Designation: F 1361 – 99

Standard Test Method for Performance of Open Deep Fat Fryers[1]

This standard is issued under the fixed designation F 1361; 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, deep fat 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 floor model gas and electric units with 35- to 60-lb frying medium capacity.

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 (10.10), and

1.3.6 Production capacity and frying medium temperature recovery time (10.10).

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 3588 Method for Calculating Calorific Value and Specific Gravity Relative Density of Gaseous Fuels[2]

2.2 *ANSI Document:*[3]

ANSI Z83.13 American National Standard for Gas Food Service Equipment—Deep Fat Fryers

2.3 *AOAC Documents:*[4]

AOAC 984.25 Moisture (Loss of Mass on Drying) in Frozen French Fried Potatoes

AOAC 983.23 Fat in Foods: Chloroform-Methanol Extraction Method

2.4 *ASHRAE Document:*[5]

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 *Descriptions 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.

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

3.2.3 *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-, medium-, and light-load tests.

---

[1] This test method is under the jurisdiction of ASTM Committee F-26 on Food Service Equipment and is the direct responsibility of Subcommittee F26.06 on Productivity and Energy Protocol.

Current edition approved Oct. 10, 1999. Published January 2000. Originally published as F 1361 – 91. Last previous edition F 1361 – 95.

[2] *Annual Book of ASTM Standards*, Vol 05.05.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY, 10036.

[4] *Official Methods of Analysis of the Association of Official Analytical Chemists*. Available from the Association of Official Analytical Chemists, 1111 N. 19th St., Arlington, VA 22209.

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

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

3.2.5 *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.

3.2.6 *heavy load*, *n*—3 lb (1360 g) of fries, divided evenly into 1½-lb (680-g) loads and placed in two baskets for cooking.

3.2.7 *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.

3.2.8 *light load*, *n*—¾ lb (340 g) of fries, all placed in one basket for cooking.

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

3.2.10 *medium load*, *n*—1½ lb (680 g) of fries, all placed in one basket for cooking.

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

3.2.12 *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.

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

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

3.2.15 *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.

3.2.16 *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.

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

3.2.18 *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 six 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-, medium-, 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 of at least 10 Wh and a maximum uncertainty no greater than 1.5 % of the measured value for any demand greater than 100 W. For any demand less than 100 W, the meter shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 10 %.

6.2 *gas meter*, for measuring the gas consumption of a fryer, shall be a positive displacement type with a resolution of at least 0.01 ft^3 (0.0003 m^3) and a maximum error no greater than 1 % of the measured value for any demand greater than 2.2 ft^3 (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 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 Type T or Type K thermocouples capable of immersion, with a range from 50° to 400°F and an uncertainty of ±1°F (0.56°C).

6.4 *analytical balance scale*, for measuring weights up to 10 lb, with a resolution of 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 (100 ± 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 twelve baskets is 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 of 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 gage*, for monitoring gas pressure. Shall have a range from 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.

6.12 *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 ±1°F (0.56°C).

7. Reagents and Materials

7.1 *French Fries (Shoestring Potatoes)*—Order sufficient quantity of french fries to conduct both the french fry cook-time determination test and the heavy-, medium-, and light-load cooking tests. All cooking tests are to be conducted using ¼-in. (6-mm) blue ribbon product, par-cooked, frozen, shoestring potatoes. Fat and moisture content of the french fries shall be 6 ± 1 % by weight and 66 ± 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—Mel-fry[6] 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

[6] Available from Van Den Berg Foods, 3701 Southwestern Blvd., Baltimore, MD 21229.

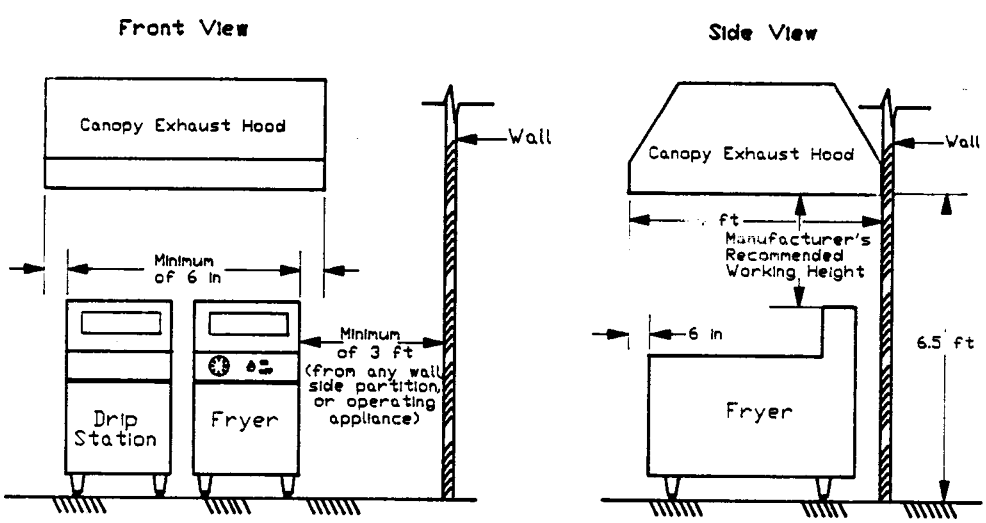


FIG. 1 Equipment Configuration

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 Z83.13.

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 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 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.

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.

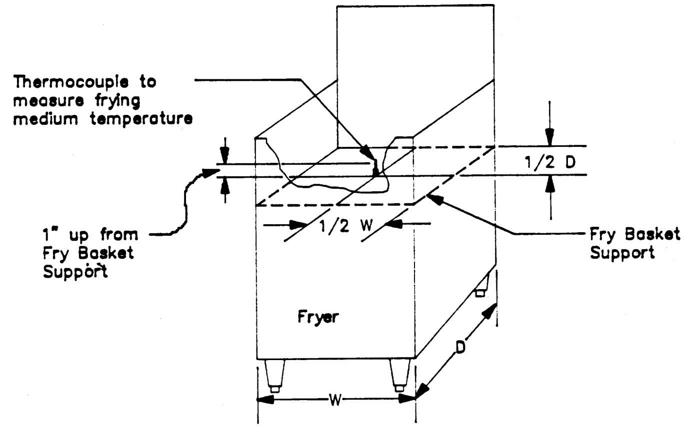


FIG. 2 Thermocouple Placement

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 water to the indicated fill line and turn the fryer on with the temperature controls set to the maximum setting possible.

10.2.2 Let the fryer run for a period of 15 min, then monitor the time required for the fryer to consume 5 ft^3 (0.14 m^3) of gas. 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 30-s intervals for 15 min. Calculate the average of the 30 recorded 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°F (177°C) for at least 30 min after the last thermostat has commenced cycling about the thermostat set point.

10.5.2 Proceed to monitor the elapsed time and the energy consumption of the fryer while it is operated under this "idle" condition for a minimum of 2 h. 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 blue-ribbon product, par-cooked, frozen, ¼-in. (6-mm) shoestring potatoes. Fat and moisture content of the french fries shall be 6 ± 1 % by weight and 66 ± 2 % by weight respectively. This composition data can be provided by the manufacturer or determined using AOAC 984.23 and 984.25. Moisture content may also be determined using the procedure in Annex A2.

10.7.2 Prepare french fries for test by weighing individual basket loads (1.5 ± 0.01 lb (680 ± 5 g)) for heavy and medium loads, and 0.75 ± 0.01 lb (340 ± 5 g) for light loads). Store each load in a self-sealing plastic 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 1.5-lb (680-g) bags, that shall be located in a freezer with the test bags.

NOTE 7—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 time determination test (10.9) 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 time determination test will not be averaged in the weight loss calculation. When cooking the six loads of the cooking time determination 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 six-load cooking time determination test, the cooking time shall be adjusted and the six-load cooking time determination test shall be repeated.

NOTE 8—It may take several cooking-time determination tests to establish a 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 number of bags needs to be prepared:

10.7.4.1 *Stir-Up Load*—12 bags, 1½ lb (680 g) each,

10.7.4.2 *Full Load*—36 bags, 1½ lb (680 g) each,

10.7.4.3 *Medium Load*—18 bags, 1½ lb (680 g) each, and

10.7.4.4 *Light Load*—18 bags, ¾ lb (340 g) each.

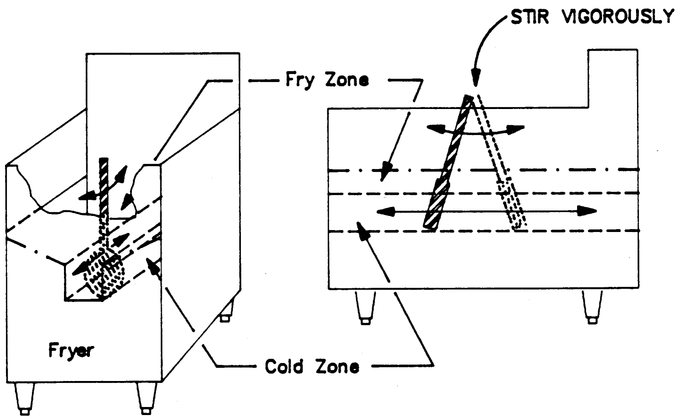
10.8 *Cold-Zone Temperature Stabilization*:

NOTE 9—During test method development, it was found that a gradual warming of the cold zone had a significant affect on the cooking time of the fries as well as the energy input to the fryer. As the cold zone temperature increased, less energy was required and the measured energy efficiency would increase. To stabilize the cold zone, thus minimizing the variation in cook time and energy consumption, 10.8.2 and 10.8.5 were developed.

10.8.1 Ensure that the frying medium is loaded to the indicated fryer fill line. Confirm that the frying-medium temperature is 350 ± 5°F (177 ± 3°C) as calibrated in 10.3. Allow the fryer to stabilize for 30 min after being turned on.

10.8.2 After the 30-min stabilization, vigorously stir the cold zone with a long spoon or equivalent for 5 min ± 30 s (see Fig. 3).

NOTE 10—While it was recognized that stirring the cold zone is not practiced in industry, it was included in this procedure because stirring provided a simple way to eliminate the variations in cold zone temperature that caused a significant fluctuation in the measured cooking-energy



NOTE 1—Fry basket support may need to be removed before stirring.

FIG. 3 Stirring of the Cold Zone

efficiency. To make the cooking-energy efficiency test repeatable, the cold zone must be at the same temperature when beginning each test. This is accomplished with minimal time and effort through manual stirring followed by conducting one 6-load cold-zone-stabilization procedure.

10.8.3 All test loads shall be cooked in preconditioned fry baskets held at room temperature (75 ± 10°F (24 ± 3°C)) prior to being loaded with frozen french fries. The fry baskets shall be clean and free of moisture so that they do not contaminate the frying medium. The baskets shall remain at room temperature throughout the cold-zone stabilization, cooking time determination, cooking energy efficiency, and production capacity tests.

10.8.4 Remove the french fries from the freezer and place directly in the fry baskets. The time from the fries being removed from the freezer until they are lowered into the oil shall not be longer than 30 s. When transferring the fries from the freezer, handle the fries as little as possible. Once the fries are loaded into the baskets, gently shake each basket so that the fries are distributed evenly within the fry basket. Follow this procedure for the cold-zone stabilization tests, cooking time determination tests, cooking-energy efficiency tests, and production capacity tests.

NOTE 11—The 30-s period for the fries to be removed from the freezer (at −5 ± 5°F (−20 ± 3°C)) and loaded into the fryer is specified to keep the fries from warming to a temperature of no less than −5°F (−20°C) and no greater than +5°F (−15°C). This ensures that all fries are dropped into the oil at approximately the same temperature (0 ± 5°F (−17 ± 3°C)).

10.8.5 After stirring, allow the cold zone to statically stabilize for 3 min ± 30 s. A sequential six-load stir-up test shall be run immediately to further stabilize the cold-zone temperature. This six-load test shall be a heavy-load test. The cook time shall be estimated for this first six-load, cold-zone stabilization test, but the following sequence shall be followed:

10.8.5.1 After burner(s) or element(s) cycle off, drop the first two baskets of fries into the fryer. Commence monitoring the elapsed time of the cold-zone stabilization test when the first baskets contact the frying-medium.

10.8.5.2 Cook the fries for the estimated cook time.

10.8.5.3 Thirty seconds before removing the first load, take the next load out of the freezer and place in baskets ready for cooking.

10.8.5.4 Remove cooked fries to drip station and drain for 2 min.

10.8.5.5 Set the next load of fries into fryer precisely 10 s after removing the previous load from the fryer or after the cook-zone thermocouple indicates that the oil temperature has reached 340°F (171°C), whichever is longer. Repeat 10.8.5.2-10.8.5.5 until all six loads are cooked.

NOTE 12—The 10 s allowed between loads is a preparation time necessary for logistic considerations of running a test (that is, removing one load and placing the next load into the fryer). The actual recovery time may be less than the 10-s preparation time.

NOTE 13—The 2-min drip period must not occur with the fry baskets over the frying medium. Use a drip station or appropriate pan placed beneath the baskets.

10.9 *Cooking-Time Determination*:

NOTE 14—For precision and logistics, two people are required to perform the cooking-time determination (see 10.9) and the cooking-energy efficiency tests (see 10.10).

10.9.1 Ten ± 1 min after completing the cold-zone stabilization test, begin the initial cook-time determinations. Estimate a cook time for the first heavy-, medium-, and light-load tests. A separate cook time determination shall be done for each loading scenario. Do not assume the same cook time for heavy, medium, and light loads.

10.9.2 Undertake a six-load test for the heavy-, medium-,and light-load scenarios in the sequence described in 10.8.5. No more than a 10 ± 1 min interval shall elapse between each six-load cooking time determination test. The weight loss shall be an average of the last five loads of each six-load test.

10.9.3 If the average weight loss over the last five loads of the six-load test is not 30 ± 1 %, adjust the cook time and repeat the cooking time determination test (all six loads) as necessary, to produce an average 30 ± 1 % weight loss for the five-load average.

NOTE 15—The specified times between each six-load test (10 ± 1 min) are important to maintain the cold zone at its "stabilized" temperature. A stabilized cold zone will reduce the variation in cook times, which ultimately yields a more precise cooking-energy efficiency determination. To keep the cold zone "stabilized" allow no more than 10 ± 1 min to elapse between six-load tests.

10.9.4 Use the cooking times established for heavy-, medium-, and light-load conditions for the cooking energy efficiency determination and production capacity tests (10.10).

10.10 *Cooking-Energy Efficiency and Production Capacity for Heavy-, Medium-, and Light-Load Fry Tests*:

10.10.1 The cooking energy efficiency and production capacity tests are to be run a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (see Annex A1). The minimum three test runs for each loading scenario shall be run on the same day.

10.10.2 Prepare the required quantity of french fries making up three replicates of a heavy-, medium-, and light-load test as described in 10.7.4.

10.10.3 Prepare the required quantity of fries for the six load cold-zone stabilization test (twelve 1½-lb (680-g) bags) as described in 10.7.4.

10.10.4 Prepare an additional ½ lb (225 g) of frozen fries and store in freezer in a glass canning jar (to prevent moisture migration). Reserve these fries for analysis of moisture content.

10.10.5 Load the fryer to the indicated 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 "idle" for 30 min after being turned on.

10.10.6 Use a total of twelve fry baskets to cook the six loads of fries (also required for the cook-time determination tests). 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.

10.10.7 If the cooking-energy efficiency test is done immediately following the cooking-time determination test, no more than 10 ± 1 min shall elapse between the end (the removal of the last basket) of the cooking-time determination test and the beginning of the cooking-energy efficiency test. If the cooking-energy efficiency test is not done immediately following the cooking-time determination test, then the manual stir of the cold zone and a six-load cold-zone stabilization test must be repeated prior to beginning the cooking energy efficiency test. The manual cold zone stir-up and the cold-zone stabilization test shall be done in accordance with 10.8. Also, no more than 10 ± 1 min must elapse between the removal of the last basket of the six-load stir-up test and the start of the cooking-energy efficiency test.

10.10.8 Cook the fries for the time required to produce a 30 ± 1 % weight loss, determined by averaging the last five loads of each six-load test (10.9). The weight loss for each load is determined after the cooked fries have drained for 2 min following removal from the frying medium.

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

10.10.9.1 After the burner(s) or element(s) cycle off, drop the first load into the fryer. The first load of each six-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 second load contacts the frying medium (the first load may be manually timed).

10.10.9.2 Cook the load of fries for the determined cook time.

10.10.9.3 Thirty seconds before removing the cooking load, take the next load out of the freezer and place in basket(s) conditioned to room temperature ready for cooking (see 10.8.4).

10.10.9.4 Remove cooked fries to drip station and drain for 2 min.

10.10.9.5 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 10.10.9.2-10.10.9.5 until all six loads have been cooked (Fig. 4).

10.10.10 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 each six-load test.

10.10.11 Reserve ¼ lb (110 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 glass canning jar and place the jar in the freezer.

10.10.12 The three loading scenarios shall be run in the following order: three replicates of the heavy load, three replicates of the medium load, and three replicates of the light load. A 10 ± 1 min interval shall elapse between each test scenario. The overall order of the tests shall be as follows:

10.10.12.1 Perform manual stir and six-load cold-zone stabilization as specified in 10.8.

10.10.12.2 10 ± 1-min interval wait period,

10.10.12.3 Cook the first replicate of the heavy-load test as specified in 10.10.8-10.10.11,

10.10.12.4 10 ± 1-min interval wait period,

10.10.12.5 Cook the second replicate of the heavy-load test,

10.10.12.6 10 ± 1-min interval wait period,

10.10.12.7 Cook the third replicate of the heavy-load test.

10.10.13 Replicate each french fry cooking test (three replicates of the heavy-, medium-, and light-load tests) using the order detailed above, allowing not more than a 10 ± 1 min interval to elapse between replications. The reported cooking energy efficiency and production capacity for each loading scenario shall be an average of at least three tests (see Annex A1).

10.10.14 If it is not possible to replicate the heavy-, medium-, and light-load cooking-energy efficiency tests in the manner described in 10.10, a break may occur in the testing at the end of any test as long as the cold zone is restabilized before continuing with the cooking-energy efficiency tests. The restabilization of the cold zone shall be in accordance with all procedures in 10.8. See Fig. 5 for a flowchart of the fry test procedure.

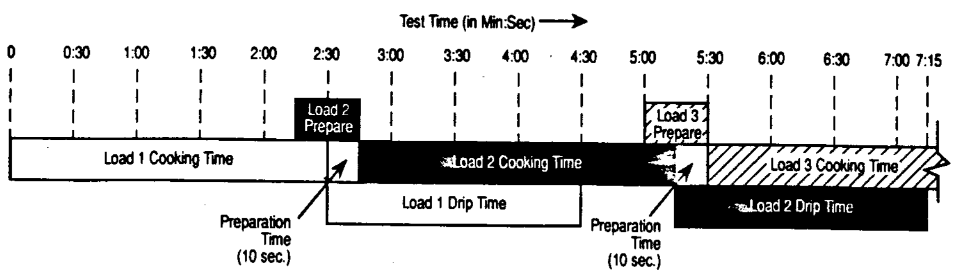


FIG. 4 Sequence of Stir-Up Cook Test (Not to Scale)

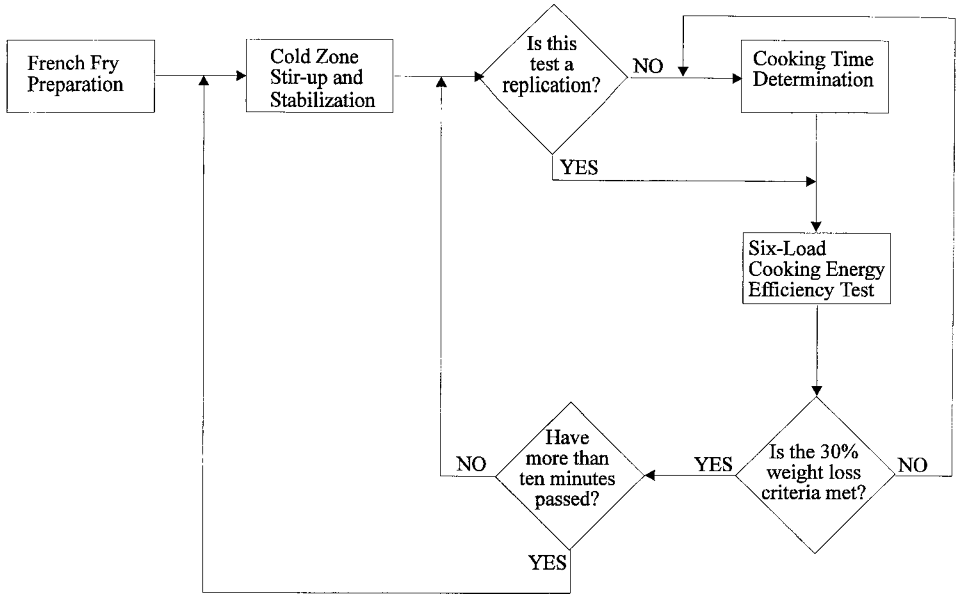


FIG. 5 Fry Test Flowchart

10.10.15 Determine moisture content in accordance with recognized procedures (for example, Official Methods of Analysis of the Association of Official Analytical Chemists[3], or the procedure 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).

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.

11.2 *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:

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

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

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

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

P_{cf} = pressure correction factor

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

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

NOTE 16—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 Method D 3588 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:

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

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:

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

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 17—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-, medium-, and light-load cooking tests based on:

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

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-, medium-, and light-load cooking tests based on:

$$q_{per\ pound} = \frac{E}{W} \quad (6)$$

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-, medium-, and light-load cooking tests based on:

$$\eta_{cook} = \frac{E_{food}}{E_{fryer}} \times 100 \quad (7)$$

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 18—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 19—Research conducted by PG&E[7] 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,

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

$= W_{loss} \times H_v$

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:

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

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 medium- and light-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-, medium-, and light-load tests. Also report the cook time for the heavy-, medium-, and light-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:*

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:

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

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

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:

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

where:

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

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

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

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

A1.4.2.1 The formula for the absolute uncertainty (3 test runs) is as follows:

$$U_3 = C_3 \times S_3, \quad \text{(A1.3)}$$
$$U_3 = 2.48 \times S_3$$

where:

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

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

A1.4.3.1 The formula for the percent uncertainty (3 test runs) is as follows:

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

where:

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

A1.4.4 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 = $(¼) \times (X_1 + X_2 + X_3 + X_4)^2$.

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 = 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:

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

where:

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

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

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

where:

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

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

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

where:

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

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

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

where:

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

When the percent uncertainty, % U_n, is less than or equal to ±10 % for the cooking energy 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 A1.5—The researcher may compute a test result that deviates significantly from the other test results. Such a result should be discarded only if there is some physical evidence that the test run was not performed according to the conditions specified in this method. For example, a thermocouple was out of calibration, the appliance's input capacity was not within 5 % of the rated input, or the food product was not within specification. To ensure that all results are obtained under approximately the same conditions, it is good practice to monitor those test conditions specified in this test method.

A1.5 *Example of Determining Uncertainty in Average Test Result:*

A1.5.1 Three test runs for the full-load cooking scenario yielded the following production capacity (PC) results:

Test	PC, lb/h (kg/h)
Run #1	33.8 (15.3)
Run #2	34.1 (15.5)
Run #3	31.0 (14.1)

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

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

$$Xa_3 = \left(\frac{1}{3}\right) \times (X_1 + X_2 + X_3), \quad (A1.13)$$

$$Xa_3 = \left(\frac{1}{3}\right) \times (33.8 + 34.1 + 31.0), \text{and}$$

$$Xa_3 = 33.0 \text{ lb/h (15 kg/h)}$$

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

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

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

$$A_3 = 3266,$$

$$B_3 = \left(\frac{1}{3}\right) \times [(X_1 + X_2 + X_3)^2],$$

$$B_3 = \left(\frac{1}{3}\right) \times [(33.8 + 34.1 + 31.0)^2], \text{ and}$$

$$B_3 = 3260.$$

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

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

$$S_3 = 1.71 \text{ lb/h (0.77 kg/h)}$$

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

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

$$U_3 = 2.48 \times 1.71, \text{ and}$$

$$U_3 = 4.24 \text{ lb/h. (1.92 kg/h)}$$

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

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

$$\%\ U_3 = (4.24/33.0) \times 100\ \%, \text{ and}$$

$$\%\ U_3 = 12.9\ \%.$$

A1.5.5 *Step 4*—Run a fourth test. Since the percent uncertainty for the production capacity is greater than ±10 %, the precision requirement has not been satisfied. An additional test is run in an attempt to reduce the uncertainty. The PC from the fourth test run was 32.5 lb/h (14.7 kg/h).

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

A1.5.6.1 The new average PC is as follows:

$$Xa_4 = \left(\frac{1}{4}\right) \times (X_1 + X_2 + X_3 + X_4), \quad (A1.18)$$

$$Xa_4 = \left(\frac{1}{4}\right) \times (33.8 + 34.1 + 31.0 + 32.5), \text{ and}$$

$$Xa_4 = 32.9 \text{ lb/h (14.9 kg/h)}.$$

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

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

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

$$A_4 = 4323,$$

$$B_4 = \left(\frac{1}{4}\right) \times [(X_1 + X_2 + X_3 + X_4)^2],$$

$$B_4 = \left(\frac{1}{4}\right) \times [(33.8 + 34.1 + 31.0 + 32.5)^2], \text{ and}$$

$$B_4 = 4316.$$

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

$$S_4 = (1/\sqrt{3}) \times \sqrt{(4323 - 4316)}, \quad (A1.20)$$

$$S_4 = 1.42 \text{ lb/h (0.64 kg/h)}.$$

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

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

$$U_4 = 1.59 \times 1.42, \text{ and}$$

$$U_4 = 2.25 \text{lb/h } (1.02 \text{ kg/h}).$$

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

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

$$\% U_4 = (2.25/32.9) \times 100 \%, \text{ and}$$

$$\% U_4 = 6.8 \%.$$

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

$$PC = 32.9 \pm 2.25 \text{ lb/h } (14.9 \pm 1.02 \text{ kg/h}) \quad \text{(A1.23)}$$

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

A2. PROCEDURE FOR DETERMINING THE MOISTURE CONTENT OF FOOD PRODUCTS USING GRAVIMETRIC WEIGHT LOSS

INTRODUCTION

Moisture content of food products can have a significant effect on the amount of energy required for cooking. It was imperative for researchers to be able to quickly and accurately determine whether a food product was within specifications before commencing testing. Moisture contents are also used in energy-to-food calculations. The moisture content of raw and cooked food can be determined using an air drying method and determining the gravimetric weight loss.

A2.1 Scope

A2.1.1 The test procedure in this annex determines the moisture content of raw and cooked food products using gravimetric weight loss on air drying.

A2.2 Referenced Documents

A2.2.1 *AOAC Document*[4]:

AOAC Official Action 984.25 Moisture (Loss of Mass on Drying) in Frozen French Fried Potatoes

A2.3 Apparatus

A2.3.1 *Convection Drying Oven*, with temperature controlled at 215 to 220°F, used to determine moisture content of both the raw and cooked food product.

A2.4 Reagents and Materials

A2.4.1 *Half-Size Aluminum Sheet Pans*, measuring 9 by 13 by 1 in. for holding the sample food product.

A2.5 Procedure

NOTE A2.1—This procedure has been adapted from AOAC Official Action 984.25. A larger sample is used to reduce the uncertainty in the results.

A2.5.1 Weight and record the weight of a dry, lined half-size sheet pan.

A2.5.2 Place the food sample onto the sheet pan. Weigh and record the weight of the sample.

NOTE A2.2—To obtain an accurate determination of the moisture content in the test food product, a representative sample of the food product (for example, ½ lb or more) must be used for air drying.

A2.5.3 Thoroughly chop, grind, or otherwise break apart the food sample into ⅛-in. or smaller cubes. Evenly spread the sample over the area of the pan.

A2.5.4 Place into a preheated convection drying oven set at 220 ± 5°F for a period of 18 h.

A2.5.5 After 18 h have elapsed, weigh and record the weight of the dried sample.

A2.5.6 Return the sample to the oven and dry for an additional 2 h.

A2.5.7 Weigh and record the weight of the sample.

A2.5.8 Compare this weight to the previously recorded weight of the dried sample. Repeat A2.5.6 and A2.5.7 until the difference between successive weighings does not exceed 0.01 lb.

A2.6 Calculation

A2.6.1 Calculate the moisture content of the sample food product based on the following:

$$M = \frac{(W_i - W_f)}{W_i} \times 100 \quad \text{(A2.1)}$$

where:

M_f = moisture content (by weight) of the sample food product, %,
W_i = initial weight of the food sample, lb, and
W_f = final dried weight of the food sample, lb.

APPENDIXES

(Nonmandatory Information)

X1. PROCEDURE FOR DETERMINING THE WATER-BOIL EFFICIENCY

INTRODUCTION

The following procedure evaluates the fryer efficiency when boiling water. Experience indicates that the water-boil test is a customary and valuable tool for product development. The water-boil test may be used as a quick indicator of improvement in heat exchanger design or other features. Accordingly, it is referenced as an appendix to this test method as a research and development tool.

The water-boil test does not replicate or represent the efficiency of fryers when cooking for the following technical reasons:

(*1*) The physical properties of water and typical frying media (cooking oil, shortening, etc.) are different.

(*2*) Water boils at 212°F (100°C), while the frying medium during cooking tests is at 350°F (177°C). Accordingly, radiant and convective heat losses from the fryer are greater and heat transfer from the heat source to the frying medium is less efficient during cooking tests.

(*3*) Control features, such as cycling, modulation, "soft landing," or built-in" cooking curves" are effectively bypassed during water-boil tests.

(*4*) Fryer design features, such as the shape of the cold zone, or tubes versus "open" frypot design, may impede convective heat transfer more when boiling water than when heating frying medium.

Accordingly, the water-boil test may be used as a research and development tool, but shall not be used to imply energy efficiencies during actual cooking operations.

X1.1 Scope

X1.1.1 The test procedure in this appendix determines the efficiency of the fryer when boiling water at its rated energy input rate.

X1.2 Terminology

X1.2.1 *water-boil efficiency, n*—quantity of energy (latent heat of vaporization) required to boil water from the fryer, expressed as a percentage of the quantity of energy input to the fryer during the boil-off period.

X1.3 Summary of Test Method

X1.3.1 The fryer is placed on a platform scale and operated with a known weight of water contained in the fryer and the thermostat(s) set to the maximum setting. After a specified amount of water has boiled off the water-boil efficiency is calculated.

X1.4 Significance and Use

X1.4.1 The water-boil test may be used as a quick indicator of improvement in heat exchanger or other design features.

X1.5 Apparatus

X1.5.1 *Platform Balance Scale*, or appropriate load cells, used to measure the loss of water from the fryer during water boil test. Shall have capacity to accommodate the total weight of the fryer plus 70 lb (30 kg) of water per square foot of cooking surface with a resolution of 0.2 lb (10 g) and an uncertainty of 0.2 lb.

X1.6 Reagents and Materials

X1.6.1 Water used shall have a maximum hardness of three grains per gallon. Distilled water may be used.

X1.7 Preparation of Apparatus

X1.7.1 Install the appliance under a canopy exhaust hood in accordance with 9.1-9.5.

X1.7.2 Place the fryer on a platform balance scale, or load cells, located under the exhaust ventilation hood described in X1.7.1. The scale, or load cells, shall not reduce the distance between the cooking surface and the lower edge of the exhaust hood by more than 8 in. (200 mm).

X1.8 Procedure

X1.8.1 The water-boil efficiency test is to be run a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (see Annex A1). The minimum three test runs shall be run on the same day within the shortest time possible.

X1.8.2 Tare the fryer on a balance scale or load cell(s) with a precision of 0.1 lb (50 g) calibrated to an accuracy of ±0.5 %, taking care that gas hoses or wires do not interfere with any weight readings.

X1.8.3 Fill the fryer with water to a level which covers any heat transfer surface or electric elements by at least 1.0 in. (25 mm). Note this weight. Continue filling the fryer to the fill line and note this weight. Add an additional 5 lb (2.3 kg) of water to the fryer.

X1.8.4 Set the thermostat(s) on the fryer at the maximum setting so that the burner(s) or element(s) will operate continuously. Bring the water to a boil. Proceed to boil off the 5 lb (2.3 kg) of water that was added above the fill line. When the weight of the boiling water in the fryer equals the weight recorded at the fill line, simultaneously begin recording the time, weight loss of water, and energy consumption.

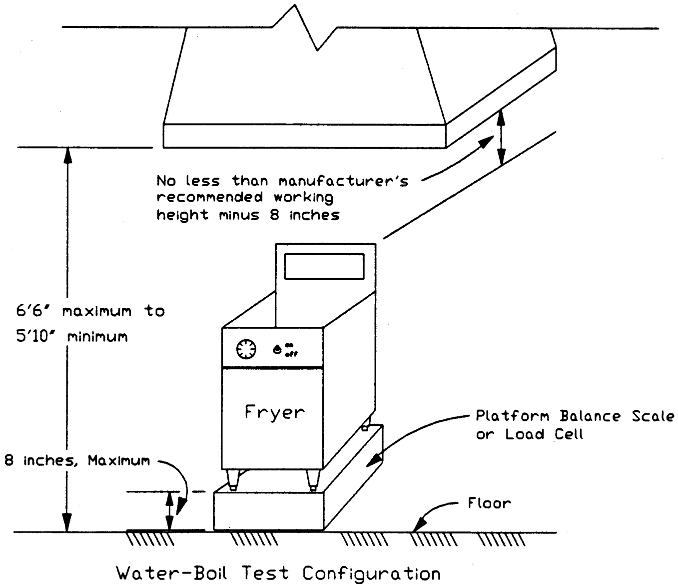


FIG. X1.1 Water-Boil Test Configuration

X1.8.5 Continue boiling until the weight of the water remaining in the fryer equals the weight of water that covered the heat transfer surface or electric elements by 1.0 in. (25 mm). Note the final time, weight, and energy consumed. Record the barometric pressure during the test (to be used to determine the applicable heat of vaporization from the *1989 ASHRAE Handbook of Fundamentals*.[5]) Also measure and record all electric energy consumed by gas fryers during the test.

X1.9 Calculation and Report

NOTE X1.1—The reported water-boil efficiency parameters are the average values from the three test replicates.

X1.9.1 Calculate and report the water-boil efficiency (%) based on:

$$\eta_{water\ boil} = \frac{E_{water}}{E_{appliance}} \times 100 \quad \text{(X1.1)}$$

where:

$\eta_{water\ boil}$ = water-boil efficiency, %
E_{water} = energy into water, Btu (kJ)
= $(W_i - W_f) \times E_{vap}$

where:

W_i = initial weight of water, lb (kg),
W_f = final weight of water, lb (kg), and
E_{vap} = heat of vaporization of water at test conditions, Btu/lb (kJ/kg).

NOTE X1.2—E_{vap} = 970 Btu/lb (2256 kJ/kg) at 14.73 psia (101.5 kPa).

E_{fryer} = energy into the fryer, Btu (kJ).

X1.9.2 Report ambient temperature and barometric pressure measured during the test.

X2. RESULTS REPORTING SHEETS

Manufacturer ______________________________
Model ______________________________
Date ______________________________
Test Reference Number (optional) ______________________________

Section 11.1 Test Fryer

Description of operational characteristics: ______________________________
____
____
____
____
____
____

Section 11.2 Apparatus

____Check if testing apparatus conformed to specifications in Section 6.
Deviations ______________________________
____
____
____
____

Section 11.3 Energy Input Rate

Test Voltage (V) ______________
Gas Heating Value (Btu/ft³(kJ/m³)) ______________
Measured (Btu/h (kJ/h) or kW) ______________
Rated (Btu/h (kJ/h) or kW) ______________
Percent Difference between Measured and Rated (%) ______________

Section 11.5 Thermostat Calibration

Average Cook Zone Temperature (°F (°C)) ______________
Dial Setting (°F (°C)) ______________

Section 11.6 Preheat Energy and Time

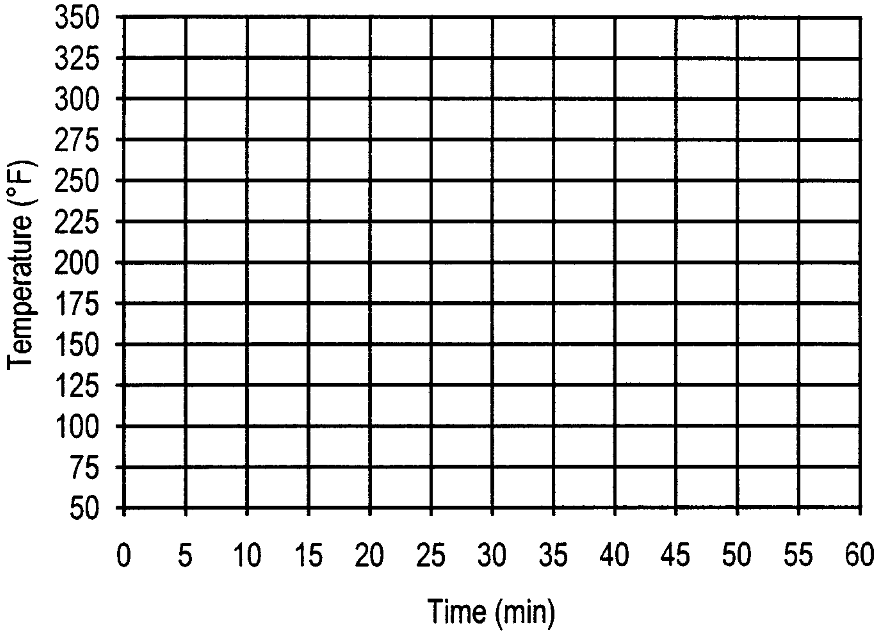
Test Voltage (V) ________

Gas Heating Value (Btu/ft^3(kJ/m^3)) ________

Energy Consumption (Btu (kJ) or kWh) ________

Time from ________°F (°C) to 350°F (177°C) (min) ________

Preheat Rate (°F/min (°C/min)) ________



Preheat Curve

Section 11.7 Idle Energy Rate

Test Voltage (V) ________

Gas Heating Value (Btu/ft^3(kJ/m^3)) ________

Idle Energy Rate (Btu/h (kJ/h) or kW) ________

Electric Energy Rate (kW, gas fryers only) ________

Section 11.8 Pilot Energy Rate (if applicable)

Gas Heating Value (Btu/ft^3(kJ/m^3)) ________

Pilot Energy Rate (Btu/h (kJ/h) or kW) ________

Section 11.9 Cooking Enery Efficiency and Cooking Energy Rate

Heavy Load:

Test Voltage (V) ________

Gas Heating Value (Btu/ft^3(kJ/m^3)) ________

Cooking Time (min) ________

Average Cook Zone Recovery Time (s) ________

Production Capacity (lb/h (kJ/h)) ________

Energy to Food (Btu/lh (kJ/kg)) ________

Cooking Energy Rate (Btu/h (kJ/h) or kW) ________

Electric Energy Rate (kW, gas fryers only) ________

Energy per Pound of Food Cooked (Btu/lb (kJ/kg) or kWh/lb (kWh/kg)) ________

Cooking Energy Efficiency (%) ________

Medium Load:

Test Voltage (V) ________

Gas Heating Value (Btu/ft^3(kJ/m^3)) ________

Cooking Time (min) ________

Average Cook Zone Recovery Time (s) ________

Production Capacity (lb/h (kg/h)) ________

Energy to Food (Btu/lb (kJ/kg)) ________

Cooking Energy Rate (Btu/h (kJ/h) or kW) ________

Electric Energy Rate (kW, gas fryers only) ________

Energy per Pound of Food Cooked (Btu/lb (kJ/kg) or kWh/lb (kWh/kg)) ________

Cooking Energy Efficiency (%) ________

Light Load:

Test Voltage (V) ________

Gas Heating Value (Btu/ft^3(kJ/m^3)) ________

Cooking Time (min) ________

Average Cook Zone Recovery Time (s) ________

Production Capacity (lb/h (kg/h)) ________

Energy to Food (Btu/lb (kJ/h) or kW) ________

Cooking Energy Rate (Btu/h (kJ/h) or kW) ________

Electric Energy Rate (kW, gas fryers only) ________

Energy per Pound of Food Cooked (Btu/lb (kJ/kg) or kWh/lb (kWh/kg)) ______________________________
Cooking Energy Efficiency (%) ______________________________

X3. PROCEDURE FOR CALCULATING THE DAILY ENERGY CONSUMPTION OF AN OPEN DEEP FAT FRYER 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 fryer 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 fryer 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, medium, and light loads).

X3.3 The appropriate fryer performance parameters are obtained from Section 11 in this test method.

X3.4 Procedure

NOTE X3.1—Sections X3.5 and X3.6 show how to apply this 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 between heavy (two 1½–lb baskets), medium (one 1½–lb basket, and light (one ¾–lb basket) loads. For example, a fryer operating for 12 h a day with one preheat cooked 100 lb of food: 36 % of the food was cooked under heavy-load conditions, 48 % was cooked under medium-load conditions, and 16 % was cooked under light-load conditions. Calculate the energy due to cooking at heavy-, medium-, and light-load cooking rates, and then calculate the idle energy consumption. 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.

X3.4.2 *Step 1*—Determine the fryer operating time, number of preheats, and amount of food cooked under heavy- (two 1½-lb baskets) medium- (one 1½-lb basket), and light- (one ¾-lb basket) load conditions.

X3.4.3 *Step 2*—Calculate the time and energy involved in cooking heavy (3-lb) loads. Heavy loads are the equivalent of cooking two standard (1½-lb) baskets of fries at the same time.

X3.4.3.1 Determine the total time cooking heavy loads as follows:

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

where:

t_h = total time cooking heavy loads, h,
$\%h$ = percentage of food cooked under heavy-load conditions during the day,
W = total weight of food cooked per day, lb, and
PC = fryer's production capacity as determined in 11.9.4, lb/h.

X3.4.3.2 Calculate the heavy-load energy consumption using the following set of equations. For gas fryers, determine seperately any electric energy using the electric equations.

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

where:

$E_{gas,h}$ = total gas heavy-load energy consumption, Btu,
$q_{gas,h}$ = gas heavy-load cooking energy rate as determined in 11.9.1, 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 11.9.1, kW.

X3.4.4 *Step 3*—Calculate the time and energy involved in cooking medium (1½-lb) loads. Medium loads are the equivalent of cooking one standard basket of fries.

X3.4.4.1 Determine the total time cooking medium-loads as follows:

$$t_m = \frac{\%m \times W}{PRm} \quad \text{(X3.3)}$$

where:

t_m = total time cooking medium loads, h,
$\%m$ = percentage of food cooked under medium-load conditions during the day,
W = total weight of food cooked per day, lb, and
PR_m = fryer's medium-load production rate as determined in 11.9.5, lb/h.

X3.4.4.2 Calculate the medium-load energy consumption using the following set of equations. For gas fryers, determine seperately any electric energy using the electric equations.

$$E_{gas,m} = q_{gas,m} \times t_m \quad \text{(X3.4)}$$
$$E_{elec,m} = q_{elec,m} \times t_m$$

where:

$E_{gas,m}$ = total gas medium-load energy consumption, Btu,
$q_{gas,m}$ = gas medium-load cooking energy rate as determined in 11.9.1, Btu/h,
$E_{elec,m}$ = total electric medium-load energy consumption, kWh, and
$q_{elec,m}$ = electric medium-load cooking energy rate as determined in 11.9.1, kW.

X3.4.5 *Step 4*—Calculate the time and energy involved in cooking light (¾-lb) loads. Light loads are the equivalent of cooking one half of a standard basket of fries.

X3.4.5.1 Determine the total time cooking light-loads as follows:

$$t_l = \frac{\%_l \times W}{PR_l} \quad (X3.5)$$

where:

t_l = total time cooking light loads, h,
$\%l$ = percentage of food cooked under light-load conditions during the day,
W = total weight of food cooked per day, lb, and
PR_l = fryer's light-load production rate as determined in 11.9.5, lb/h.

X3.4.5.2 Calculate the light-load energy consumption using the following set of equations. For gas fyrers, determine separately any electric energy using the electric equations.

$$E_{gas,1} = q_{gas,1} \times t_l \quad (X3.6)$$
$$E_{elec,l} = q_{elec,l} \times t_l$$

where:

$E_{gas,1}$ = total gas light-load energy consumption, Btu,
$q_{gas,1}$ = gas light-load cooking energy rate as determined in 11.9.1, Btu/h,
$E_{elec,l}$ = total electric light-load energy consumption, kWh, and
$q_{elec,l}$ = electric light-load cooking energy rate as determined in 11.9.1, kW.

X3.4.6 *Step 5*—Calculate the total idle time and energy consumption.

X3.4.6.1 Determine the total idle time as follows:

$$t_i = t_{on} - t_h - t_m - t_l - \frac{n_p \times t_p}{60} \quad (X3.7)$$

where:

t_i = total idle time, h,
t_{on} = total daily on-time, h,
n_p = number of preheats, and
t_p = preheat time, as determined in 11.6.1, min.

X3.4.6.2 Calculate the idle energy consumption using the following set of equations. For gas fryers, determine separately any electric energy using the electric equations.

$$E_{gas,i} = q_{gas,i} \times t_i \quad (X3.8)$$
$$E_{elec,i} = q_{elec,i} \times t_i$$

where:

$E_{gas,i}$ = total gas idle energy consumption, Btu,
$q_{gas,i}$ = gas idle energy rate as determined in 11.7.1, Btu/h,
$E_{elec,i}$ = total electric idle energy consumption, kWh, and
$q_{elec,i}$ = electric idle energy rate as determined in 11.7.1, kW.

X3.4.7 *Step 6*—Calculate the total daily energy consumption as follows:

$$E_{gas,daily} = E_{gas,h} + E_{gas,m} + E_{gas,l} + E_{gas,i} + n_p \times E_{gas,p} \quad (X3.9)$$
$$E_{elec,daily} = E_{elec,h} + E_{elec,m} + E_{lec,l} + E_{elec,i} + n_p \times E_{elec,p}$$

where:

$E_{gas,daily}$ = total daily gas energy consumption, Btu,
n_p = total number of preheats per day,
$E_{gas,p}$ = gas preheat energy consumption as determined in 11.6.1, Btu,
$E_{elec,daily}$ = total daily electric energy consumption, Btu, and
$E_{elec,p}$ = electric preheat energy consumption as determined in 11.6.1, Btu.

X3.4.8 *Step 7*—Calculate the average electric demand for fryers in accordance with the following equation:

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

NOTE X3.2—It has been assumed that the appliance's contribution to the building's probable 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.

where:

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

X3.5 *Example of Calculating the Daily Energy Consumption for an Electric Fryer*:

X3.5.1 Application of the test method to an electric fryer yielded the results in Table X3.1.

X3.5.2 *Step 1*—The operation being modeled has the parameters in Table X3.2.

X3.5.3 *Step 2*—Calculate the total heavy-load energy.

X3.5.3.1 The total time cooking heavy-loads is as follows:

$$t_h = \frac{\%_h \times W}{PC} \quad (X3.11)$$

$$t_h = \frac{36\ \% \times 100\ \text{lb}}{60\ \text{lb/h}}$$

$$t_h = 0.60\ \text{h}$$

X3.5.3.2 Then calculate the total heavy-load energy consumption as follows:

$$E_{elec,h} = q_{elec,h} \times t_h \quad (X3.12)$$
$$E_{elec,h} = 13.5\ \text{kW} \times 0.60\ \text{h}$$
$$E_{elec,h} = 8.1\ \text{kWh}$$

X3.5.4 *Step 3*—Calculate the total medium-load energy.

X3.5.4.1 The total time cooking medium-loads is as follows:

$$t_m = \frac{\%_m \times W}{PR_m} \quad (X3.13)$$

TABLE X3.1 Electric Fryers Performance Parameters

Test	Result
Preheat time	10.0 min
Preheat energy	1.8 kWh
Idle energy rate	1.0 kW
Heavy-load cooking energy rate	13.5 kW
Medium-load cooking energy rate	7.9 kW
Light-load cooking energy rate	4.8 kW
Production capacity	60 lb/h
Medium-load production rate	33 lb/h
Light-load production rate	18 lb/h

TABLE X3.2 Fryers 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	36 % (× 100 lb = 36 lb)
Percentage of food cooked under medium-load conditions	48 % (× 100 lb = 48 lb)
Percentage of food cooked under light-load conditions	16 % (× 100 lb = 16 lb)

$$t_m = \frac{48\ \% \times 100\ \text{lb}}{33\ \text{lb/h}}$$

$$t_m = 1.45\ \text{h}$$

X3.5.4.1.1 Then calculate the total medium-load energy consumption as follows:

$$E_{elec,m} = q_{elec,m} \times t_m \quad \text{(X3.14)}$$

$$E_{elec,m} = 7.9\ \text{kW} \times 1.45\ \text{h}$$

$$E_{elec,m} = 11.5\ \text{kWh}$$

X3.5.5 *Step 4*—Calculate the total light-load energy.

X3.5.5.1 The total time cooking light-loads is as follows:

$$t_l = \frac{\%_l \times W}{PR_l} \quad \text{(X3.15)}$$

$$t_l = \frac{16\ \% \times 100\ \text{lb}}{18\ \text{lb/h}}$$

$$t_l = 0.89\ \text{h}$$

X3.5.5.2 Then, calculate the total light-load energy consumption as follows:

$$E_{elec,l} = q_{elec,l} \times t_l \quad \text{(X3.16)}$$

$$E_{elec,1} = 4.8\ \text{kW} \times 0.89\ \text{h}$$

$$E_{elec,l} = 4.3\ \text{kWh}$$

X3.5.6 *Step 5*—Calculate the total idle time and energy consumption.

X3.5.6.1 Determine the total idle time as follows:

$$t_i = t_{on} - t_h - t_m - t_l - \frac{n_p \times t_p}{60} \quad \text{(X3.17)}$$

$$t_i = 12.0\ \text{h} - 0.60\ \text{h} - 1.45\ \text{h} - 0.89\ \text{h} - \frac{1\ \text{preheat} \times 10.0\ \text{min}}{60\ \text{min / h}}$$

$$t_i = 8.89\ \text{h}$$

X3.5.6.2 Then calculate the idle energy consumption as follows:

$$E_{elec,i} = q_{elec,i} \times t_i \quad \text{(X3.18)}$$

$$E_{elec,i} = 1.0\ \text{kW} \times 8.89\ \text{h}$$

$$E_{elec,i} = 8.9\ \text{kWh}$$

X3.5.7 *Step 6*—Calculate the total daily energy consumption as follows:

$$E_{elec,daily} = E_{elec,h} + E_{elec,m} + E_{elec,l} + E_{elec,i} + n_p \times E_{elec,p} \quad \text{(X3.19)}$$

$$E_{elec,daily} = 8.1\ \text{kWh} + 11.5\ \text{kWh} + 4.3\ \text{kWh} + 8.9\ \text{kWh} + 1 \times 1.8\ \text{kWh}$$

$$E_{elec,daily} = 34.6\ \text{kWh/day}$$

X3.5.8 *Step 7*—Calculate the average demand as follows:

$$q_{avg} = \frac{E_{elec,\ daily}}{t_{on}} \quad \text{(X3.20)}$$

$$q_{avg} = \frac{34.6\ \text{kWh}}{12.0\ \text{h}}$$

$$q_{avg} = 2.88\ \text{kW}$$

X3.6 *Example of Calculating the Daily Energy Consumption for a Gas Fryer*:

X3.6.1 Application of the test method to an electric fryer yielded the results in Table X3.3.

X3.6.2 *Step 1*—The operation being modeled has the parameters in Table X3.4.

X3.6.3 *Step 2*—Calculate the total heavy-load energy.

X3.6.3.1 The total time cooking heavy loads is as follows:

$$t_h = \frac{\%_h \times W}{PC} \quad \text{(X3.21)}$$

$$t_h = \frac{36\ \% \times 100\ \text{lb}}{50\ \text{lb / h}}$$

$$t_h = 0.72\ \text{h}$$

X3.6.3.2 Then, calculate the total heavy-load energy consumption as follows:

$$E_{gas,h} = q_{gas,h} \times t_h \quad \text{(X3.22)}$$

$$E_{gas,h} = 83\,000\ \text{Btu/h} \times 0.72\ \text{h}$$

$$E_{gas,h} = 59\,800\ \text{Btu}$$

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

$$E_{elec,h} = 75\ \text{W} \times 0.72\ \text{h}$$

$$E_{elec,h} = 54\ \text{Wh}$$

X3.6.4 *Step 3*—Calculate the total medium-load energy.

X3.6.4.1 The total time cooking medium-loads is as follows.

$$t_m = \frac{\%_m \times W}{PR_m} \quad \text{(X3.23)}$$

$$t_m = \frac{48\ \% \times 100\ \text{lb}}{28\ \text{lb / h}}$$

$$t_m = 1.71\ \text{h}$$

X3.6.4.2 Then, calculate the total medium-load energy consumption as follows:

$$E_{gas,m} = q_{gas,m} \times t_m \quad \text{(X3.24)}$$

$$E_{gas,m} = 52\,000\ \text{Btu/h} \times 1.71\ \text{h}$$

$$E_{gas,m} = 88\,900\ \text{Btu}$$

$$E_{elec,m} = q_{elec,m} \times t_m$$

$$E_{elec,m} = 50\ \text{W} \times 1.71\ \text{h}$$

$$E_{elec,m} = 86\ \text{Wh}$$

X3.6.5 *Step 4*—Calculate the total light-load energy.

TABLE X3.3 Gas Fryer Performance Parameters

Test	Result
Preheat time	14.0 min
Preheat energy	16 000 Btu + 10 Wh
Idle energy rate	12 000 Btu/h + 10 W
Heavy-load cooking energy rate	83 000 Btu/h + 75 W
Medium-load cooking energy rate	52 000 Btu/h + 50 W
Light-load cooking energy rate	32 000 Btu/h + 34 W
Production capacity	50 lb/h
Medium-load production rate	28 lb/h
Light-load production rate	14 lb/h

TABLE X3.4 Fryers 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	36 % (× 100 lb = 36 lb)
Percentage of food cooked under medium-load conditions	48 % (× 100 lb = 48 lb)
Percentage of food cooked under light-load conditions	16 % (× 100 lb = 16 lb)

X3.6.5.1 The total time cooking light loads is as follows:

$$t_l = \frac{\%_l \times W}{PR_l} \quad (X3.25)$$

$$t_l = \frac{16\ \% \times 100\ \text{lb}}{14\ \text{lb / h}}$$

$$t_l = 1.14\ \text{h}$$

X3.6.5.2 Then, calculate the total light-load energy consumption as follows:

$$E_{gas,l} + q_{gas,l} \times t_l \quad (X3.26)$$

$$E_{gas,l} = 32\,000\ \text{Btu/h} \times 1.14\ \text{h}$$

$$E_{gas,l} = 36\,500\ \text{Btu}$$

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

$$E_{elec,l} = 35\ \text{W} \times 1.14\ \text{h}$$

$$E_{elec,l} = 40\ \text{Wh}$$

X3.6.6 *Step 5*—Calculate the total idle time and energy consumption.

X3.6.6.1 The total idle time is determined as follows:

$$t_i = t_{on} - t_h - t_m - t_l - \frac{n_p \times t_p}{60} \quad (X3.27)$$

$$t_i = 12.0\ \text{h} - 0.72\ \text{h} - 1.71\ \text{h} - 1.14\ \text{h} - \frac{1\ \text{preheat} \times 14.0\ \text{min}}{60\ \text{min / h}}$$

$$t_i = 8.2\ \text{h}$$

X3.6.6.2 Then, calculate the idle energy consumption as follows:

$$E_{gas,i} = q_{gas,i} \times t_i \quad (X3.28)$$

$$E_{gas,i} = 12\,000\ \text{Btu/h} \times 8.2\ \text{h}$$

$$E_{gas,i} = 98\,400\ \text{Btu}$$

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

$$E_{elec,i} = 10\ \text{W} \times 8.2\ \text{h}$$

$$E_{elec,i} = 82\ \text{Wh}$$

X3.6.7 *Step 6*—Calculate the total daily energy consumption as follows:

$$E_{gas,daily} = E_{gas,h} + E_{gas,m} + E_{gas,l} + E_{gas,i} + n_p \times E_{gas,p} \quad (X3.29)$$

$$E_{gas,daily} = 59\,800\ \text{Btu} + 88\,900\ \text{Btu} + 36\,500\ \text{Btu} + 98\,400\ \text{Btu} + 1 \times 16\,000\ \text{Btu}$$

$$E_{gas,daily} = 299\,600\ \text{Btu/day} = 3.00\ \text{therms/day}$$

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

$$E_{elec,daily} = 54\ \text{Wh} + 86\ \text{Wh} + 40\ \text{Wh} + 82\ \text{Wh} + 1 \times 10\ \text{Wh}$$

$$E_{elec,daily} = 272\ \text{Wh/day}$$

X3.6.8 *Step 7*—Calculate the average demand as follows:

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}} \quad (X3.30)$$

$$q_{avg} = \frac{272\ \text{Wh}}{12.0\ \text{h}}$$

$$q_{avg} = 23\ \text{W}$$