Designation: F1361 – 21

An American National Standard

Standard Test Method for Performance of Open Vat Fryers[1]

This standard is issued under the fixed designation F1361; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the evaluation of the energy consumption and cooking performance of open vat fryers. The food service operator can use this evaluation to select a fryer and understand its energy efficiency and production capacity.

1.2 This test method is applicable to Types 1 (counter), 2 (drop-in), 3 (floor-mounted, portable), and 4 (floor-mounted, stationary), size A, B, and C, electric (Style A, B and C) and gas (Style D) open vat fryers as defined by Specification F1963, with nominal frying medium capacity up to 50 lb (23 kg) or a vat size less than 18 in. in width. For size C, D, E and F and large open vat fryers with a nominal frying medium capacity greater than 50 lb (23 kg), or a vat size of 18 in. in width or greater, refer to Test Method F2144.

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

1.3.1 Energy input rate (10.2),

1.3.2 Preheat energy and time (10.4),

1.3.3 Idle energy rate (10.5),

1.3.4 Pilot energy rate (10.6),

1.3.5 Cooking energy rate and efficiency (10.8), and

1.3.6 Production capacity and frying medium temperature recovery time (10.8).

1.4 This test method is not intended to answer all performance criteria in the evaluation and selection of a fryer, such as the significance of a high energy input design on maintenance of temperature within the cooking zone of the fryer.

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

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F1963 Specification for Deep-Fat Fryers, Gas or Electric, Open

F2144 Test Method for Performance of Large Open Vat Fryers

2.2 *ANSI Document:*[3]

ANSI Z83.11 American National Standard for Gas Food Service Equipment

2.3 *ASHRAE Document:*[4]

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

3. Terminology

3.1 *Definitions:*

3.1.1 *open, deep fat fryer, n*—(hereafter referred to as fryer) an appliance, including a cooking vessel, in which oils are placed to such a depth that the cooking food is essentially supported by displacement of the cooking fluid rather than by the bottom of the vessel. Heat delivery to the cooking fluid varies with fryer models.

3.1.2 *test method, n*—a definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cold zone, n*—the volume in the fryer below the heating element or heat exchanger surface designed to remain cooler than the cook zone.

[1] This test method is under the jurisdiction of ASTM Committee F26 on Food Service Equipment and is the direct responsibility of Subcommittee F26.06 on Productivity and Energy Protocol.

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

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329.

3.2.2 *cook zone, n*—the volume of oil in which the fries are cooked. Typically, the entire volume from just above the heating element(s) or heat exchanger surface to the surface of the frying medium.

3.2.3 *cooking energy, n*—total energy consumed by the fryer as it is used to cook french fries under heavy- and light-load conditions.

3.2.4 *cooking-energy efficiency, n*—quantity of energy to the French fries during the cooking process expressed as a percentage of the quantity of energy input to the fryer during the heavy- and light-load tests.

3.2.5 *cooking energy rate, n*—average rate of energy consumed by the fryer while "cooking" a heavy- or light-load of French fries.

3.2.6 *idle energy rate, n*—average rate of energy consumed (Btu/h (kJ/h) or kW) by the fryer while "holding" or "idling" the frying medium at the thermostat(s) set point.

3.2.7 *measured energy input rate, n*—peak rate at which a fryer consumes energy, typically reflected during preheat.

3.2.8 *pilot energy rate, n*—average rate of energy consumption (Btu/h (kJ/h)) by a fryer's continuous pilot (if applicable).

3.2.9 *preheat energy, n*—amount of energy consumed (Btu (kJ) or kWh) by the fryer while preheating the frying medium from ambient room temperature to the calibrated thermostat(s) set point.

3.2.10 *preheat time, n*—time required for the frying medium to preheat from ambient room temperature to the calibrated thermostat(s) set point.

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

3.2.12 *production rate, n*—average rate (lb/h (kg/h)) at which a fryer brings the specified food product to a specified "cooked" condition. Does not necessarily refer to maximum rate. Production rate varies with the amount of food being cooked.

3.2.13 *recovery time, n*—the time from the removal of the fry basket containing the French fries until the cooking medium is back up to within 10°F (5.56°C) of the set temperature and the fryer is ready to be reloaded.

3.2.14 *test, n*—a set of six loads of French fries cooked in a prescribed manner and sequential order.

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

4. Summary of Test Method

NOTE 1—All of the fryer tests shall be conducted with the fryer installed under a wall-mounted canopy exhaust ventilation hood that shall operate at an air flow rate based on 300 cfm per linear foot (460 L/s per linear metre) of hood length. Additionally, an energy supply meeting the manufacturer's specifications shall be provided for the gas or electric fryer under test.

4.1 The fryer under test is connected to the appropriate metered energy source. The measured energy input rate is determined and checked against the rated input before continuing with testing.

4.2 The frying-medium temperature in the cook zone of the fryer is monitored at a location chosen to represent the average temperature of the frying-medium while the fryer is "idled" at 350°F (177°C). Fryer temperature calibration to 350°F (177°C) is achieved at the location representing the average temperature of the frying medium.

4.3 The preheat energy and time, and idle-energy consumption rate are determined while the fryer is operating with the thermostat(s) set at a calibrated 350°F (177°C). The rate of pilot energy consumption also is determined when applicable to the fryer under test.

4.4 Energy consumption and time are monitored while the fryer is used to cook seven loads of frozen, ¼-in. (6-mm) shoestring potatoes to a condition of 30 ± 1 % weight loss with the thermostat set at a calibrated 350°F (177°C). Cooking-energy efficiency is determined for heavy-, (optional) extra-heavy, and (optional) and light-load test conditions. Production capacity is based on the heavy-load test.

5. Significance and Use

5.1 The measured energy input rate test is used to confirm that the fryer under test is operating in accordance with its nameplate rating.

5.2 Fryer temperature calibration is used to ensure that the fryer being tested is operating at the specified temperature. Temperature calibration also can be used to evaluate and calibrate the thermostat control dial.

5.3 Preheat-energy consumption and time can be used by food service operators to manage their restaurants' energy demands, and to estimate the amount of time required for preheating a fryer.

5.4 Idle energy and pilot energy rates can be used by food service operators to manage their energy demands.

5.5 Preheat energy consumption, idle energy, and pilot energy can be used to estimate the energy consumption of an actual food service operation.

5.6 Cooking-energy efficiency is a direct measurement of fryer efficiency at different loading scenarios. This data can be used by food service operators in the selection of fryers, as well as for the management of a restaurant's energy demands.

5.7 Production capacity can be used as a measure of fryer capacity by food service operators to choose a fryer to match their particular food output requirements.

6. Apparatus

6.1 *watt-hour meter,* for measuring the electrical energy consumption of a fryer, shall have a resolution value 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 value of at least 10 Wh and a maximum uncertainty no greater than 10 %.

6.2 *gas meter,* for measuring the gas consumption of a fryer, shall be a positive displacement type with a resolution value of at least 0.01 ft^3 (0.0003 m^3) and a maximum error no greater than 1 % of the measured value for any demand greater than 2.2 ft^3 (0.06 m^3) per hour. If the meter is used for measuring the gas consumed by the pilot lights, it shall have a resolution value of at least 0.01 ft^3 (0.0003 m^3) and have a maximum error no greater than 2 % of the measured value.

6.3 *thermocouple probe(s),* industry standard thermocouples capable of immersion, with a range from 50° to 400°F and an uncertainty of ±2°F (1.1°C).

6.4 *analytical balance scale,* for measuring weights up to 10 lb (4.5 kg), with a resolution value of at least 0.01 lb (0.004 kg) and an uncertainty of 0.01 lb.

6.5 *convection drying oven,* with temperature controlled at 220 ± 5°F (104 ± 3°C), to be used to determine moisture content of both the raw and cooked fries.

6.6 *canopy exhaust hood,* 4 ft (1.2 m) in depth, wall-mounted with the lower edge of the hood 6 ft, 6 in. (1.98 m) from the floor and with the capacity to operate at a nominal net exhaust ventilation rate of 300 cfm per linear foot (460 L/s per linear metre) of active hood length. This hood shall extend a minimum of 6 in. (152 mm) past both sides and the front of the cooking appliance and shall not incorporate side curtains or partitions. Makeup air shall be delivered through face registers or from the space, or both.

6.7 *fry basket,* supplied by the manufacturer of the fryer under testing, shall be a nominal size of 6⅜ by 12 by 5⅜ in. (160 by 300 by 140 mm). A total of six baskets are required to test each fryer in accordance with these procedures.

6.8 *freezer,* with temperature controlled at −5 ± 5°F (−20 ± 3°C), with capacity to cool all fries used in a test.

6.9 *barometer,* for measuring absolute atmospheric pressure, to be used for adjustment of measured gas volume to standard conditions. Shall have a resolution value of at least 0.2 in. Hg (670 Pa) and an uncertainty of 0.2 in. Hg (670 Pa).

6.10 *data acquisition system,* for measuring energy and temperatures, capable of multiple temperature displays updating at least every 2 s.

6.11 *pressure gauge,* for monitoring gas pressure. Shall have a range from 0 to 15 in. H_2O (0 to 3.7 kPa), a resolution value of at least 0.5 in. H_2O (125 Pa), and a maximum uncertainty of 1 % of the measured value.

6.12 *stopwatch,* with a 1-s resolution.

6.13 *temperature sensor,* for measuring gas temperature in the range from 50 to 100°F (10 to 93°C) with an uncertainty of ±2°F (1.1°C).

7. Reagents and Materials

7.1 *French Fries (Shoestring Potatoes)*—Order a sufficient quantity of French fries to conduct both the French fry cook-time determination test and the heavy- and light-load cooking tests. All cooking tests are to be conducted using ¼-in. (6-mm) par-cooked, frozen, shoestring potatoes. Fat and moisture content of the French fries shall be 6 ± 1 % by weight and 68 ± 2 % by weight, respectively.

7.2 *frying medium,* shall be partially hydrogenated, 100 % pure vegetable oil. New frying medium shall be used for each fryer tested in accordance with this test method. The new frying medium that has been added to the fryer for the first time shall be heated to 350°F (177°C) at least once before any test is conducted.

NOTE 2—Generic partially hydrogenated all vegetable oil (soybean oil) has been shown to be an acceptable product for testing by PG&E.

8. Sampling, Test Specimens, and Test Units

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

9. Preparation of Apparatus

9.1 Install the appliance according to 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. (1.98 m) from the floor. Position the fryer with the front edge of frying medium inset 6 in. (152 mm) from the front edge of the hood at the manufacturer's recommended working height. The length of the exhaust hood and active filter area shall extend a minimum of 6 in. past the vertical plane of both sides of the fryer. In addition, both sides of the fryer shall be a minimum of 3 ft (0.9 m) from any side wall, side partition, or other operating appliance. A "drip" station positioned next to the fryer is recommended. Equipment configuration is shown in Fig. 1. The exhaust ventilation rate shall be based on 300 cfm per linear foot (460 L/s per linear metre) of hood length. The associated heating or cooling system shall be capable of maintaining an ambient temperature of 75 ± 5°F (24 ± 3°C) within the testing environment when the exhaust system is operating.

9.2 Connect the fryer 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 fryer, as well as the barometric pressure, shall be recorded during each test so that the measured gas flow can be corrected to standard conditions. For electric installations, a voltage regulator may be required to maintain a constant "nameplate" voltage during tests if the voltage supply is not within ±2.5 % of the manufacturer's "nameplate" voltage (see 9.4).

9.3 For a gas fryer, adjust (during maximum energy input) the gas supply pressure downstream from the fryer's pressure regulator to within ±2.5 % of the operating manifold pressure specified by the manufacturer. Make adjustments to the fryer following the manufacturer's recommendations for optimizing combustion. Proper combustion may be verified by measuring air-free CO in accordance with ANSI Z83.11.

9.4 For an electric fryer, confirm (while the fryer elements are energized) that the supply voltage is within ±2.5 % of the operating voltage specified by the manufacturer. Record the test voltage for each test.

NOTE 3—It is the intent of the testing procedure herein to evaluate the performance of a fryer at its rated gas pressure or electric voltage. If an electric fryer is rated dual voltage (that is, designed to operate at either 208

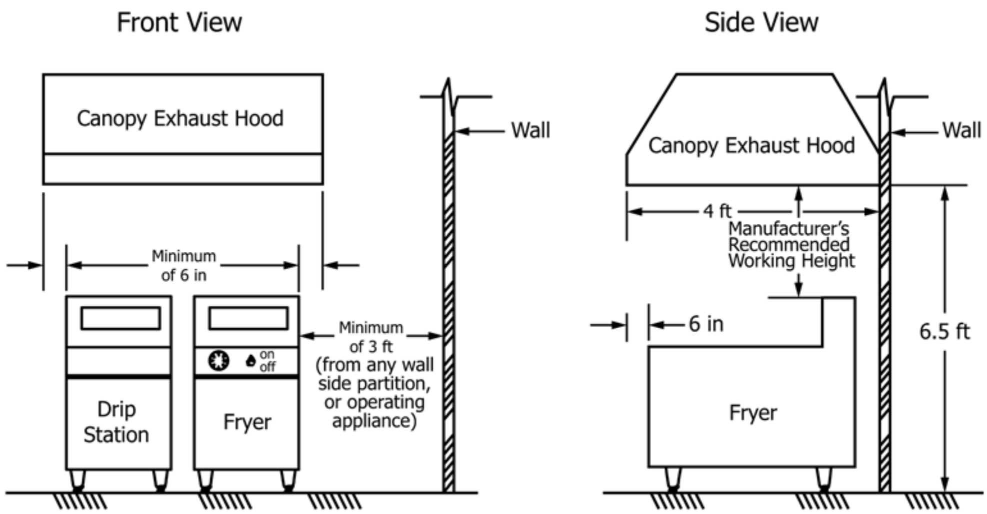

FIG. 1 Equipment Configuration

or 240 V with no change in components), the voltage selected by the manufacturer or tester, or both, shall be reported. If a fryer is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the fryer (for example, preheat time) may differ at the two voltages.

9.5 Make the fryer ready for use in accordance with the manufacturer's instructions. Clean the fryer by "boiling" with the manufacturer's recommended cleaner and water and then rinsing the inside of the fry vat thoroughly.

9.6 To prepare the fryer for temperature calibration, attach an immersion-type thermocouple in the fry vat before beginning any tests. The thermocouple used to calibrate the fryer shall be located in the center of the fry vat, about 1 in. (25 mm) up from the platform the fry baskets rest on as shown in Fig. 2.

NOTE 4—For single-basket or split-vat fryers, the thermocouple may be placed at about ⅛ in. (3 mm) up from the platform the fry baskets rest on.

9.7 If applicable, cold-zone temperature shall be measured using an immersion-type thermocouple placed 0.5 in. (12 mm) above the bottom and 1 in. (25 mm) away from the rear wall of the fry vat. The portion of the rear wall not immersed in oil may be used for thermocouple support. A stiff wire attached to the rear wall of the fryer may also be used for thermocouple support.

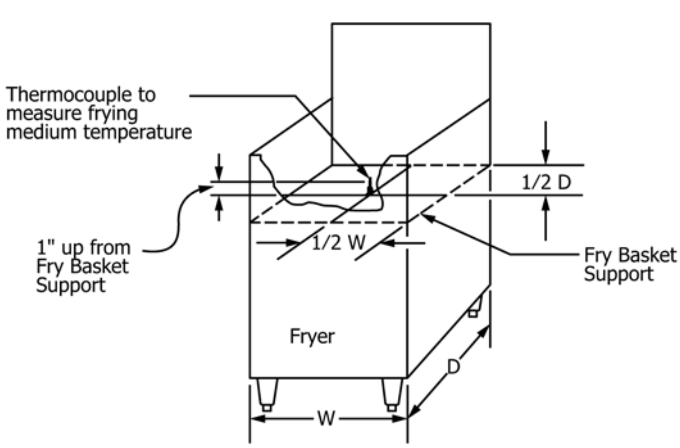

FIG. 2 Thermocouple Placement

9.8 The temperature seen by the fryer's temperature probe shall be measured using an immersion-type thermocouple placed within 0.5 in. of the temperature probe.

10. Procedure

10.1 *General:*

10.1.1 For gas fryers, record the following for each test run: (*1*) higher heating value, (*2*) standard gas pressure and temperature used to correct measured gas volume to standard conditions, (*3*) measured gas temperature, (*4*) measured gas pressure, (*5*) barometric pressure, (*6*) ambient temperature, and (*7*) energy input rate during or immediately prior to test.

NOTE 5—Using a calorimeter or gas chromatograph in accordance with accepted laboratory procedures is the preferred method for determining the higher heating value of gas supplied to the fryer under test. It is recommended that all testing be performed with gas having a higher heating value of 1000 to 1075 Btu/ft^3 (37 300 to 40 100 kJ/m^3).

10.1.2 For gas fryers, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (10.2).

10.1.3 For electric fryers, record the following for each test run: (*1*) voltage while elements are energized, (*2*) ambient temperature, and (*3*) energy input rate during or immediately prior to test run.

10.1.4 For each test run, confirm that the peak input rate is within ±5 % of the rated nameplate input. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the fryer.

10.2 *Energy Input Rate:*

10.2.1 Load the fryer with oil to the indicated fill line and turn the fryer on with the temperature controls set to 350°F. If the fryer does not have an indicated fill line, fill to the manufacturer's recommended weight with a 5 % tolerance of oil. After the fryer has been preheated, use a sharpie to mark ¼ in. above the oil level to indicate a fill line. For any test, oil must be added to the fryer if the oil level drops below ½ in. below the manufacturer's recommended hot fill line.

10.2.2 Let the fryer run until the burner or heating element first cycles off. Calculate the input rate for the last three minutes before the burner or heating element cycles off. Adjustments to input rate may be made by adjusting gas manifold pressure (gas fryers).

10.2.3 Confirm that the measured energy input rate is within ±5 % of nameplate energy input rate. 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 fryer. Also, the power supply may be changed to conform with manufacturer's specifications. It is the intent of the testing procedures herein to evaluate the performance of a fryer at its rated energy input rate.

10.3 *Calibration:*

10.3.1 Ensure that frying medium is loaded to the indicated fryer fill line. Preheat and allow the fryer to stabilize for 30 min before beginning temperature calibration.

10.3.2 The frying-medium temperature shall be measured by attaching a calibrated immersion-type thermocouple in the fry zone as detailed in 9.6. Record the frying-medium temperature at 5-s intervals for 3 complete duty cycles after stabilization and calculate the average of these temperatures.

10.3.3 Where required, adjust the fryer temperature control(s) to calibrate the fryer at an average frying-medium temperature of 350 ± 5°F (177 ± 3°C). Record the frying-medium temperature at 30-s intervals for 15 min. Calculate the average of the 30 recorded temperatures to verify that the average measured temperature at the frying-medium sensor location is 350 ± 5°F (177 ± 3°C).

10.4 *Preheat Energy and Time:*

10.4.1 Ensure that the frying medium is loaded to the indicated fryer fill line. Record the frying medium temperature and ambient kitchen temperature at the start of the test. The frying medium temperature shall be 75 ± 5°F (24 ± 3°C) at the start of the test.

NOTE 6—The preheat test should be conducted prior to appliance operation on the day of the test.

10.4.2 Turn the fryer on with the temperature controls set to attain a temperature within the frying-medium of a calibrated 350°F (177°C).

10.4.3 Record the frying medium temperatures at a minimum of 5-s intervals during the course of preheat.

10.4.4 Begin monitoring energy consumption and time as soon as the fryer is turned on. For a gas fryer, the preheat time shall include any delay between the time the unit is turned on and the burners actually ignite. Preheat is judged complete when the temperature at the center of the vat reaches 340°F (177°C).

10.4.5 Continue recording the frying medium temperature at a minimum of 5-s intervals until the temperature has exceeded, then returned to 350°F to characterize any possible temperature overshoot.

10.5 *Idle-Energy Rate:*

10.5.1 Allow the frying medium to stabilize at 350 ± 5°F (177°C) for at least 60 min after the last thermostat has commenced cycling about the thermostat set point.

10.5.2 After a minimum 60 min stabilization period, wait for the fryer to reach the top of a thermal cycle (units with proportional controls) or the heater cycle off (units with snap-action controls), then immediately start monitoring elapsed time, vat temperature(s) and energy consumption.

10.5.3 The idle energy rate test shall be run for a minimum of 2 h and include a minimum of 10 complete thermal cycles or heater cycles. After the test period (either 2 h or 10 thermal/heater cycles, whichever is longer), end the test. If the test unit does not exhibit clear thermal cycles, then the test shall be run for 3 h.

NOTE 7—Models with proportional controls may not exhibit distinct heater cycles. The intent of the test is to accurately represent the average energy consumption of the holding cabinet, while minimizing any error that may be introduced as a result of capturing partial thermal cycles.

10.5.4 Monitor and record the time elapsed, number of duty cycles and energy consumed between the first and last duty cycle. For gas fryers, monitor and record all electric energy consumed during the idle test.

10.6 *Pilot-Energy Rate (Gas Models With Standing Pilots):*

10.6.1 Where applicable, set gas valve controlling gas supply to appliance at the "pilot" position. Otherwise set fryer temperature controls to the "off" position.

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

10.6.3 Record gas reading, electric energy consumed, and time before and after a minimum of 8 h of pilot operation.

10.7 *French Fry Preparation:*

10.7.1 All cooking tests are to be conducted using parcooked, frozen, ¼-in. (6-mm) shoestring potatoes. Fat and moisture content of the French fries shall be 6 ± 1 % by weight and 68 ± 2 % by weight, respectively. The fat composition shall be provided by the manufacturer. The moisture composition data shall be determined using the moisture content determination procedure in Annex A2.

10.7.2 Prepare French fries for the cooking test by weighing individual basket loads. For individual load sizes, refer to Table 1. An individual basket load shall be ½ the weight of the individual load (that is, for a total load of 3 lb, each basket shall have 1.5 lb of fries). Store each load in a self-sealing plastic

TABLE 1 French Fry Load Sizes Based on Nominal Shortening Capacity

Size	Nominal Shortening Capacity (lb)	Stir-Up Load Size	Heavy-Load Size	Extra-Heavy Load Size[A]	Light-Load Size
B, C	30 – 50	3.00 ± 0.02 lb	3.00 ± 0.02 lb	4.00 ± 0.02 lb	0.75 ± 0.01 lb
A	20 – 29	2.00 ± 0.02 lb	2.00 ± 0.02 lb	3.00 ± 0.02 lb	0.75 ± 0.01 lb
	<20	1.50 ± 0.01 lb	1.50 ± 0.01 lb	2.00 ± 0.01 lb	0.75 ± 0.01 lb

[A] Note that the Extra-Heavy load test is optional.

freezer bag and place the bags in a freezer (operated at –5 ± 5°F) (–20 ± 3°C) in the proximity of the fryer test area until the temperature of the fries has stabilized at the freezer temperature. Monitor the temperature of the fries by implanting a thermocouple in a fry, and placing the fry into one of the bags, that shall be located in a freezer with the test bags. An additional basket load of fries shall be prepared and reserved for moisture content analysis. Fries shall be minimally handled and shall spend minimal time in ambient air.

NOTE 8—Fries should not be stored in plastics bags for more than three days. It was observed by PG&E that ice develops on the inside of the bags indicating that the fries lose moisture.

10.7.3 The number of bags to be prepared for the cooking-energy efficiency and production capacity fry tests (10.8) will vary with the number of trials needed to establish a cooking time that demonstrates a 30 ± 1 % fry weight loss during cooking. The first load of each cooking test will not be averaged in the weight loss calculation. When cooking the seven loads of the cooking test, the weight loss may increase with each load cooked. For example, Load Three may have a greater weight loss than Load Two, Load Four may have a greater weight loss than Load Three, etc. If the estimated cooking time does not yield a 30 ± 1 % weight loss averaged over the last five loads of the seven-load cooking test, the cooking time shall be adjusted and the seven-load cooking test shall be repeated.

NOTE 9—It may take several loads to establish a stable cook time that yields a 30 ± 1 % weight loss. For example, it may take 24 or 36 bags (two or three tests) to establish a cooking time for a heavy load. It is better to prepare more fries than to not have enough fries to determine the proper cooking time.

10.7.4 For the cooking-energy efficiency and production-capacity tests, the following are the recommended number of bags that need to be prepared:

10.7.4.1 *Heavy Load*—64 bags,

10.7.4.2 *Extra-Heavy Load (Optional)*—64 bags, and

10.7.4.3 *Light Load (Optional)*—32 bags.

10.8 *Cooking-Energy Efficiency and Production Capacity Fry Tests:*

10.8.1 The cooking-energy efficiency and production capacity fry tests are to be run a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (see Annex A1).

10.8.2 Prepare an additional 1 lb (454 g) of frozen fries consisting of an apportioned number of fries from multiple bags of frozen French fries, and store in freezer in a sealable freezer-safe plastic bag (to prevent moisture migration). Reserve these fries for analysis of moisture content.

10.8.3 Load the fryer to the indicated manufacturer's recommended fill line with the frying medium. Set the thermostat of the fryer to the calibrated frying medium temperature of 350 ± 5°F (177 ± 3°C). Allow the fryer to stabilize at the operating temperature for a minimum of 60 min after being turned on.

10.8.4 Use a total of six fry baskets to cook the seven loads of fries. Hold the fry baskets at room temperature (75 ± 5°F (24 ± 3°C)) prior to being loaded with frozen French fries. Also, the fry baskets shall be clean and moisture-free so as not to contaminate the frying medium.

10.8.5 Determine the cook time for the selected French Fry load (for example, heavy, extra-heavy, light):

10.8.5.1 Select an appropriate cook time to achieve a 30 ± 1% weight loss. Cook the fries for the estimated time required to produce a 30 ± 1 % weight loss. The weight loss for each load is determined after the cooked fries have drained for 2 min following removal from the frying medium.

10.8.5.2 The first load of each seven-load cooking test shall be used to stabilize the fryer and shall not be counted in the calculation of elapsed time and energy. Commence monitoring cooking energy when the third load contacts the frying medium.

10.8.5.3 After the cook-zone thermocouple indicates that the oil temperature has recovered to 340°F, or 10 s, whichever is longer, cook the next load.

10.8.5.4 Measure and record the weight loss of the cooked fries. If the percent weight loss is not 30 ± 1 %, adjust the total cooking time for the subsequent loads as appropriate and repeat 10.8.5. Once the cooking time has been confirmed to be stable over a series of at least three sequential loads, then proceed to 10.8.6.

10.8.6 The cooking-energy efficiency test shall be performed in the following sequence:

10.8.6.1 Confirm that the fryer is filled with frying medium to the manufacturer's recommended fill-line. Allow the fryer to cycle a minimum of three times after returning to the setpoint.

10.8.6.2 When the heaters have cycled off, place the first load into the fryer. The first two loads of each seven-load cooking test shall be used to stabilize the fryer and shall not be counted in the calculation of elapsed time and energy. Commence monitoring test time and cooking energy when the third load contacts the frying medium.

10.8.6.3 Cook the load of fries for the determined cook time. For the first two loads, use the estimated cook time from 10.8.5.

10.8.6.4 Shortly before the end of the cook time, remove the next load of fries from the freezer and place in the next baskets to be cooked. The time from the fries being removed from the freezer until they are lowered into the oil shall not be longer than 60 s.

10.8.6.5 Remove cooked fries to drip station and drain for 2 ± 0.25 min.

10.8.6.6 Set the next load into the fryer 10 s after removing the first load from the fryer or after the cook zone thermocouple indicates that the oil temperature has recovered to 340°F (171°C), whichever is longer. Repeat 10.8.6.3 – 10.8.6.6 until all seven loads have been cooked (Fig. 3).

10.8.6.7 Confirm that the weight loss of each subsequent load is 30 ± 1 %. If at any point during testing two sequential loads (excluding the stabilization loads at the beginning of each test run) do not produce a 30 ± 1 % weight loss, adjust the cook time accordingly and continue testing until a total of five successive loads consistently achieve 30 ± 1 % weight loss.

10.8.6.8 Reserve 1 lb (440 g) of cooked fries (consisting of an apportioned number of fries from each of the five loads) for the determination of moisture content. Unless the moisture content test is conducted immediately, place the fries in a

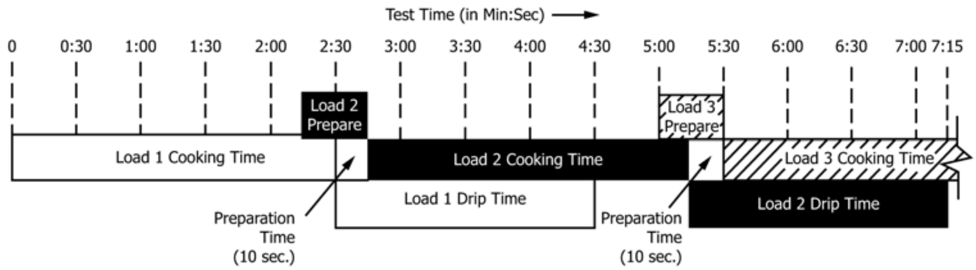

FIG. 3 Sequence of Stir-Up Cook Test (Not to Scale)

freezer-safe ziplock bag. Ensure that the ziplock bag stays closed in between taking samples from different loads.

10.8.6.9 Terminate the test after removing the last load and either allowing 10 s to pass or waiting for the cook-zone thermocouple to indicate that the oil temperature has recovered to 340°F, whichever is longer (to be consistent with previous loads). Record total elapsed time and consumption of energy for the last five loads of the cooking test.

10.8.7 Perform Run Nos. 2 and 3 by repeating the steps given in 10.8.6. Follow the procedure in Annex A1 to determine whether more than three test runs are required. Report the results for the cooking energy efficiency, production rate, cooking energy rate, and cook time as described in Annex A1. See Fig. 4 for a flowchart of the fry test procedure.

10.8.8 Determine the average moisture content of the cooked fries for each test replicate in accordance with the procedure outlined in Annex A2 and calculate the moisture loss based on initial moisture content of the French fries. Use this value in the cooking-energy efficiency calculation (see 11.9).

10.8.9 *Optional*—When requested, repeat 10.8.1 – 10.8.8 for the optional extra-heavy and light-load cooking tests.

11. Calculation and Report

11.1 *Test Fryer:*

11.1.1 Summarize the physical and operating characteristics of the fryer. If needed, describe other design or operating characteristics that may facilitate interpretation of the test results.

11.1.2 Report fryer vat volume in pounds (lb) according to the manufacturer's recommended fill line.

11.2 *Apparatus and Procedure:*

11.2.1 Confirm that the testing apparatus conforms to all of the specifications in Section 6. Describe any deviations from those specifications.

11.2.2 For electric fryers, report the voltage for each test.

11.2.3 For gas fryers, report the higher heating value of the gas supplied to the fryer during each test.

11.3 *Gas Energy Calculations:*

11.3.1 For gas fryers, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (10.2).

11.3.2 For all gas measurements, calculate the energy consumed based on:

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

where:

E_{gas} = energy consumed by the fryer
HV = higher heating value
= energy content of gas measured at standard conditions, Btu/ft^3 (kJ/m^3),
V = actual volume of gas corrected for temperature and pressure at 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)
T_{cf} = temperature correction factor

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

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

P_{cf} = pressure correction factor

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

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

NOTE 10—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Standard conditions in accordance with ANSI Z83.11 are 14.696 psia (101.33 kPA) and 60°F (519.67°R, (288.71°K)).

11.4 *Energy Input Rate:*

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

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

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

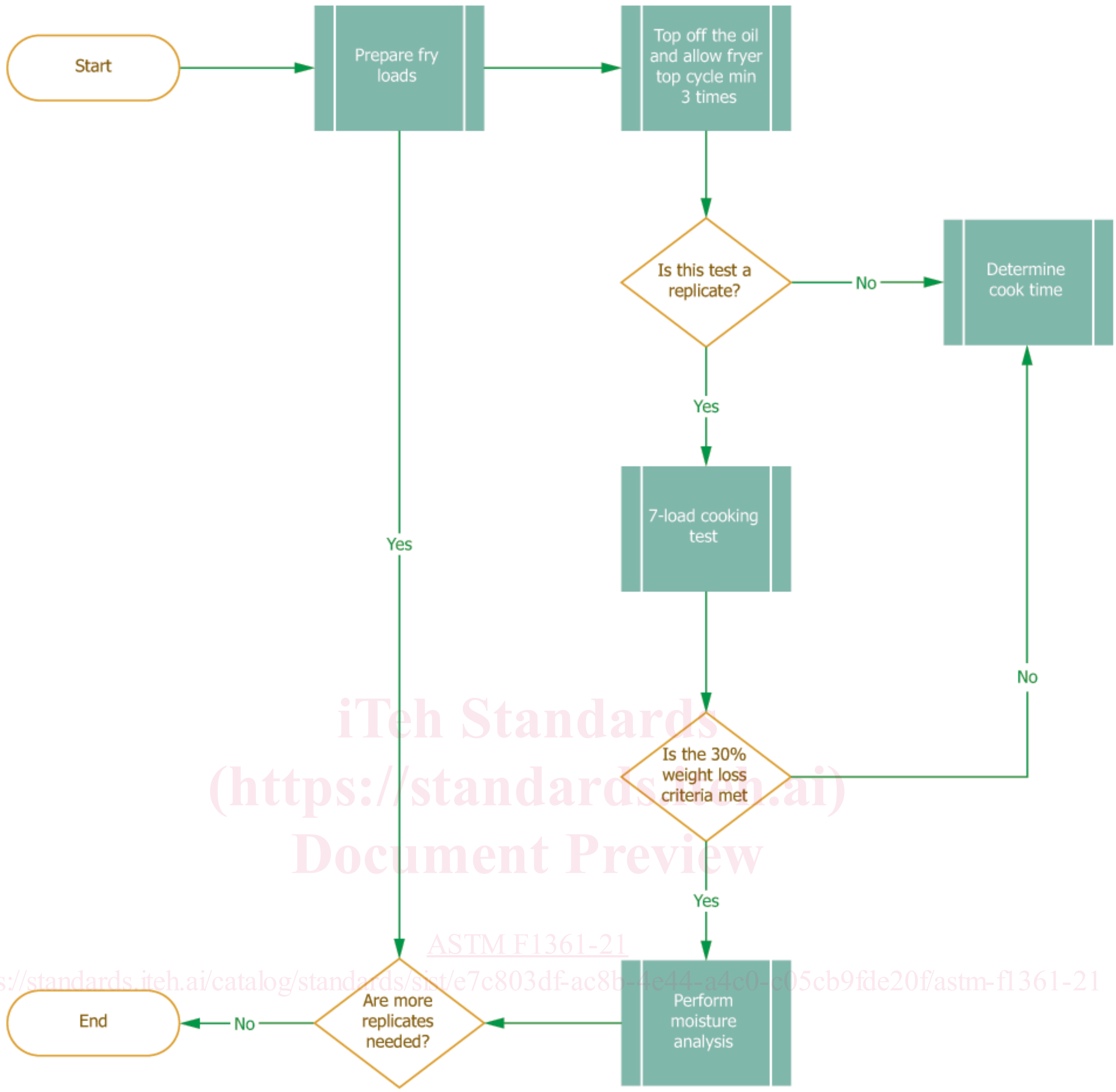

FIG. 4 Fry Test Flowchart

where:

q_{input} = measured peak energy input rate, Btu/h (kJ/h) or kW,

E = energy consumed during period of peak energy input, Btu or kWh, and

t = period of peak energy input, min.

11.5 *Fryer Temperature Calibration:*

11.5.1 Report the average bulk temperature for the frying medium in the cook zone after calibration. Report any discrepancies between the temperature indicated on the control and the measured average frying-medium temperature.

11.6 *Preheat Energy and Time:*

11.6.1 Report the preheat energy consumption (Btu (kJ) or kWh) and preheat time (min).

11.6.2 Calculate and report the average preheat rate (°F (°C)/min) based on the preheat period.

11.6.3 Generate a graph showing frying medium temperature versus time for the preheat period including temperature overshoot, if any.

11.7 *Idle Energy Rate:*

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

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

where:

q_{idle} = idle energy rate, Btu/h (kJ/h) or kW,

E = energy consumed during the test period, Btu (kJ) or kWh, and
t = test period, min.

11.8 *Pilot Energy Rate:*

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

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

where:

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

11.9 *Cooking-Energy Efficiency and Cooking Energy Rate:*

NOTE 11—The reported cooking-energy efficiency parameters are the average values from the three test replicates cooked for each loading scenario.

11.9.1 Calculate and report the cooking energy rate for heavy- and light-load, and if applicable, the extra-heavy load cooking tests based on:

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

where:

q_{cook} = cooking energy rate, Btu/h (kJ/h) or kW,
E = energy consumed during cooking test, Btu (kJ) or kWh, and
t = cooking test period, min.

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

11.9.2 Calculate and report the energy consumption per pound of food cooked for heavy- and light-load, and if applicable, the extra heavy load cooking tests based on:

$$q_{per\ pound} = \frac{E}{W} \tag{6}$$

where:

$q_{per\ pound}$ = energy per pound, Btu/lb (kJ/kg) or kWh/lb (kWh/kg),
E = energy consumed during cooking test, Btu (kJ) or kWh, and
W = total initial weight of the frozen french fries, lb (kg).

11.9.3 Calculate and report the cooking-energy efficiency for heavy- and light-load, and if applicable, the extra-heavy load cooking tests based on:

$$\eta_{cook} = \frac{E_{food}}{E_{fryer}} \times 100 \tag{7}$$

where:

η_{cook} = cooking-energy efficiency, %, and
E_{food} = energy into food, Btu (kJ),
= $E_{sens} + E_{thaw} + E_{evap}$.

where:

E_{sens} = quantity of heat added to the French fries, which causes their temperature to increase from the starting temperature to the average bulk temperature of a done load of French fries (212°F (100°C)), Btu (kJ)
= $(W_i)(C_p)(T_f - T_i)$

where:

W_i = initial weight of French fries, lb (kg), and
C_p = specific heat of French fry, Btu/lb, °F (kJ/kg,° C),
= 0.695 (0.898).

NOTE 12—For this analysis, the specific heat (C_p) of a load of French fries is considered to be the weighted average of the specific heat of its components (for example, water, fat, and nonfat protein). Research conducted by PG&E determined that the weighted average of the specific heat for frozen French fries cooked in accordance with this test method was approximately 0.695 Btu/lb, °F (0.898 kJ/kg, °C).

NOTE 13—Research conducted by PG&E[5] has determined that the bulk temperature of a cooked load of French fries under all loading scenarios is 212°F (100°C). This was determined by cooking a load of French fries with thermocouples and measuring the bulk temperature in a calorimeter. Therefore the average bulk temperature of a cooked load of French fries will be assumed to be 212°F (100°C).

T_f = final internal temperature of the cooked French fries, °F (°C),
= 212 (100)
T_i = initial internal temperature of the frozen French fries, °F (°C)
E_{thaw} = latent heat (of fusion) added to the French fries, which causes the moisture (in the form of ice) contained in the fries to melt when the temperature of the fries reaches 32°F (0°C) (the additional heat required to melt the ice is not reflected by a change in the temperature of the fries), Btu (kJ)
= $W_{iw} \times H_f$

where:

W_{iw} = initial weight of water in fries, lb (kg),
H_f = heat of fusion, Btu/lb (kJ/kg),
= 144 Btu/lb (336 kJ/kg) at 32°F (0°C), and
E_{evap} = latent heat (of vaporization) added to the French fries, which causes some of the moisture contained in the fries to evaporate. Similar to the heat of fusion, the heat of vaporization cannot be perceived by a change in temperature and must be calculated after determining how much moisture was lost from a done load of fries,
= $W_{loss} \times H_v$

where:

W_{loss} = weight loss of water during cooking, lb (kg),
= $M_i \times W_i - M_f \times W_f$

where:

M_i = initial moisture content (by weight) of the raw fries, %,
W_i = initial weight of the raw fries, lb,
M_f = final moisture content (by weight) of the cooked fries, %,
H_v = heat of vaporization, Btu/lb (kJ/kg),
= 970 Btu/lb (2256 kJ/kg) at 212°F (100°C), and
E_{fryer} = energy into the fryer, Btu (kJ).

11.9.4 Calculate production capacity (lb/h (kg/h)) based on:

$$PC = \frac{W \times 60}{t} \tag{8}$$

[5] *Development and Application of a Uniform Testing Procedure for Fryers*, Pacific Gas and Electric Company, November 1990.

where:

PC = production capacity of the fryer, lb/h (kg/h),
W = total weight of food cooked during heavy-load cooking test, lb (kg), and
t = total time of heavy-load cooking test, min.

11.9.5 Calculate production rate (lb/h (kg/h)) for the light-load, and if applicable, the extra-heavy load tests using the relationship from 11.9.4, where W is the total weight of food cooked during the test run and t is the total time of the test run.

11.9.6 Determine the average frying medium recovery time for the heavy-, light-load, and if applicable, the extra-heavy load tests. Also report the cook time for the heavy- and light-load, and if applicable, the extra-heavy load tests.

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 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 procedure in this test method for measuring each reported parameter is being determined.

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

13. Keywords

13.1 efficiency; energy; fryer; performance; production capacity; test method; throughput

ANNEXES

(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 and the 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 (13.6 kg/h), the uncertainty must not be greater than ±3 lb/h (±1.4 kg/h). Thus, the true production capacity is between 27 and 33 lb/h (12.2 and 15 kg/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:*

TABLE A1.1 Uncertainty Factors

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

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

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

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

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

where:

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

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

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

where:

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

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

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

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

$$U_3 = C_3 \times S_3, \tag{A1.3}$$

$$U_3 = 2.48 \times S_3$$

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 (3 test runs) is as follows:

$$\%\, U_3 = (U_3/Xa_3) \times 100\,\% \tag{A1.4}$$

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 $\pm 10\,\%$ 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 $\pm 10\,\%$ 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 $\pm 10\,\%$.

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:

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

where:

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

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

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

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:

$$U_4 = C_4 \times S_4, \tag{A1.7}$$

$$U_4 = 1.59 \times S_4$$

where:

U_4 = absolute uncertainty in average for four test runs, and

C_4 = 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:

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

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 $\pm 10\,\%$ 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 $\pm 10\,\%$ 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:

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

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: