under the fixed designation F1484; 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 evaluate the energy consumption and cooking performance of steam cookers. The food service operator can use this evaluation to select a steam cooker and understand its energy consumption.

1.2 These test methods are applicable to the following steam cookers: high-pressure, low-pressure, pressureless and vacuum steam cookers (Specification F1217 Grades A, B, C and D); convection and non-convection steam cookers; steam cookers with self-contained gas-fired, electric, or steam coil steam generators, and those connected directly to an external potable steam source (Specification F1217 Styles i, ii, iii, and iv). The steam cookers will be tested for the following (where applicable):

1.2.1 Maximum energy input rate (see 10.2).

1.2.2 Preheat energy consumption and duration (see 10.3).

1.2.3 Idle energy rate (see 10.5).

1.2.4 Pilot energy rate (see 10.6).

1.2.5 Frozen green pea cooking energy efficiency (see 10.8).

1.2.6 Frozen green pea production capacity (see 10.8).

1.2.7 Whole potato cooking energy efficiency (see 10.9).

1.2.8 Whole potato production capacity (see 10.9).

1.2.9 Water consumption (see 10.7, 10.9, and 10.10).

1.2.10 Condensate temperature (see 10.8 and 10.9).

1.2.11 Cooking uniformity (see 10.11).

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

1.4 *This standard may involve hazardous materials, operations, and equipment. It does not 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

F1217 Specification for Cooker, Steam

2.2 *ASHRAE Documents:*[3]

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

ASHRAE Handbook of Fundamentals Thermodynamic Properties of Water at Saturation, Chapter 6, Table 2, 1989

2.3 *Other Document:*[4]

Development and Application of a Uniform Testing Procedure for Steam Cookers

3. Terminology

3.1 *Definitions:*

3.1.1 *boiler, n*—self-contained vessel, separate from the cooking cavity, wherein water is boiled to produce steam for the steam cooker. Also called a steam generator.

3.1.2 *condensate, n*—mixture of condensed steam and cooling water, exiting the steam cooker and directed to the floor drain.

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

3.1.4 *cooking energy rate, n*—average rate of energy consumption (kBtu/h or kW) during the cooking energy efficiency test. Refers to any loading scenario in the green pea or potato load tests.

3.1.5 *electric energy rate, n*—refers to rate of electric energy consumption (kW) by steam cookers whose primary fuel source is not electricity (for example, gas). Electric energy is

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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., 1791 Tullie Circle, NE, Atlanta, GA 30329.

[4] Available from the Food Service Technology Center, 12949 Alcosta Blvd., #101, San Ramon, CA 94583.

measured and reported separately from the primary fuel energy so that the respective fuel prices can be applied to estimate energy costs.

3.1.6 *green pea load, n*—12 by 20 by 2½ in. (300 by 500 by 65 mm) perforated hotel pan filled with 8.0 ± 0.01 lb (3.6 ± .005 kg) of fresh-frozen, grade A, green peas.

3.1.7 *high-pressure steam cooker, n*—steam cooker wherein cooking compartment operates between 10 and 15 psig (Specification F1217 Classification Grade C).

3.1.8 *idle energy rate, n*—rate of energy consumed by the steam cooker while maintaining the boiler or reservoir at a manufacturer-defined operating pressure or temperature with no cooking taking place.

3.1.9 *low-pressure steam cooker, n*—steam cooker wherein cooking compartment operates between 3 and 9.9 psig (Specification F1217 Classification Grade B).

3.1.10 *maximum energy input rate, n*—peak rate at which an appliance consumes energy, typically reflected during preheat.

3.1.11 *pilot energy rate, n*—rate of energy consumption (kBtu/h) by a gas steam cooker's standing pilot (if applicable).

3.1.12 *potato load, n*—one 12 by 20 by 2½ in. (300 by 500 by 65 mm) perforated hotel pan filled with 50 ± 2 fresh, whole, US No. 1, size B, red potatoes, weighing 8.0 ± 0.2 lb (3.6 ± 0.1 kg).

3.1.13 *preheat, n*—process of bringing the steamer (boiler) water from city supply temperature to operating temperature (pressure).

3.1.14 *preheat duration, n*—total time required for preheat, from preheat initiation at controls to when the steam cooker is ready to cook.

3.1.15 *preheat energy, n*—amount of energy consumed by the steam cooker during a preheat.

3.1.16 *pressureless steam cooker, n*—steam cooker wherein cooking compartment operates between 0 and 2.9 psig (Specification F1217 Classification Grade A).

3.1.17 *production capacity, n*—maximum rate (lb (kg)/h) at which steam cooker can bring the specified food product to a specified "cooked" condition.

3.1.18 *production rate, n*—rate (lb (kg)/h) at which steam cooker brings the specified food product to a specified "cooked" condition. Does not necessarily refer to maximum rate. The production rate varies with the loading scenario and the amount of product being cooked.

3.1.19 *steam cooker, n*—cooking appliance wherein heat is imparted to food in a closed compartment by direct contact with steam. The compartment can be at or above atmospheric pressure. The steam can be static or circulated.

3.1.20 *water consumption, n*—water consumed by the steam cooker. Includes both water used in the production of steam and cooling water (if applicable) for condensing/cooling unused steam.

4. Summary of Test Method

4.1 The maximum energy input rate is determined to check whether the steam cooker is operating properly. If the measured input rate is not within 5 % of the rated input, all further testing ceases and the manufacturer is contacted. The manufacturer may make appropriate changes or adjustments to the steam cooker.

4.2 The energy and time required to preheat the steamer to an operating condition are determined.

4.3 Idle energy rate is determined for the steamer while it is maintaining operating pressure or temperature when no cooking is taking place.

4.4 Pilot energy rate is determined when applicable to a gas fired steam cooker under test.

4.5 Green pea cooking energy efficiency is determined by cooking a capacity number of frozen green pea loads from 0 to 180°F (–18 to 82°C).

4.6 Whole potato cooking energy efficiency is determined by cooking a capacity number of fresh whole potatoes to a specified doneness.

4.7 Green pea load and whole potato load production capacities (lb_{pea}/h or lb_{potato}/h (kg_{pea}/h or kg_{potato}/h)) are determined by the respective cooking energy efficiency tests.

4.8 Water consumption (gal/h (L/h)) is monitored during all cooking energy efficiency tests to determine the rate of water usage.

4.9 Condensate temperature is monitored during all cooking energy efficiency tests.

4.10 The uniformity of heating within the steamer's compartment is determined and reported based on the average temperature on each pan during ice load cooking tests (pans of ice simulating pans of frozen food).

5. Significance and Use

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

5.2 Preheat energy and duration can be useful to food service operators for managing power demands and knowing how quickly the steam cooker can be ready for operation.

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

5.4 Green pea cooking energy efficiency is an indicator of steam cooker energy performance when cooking frozen products under various loading conditions. This allows the food service operator to consider energy costs when selecting a steam cooker.

5.5 Potato cooking energy efficiency is an indicator of steam cooker energy performance when cooking foods that require long cook times (for example, potatoes, beans, rice, lasagna or casserole rethermalization). The test demonstrates the difference in energy efficiency between pressure and pressureless steam cookers for this type of cooking event. The information may help a food service operator to evaluate what type of steamer to select (pressure versus pressureless versus dual pressure mode) from an energy performance perspective.

5.6 Green pea production capacity and potato production capacity can be used by food service operators to choose a steam cooker to match their particular food output requirements.

5.7 Water consumption characterization is useful for estimating water and sewerage costs associated with appliance operation.

5.8 Condensate temperature measurement is useful to verify that the temperature does not exceed regional building code limits.

5.9 Cooking uniformity provides information regarding the steamer's ability to cook food at the same rate throughout the steamer's compartment.

6. Apparatus

6.1 *Watt-Hour Meter,* for measuring the electrical energy consumption of a steam cooker, 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 1.5 Wh and a maximum uncertainty no greater than 1.5 %.

6.2 *Gas Meter,* for measuring the gas consumption of a steam cooker, shall be a positive displacement type with a resolution of at least 0.01 ft^3 (0.0003 m^3) and a maximum uncertainty 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 uncertainty no greater than 2 % of the measured value.

6.3 *Steam Flow Meter,* for measuring the flow of steam to a steam cooker that uses either a direct external potable steam source or a steam coil steam generator. Shall have a resolution of 0.01 ft^3 (0.0003 m^3) and a maximum uncertainty of 1 % of the measured value.

6.4 *Pressure Gauge,* for measuring pressure of steam to a steam cooker that uses either a direct external potable steam source or a steam coil steam generator. Shall have a resolution of 0.5 psig (3.4 kPa) and a maximum uncertainty of 1 % of the measured value.

6.5 *Canopy Exhaust Hood,* 4 ft (1.2 m) in depth, wall-mounted with the lower edge of the hood 6 ft, 6 in. (2.0 m) from the floor and with the capacity to operate at a nominal exhaust ventilation rate of 300 cfm per linear foot (230 L/s per linear meter) of active hood length. This hood shall extend a minimum of 6 in. (150 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.

6.6 *Pressure Gauge,* for monitoring boiler pressure. The gauge shall have a resolution of 0.5 psig (3.4 kPa) and a maximum uncertainty of 1 % of the measured value.

6.7 *Pressure Gauge,* for monitoring natural gas pressure. The gauge shall have a range of 0 to 15 in. H_2O (0 to 3.7 kPa), a resolution of 0.5 in. H_2O (125 Pa), and a maximum uncertainty of 1 % of the measured value.

6.8 *Temperature Sensor,* for measuring gas temperature in the range of 50 to 100°F (10 to 40 °C), with a resolution of 0.1°F (0.05°C) and an uncertainty of ±1.0°F (0.6°C).

6.9 *Barometer,* for measuring absolute atmospheric pressure, to be used for adjustment of measured natural gas volume to standard conditions, having a resolution of 0.2 in. Hg (670 Pa) and an uncertainty of 0.2 in. Hg (670 Pa).

6.10 *Flow Meter,* for measuring total water consumption of the appliance. The meter shall have a resolution of 0.01 gal (40 ml), and an uncertainty of 0.01 gal (40 ml), at flow rate as low as 0.2 gpm (13 ml/s).

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

6.12 *Analytical Balance Scale,* for measuring weight of food for cooking test loads and for weighing hotel pans. It shall have a resolution of 0.01 lb (5 g) and an uncertainty of 0.01 lb (5 g).

6.13 *Calibrated Exposed Junction Thermocouple Probes,* with a range from –20 to 400°F (–30 to 200°C), with a resolution of 0.2°F (0.1°C) and an uncertainty of ±1.0°F (0.6°C), for measuring temperature of frozen green peas, potatoes, calorimeter water, water entering the boiler, and condensate. Calibrated Type K thermocouples (24 GA wire) are a good choice.

6.14 *Hotel Pans,* perforated, for frozen green pea and potato tests, with 12 by 20 by 2½ in. dimensions (300 by 500 by 65 mm) stainless steel weighing 2.5 ± 0.5 lb (1.1 ± 0.2 kg).

6.15 *Water-Bath Calorimeter,* for temperature determination of the cooked green pea load. The calorimeter is comprised of five components and are shown in Fig. 1: inner container—cylindrical, 0.087-in. (2.2-mm) thick walled, plastic drum (PG&E found that a 15-gal container is adequate for most applications); drum insulation—R-25 fiberglass insulation; drum lid—plastic lid double reinforced with 2-in. (50 mm) thick polystyrene board; stirrer—3-ft long, ¼-in. diameter, steel rod with propeller welded to one end; thermocouple tree—¼-in. diameter pipe with five temperature sensors attached laterally equidistant from one another. The sensors must be adjusted so that they are fully submerged for each loading

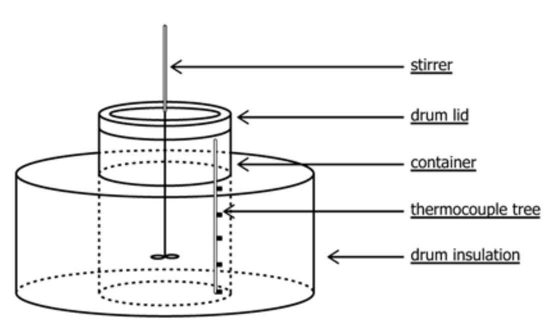

FIG. 1 Water-Bath Calorimeter

scenario. A convenient way to construct the water-bath calorimeter is to place the inner container on a 2-in. (50 mm) thick polystyrene board. Wrap the outside of the drum with 1 ft thick R-25 fiberglass insulation so no drum wall is exposed. Cover the fiberglass insulation with plastic liner to waterproof the interior. Construct the thermocouple tree by affixing five type K thermocouple probes 3 in. apart along the copper pipe. Fix the thermocouple tree vertically along the drum wall as to avoid contact with the stirrer. Drill a ½-in. hole in the center of the plastic/polystyrene lid. Place the propeller end of the stirrer in the drum and close the lid, allowing the opposite end of the stirrer to pass through the center of the lid. The calorimeter can be placed on castors for ease in mobility, and the content can be stirred manually or with the aid of a portable, handheld drill during a test.

6.16 *Hypodermic-Style Thermocouple Probe* for measuring potato temperatures. Minimum diameter makes for easier insertion and faster response. Resolution and uncertainty shall be the same as in 6.13.

6.17 *Platform Balance Scale,* or appropriate load cells, used to measure the weight of the water-bath calorimeter and content during the frozen green pea load test. Shall have the capacity to accommodate the total weight of calorimeter plus the cooked food product and water. The resolution shall be 0.2 lb (10 g) with an uncertainty of 0.2 lb (10 g).

6.18 *Hotel Pans,* for ice loads, solid 12 by 20 by 2½-in. (300 by 500 by 65-mm) stainless steel, weighing 2.8 ± 0.2 lb (1.3 ± 0.1 kg), with a temperature sensor located in the center of each pan ⅝ in. (16 mm) from the bottom. A convenient method is to have Type K thermocouple probes with a stainless-steel protective sheath fabricated in the shape shown in Fig. 2. The sensing point is exposed and isolated thermally from the stainless-steel sheath. The probe is strapped to the pan using steel shim stock welded to the pan using a strain gauge welder. The thermocouple lead TFE-fluorocarbon sheath is minimum thickness (TFE-fluorocarbon wrap rather than extruded TFE-fluorocarbon) to minimize the escape of steam where the thermocouple exits the cooking compartment. The lead is long enough to allow connection to the monitoring device while the ice loads are in the freezer, while they are being weighed, and while they are in the steam cooker.

6.19 *Water Bucket*—Plastic water bucket able to withstand temperatures above 210°F (i.e. HDPE) used for measuring the amount of water in a connectionless, boilerless steamer (ASTM F1217 Type IB).

7. Reagents and Materials

7.1 Quality of water used to fill the boiler shall meet the manufacturer's specifications.

7.2 Green peas shall be fresh-frozen, grade A, stabilized at 0 ± 5°F (–18 ± 2°C).

7.3 Potatoes shall be fresh, whole, US No. 1, Size B, red potatoes. The average weight of the potatoes shall be 0.16 ± 0.02 lb (73 ± 9 g).

NOTE 1—Red potatoes are sold in three sizes: A, B, and C. This test uses Size B.

7.4 Water used for the cooking uniformity test shall have a maximum hardness of three grains per gallon. Distilled water may be used.

8. Sampling

8.1 *Steam Cooker*—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 the wall, with the lower edge of the hood 6 ft, 6 in. (2.0 m) from the floor. Position the steam cooker so that

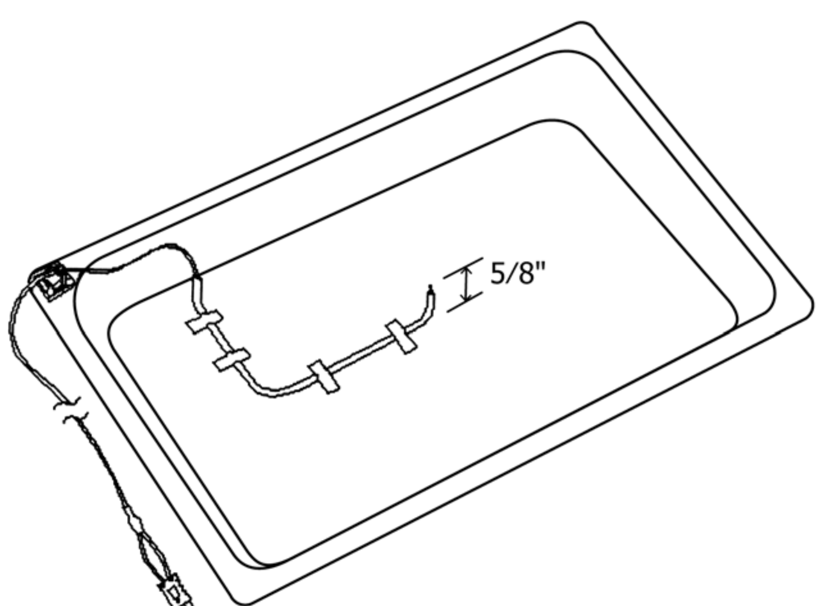

FIG. 2 Hotel Pan with Thermocouple Probe

any edge is at least 6 in. (150 mm) from the inside edge of the hood. In addition, both sides of the steam cooker shall be a minimum of 3 ft (1.1 m) from any wall, side partition, or other operating appliance. Equipment configuration is shown in Fig. 3. The exhaust ventilation rate shall be 300 cfm per linear foot (230 L/s per linear meter) 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 when the exhaust ventilation system is working without the appliance being operated.

9.2 Connect the steam cooker 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 steam cooker, 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 a steam cooker that uses either a direct external potable steam source or a steam coil steam generator, there shall be a pressure gauge and steam flow meter to verify that the manufacturer's specified steam requirements are met. 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 steam cooker, confirm (while the steam cooker elements are energized) that the supply voltage is within ±2.5 % of the operating voltage specified by the manufacturer. The test voltage shall be recorded for each test.

NOTE 2—If an electric steam cooker is rated for dual voltage (for example, 208/240 V), the voltage selected by the manufacturer or tester, or both, shall be reported. If a steamer is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the steamer (for example, preheat time) may differ at the two voltages.

9.4 For a gas steam cooker, adjust (during a boiler preheat) 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.

9.5 Install a flow meter (6.10) to the steam cooker water inlet such that total water flow to the appliance (both boiler supply water and condensate cooling water) is measured.

9.6 Install a pressure gauge (6.6) to measure boiler pressure.

9.7 Install a temperature sensor (6.13) such that it is immersed in the condensate water path just as it exits the steam cooker.

9.8 Measure the incoming water temperature to the steamer.

10. Procedure

NOTE 3—Prior to starting these tests, the tester should read the operating manual and fully understand the operation of the appliance.

10.1 *General:*

10.1.1 For gas steam cookers, the following shall be obtained and recorded for each run of every test.

10.1.1.1 Higher heating value,

10.1.1.2 Standard gas conditions for calculation in 11.3.2,

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 Measured peak input rate during or immediately prior to test.

NOTE 4—The preferred method for determining the heating value of gas supplied to the steam cooker under test is by using a calorimeter or gas chromatography in accordance with accepted laboratory procedures. It is recommended that all testing be performed with gas having a heating value between 1000 and 1075 Btu/ft^3 (37 300 to 40 100 kJ/m^3).

10.1.2 For gas steam cookers, energy calculations shall be in accordance with 11.3.

10.1.3 For gas steam cookers, electric energy consumption shall also be measured and added to gas energy for all tests, with the exception of the maximum energy input rate test (10.2).

10.1.4 For electric steam cookers, the following shall be obtained and recorded for each run of every test.

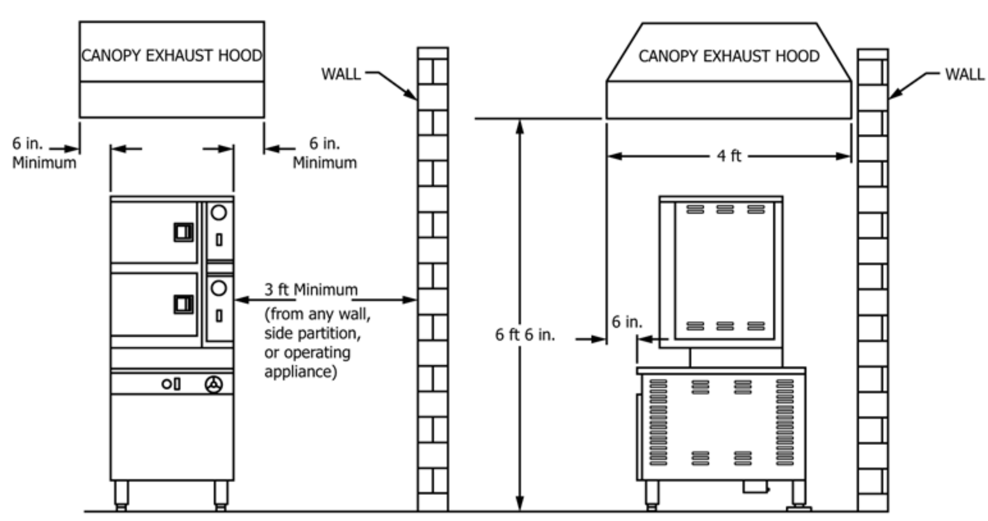

FIG. 3 Equipment Configuration

10.1.4.1 Voltage while elements are energized, and

10.1.4.2 Verify peak input rate during or immediately prior to test.

10.1.5 For steam cookers that use either a direct external potable steam source or a steam coil steam generator, the supplied steam pressure and average flow rate shall be recorded for each run of every test.

10.1.6 For each run of every test, confirm that the peak input rate is within ±5 % of rated nameplate input. If the difference is greater than 5 %, testing shall be terminated and the manufacturer contacted. The manufacturer may make appropriate changes or adjustments to the steam cooker.

10.1.7 If a steam cooker is able to operate in more than one pressure mode (for example, both low pressure and pressureless), the tester shall record the operating mode selected for testing and conduct all tests herein using the same operating mode, preferably one that correlates to a 210°F internal cavity temperature.

10.2 *Maximum Energy Input Rate:*

10.2.1 This step applies to gas steam cookers only. (For electric steam cookers, proceed directly to step 10.2.2, and for steam coil steam cookers, proceed directly to step 10.2.3.) For some gas appliances, the maximum energy input rate changes as the orifices heat up. If the steam cooker under test is gas powered, conduct a boiler fill and preheat, then immediately purge the boiler and proceed to step 10.2.3.

10.2.2 This step applies to electric steam cookers only. Monitor power during a steam cooker operation where the maximum power is drawn. Proceed directly to step 10.2.4.

10.2.3 Allow the boiler(s) or reservoir to fill with water. As soon as the boiler(s) or reservoir is (are) full, start the preheat (some boilers may start automatically after filling). Begin monitoring energy consumption and time as soon as all the burners, elements, or steam coils energize. Continue until the first burner, element, or steam coil turns off. Record final time and energy.

10.2.4 In accordance with 11.4, determine the maximum energy input rate for the steam cooker under test. Report the measured input rate and confirm that it is within 5 % of the rated nameplate input. If the difference is greater than 5 %, testing shall be terminated and the manufacturer contacted. The manufacturer may make appropriate changes or adjustments to the steam cooker.

10.3 *Preheat Energy Consumption and Duration:*

10.3.1 Fill the boiler or reservoir. Record the time required to fill it. Monitor the average temperature of the water as it enters the boiler or reservoir. If the average temperature was not 70 ± 5°F (21 ± 3°C), then allow the filled boiler or reservoir to sit until the temperature is within that range. Temperature of the water in the boiler can be estimated by measuring the boiler surface temperature using a surface temperature probe (6.17).

10.3.2 Record the temperature of the water in the boiler or reservoir. Start the preheat and monitor energy consumption and time as soon as the boiler is turned on. For a gas steam cooker, the recorded preheat time shall include any delay between the time the unit is turned on and when the burners actually ignite. For a gas steam cooker, measure and record any electric energy consumption as well. Preheat is judged complete when the primary burners, elements, or steam coil cycles off or when the steamer compartment reaches 205°F (boilerless steamers). Record preheat energy consumption, duration, and final pressure (if applicable).

10.3.3 In accordance with 11.5, report preheat energy consumption and duration.

10.4 *Ready to Cook Idle Energy Rate:*

10.4.1 Set the steamer to a ready-to-cook state (boiler[s] on) for a minimum of 1 h. A ready-to-cook state is defined as 212 ± 5°F (100 ± 3°C) compartment temperature.

10.4.2 Allow the steamer to operate in standby for at least 60 min after the preheat. Then commence monitoring the elapsed time and the energy consumption of the steam cooker while it is operated under this standby condition for a minimum of 2 h. For gas steam cookers, monitor electric energy in addition to gas consumption.

10.4.3 This step applies to non-atmospheric boilers only. In addition to monitoring total energy for the test period, record the quantity of energy consumed during each individual cycle for three cycles of the boiler. Record the average of these values as the energy required to raise the boiler from minimum operating pressure/temperature to maximum pressure/temperature. This value is used in the green pea and potato energy efficiency calculations.

10.4.4 If there is a separate boiler for each compartment, then apply this test (and report an idle rate) for each compartment separately and then for all compartments simultaneously.

10.4.5 In accordance with 11.6, calculate and report the ready-to-cook idle energy rate(s).

10.5 *Standby Idle Energy Rate:*

10.5.1 If the steamer is equipped with a standby (that is, idle, hold) mode, then set the appliance controls to this mode. Allow the steamer to operate in standby for at least 60 min after the preheat. Then commence monitoring the elapsed time and the energy consumption of the steam cooker while it is operated under this standby condition for a minimum of 2 h. For gas steam cookers, monitor electric energy in addition to gas consumption.

10.5.2 If there is a separate boiler for each compartment, then apply this test (and report an idle rate) for each compartment separately and then for all compartments simultaneously.

10.5.3 In accordance with 11.7, calculate and report standby idle energy rate(s).

10.6 *Pilot Energy Rate (Gas Models with Standing Pilots)*—With the pilot lit and the boiler off, record time and gas consumption for a minimum of 8 h. In accordance with 11.8, calculate and report pilot energy rate.

10.7 *Green Pea Preparation:*

10.7.1 This section outlines preparation of the frozen green peas used in the green pea load cooking energy-efficiency and production-capacity test (10.8).

10.7.2 The number of green pea loads to be prepared depends on which loading scenario is to be performed. There are two loading scenarios: heavy and light. The heavy load is the manufacturer's stated capacity of 12 by 20 by 2½-in. (300 by 500 by 65-mm) hotel pans. For light load scenarios, consult Table 1 for the proper number of green pea pans to prepare.

NOTE 5—When the test calls for a less than capacity number of loads for a compartment, the loads should be placed in the most centrally located slots. When symmetry about the center is not possible, then use the upper central slots first. For example, one pan in a four-pan capacity compartment should be located in the second slot from the top.

10.7.3 The perforated hotel pans shall be as specified in 6.14.

10.7.4 Number each pan and record the weight of each of the (empty) pans. The weight of the pan(s) will be the total weight of all pans used for the test.

10.7.5 Prepare enough green peas for testing by using 8.0 ± 0.01 lb (3.6 ± 0.005 kg) (see 7.2) green peas for each pan as determined in 10.7.2. Seal the frozen green peas in plastic zip bags and place them the freezer allowing the pea temperature to stabilize at 0 ± 5°F (–18 ± 2°C) for a 24 h period.

10.7.6 The water-bath calorimeter shall be as specified in 6.15. Record the weight of the empty calorimeter using the platform balance scale (6.6).

10.7.7 Place 10 lb of potable water for every pan of green peas into the calorimeter drum. (For example, the total weight of water for a heavy load test of a six-pan capacity, steamer would be 60 lb (10 lb water/pan × 6 pans = 60 lb).

NOTE 6—The initial water temperature for the water-bath need not be 70 ± 5°F (21 ± 3°C). As long as the initial and final temperatures are recorded, the change in water-bath temperature can be obtained.

10.7.8 Record the weight of the water in the water-bath calorimeter.

10.8 *Green Pea Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature:*

10.8.1 This procedure applies to two possible loading scenarios: heavy and light. Repeat each loading scenario a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (Annex A1). The reported values of cooking energy efficiency, production capacity, condensate temperature, and water consumption shall be the average of the replications (runs).

10.8.2 Prepare the frozen green pea load(s) in accordance with 10.7. Record the weight of the empty pan(s) and the weight of the green pea load(s).

10.8.3 Measure and record the average temperature of the green peas by probing the content of the sealed bags. Confirm that they are at 0 ± 5°F (–18 ± 3°C).

10.8.4 Choose a cooking time either based on the manufacturer's recommendation or by experience.

10.8.5 Allow the steam cooker to idle in a ready-to-cook state (boiler[s] on) for a minimum of 1 h. If the manufacturer recommends leaving the cooking cavity doors open when not cooking, then leave them open during the stabilization period and record the door position during the stabilization period.

NOTE 7—The steamer shall be stabilized in the same operating mode that will be used for the cooking test. If the steamer is to be tested in a reduced-input mode, then the steamer shall be stabilized in the same mode for at least 1 h prior to loading with food product.

10.8.6 After the 60 min stabilization period, wait for the burners, elements, or steam coil to cycle on and then off again. This assures that the boiler is at maximum operating pressure/temperature when the efficiency test starts.

10.8.7 Manual-fill steamers (no water connection): Record the starting weight of water in the reservoir according to the following steps:

10.8.7.1 After the required stabilization period, tare a five gallon bucket and drain the water from the steam cavity into a bucket while the keeping the door closed. Once drained, weigh the contents and write down the weight of water. (Note: two buckets may be needed for safety)

10.8.7.2 Open the cavity door and fill the cavity using the previously removed water. Top off the water level to return to the fill manufacturer's line if necessary, then close the door. Record any additional amount of water placed in the cavity to return to the fill line and include this in the total starting water weight.

TABLE 1 Number of Loads for Light Loading Scenario

	Light Loading Scenario
1 Compartment 3 Pan Capacity	1 Pan
1 Compartment 4 Pan Capacity	1 Pan
1 Compartment 5 Pan Capacity	1 Pan
1 Compartment 6 Pan Capacity	1 Pan
2 Compartments 3 Pan Capacity Per Compartment	1 Pan in top compartment None in bottom
2 Compartments 4 Pan Capacity Per Compartment	1 Pan in top compartment None in bottom
2 Compartments 5 Pan Capacity Per Compartment	2 Pans in top compartment None in bottom
2 Compartments 6 Pan Capacity Per Compartment	2 Pans in top compartment None in bottom
2 Compartments 8 Pan Capacity Per Compartment	2 Pans in top compartment None in bottom
3 Compartments 3 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
3 Compartments 4 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
3 Compartments 5 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
3 Compartments 6 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
3 Compartments 8 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom

10.8.7.3 The drain, weigh, refill and top off procedure shall not take longer than 5 min. During this period, do not leave the door open longer than 0.75 min per cavity.

10.8.7.4 Start monitoring time immediately after the door is closed and allow the steamer to reach its maximum energy state. The maximum energy state is reached immediately after the heating elements cycle off or after 5 min of continuous burner operation, whichever comes first.

10.8.8 Start monitoring time. Transport the green pea loads to the testing location. Empty the bagged green peas into the pan(s). Open one steam compartment, load the pan(s), close the compartment, and start steam to steamer. Open the next steam compartment (if applicable), load it, close it, start cooking, and note the starting time. After starting steam to the first compartment, commence monitoring energy consumption, water consumption, and condensate temperature. For gas steam cookers, monitor and record the electric energy as well as gas consumption. The total loading time (the time from opening the first compartment to closing and starting the last compartment) shall be a total of 5 s per compartment and an additional 5 s for each pan used. (For example, the total loading time for a heavy load test of a six-pan capacity, two-compartment steam cooker would be 5 s/compartment × 2 compartments + 5 s/pan × 6 pan = 40 s).

NOTE 8—Care shall be taken to minimize heat gain by the frozen green pea loads on the way from the freezer to the steam cooker. During that time they shall be isolated from any warmer surface by R10 or better insulation. PG&E found 2 in. (50 mm) thick square-edged polystyrene boards to be convenient as an insulating surface.

NOTE 9—For gas steamers, the "electric energy rate" during the heavy load test will be reported separately from the gas "cooking energy rate." The two values are reported separately so that the respective fuel prices may be applied to estimate energy costs.

10.8.9 For three cycles of the boiler pressure near the end of the test, measure the maximum and minimum pressures. Record the average maximum and average minimum boiler pressure.

NOTE 10—The boiler is at maximum pressure when the test starts, but it may be at a lower pressure at the end of the test. This difference between the initial and final energy content (pressure/temperature) of the boiler must be added back to the boiler to correctly calculate the energy efficiency. Maximum, minimum and final boiler pressure is measured so that this energy deficit can be estimated.

10.8.10 Terminate steam to the compartments as the predetermined cooking time elapses for each compartment. After stopping steam to the last compartment, record the final time, water consumption, and average condensate temperature. For a steamer using manual fill, turn the steamer completely off and drain the remaining tank water into a bucket. Weigh the final amount of water, this will be used to calculate water consumption.

10.8.11 If the boiler is on when the cooking time for the last compartment has elapsed, continue to monitor energy consumption until the primary burners, elements, or steam coils cycle off. Record final energy. Note that the initial and final energy content of the boiler is the same; therefore, the pressure measurements in step 10.8.9 are not needed.

10.8.12 If the boiler is not on when the last compartment cooking time elapsed, then the following steps will be required to estimate the energy deficit in the boiler:

10.8.12.1 Perform this step if the boiler pressure is controlled by a pressure switch that can be manually actuated. Otherwise, proceed directly to step 10.8.12.2. When the time for the last compartment has elapsed, continue to monitor energy consumption and actuate the pressure switch. This returns the boiler energy content to the initial test condition. Record the final energy.

10.8.12.2 Perform this step if the boiler pressure control cannot be manually actuated. When the cooking time for the last compartment has elapsed, record the final energy and the boiler pressure (used to calculate the energy deficit of the boiler, as described in Note 10).

10.8.13 Record the initial temperature of the water-bath calorimeter immediately before the cook time elapsed. The unloading time shall be the same as the loading time. Remove the calorimeter lid and empty the cooked green pea pan(s) into the water-bath calorimeter. Replace the lid on the water-bath calorimeter.

10.8.14 Using the stirrer, agitate the content for 1 min, then allow the contents of the water-bath calorimeter to stabilize for 3 min. Repeat the agitation and stabilization process every 3 min until the bulk temperature fluctuation is less than ±0.1°F within a 3 min period. Record this temperature as the final bulk temperature.

10.8.15 Record the total weight of the water-bath calorimeter containing the cooked green peas and water with the platform balance scale. This will be used to determine the weight of the cooked green peas.

10.8.16 In accordance with 11.9.2, calculate the final cooked bulk temperature of the green peas. The cook temperature must be 180 ± 5°F (82 ± 3°C) for the test run. If the temperature does not fall within this range, the test must be repeated with an adjusted cook time.

10.8.17 If the temperature is within the range, prepare the next frozen green pea load (10.7) and the water-bath calorimeter, unless this was the final run (Run No. 3), and perform the test again until a minimum of three tests have been completed.

10.8.18 Confirm that the multi-test (three run) average final pea temperature is between 180 ± 2°F (82 ± 1°C). If the average final pea temperature does not fall within this range, then repeat 10.8.2 – 10.8.17 with an appropriately adjusted cook time to achieve this average temperature.

10.8.19 Calculate the cooking energy efficiency, production capacity, water consumption, and average condensate temperature in accordance with 11.9 and report the results as the average of three replications.

10.9 *Whole Potato Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature:*

10.9.1 This procedure applies to two possible loading scenarios: heavy and light. Each loading scenario shall be repeated a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (Annex A1). The reported values of cooking energy efficiency, production capacity, condensate temperature, and water consumption shall be the average of the replications (runs).

10.9.2 The perforated hotel pans shall be as specified in 6.14. Number each pan and record the weight of each (empty) pan.

10.9.3 Load each pan with 8.0 ± 0.2 lb (3.6 ± 0.1 kg) of red potatoes (7.3). Each pan shall contain between 48 and 52 red potatoes. Record the actual weight and count of the potato load in each pan.

NOTE 11—If the weight of the potatoes on a pan is outside the 8.0 ± 0.2 lb (3.6 ± 0.1 kg) weight range specified above, substitute smaller or larger potatoes, as necessary, until the weight of the potatoes on each pan is within the required weight range while maintaining a count of 50 ± 2 potatoes per pan.

10.9.4 Choose a cooking time either based on the manufacturer's recommendation or by experience.

10.9.5 Shortly before each test run, randomly select potatoes from each pan for temperature monitoring. For steamers with at least two pans, record the temperature of at least five potatoes evenly spaced out among the pans. For light load tests, record the temperature of at least three potatoes. Place a hypodermic-style thermocouple probe into the center of the randomly-selected potatoes. Secure each thermocouple wire in such a manner that its junction will remain at the center of the potato throughout the cooking period. The temperature of the potatoes at the start of each test shall be 75 ± 5°F (24 ± 3°C).

NOTE 12—Steamers that operate with the cooking compartment under pressure or vacuum may not function properly with thermocouples passing through the door seal. For these steamers, it may not be possible to monitor potato temperature during the cooking cycle.

10.9.6 Allow the steam cooker to stabilize in a ready-to-cook state (boiler on) for a minimum of 1 h. If the manufacturer recommends leaving the cooking cavity doors open when not cooking, leave them open during the stabilization period. Record the door position during the stabilization period. Fig. 4 shows the cooking energy efficiency test sequence.

NOTE 13—The steamer shall be stabilized in the same operating mode that will be used for the cooking test. If the steamer is to be tested in a reduced-input mode, then the steamer shall be stabilized in the same mode for at least 1 h prior to loading with food product.

10.9.7 After the stabilization period, wait for the burners, elements, or steam coil to cycle on and then off again. This assures that the boiler is at maximum operating pressure/temperature when the efficiency test cooking starts.

NOTE 14—The boiler is at maximum pressure when the test starts, but it may be at a lower pressure at the end of the test. This difference between the initial and final energy content (pressure/temperature) of the boiler must be added back to the boiler to correctly calculate the energy efficiency. Maximum, minimum and final boiler pressure is measured so that this energy deficit can be estimated. There are situations where the measurement of pressure in step 10.9.10 is not necessary, as noted in steps 10.9.12 and 10.9.13.1.

10.9.8 Manual-fill steamers (no water connection): Record the starting weight of the water in the reservoir according to the following steps:

10.9.8.1 After the required stabilization period, tare a five gallon bucket and drain the water from the steam cavity into a bucket while the keeping the door closed. Once drained, weigh the contents and write down the weight of water. (Note: two buckets may be needed for safety)

10.9.8.2 Open the cavity door and fill the cavity using the previously removed water. Top off the water level to return to the manufacturer's fill line if necessary, then close the door. Record any additional amount of water placed in the cavity to return to the fill line and include this in the total starting water weight.

10.9.8.3 The drain, weigh, refill and top off process shall not take longer than 5 min. During this period, do not leave the door open longer than 0.75 min per cavity.

10.9.8.4 Start monitoring time immediately after the door is closed and allow the steamer to reach its maximum energy state. The maximum energy state is reached immediately after the heating elements cycle off or after 5 min, whichever comes first.

10.9.9 Start monitoring time. Open one steam compartment, load it with potato pans, close it, and start the steam cook. Note the starting time for that compartment. Open the next steam compartment (if applicable), load it, close it, start cooking, and note the starting time. Open, load, close, start, and note starting time of the last compartment (if applicable). After starting steam to the first compartment, commence monitoring energy consumption, water consumption, potato temperature and condensate temperature. For gas steam cookers, monitor and record electric energy as well as gas consumption. The total loading time (the time from opening the first compartment to closing and starting the last compartment) shall be the total of 5 s per compartment plus 5 s for each load used (for example,

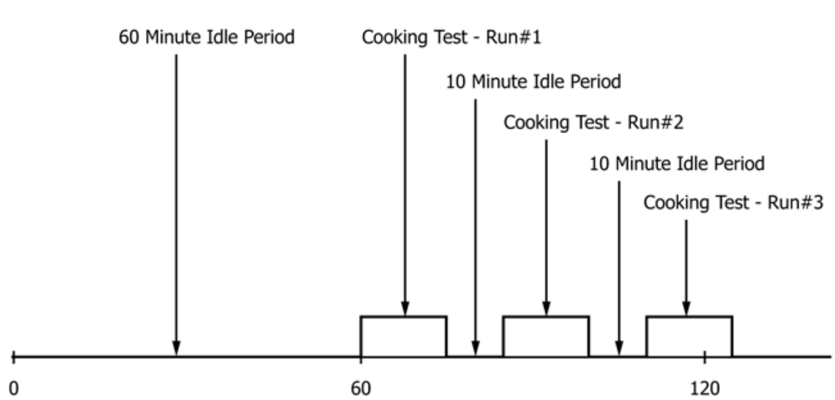

FIG. 4 Cooking Energy Efficiency Test Sequence

the total loading time for a heavy load test of a six-pan capacity, two-compartment steam cooker would be 40 s (5 s/compartment × 2 compartments + 5 s/load × 6 loads = 40 s).

10.9.10 For the last three cycles of the boiler pressure near the end of the test, measure the maximum and minimum pressures. Record the average maximum and average minimum boiler pressure.

NOTE 15—For gas steamers, the "electric energy rate" during the heavy load test will be reported separately from the gas "cooking energy rate." The two values are reported separately so that the respective fuel prices may be applied to estimate energy costs.

NOTE 16—Report the maximum condensate temperature reading taken during the entire duration of the test and recovery.

10.9.11 Terminate steam to the compartments when the average potato temperature reaches 195 ± 2°F (91 ± 1°C). After stopping steam to the last compartment, record the final time, water consumption, average potato temperature and average condensate temperature. For a steamer using manual fill, turn the steamer completely off and drain the remaining tank water into a bucket. Weigh the final amount of water, this will be used to calculate water consumption.

10.9.12 If the boiler is on when the cooking time for the last compartment has elapsed, continue to monitor energy consumption until the primary burners, elements, or steam coils cycle off. Record the final energy. Note that the initial and final energy content of the boiler is the same; therefore, the pressure measurements in step 10.9.11 are not needed.

10.9.13 If the boiler is not on when the cooking time for the last compartment has elapsed, then the following steps will be required to estimate the energy deficit in the boiler:

10.9.13.1 Perform this step if the boiler pressure is controlled by a pressure switch that can be manually actuated. When the cooking time for the last compartment has elapsed, continue to monitor energy consumption and actuate the pressure switch. This returns the boiler energy content to the initial test condition. Record the final energy.

10.9.13.2 Perform this step if the boiler pressure control cannot be manually actuated. When the cooking time for the last compartment has elapsed, record the final energy and the boiler pressure (used to calculate the energy deficit of the boiler, as described in Note 14).

10.9.14 Remove the potatoes from the cavity and confirm the cooked potato temperature by measuring and recording the temperature of five randomly selected potatoes for each pan using a hypodermic-style temperature probe. Ensure that each quadrant in each pan is represented. Temperature shall be measured immediately after cooking is terminated. The last temperature taken shall be no more than 3 min after cooking is terminated. The average bulk temperature (including monitored and spot-checked potatoes) must be 195 ± 2°F (91 ± 1°C). If the temperature does not fall in this range, the test must be repeated with an adjusted cook time.

10.9.15 Repeat 10.9.2–10.9.14 for the remaining test runs.

10.9.16 In accordance with 11.10, calculate and report cooking energy efficiency, production capacity, water consumption, and average condensate temperature. After performing this test three times for each loading scenario, report results as the average of the replications.

10.10 *Water Consumption:*

10.10.1 Use this step if the steamer is a manual fill unit, or if the steamer is not connected to a water connection to measure water consumption of the steamer. After the required stabilization period, tare a five gallon bucket and drain the water from the steam cavity into a bucket while the keeping the door closed. Once drained, weigh the contents and write down the weight of water. (Note: two buckets may be needed for safety) Next, open the cavity door and fill the cavity using the previously removed water and add water to the required fill line if necessary. Note the additional amount of water placed in the cavity and add this to the previously written down values, this will be the total initial amount of water. Close the door. Complete this process as fast as possible to minimize any heat loss from the water and cavity. The overall process should take less than 5 min and the door should not be open any longer than 0.75 min per cavity.

10.10.2 Start monitoring time immediately after the door is closed and allow the steamer to reach its maximum energy state. The maximum energy state is reached immediately after the heating elements cycle off or after 5 min of continuous burner ignition, whichever comes first.

10.10.3 Proceed to open the steamer and perform the peas cooking energy efficiency test (see 10.7) or whole potatoes cooking energy efficiency (see 10.9).

10.10.4 When the determined cook time has elapsed, turn off the steamer completely and remove the contents following green pea cooking energy efficiency testing or whole potato cooking energy efficiency procedures. Once those steps have been completed, keep the door shut and drain the cavity into a high temperature bucket, weigh and record the amount of water remaining in the cavity.

10.10.5 The difference between the initial and final water weight will be the water consumed during the cook process. Divide this weight by the cook time and multiply by 60 and dividing by 8.337 (density of water – 8.337 lb/gal) to obtain the water consumption rate in gallons per hour.

10.10.6 This procedure will be used for all heavy and light load cooking tests, and the highest water consumption rate will be reported.

10.11 *Ice Load Cooking Uniformity:*

NOTE 17—The intent of this procedure is to demonstrate potential pan-to-pan temperature variability in the steaming compartment using ice as a simulated food product. Ice loads are representative of frozen vegetable loads, while allowing for more consistent temperature measurement.

10.11.1 The cooking uniformity test must be repeated three times. The reported final pan temperatures shall be the average of the replications (runs).

10.11.2 The number of ice loads required depends on the steamer capacity. The heavy load is the manufacturer's stated capacity of 12 by 20 by 2½-in. (300 by 500 by 65-mm) hotel pans. Prepare enough ice loads for three runs.

10.11.3 The solid hotel pans shall be as specified in 6.18.

10.11.4 Number each pan and record the weight of each of the (dry) pans.

10.11.5 Fill the pans with enough water such that there will be 8.0 ± 0.2 lb (3.6 ± 0.1 kg) of ice after freezing (some water will evaporate during freezing, especially if hotel pan lids are not used). Accurate measurement of the weight of the pans plus the water prior to freezing is not required since they will be weighed again just prior to testing.

10.11.6 Freeze the loads to 0 ± 5°F (−18 ± 2°C).

10.11.7 Record the initial average ice load temperature. Confirm that they are at 0 ± 5°F (−18 ± 3°C).

10.11.8 Allow the steam cooker to stabilize in a ready-to-cook state (boiler(s) on) for a minimum of 1 h. If the manufacturer recommends leaving the cooking cavity doors open when not cooking, leave them open during the stabilization period and record the door position during the stabilization period.

10.11.9 Near the end of the stabilization period, remove each pan from the freezer, remove the lid, and weigh. Record the weight of each ice load (including the pan itself) for that run. Record the dry pan weights as determined in 10.11.4. After the stabilization period, wait for the burners, elements, or steam coil to cycle on and then off again (if applicable). This ensures that the boiler is at maximum operating pressure and temperature when the cooking uniformity test cooking starts.

10.11.10 Start monitoring time. Open one steam compartment, load it with ice loads, close it, and start steam to it. Open the next steam compartment (if applicable), load it, close it, and start it. Open, load, close, and start the last compartment (if applicable). After starting steam to the first compartment, commence monitoring the temperature of the ice loads. The total loading time (the time from opening the first compartment to closing and starting the last compartment) shall be the total of 5 s per compartment plus 5 s for each ice load used. (For example, the total loading time for a heavy load test of a six-pan capacity, two-compartment steam cooker would be 5 s/compartment × 2 compartments + 5 s/ice load × 6 ice loads = 40 s.)

NOTE 18—Care shall be taken to minimize heat gain by the ice loads on the way from the freezer to the steam cooker. During that time, they shall be isolated from any warmer surface by R10 or better insulation. PG&E found 2-in. (50-mm) thick square-edged polystyrene boards to be convenient as an insulating surface.

NOTE 19—Care shall be taken to minimize heat loss out of the cooking compartment where the sensor leads pass under the door gasket. PG&E found that heat loss was not significant as long as the sensor leads were not bunched or paired as they passed under the door gasket.

10.11.11 When the first pan reaches 170°F (77°C), record the time and continue the test. If there are two or more compartments under test, continue to monitor the ice load temperature of the other compartments, recording the elapsed time as the first pan reaches 170°F (77°C).

10.11.12 When the last pan reaches 170°F (77°C), record the time and stop the stream to that compartment. If there are two or more compartments under test, continue to monitor the ice-load temperature of the other compartments, stopping steam to the compartments as the last pan in each compartment reaches 170°F (77°C). When the last (or only) compartment's last pan reaches 170°F (77°C), terminate steam to the compartment and record total elapsed time.

10.11.13 Remove the ice loads, and unless this was the final run (Run No. 3), start timing the 10-min stabilization period before the next run. Return to 10.11.5.

10.11.14 In accordance with 11.11, calculate and report the average cook time and cooking uniformity. After performing this test at least three times, report the results as the average of the replications.

11. Calculations and Reporting

11.1 *Test Steam Cooker:*

11.1.1 Using Specification F1217 classifications summarize the physical and operating characteristics of the steam cooker. Use additional text to describe any design characteristics that may facilitate the audience's 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 9. Describe any deviations from those specifications.

11.3 *Gas and Steam Energy Calculations:*

11.3.1 For gas steam cookers, electric energy consumption shall be added to gas energy for all tests, with the exception of the maximum energy input rate test (10.2).

11.3.2 For gas steam cookers, energy consumed (E_{gas}) shall be calculated using the following formula:

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

where:

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

where:

V_{meas} = measured volume of gas ft^3(m^3),

$$= \frac{\text{absolute standard temperature °R (°K)}}{\text{absolute actual gas temperature °R (°K)}}$$

$$= \frac{\text{standard temperature° R (°K)}}{[\text{gas temp °F(°C)} + 459.67(273)]\ \text{°R(°K)}}, \text{ and}$$

P_{cf} = pressure correction factor

$$= \frac{\text{actual gas pressure psia (kPa)}}{\text{standard pressure psia (kPa)}}$$

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

NOTE 20—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining of the heating value. Standard conditions using Practice D3588 are 14.696 psia (101.33 kPa) and 60°F (519.67 °R (288.71 °K)).

11.3.3 For steam cookers that use either a direct external potable steam source or a steam coil steam generator, steam energy shall be calculated as follows:

$$E_{steam} = W_s \times t \times h_s \tag{2}$$

where:

W_s = steam flow rate, lb (kg)/h,
t = steam flow duration, h, and
h_s = latent heat of steam as derived from the measured supply steam pressure (10.1.5) and thermodynamic properties of water at saturation (see 2.2), Btu/lb (kJ/g).

11.4 *Maximum Energy Input Rate:*

11.4.1 Report the manufacturer's rated input in Btu/h for a gas steam cooker, kW for an electric steam cooker, and lb $(kg)_{steam}$/h for direct steam or steam coil steam cookers.

11.4.2 For gas steam cookers calculate and report the maximum energy input rate (Btu/h (kJ/h)) based on the energy consumed by the steam cooker during the input period according to the following relationship:

$$q_{input} = \frac{E \times 60}{t} \tag{3}$$

where:

q_{input} = measured peak energy input rate, Btu/h (kW),
E = energy consumed during period of peak energy input, Btu (kWh), and
t = period of peak energy input, min.

11.4.3 For electric steam cookers, report the measured maximum energy input rate (kW).

11.4.4 For direct steam or steam coil steam cookers, report the measured maximum rate of steam consumption (lb(kg)/h).

11.5 *Preheat Energy Consumption and Duration:*

11.5.1 Report the preheat energy consumption (Btu(kJ) or kWh) and preheat time (min) where the preheat time is the time elapsed from initiation at the controls to the time that the primary burner, element, or steam coil cycles off. This includes any delay between initiation at the controls and actual energizing or ignition of the elements, steam coil, or burners.

11.6 *Ready-to-Cook Idle Energy Rate:*

11.6.1 Calculate and report the idle energy rate (Btu/h (kJ/h) or kW) based on the energy consumption of the steam cooker during the idle period in accordance with the following relationship:

$$q_{idle} = \frac{E \times 60}{t} \tag{4}$$

where:

q_{idle} = ready-to-cook idle energy rate, Btu/h (kW),
E = energy consumed during the ready-to-cook test period, Btu (kWh), and
t = test period, min.

11.6.2 Report the average compartment temperature during the 2-h idle period.

11.7 *Standby Idle Energy Rate:*

11.7.1 Calculate and report the idle energy rate (Btu/h (kJ/h) or kW) based on the energy consumption of the steam cooker during the idle period in accordance with the following relationship:

$$q_{standby} = \frac{E \times 60}{t} \tag{5}$$

where:

$q_{standby}$ = standby idle energy rate, Btu/h (kW),
E = energy consumed during the standby test period, Btu (kWh), and
t = test period, min.

11.7.2 Report the average compartment temperature during the 2-h idle period.

11.8 *Pilot Energy Rate:*

11.8.1 Calculate and report the energy input rate (Btu/h (kJ/h) or kW) based on the energy consumed by the steam cooker during the pilot test period according to the following relationship:

$$q_{pilot} = \frac{E \times 60}{t} \tag{6}$$

where:

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

11.9 *Frozen Green Pea Load Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature:*

11.9.1 Report a minimum of three run average value of frozen green pea load cooking energy efficiency, production capacity, and water consumption.

11.9.2 Calculate the final cooked green pea load temperature by applying the following relationship:

$$T_{peas,\ f} = \frac{W_{water} \times Cp_{water}}{W_{peas} \times Cp_{peas}} \times \left(T_{water,\ f} - T_{water,\ i}\right) + T_{water,\ f} \tag{7}$$

where:

$T_{pea,\ f}$ = temperature of the cooked peas, °F,
W_{water} = weight of water in water-bath calorimeter, lb,
Cp_{water} = specific heat of water, Btu/lb°F,
= 1 Btu/lb°F (see 2.2),
W_{peas} = weight of cooked green pea load, lb,
= $W_{full\ calorimeter} - W_{calorimeter} - W_{water}$,
$T_{water,\ i}$ = initial water temperature in water-bath calorimeter, °F,
$T_{water,\ f}$ = final equilibrium temperature of water and cooked green peas mixture in water-bath calorimeter, °F, and
$Cp_{peas,thawed}$ = specific heat of thawed green peas, Btu/lb°F
= 0.84 Btu/lb°F (see 2.2).

11.9.3 Calculate the green pea load cooking energy efficiency according to the following relationship:

$$\eta_{peas} = \frac{(E_{peas} + E_{pan})}{(E_{steam\ cooker} + E_{boiler\ re-init})} \tag{8}$$

where:

η_{peas} = cooking energy efficiency (%), and
E_{peas} = heat gained by the green pea load,
= $[W_{peas,\ frozen} \times Cp_{peas,\ frozen} \times \Delta T_{peas,\ frozen}] + [W_{peas,\ cooked} \times Cp_{peas,\ cooked} \times \Delta T_{peas,\ cooked}] + [W_{moisture} \times E_{fusion}]$.

where:

$W_{peas,\ frozen}$ = weight of frozen green peas, lb,

$Cp_{peas,\ frozen}$ = specific heat of frozen green peas, Btu/lb°F
= 0.44 Btu/lb°F (see 2.2),
$\Delta T_{peas,\ frozen}$ = temperature rise in frozen green peas, °F,
= 32°F – initial temperature of frozen green pea load,
$W_{peas,\ cooked}$ = weight of cooked green peas, lb,
= weight of full calorimeter – weight of empty calorimeter – weight of water in calorimeter,
$Cp_{peas,\ cooked}$ = specific heat of cooked green peas, Btu/lb°F,
= 0.84 Btu/lb°F (see 2.2),
$\Delta T_{peas,\ cooked}$ = temperature rise in cooked green peas, °F,
= final temperature of cooked pea load – 32°F,
E_{fusion} = latent heat of fusion of ice,
= 144 Btu/lb (see 2.2),
$W_{moisture}$ = weight of moisture in frozen green peas—81 % (see 2.2),
= $0.81 \times W_{peas,frozen}$, and
E_{pan} = heat gained by the stainless-steel hotel pan(s)
= $W_{pan} \times Cp_{pan} \times \Delta T_{pan}$

where:

W_{pan} = weight of pan(s), lb,
Cp_{pan} = specific heat of stainless-steel, Btu/lb°F,
= 0.11 Btu/lb°F (see 2.2),
ΔT_{pan} = temperature rise in pan °F,
= $T_{pan,\ f} - T_{pan,\ i}$,
= $T_{pea,\ f} - T_{pea,\ i}$,
= final temperature of cooked green pea load - initial temperature frozen green pea load,
$E_{steam\ cooker}$ = total energy consumed by the steam cooker, Btu(kJ). Includes sum of all fuel types used (for example, gas energy for heating plus electric energy used by steam circulating fans or controls, or both), and
$E_{boiler\ re\text{-}init}$ = energy required to restore the final boiler energy content (pressure) to the initial boiler energy content (Btu(kJ)). Calculation of this energy quantity is required only if the conditional step 10.8.12.2 was applicable. Otherwise this energy quantity is already included in the $E_{steam\ cooker}$ value. If conditional step 10.8.12.2 was applicable, then $E_{boiler\ re\text{-}init}$ is calculated as follows:

$$= E_{cycle} \times \frac{P_{max} - P_{final}}{P_{max} - P_{min}} \tag{9}$$

where:

E_{cycle} = energy required to raise the boiler pressure from minimum operating pressure to maximum operating pressure, Btu (kJ),
P_{max} = the average maximum boiler pressure, psi (kPa),
P_{min} = the average minimum boiler pressure, psi (kPa), and
P_{final} = the boiler pressure at the end of the test, psi (kPa).

11.9.4 Calculate the green pea load cooking energy rate as follows:

$$q_{peas} = \frac{E_{steam\ cooker} + E_{boiler\ re-init}}{t} \times 60 \tag{10}$$

where:

q_{peas} = green pea load cooking energy rate, Btu/h (kJ/h),
t = test period, min, and
$E_{steam\ cooker}$ and $E_{boiler\ re\text{-}init}$ = are as defined in 11.9.3.

For gas steam cookers, $E_{steam\ cooker}$ in the above equation does not include the electric energy. The electric energy rate is reported separately in 11.9.5. For direct steam or steam coil steam cookers, report the cooking energy rate in both Btu(kJ)/h and $lb(kg)_{steam}$/h.

11.9.5 This step applies to heavy load tests of gas, direct steam, and steam coil steam cookers only. Calculate the green pea load electric energy rate as follows:

$$q_{peas,ele} = \frac{E_{steam\ cooker,\ ele}}{t} \times 60 \tag{11}$$

where:

$q_{peas,ele}$ = green pea load electric cooking energy rate, Btu/h (kJ/h),
t = test period, min, and
$E_{steam\ cooker,\ ele}$ = electric energy consumed by the steam cooker, Btu (kWh).

11.9.6 Calculate green pea load production capacity (lb (kg)) using the following definition:

$$PC_{peas} = \frac{W_{pea}}{t} \times 60 \tag{12}$$

where:

PC_{peas} = production capacity, lb/h (kg/h),
W_{peas} = weight of green pea load, lb (kg), and
t = test period, min.

11.9.7 Report the green pea load cooking water consumption rate, gal/h (L/h) (10.8.10).

11.9.8 Report the average temperature of the green pea load cooking condensate during the last 5 min of the test, °F (°C) (10.8.10).

11.10 *Whole Potato Load Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature:*

11.10.1 Report a minimum of three run average value of whole potato load cooking energy efficiency, production capacity and water consumption.

11.10.2 Calculate whole potato load cooking energy efficiency according to the following relationship:

$$\eta_{potato} = \frac{(E_{potato} + E_{pan})}{(E_{steam\ cooker} + E_{boiler\ re-init})} \tag{13}$$

where:

η_{potato} = cooking energy efficiency, %,
E_{potato} = heat gained by the potato,
= $W_p \times Cp_p \times \Delta T$,

where:

W_p = weight of potatoes, lb,
Cp_p = specific heat of potatoes, Btu/lb°F,

= 0.87 Btu/lb°F (see 2.3),
ΔT = temperature rise in potatoes, °F,
= $T_{potato,\ f} - T_{potato,\ i}$,
E_{pan} = heat gained by the stainless-steel hotel pan(s),

$$W_{pan} \times Cp_{pan} \times (T_f - T_i) \quad (14)$$

where:

W_{pan} = weight of pan(s), lb,
Cp_{pan} = specific heat of stainless-steel, Btu/lb°F,
= 0.11 Btu/lb°F (see 2.2), and
ΔT = temperature rise in stainless-steel pan, °F,
= $T_{pan,\ f} - T_{pan,\ i}$
$E_{steam\ cooker}$ = total energy consumed by the steam cooker, Btu (kJ). Includes sum of all fuel types used (for example, gas energy for heating plus electric energy used by steam circulating fans and/or controls).
$E_{boiler\ re\text{-}init}$ = energy required to restore the final boiler energy content (pressure) to the initial boiler energy content (Btu (kJ)). Calculation of this energy quantity is required only if the conditional step 10.9.13.2 was applicable. Otherwise this energy quantity is already included in the $E_{steam\ cooker}$ value. If conditional step 10.9.13.2 was applicable, then $E_{boiler\ re\text{-}init}$ is calculated as follows:

$$E_{cycle} \times \frac{P_{max} - P_{final}}{P_{max} - P_{min}} \quad (15)$$

where:

E_{cycle} = energy required to raise the boiler pressure from minimum operating pressure to maximum operating pressure, Btu (kJ),
P_{max} = the average maximum boiler pressure, psi (kPa),
P_{min} = the average minimum boiler pressure, psi (kPa), and
P_{final} = the boiler pressure at the end of the test, psi (kPa).

11.10.3 Calculate the potato load cooking energy rate as follows:

$$q_{potato} = \frac{E_{steam\ cooker} + E_{boiler\ re-init}}{t} \times 60 \quad (16)$$

where:

q_{potato} = potato load cooking energy rate, Btu/h (kJ/h),
t = test period, min, and
$E_{steam\ cooker}$ and $E_{boiler\ re\text{-}init}$ = are as defined in 11.10.2.

For gas steam cookers, $E_{steam\ cooker}$ in the above equation does not include the electric energy. The electric energy rate is reported separately in 11.10.4. For direct steam or steam coil steam cookers, report the cooking energy rate in both Btu (kJ)/h and lb $(kg)_{steam}$/h.

11.10.4 This step applies to heavy load tests of gas, direct steam, and steam coil steam cookers only. Calculate the potato load electric energy rate as follows:

$$q_{potato,ele} = \frac{E_{steam\ cooker,\ ele}}{t} \times 60 \quad (17)$$

where:

$q_{potato,ele}$ = potato load electric cooking energy, rate, Btu/h (kJ/h),
t = test period, min, and
$E_{steam\ cooker,\ ele}$ = electric energy consumed by the steam cooker, Btu (kWh).

11.10.5 Calculate whole potato load production capacity (lb(kg)) using the following equation:

$$PC_{potato} = \frac{W_{potato}}{t} \times 60 \quad (18)$$

where:

PC_{potato} = production capacity, lb/h (kg/h),
W_{potato} = weight of potatoes, lb (kg), and
t = test period, min.

11.10.6 Report the potato load cooking water consumption rate, gal/h (L/h) (see 10.9.11).

11.10.7 Report the average temperature of the potato load cooking condensate during the last 5 min of the test, °F (°C) (see 10.9.11).

11.11 *Cooking Uniformity:*

11.11.1 For each pan, report the average initial temperature of the water in the pans.

11.11.2 For each pan, report the final temperature of the water in the pans at the end of the test using the corresponding average temperatures for the three test runs.

11.11.3 For each cooking compartment, calculate and report the maximum temperature difference between the hottest pan and the coolest pan at the end of the test.

11.11.4 Report the average test time for the three test runs.

11.11.5 For each separate cooking compartment, report the time difference between the first pan to reach 170°F (77°C) and the last pan to reach 170°F (77°C).

11.11.6 Generate a graph showing pan temperature versus time for each pan during the cooking uniformity test.

12. Precision and Bias

12.1 *Precision:*

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

12.1.1.1 For the cooking energy efficiency, cooking energy rate, and production capacity results, the percent uncertainty in each result has been specified to be no greater than ±10 % based on at least three test runs.

12.1.1.2 The repeatability of each remaining reported parameter is being determined.

12.1.2 *Reproducibility (multiple laboratories):*

12.1.2.1 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; steam cooker; 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 2-1986(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 efficiency 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 efficiency 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*:

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:

TABLE A1.1 Uncertainty Factors

Test Results, *n*	Uncertainty Factor, C_n
3	2.48
4	1.59
5	1.24
6	1.05
7	0.92
8	0.84
9	0.77
10	0.72

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

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

where:

$X a_3$ = average of results for three test runs, and
X_1, X_2, X_3 = results for each test run.

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

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

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

NOTE A1.2—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 A1.3—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 (1/3 in this case).

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

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

$$U_3 = C_3 \times S_3, \quad (A1.3)$$

$$U_3 = 2.48 \times S_3$$

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:

$$\%\ U_3 = (U_3/Xa_3) \times 100\,\% \quad (A1.4)$$

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 If the percent uncertainty, % U_3, is not greater than ±10 % for the cooking-energy efficiency 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 efficiency 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:

$$Xa_4 = \left(\frac{1}{4}\right) \times (X_1 + X_2 + X_3 + X_4) \quad \text{(A1.5)}$$

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:

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

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:

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

$$U_4 = 1.59 \times S_4$$

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:

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

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 efficiency 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 efficiency 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:

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

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:

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

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:

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

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:

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

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 efficiency 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 A1.4—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.

APPENDIXES

(Nonmandatory Information)

X1. PROCEDURE FOR DETERMINING THE ICE LOAD COOKING ENERGY EFFICIENCY, PRODUCTION CAPACITY, WATER CONSUMPTION, AND CONDENSATE TEMPERATURE

INTRODUCTION

The following procedure evaluates the steam cooker efficiency, production capacity, water consumption, and condensate temperature when heating ice loads. Experience indicates that the ice load test is a simple yet valuable tool for product development. Ice load tests are easily and inexpensively prepared while yielding repeatable and reproducible results. The test may be used as a quick indicator of improvements in steam delivery mechanism, insulation, or other design features. Accordingly, it is referenced as an appendix to these test methods as a research and development tool.

The ice load test does not replicate or represent the efficiency and production capacity of steam cookers when cooking for the following technical reasons:

(1) The physical properties, such as specific heat, of ice and food products are often different.

(2) Ice loads have lower production rate due to smaller surface area. Food products generally exhibit greater surface area allowing a faster rate of condensation.

(3) Solid hotel pans, which restrict convection in the cavity, must be used for ice load test. Loads closer to the steam source are heated quicker while further loads lag.

The ice load test may be used as a research and development tool, but shall not be used to imply the overall steamer performance during actual cooking operations.

X1.2 Scope

X1.2.1 The test procedure in this appendix determines the efficiency, production capacity, water consumption, and condensate temperature.

X1.3 Terminology

X1.3.1 *ice load, n*—12 by 20 by 2½-in. (300 by 500 by 65-mm) hotel pan filled with 8.0 ± 0.2 lb (3630 ± 90 g) of water and subsequently frozen to 0 ± 2°F (–18 ± 1°C).

X1.4 Summary of Test Methods

X1.4.1 Ice load cooking energy efficiency is determined by cooking a capacity number of ice loads from 0 to 180°F (–18 to 82°C).

X1.4.2 Ice load production capacity (lb_{ice}/h (kg_{ice}/h) is determined by the respective cooking energy efficiency tests.

X1.4.3 Water consumption (gal/h (L/h)) is monitored during the cooking energy efficiency tests to determine the rate of water usage.

X1.4.4 Condensate temperature is monitored during the last 3 min of the cooking energy efficiency tests.

X1.5 Significance and Use

X1.5.1 The ice load test may be used as a quick indicator of improvement in steam cooker design.

X1.6 Apparatus

X1.6.1 *Hotel pans,* for ice loads, solid 12 by 20 by 2½-in. (300 by 500 by 65-mm) stainless steel, weighing 2.8 ± 0.2 lb (1.3 ± 0.1 kg), with a temperature sensor located in the center of each pan ⅝ in. (16 mm) from the bottom. A convenient method is to have Type K thermocouple probes with a stainless-steel protective sheath fabricated in the shape shown in Fig. X1.1. The sensing point is exposed and isolated thermally from the stainless-steel sheath. The probe is strapped to the pan using steel shim stock welded to the pan using a strain gauge welder. The thermocouple lead TFE-fluorocarbon sheath is minimum thickness (TFE-fluorocarbon wrap rather than extruded TFE-fluorocarbon) to minimize the escape of steam through the door gasket where the thermocouple exits the cooking compartment. The lead is long enough to allow connection to the monitoring device while the ice loads are in the freezer, while they are being weighed, and while they are in the steam cooker.

NOTE X1.1—PG&E found that 10-ft (3-m) sensor leads allowed for flexibility in test equipment setup while still being manageable (tangle free).

X1.7 Reagents and Materials

X1.7.1 Water used shall have a maximum hardness of three grains per gallon. Distilled water may be used.

X1.8 Sampling

X1.8.1 *Steam Cooker*—A representative production model shall be selected for performance testing.

X1.9 Preparation of Apparatus

X1.9.1 Install the appliance under a canopy exhaust hood in accordance with 9.1 – 9.8.

X1.10 Procedure

X1.10.1 *Ice Load Preparation:*

X1.10.1.1 This section outlines preparation of the ice loads in the ice load cooking energy efficiency and production-capacity tests.

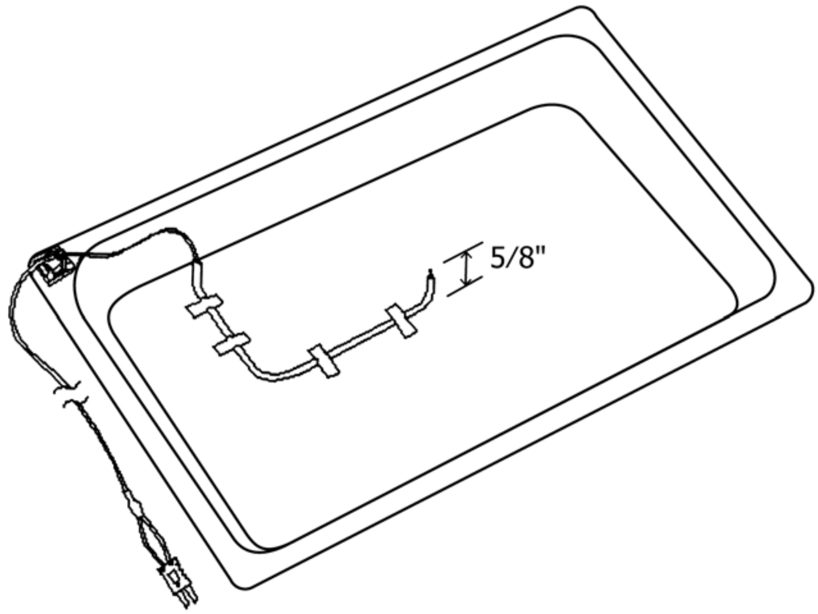

FIG. X1.1 Hotel Pan with Thermocouple Probe

X1.10.1.2 The number of ice loads required depends on the steamer capacity. The heavy load is the manufacturer's stated capacity of 12 by 20 by 2½-in. (300 by 500 by 65-mm) hotel pans. Prepare enough ice loads for three runs.

X1.10.1.3 The solid hotel pans shall be as specified in X1.6.1.

X1.10.1.4 Number each pan and record the weight of each of the (dry) pans.

X1.10.1.5 Fill the pans with enough water such that there will be 8.0 ± 0.2 lb (3.6 ± 0.1 kg) of ice after freezing (some water will evaporate during freezing, especially if hotel pan lids are not used). Accurate measurement of the weight of the pans plus the water prior to freezing is not required since they will be weighed again just prior to testing.

X1.10.1.6 Freeze the loads to 0 ± 5°F (–18± 2°C).

X1.10.2 *Ice Load Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature:*

X1.10.2.1 This procedure applies to two possible loading scenarios: light and heavy. Repeat each loading scenario at least three times. The reported values of cooking energy efficiency, production capacity, condensate temperature, and water consumption shall be the average of the replications (runs).

X1.10.2.2 Prepare the ice loads in accordance with X1.10.1. Record the quantity of ice loads for the test.

X1.10.2.3 Record the initial average ice load temperature. Confirm that they are at 0 ± 5°F (–18 ± 3°C).

X1.10.2.4 Allow the steam cooker to sit idle (boiler(s) on) for a minimum of 1 h. If the manufacturer recommends leaving the cooking cavity doors open when not cooking, leave them open during the idle period and record the door position during the idle period.

X1.10.2.5 Near the end of the idle period, remove each pan from the freezer, remove the lid, and weigh. Record the weight of each ice load (including the pan itself) for that run. Record the dry pan weights as determined in X1.10.1.4. After the idle period, wait for the burners, elements, or steam coil to cycle on and then off again (if applicable). This ensures that the boiler is at maximum operating pressure and temperature when the efficiency-test cooking starts.

X1.10.2.6 Start monitoring time. Open one steam compartment, load it with ice loads, close it, and start steam to it. Open the next steam compartment (if applicable), load it, close it, and start it. Open, load, close, and start the last compartment (if applicable). After starting steam to the first compartment, commence monitoring energy consumption, water consumption, condensate temperature, and, for each compartment under test, monitor the average temperature of the ice loads. For gas steam cookers, monitor and record electric energy as well as gas consumption. The total loading time (the time from opening the first compartment to closing and starting the last compartment) shall be the total of 5 s per compartment plus 5 s for each ice load used. (For example, the total loading time for a heavy load test of a six-pan capacity, two-compartment steam cooker would be 5 s/compartment× 2 compartments + 5 s/ice load × 6 ice loads = 40 s.)

NOTE X1.2—For gas steamers, the electric energy rate during the heavy load test will be reported separately from the gas cooking energy rate. The two values are reported separately so that the respective fuel prices may be applied to estimate energy costs.

NOTE X1.3—Care shall be taken to minimize heat gain by the ice loads on the way from the freezer to the steam cooker. During that time, they shall be isolated from any warmer surface by R10 or better insulation. PG&E found 2-in. (50-mm) thick square-edged polystyrene boards to be convenient as an insulating surface.

NOTE X1.4—Care shall be taken to minimize heat loss out of the cooking compartment where the sensor leads pass under the door gasket. PG&E found that heat loss was not significant as long as the sensor leads were not bunched or paired as they passed under the door gasket.

NOTE X1.5—The boiler is at maximum pressure when the test starts, but it may be at a lower pressure at the end of the test. This difference between the initial and final energy content (pressure and temperature) of the boiler must be added back to the boiler to calculate the energy efficiency correctly. Maximum, minimum, and final boiler pressure is measured so that this energy deficit can be estimated. There are situations in which the measurement of pressure in X1.10.2.7 is not necessary, as noted in X1.10.2.9 and X1.10.2.11.

NOTE X1.6—The average condensate temperature for the final 3 min of the run will be reported rather than the average over the entire run; therefore, condensate temperature monitoring need not begin immediately upon commencement of the test run.

X1.10.2.7 Measure the maximum and minimum pressures for three cycles of the boiler pressure near the end of the test. Record the average maximum and average minimum boiler pressure.

X1.10.2.8 When the average ice load temperature of any cooking compartment has reached 180°F, stop the steam to that compartment. If there are two or more compartments under test, continue to monitor the average ice load temperature of the others, stopping steam to the compartments as the average temperature reaches 180°F (82°C). When the last (or only) compartment's average ice load temperature reaches 180°F, terminate steam to the compartment and record time, water consumption and condensate temperature.

X1.10.2.9 If the boiler is on when the last compartment ice load temperature reaches 180°F (82°C), continue to monitor energy consumption until the primary burners, elements, or steam coils cycle off. Record the final energy. Note that the initial and final energy content of the boiler is the same; the pressure measurements in X1.10.2.7 are therefore not necessary.

X1.10.2.10 If the boiler is not on when the last compartment's average ice load temperature reaches 180°F (82°C), proceed to one of the next two conditional steps (X1.10.2.11 or X1.10.2.12).

X1.10.2.11 Perform this step if the boiler pressure is controlled by a pressure switch that can be actuated manually. Otherwise, proceed directly to X1.10.2.12. When the last compartment's average ice load temperature reaches 180°F (82°C), continue to monitor energy consumption and actuate the pressure switch. This returns the boiler energy content to the initial test condition; the pressure measurements in X1.10.2.7 and energy measurements in 10.4.2 are therefore not necessary. Record the final energy.

X1.10.2.12 Perform this step if the boiler pressure control cannot be actuated manually. When the last compartment's average ice load temperature reaches 180°F (82°C), record the final energy and boiler pressure (used to calculate the energy deficit of the boiler, as described in Note X1.5).

X1.10.2.13 Remove the ice loads, and unless this was the final run (Run No. 3), repeat X1.10.2.5 through X1.10.2.13.

X1.10.2.14 In accordance with X1.10, calculate and report the cooking energy efficiency, cooking energy rate, electric energy rate (if applicable, for gas steam cookers), production capacity, water consumption, and condensate temperature. After performing this test at least three times, report the results as the average of the replications.

X1.11 *Ice Load Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature*:

X1.11.1 Report the three run average value of ice load cooking-energy efficiency, production capacity, and water consumption.

X1.11.2 Calculate ice load cooking energy efficiency according to the following relationship:

$$\eta_{ice} = \frac{(E_{ice} + E_{pan})}{(E_{steam\ cooker} + E_{boiler\ re-init})} \quad (X1.1)$$

where:

η_{ice} = cooking energy efficiency, %,
E_{ice} = heat gained by the ice load, and
= $[W_{ice} \times Cp_{ice} \times \Delta T_{ice}] + [W_{water} \times Cp_{water} \times \Delta T_{water}] + [W_{ice} \times E_{fusion}]$

where:

W_{ice} = weight of ice load, lb,
Cp_{ice} = specific heat of ice, Btu/lb°F,
= 0.5 Btu/lb°F (see 2.2)
ΔT_{ice} = temperature rise in ice, °F,
= 32°F - initial temperature of ice loads,
W_{water} = weight of water (same as W_{ice}), lb,
Cp_{water} = specific heat of water, Btu/lb°F,
= 1 Btu/lb°F (see 2.2),
ΔT_{water} = temperature rise in water, °F,
= final water temperature - 32°F,
E_{fusion} = latent heat of fusion of ice,
= 144 Btu/lb (see 2.2), and
E_{pan} = heat gained by the stainless-steel hotel pan(s),
= $W_{pan} \times Cp_{pan} \times \Delta T_{pan}$

where:

W_{pan} = weight of pan(s), lb
Cp_{pan} = specific heat of stainless-steel, Btu/lb°F,
= 0.11 Btu/lb°F (see 2.2)
ΔT_{pan} = temperature rise in ice, °F,
= final pan temperature - initial pan temperature,
= final water temperature - initial ice temperature,
T_i = initial temperature of steel pan(s), °F,
$E_{steam\ cooker}$ = total energy consumed by the steam cooker, Btu (kJ). Includes sum of all fuel types used (for example, gas energy for heating plus electric energy used by steam circulating fans and/or controls),
$E_{boiler\ re-init}$ = energy required to restore the final boiler energy content (pressure) to the initial boiler energy content (Btu (kJ)). Calculation of this energy quantity is required only if the conditional step X1.10.2.11 was applicable. Otherwise this energy quantity is already included in the $E_{steam\ cooker}$ value. If conditional step X1.10.2.11 was applicable, then $E_{boiler\ re-init}$ is calculated as follows:

$$E_{cycle} \times \frac{P_{max} - P_{final}}{P_{max} - P_{min}} \quad (X1.2)$$

where:

E_{cycle} = energy required to raise the boiler pressure from minimum operating pressure to maximum operating pressure, Btu (kJ),
P_{max} = the average maximum boiler pressure, psi (kPa),
P_{min} = the average minimum boiler pressure, psi (kPa), and
P_{final} = the boiler pressure at the end of the test, psi (kPa).

X1.11.3 Calculate the ice load cooking energy rate as follows:

$$q_{ice} = \frac{E_{steam\ cooker} + E_{boiler\ re-init}}{t} \times 60 \quad (X1.3)$$

where:

q_{ice} = ice load cooking energy rate, Btu/h (kJ/h),
t = test period, min, and
$E_{steam\ cooker}$ and $E_{boiler\ re-init}$ = as defined in X1.11.2.

For gas steam cookers, $E_{steam\ cooker}$ in the above equation does not include the electric energy. The electric energy rate is reported separately in X1.11.4. For direct steam or steam coil steam cookers, report the cooking energy rate in both Btu (kJ)/h and lb $(kg)_{steam}$/h.

X1.11.4 This step applies to heavy load tests of gas, direct steam, and steam coil steam cookers only. Calculate the ice load electric energy rate as follows:

$$q_{ice,ele} = \frac{E_{steam\ cooker,\ ele}}{t} \times 60 \quad (X1.4)$$

where:

$q_{ice,ele}$ = ice load electric cooking energy rate, Btu/h (kJ/h),
t = test period, min, and
$E_{steam\ cooker,ele}$ = electric energy consumed by the steam cooker, Btu (kWh).

X1.11.5 Calculate ice load production capacity (lb (kg)) using the following equation:

$$PC_{ice} = \frac{W_{ice}}{t} \times 60 \quad (X1.5)$$

where:

PC_{ice} = production capacity, lb/h (kg/h),
W_{ice} = weight of ice load, lb (kg), and
t = test period, min.

X1.11.6 Report the ice load cooking water consumption rate, gal/h (L/h) (see X1.10.2.8).

X1.11.7 Report the average temperature of the ice load cooking condensate during the last 3 min of the test, °F (°C) (see X1.10.2.8).

X2. RESULTS REPORTING SHEETS

Manufacturer ________________________
Model ________________________
Date ______________
Test Reference Number (optional) ____________

X2.1 Test Steam Cooker

List the Type, Grade, Class, Size, Style, and Capacity by following the specifications listed in the ASTM F1217 Standard Specification for Cooker, Steam. List any additional operating characteristics below:

Type ________________
Grade ________________
Style ________________
Maximum number of pans ________________

Additional description of operational characteristics:
____
____
____
____
____
____
____

Manufacturer's Rated Input __________ (Btu/h, kW or lb_{steam}/h)

X2.2 Apparatus

_____ Check if testing apparatus conformed to specifications in Section 9.
Deviations ____
____
____
____

X2.3 Maximum Energy Input Rate

☐ Test Voltage (V) _____
☐ Gas heating value (Btu/ft^3) _____
☐ Measured (Btu/h (kJ/h) or kW) _____
☐ Rated (Btu/h (kJ/h) or kW) _____
☐ Percent Difference between Measured and Rated _____ %

X2.4 Preheat Energy Consumption and Duration

☐ Test Voltage (V) _____
☐ Gas heating value (Btu/ft^3) _____
☐ Energy Consumption (Btu (kJ) or kWh) _____
☐ Duration (min) _____

X2.5 Ready-to-Cook Idle Energy Rate

☐ Test Voltage (V) _____
☐ Gas heating value (Btu/ft^3) _____
☐ Ready-to-Cook Idle Energy Rate (Btu/h (kJ/h) or kW) _____
☐ Average Compartment Temperature (°F (°C)) _____

X2.6 Standby Idle Energy Rate

☐ Test Voltage (V) _____
☐ Gas heating value (Btu/ft^3) _____
☐ Standby Idle Energy Rate (Btu/h (kJ/h) or kW) _____
☐ Average Compartment Temperature (°F (°C)) _____

X2.7 Pilot Energy Rate

- ☐ Test Voltage (V) _____
- ☐ Gas heating value (Btu/ft^3) _____
- ☐ Pilot Energy Rate (Btu/h (kJ/h) or kW) _____

X2.8 Frozen Green Pea Load Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature

- ☐ *Heavy Load:*
- ☐ Test Voltage (V) _____
- ☐ Test Voltage (V) _____
- ☐ Number of Test Pans _____
- ☐ Pea cook time (min) _____
- ☐ Pea cooking energy efficiency (%) _____
- ☐ Pea cooking energy rate (Btu/h (kJ/h), lb $(kg)_{steam}$/h, or kW) _____
- ☐ Electric energy rate (kW, gas or steam coil steam cookers only) _____
- ☐ Pea production capacity (lb/h (kg/h)) _____
- ☐ Pea water consumption rate (gal/h (L/h)) _____
- ☐ Condensate temperature (°F (°C)) _____
- ☐ *Light Load:*
- ☐ Test Voltage (V) _____
- ☐ Gas heating value (Btu/ft^3) _____
- ☐ Pea cook time (min) _____
- ☐ Pea cooking energy efficiency (%) _____
- ☐ Pea cooking energy rate (Btu/h (kJ/h), lb$(kg)_{steam}$/h, or kW) _____
- ☐ Electric energy rate (kW, gas or steam coil steam cookers only) _____
- ☐ Pea water consumption rate (gal/h (L/h)) _____
- ☐ Condensate temperature (°F (°C)) _____

X2.9 Whole Potato Load Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature

- ☐ *Heavy Load:*
- ☐ Test Voltage (V) _____
- ☐ Gas heating value (Btu/ft^3) _____
- ☐ Number of test pans _____
- ☐ Total number of potatoes _____
- ☐ Whole potato cook time (min) _____
- ☐ Whole potato cooking energy efficiency (%) _____
- ☐ Whole potato cooking energy rate (Btu/h (kJ/h), lb $(kg)_{steam}$/h, or kW) _____
- ☐ Electric energy rate (kW, gas or steam coil steam cookers only) _____
- ☐ Whole potato production capacity (lb/h (kg/h)) _____
- ☐ Whole potato water consumption rate (gal/h (L/h)) _____
- ☐ Condensate temperature (°F (°C)) _____
- ☐ *Light Load:*
- ☐ Test Voltage (V) _____
- ☐ Gas heating value (Btu/ft^3) _____
- ☐ Whole potato cook time (min) _____
- ☐ Whole potato cooking energy efficiency (%) _____
- ☐ Whole potato cooking energy rate (Btu/h (kJ/h), lb $(kg)_{steam}$/h, or kW) _____
- ☐ Electric energy rate (kW, gas or steam coil steam cookers only) _____
- ☐ Whole potato water consumption rate (gal/h (L/h)) _____
- ☐ Condensate temperature (°F (°C)) _____

X2.10 Cooking Uniformity

Number of Pans _____
Initial Pan Temperature (°F (°C)) _____
Final Pan Temperatures:

Pan	*Pan Temperature* (°F (°C))
1 (top)	_____
2	_____
3	_____
4	_____
5	_____
6 (bottom)	_____

Maximum Temperature Difference (°F (°C)) _____
Cooking Time (min) _____
Maximum Time Delay (min) _____

X3. PROCEDURE FOR CALCULATING THE ENERGY CONSUMPTION OF A STEAMER BASED ON REPORTED TEST RESULTS

X3.1 Appliance test results are useful not only for benchmarking appliance performance, but also for estimating appliance energy consumption. The following procedure is a guideline for estimating steamer energy consumption based on data obtained from applying the appropriate test method.

X3.2 The intent of this appendix is to present a standard method for estimating steamer energy consumption based on ASTM performance test results. The examples contained herein are for information only and should not be considered an absolute. To obtain an accurate estimate of energy consumption for a particular operation, parameters specific to that operation should be used (for example, operating time, and amount of food cooked under heavy and light loads).

X3.3 The appropriate steamer performance parameters are obtained from Section 11 in the test method.

X3.4 *Procedure*:

X3.4.1 The calculation will proceed as follows: first, determine the appliance operating time and total number of preheats. Then estimate the quantity of food cooked and establish the breakdown among heavy (compartment loaded to capacity) and light (single pan) loads. For example, a steamer operating for 12 h a day with one preheat cooked 100 lb of food: 90 % of the food was cooked under heavy load conditions and 10 % was cooked under light load conditions. Calculate the energy due to cooking at heavy and light load cooking rates, and then calculate the idle energy consumption. This is added to a residual amount of energy which accounts for the times that a compartment is drawing steam, but is not cooking food. This can be estimated as the percentage of its total operating time that the steamer is operated in constant steam mode. The total daily energy is the sum of these components plus the preheat energy. For simplicity, it is assumed that subsequent preheats require the same time and energy as the first preheat of the day. Table X3.1 summarizes typical default operating assumptions for a steamer.

X3.4.2 *Step 1*—For each compartment, determine the steamer operating time, number of preheats, and amount of food cooked under heavy (full compartment) and light (single-pan) load conditions.

X3.4.3 *Step 2*—Calculate the time and energy involved in cooking heavy loads. Heavy loads are the equivalent of loading the compartment with the maximum allowable number of pans.

TABLE X3.1 Typical Steamer Operation Assumptions

Operating Time	12 h
Number of Preheats	1 preheat
Total Amount of Food Cooked	100 lb
Percentage of Food Cooked Under Heavy Load Conditions	90 % (× 100 lb = 90 lb)
Percentage of Food Cooked Under Light Load Conditions	10 % (× 100 lb = 10 lb)
Percentage time on Constant Steam Mode	90%

X3.4.3.1 The total time cooking heavy loads is determined as follows:

$$t_h = \frac{\%_h \times W}{PC} \quad (X3.1)$$

where:

t_h = total time cooking heavy loads, h,
$\%_h$ = the percentage of food cooked under heavy load conditions during the day,
W = total weight of food cooked per day, lb, and
PC = the steamer's potato load production capacity as determined in 11.10.5, lb/h.

X3.4.3.2 The heavy load energy consumption is calculated using the following set of equations. For gas steamers, any electric energy shall be determined separately using the electric equations.

$$E_{gas,h} = q_{gas,h} \times t_h \quad (X3.2)$$

$$E_{elec,h} = q_{elec,h} \times t_h$$

where:

$E_{gas,h}$ = total gas heavy load energy consumption, Btu,
$q_{gas,h}$ = gas heavy load cooking energy rate as determined in 11.10.3, Btu/h,
$E_{elec,h}$ = total electric heavy load energy consumption, kWh, and
$q_{elec,h}$ = electric heavy load cooking energy rate as determined in 11.10.3, kW.

X3.4.4 *Step 3*—Calculate the time and energy involved in cooking light loads. Light loads are the equivalent of cooking a single pan in one steamer compartment.

X3.4.4.1 The total time cooking light loads is determined as follows:

$$t_l = \frac{\%_l \times W}{PR_l} \quad (X3.3)$$

where:

t_l = total time cooking light loads, h,
$\%_l$ = the percentage of food cooked under light load conditions during the day,
W = total weight of food cooked per day, lb, and
PR_l = the steamer's light load production rate as determined in 11.10.5, lb/h.

X3.4.4.2 The light load energy consumption is calculated using the following set of equations. For gas steamers, any electric energy shall be determined separately using the electric equations.

$$E_{gas,l} = q_{gas,l} \times t_l \quad (X3.4)$$

$$E_{elec,l} = q_{elec,l} \times t_l$$

where:

$E_{gas,l}$ = total gas light load energy consumption, Btu,

$q_{gas,l}$ = gas light load cooking energy rate as determined in 11.10.3, Btu/h,
$E_{elec,l}$ = total electric light load energy consumption, kWh,
$q_{elec,l}$ = electric light load cooking energy rate as determined in 11.10.3, kW.

X3.4.5 *Step 4*—Calculate the total idle time and energy consumption and the residual energy consumption.

X3.4.5.1 The total idle time is determined as follows:

$$t_i = t_{on} - t_h - t_l - \frac{n_p \times t_p}{60} \tag{X3.5}$$

where:

t_i = the total idle time, h,
t_{on} = the total daily on-time, h,
n_p = the number of preheats, and
t_p = preheat time, as determined in 11.5, min.

X3.4.5.2 The idle energy consumption is calculated using the following set of equations. For gas steamers, any electric energy shall be determined separately using the electric equations.

$$E_{gas,i} = q_{gas,i} \times t_i \tag{X3.6}$$

$$E_{elec,i} = q_{elec,i} \times t_i$$

where:

$E_{gas,i}$ = total gas idle energy consumption, Btu,
$q_{gas,i}$ = gas idle energy rate as determined in 11.6, Btu/h,
$E_{elec,i}$ = total electric idle energy consumption, kWh, and
$q_{elec,i}$ = electric idle energy rate as determined in 11.6, kW.

X3.4.5.3 The residual energy consumption is calculated using the following set of equations. For gas steamers, any electric energy shall be determined separately using the electric equations.

$$E_{gas,r} = f_r \times q_{gas,h} \times t_i \tag{X3.7}$$

$$E_{elec,r} = f_r \times q_{elec,h} \times t_i$$

where:

$E_{gas,r}$ = total gas residual energy consumption, Btu,
f_r = the steamer's residual energy usage factor, which is equal to the percentage of time in manual, or constant steam, mode,
$q_{gas,h}$ = gas heavy load cooking energy rate as determined in 11.4.2, Btu/h,
$E_{elec,r}$ = total electric residual energy consumption, kWh, and
$q_{elec,h}$ = electric heavy load energy rate as determined in 11.4.2, kW.

NOTE X3.1—The residual energy factor approximates the human factor in steamer energy usage. It has been observed that steam compartments may be turned on (that is, drawing steam) with no food in the compartment. This usage pattern has a varying impact on steamer energy consumption, based on the type of steamer. For example, atmospheric pressure steamers typically consume more steam (hence, more energy) during these periods than pressurized compartment steamers.

X3.4.6 *Step 5*—The total daily energy consumption is calculated as follows:

$$E_{gas,daily} = q_{gas,h} + q_{gas,l} + E_{gas,i} + E_{gas,r} + n_p \times E_{gas,p} \tag{X3.8}$$

$$E_{elec,daily} = q_{elec,h} + q_{elec,l} + E_{elec,i} + E_{elec,r} + n_p \times E_{elec,p}$$

where:

$E_{gas,daily}$ = the total daily gas energy consumption, Btu/d,
n_p = the total number of preheats per day,
$E_{gas,p}$ = gas preheat energy consumption as determined in 11.5, Btu,
$E_{elec,daily}$ = the total daily electric energy consumption, Btu/d, and
$E_{elec,p}$ = electric preheat energy consumption as determined in 11.5, Btu.

The complete formulae for calculating daily energy consumption are as follows:

$$E_{gas,daily} = \frac{\%_h \times W}{PC} \times q_{gas,h} + \frac{\%_l \times W}{PR_l} \times q_{gas,l} \tag{X3.9}$$

$$+ \left(t_{on} - \frac{\%_h \times W}{PC} - \frac{\%_l \times W}{PR_l} - \frac{n_p \times t_p}{60} \right) \times q_{gas,i}$$

$$+ \left(t_{on} - \frac{\%_h \times W}{PC} - \frac{\%_l \times W}{PR_l} - \frac{n_p \times t_p}{60} \right) \times f_r \times q_{gas,r} + n_p \times E_{gas,p}$$

$$E_{elec,daily} = \frac{\%_h \times W}{PC} \times q_{elec,h} + \frac{\%_l \times W}{PR_l} \times q_{elec,l}$$

$$+ \left(t_{on} - \frac{\%_h \times W}{PC} - \frac{\%_l \times W}{PR_l} - \frac{n_p \times t_p}{60} \right) \times q_{elec,i}$$

$$+ \left(t_{on} - \frac{\%_h \times W}{PC} - \frac{\%_l \times W}{PR_l} - \frac{n_p \times t_p}{60} \right) \times f_r \times q_{elec,r} + n_p \times E_{elec,p}$$

X3.4.7 *Step 6*—The average electric demand for steamers may be calculated according to the following equation:

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}} \tag{X3.10}$$

where:

q_{avg} = the average demand for the steamer, kW,
$E_{elec,daily}$ = the total daily electric energy consumption, kWh/d, and
t_{on} = the total daily on-time, h.

NOTE X3.2—It has been assumed that the appliance's probable contribution to the building's peak demand is the average demand for the appliance. This is useful because the probability of an appliance drawing its average rate during the period that the building peak is set is significantly higher than for any other input rate for that appliance. If data exists otherwise for a given operation, the probable contribution to demand can be other than the average demand.

X3.4.8 *Step 7*—The estimated monthly appliance energy cost may be determined as follows:

$$C_{gas,monthly} = r_{gas} \times \frac{E_{gas,daily}}{100\,000 \frac{Btu}{therm}} \times d_{op} \tag{X3.11}$$

$$C_{elec,monthly} = r_{elec} \times E_{elec,daily} \times d_{op} + r_{demand} \times q_{avg} \tag{X3.12}$$

where:

$C_{gas,monthly}$ = the monthly appliance gas cost, \$/mo,
r_{gas} = the appropriate utility gas rate, \$/therm,
$E_{gas,daily}$ = the total daily gas energy consumption, Btu/d,
d_{op} = the average number of operating days per month,
$C_{elec,monthly}$ = the monthly appliance electric cost, \$/mo,

r_{elec} = the appropriate utility electric rate, \$/kWh,
$E_{elec,daily}$ = the total daily electric energy consumption, kWh/d,
r_{demand} = the appropriate utility demand charge, \$/kW,
q_{avg} = the average demand for the steamer, kW.