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An American National Standard

Standard Test Method for Performance of Chinese (Wok) Ranges[1]

This standard is issued under the fixed designation F 1991; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method evaluates the energy consumption and performance of Chinese ranges. The food service operator can use this evaluation to select a Chinese range and understand its energy performance.

1.2 This test method is applicable to nonthermostatically-controlled, gas and electric Chinese ranges, including both discreet burners, elements, and induction units.

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

1.3.1 Energy input rate (10.2),

1.3.2 Pilot energy rate, if applicable (10.3), and

1.3.3 Heatup energy efficiency and production capacity (10.5).

1.4 The values stated in inch-pound units are to be regarded as standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*

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

2.2 *ANSI Standard:*

ANSI Z83.11 American National Standard for Gas Food Service Equipment[3]

2.3 *ASHRAE Standard:*

ASHRAE Guideline 2-1986 (RA90) Engineering Analysis of Experimental Data[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *Chinese range*, *n*—an appliance that cooks food by a direct or indirect heat transfer, which is powered by a single heat source comprised of either a gas burner or an electrical element or induction technology that is independently controlled. Used in conjunction with woks.

3.1.2 *energy input rate*, *n*—peak rate at which Chinese range consumes energy (Btu/h or kW).

3.1.3 *heatup energy*, *n*—energy consumed by the Chinese ranges as it is used to raise the temperature of water in a wok from 70 ± 2°F to 200 ± 2°F under full input rate.

3.1.4 *heatup energy efficiency*, *n*—quantity of energy imparted to the water, expressed as a percentage of energy consumed by the Chinese range during the heatup event.

3.1.5 *heatup energy rate*, *n*—average rate of energy consumption (Btu/h or kW) during the heatup energy efficiency tests.

3.1.6 *heatup time*, *n*—time required to raise the temperature of the water from 70 ± 2°F to 200 ± 2°F during a heatup energy efficiency test.

3.1.7 *pilot energy rate*, *n*—average rate of energy consumption (Btu/h) by a Chinese range's continuous pilot, if applicable.

3.1.8 *production capacity*, *n*—maximum rate (lb/h) at which the Chinese range heats water in accordance with the heatup energy-efficiency test.

3.1.9 *testing capacity*, *n*—the capacity (gal) at which the wok is operated during the heatup test, which is at the water level mark.

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

3.1.11 *water level mark*, *n*—a level of water, which is even (horizontal) with the top portion of the well or chamber, that cradles the wok. This will be used to determine the *testing capacity*.

3.1.12 *well/chamber*, *n*—the ring which supports the wok over the heat source.

3.1.13 *wok*, *n*—a bowl shaped vessel used to contain the water that is being heated by the Chinese range.

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[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.

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

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4. Summary of Test Method

4.1 The Chinese range is connected to the appropriate metered energy source, and energy input rate is determined for each type of cooking well on the Chinese range and for the entire Chinese range (all cooking wells operating at the same time) to confirm that the appliance is operating within 5 % of the nameplate energy input rate. The pilot energy consumption also is determined when applicable to the Chinese range being tested.

4.2 Energy consumption and time are monitored as each well of the Chinese range is used to heat the water in the wok from 70 to 200°F (21 to 93°C) at the full-energy input rate. Heatup energy efficiency and production capacity are calculated from this data.

5. Significance and Use

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

5.2 The pilot light, where applicable, energy rate can be used by the food service operator to estimate energy consumption during noncooking periods.

5.3 Heatup energy efficiency is a precise indicator of Chinese range energy performance under full-load conditions. This information enables the food service operator to consider energy performance when selecting a Chinese range.

5.4 Production capacity is used by food service operators to choose a Chinese range that matches their food output requirements.

6. Apparatus

6.1 *Analytical Balance Scale*, for measuring water and wok weights with a resolution of 0.01 lb and an uncertainty of 0.01 lb.

6.2 *Barometer*, for measuring absolute atmospheric pressure, to be used for adjustment of measured gas volume to standard conditions, and it shall have a resolution of 0.2 in. Hg and an uncertainty of 0.2 in. Hg.

6.3 *Canopy Exhaust Hood*, 4 ft in depth, wall-mounted with the lower edge of the hood 6 ½ ft from the floor and with the capacity to operate at nominal exhaust ventilation rate of 300 cfm per linear foot. This hood shall extend a minimum of 6 in. past both sides 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.

6.4 *Data Acquisition System*, for measuring energy and temperatures, capable of multiple channel displays updating at least every 2 s.

6.5 *Gas Meter*, for measuring the gas consumption of a Chinese range, shall be a positive displacement type with a resolution of at least 0.01 ft^3 and a maximum uncertainty of no greater than 1 % of the measured value for any demand greater than 2.2 ft^3/h. If the meter is used for measuring the gas consumed by the pilot lights, it shall have a resolution of at least 0.01 ft^3 and a maximum uncertainty no greater than 2 % of the measured value.

6.6 *Pressure Gage*, for monitoring gas pressure. It shall have a range of zero to 15 in. H_2O, a resolution of 0.5 in. H_2O, and a maximum uncertainty of 1 % of the measured value.

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

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

6.9 *Thermocouple(s)*, industry standard Type T or Type K thermocouple wire with a range of 50°F to 250°F and an uncertainty of ±1°F.

6.10 *Watt-Hour Meter*, for measuring the electrical energy consumption of a Chinese range, shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 1.5 % of the measured value for any demand greater than 100 W. For any demand less than 100 W, the meter shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 10 %.

7. Reagents and Materials

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

7.2 *Wok*, due to the varying wok styles, shapes, and materials, the testing wok shall be the wok recommended by the manufacturer for the Chinese range to be tested.

8. Sampling

8.1 *Chinese Range*—Select a representative production model for performance testing.

9. Preparation of Apparatus

9.1 Install the Chinese range according to the manufacturer's instructions under a 4 ft deep canopy exhaust hood mounted against a wall with the lower edge of the hood 6 ½ft from the floor. Position the Chinese range so the front edge is 6 in. inside the front edge of the hood. The length of the exhaust hood and active filter area shall extend a minimum of 6 in. beyond both sides of the Chinese range. In addition, both sides of the Chinese range shall be 3 ft from any side wall, side partition, or other operating appliance. The exhaust hood ventilation rate shall be 300 cfm per linear foot of the hood length. The associated heating or cooling system for the space shall be capable of maintaining an ambient temperature of 75 ± 5°F within the testing environment while the exhaust ventilation system is operating.

9.2 Connect the Chinese range to a calibrated energy test meter. For gas installations, install a pressure regulator downstream from the meter to maintain a constant pressure of gas for all tests. Install instrumentation to record both the pressure and temperature of the gas supplied to the Chinese range and the barometric pressure during each test so that the measured gas flow can be corrected to standard conditions. For electric installations, a voltage regulator may be required during tests if the voltage supply is not within ±2.5 % of the manufacturer's nameplate voltage.

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

9.4 For an electric Chinese range, confirm (while the 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 1—It is the intent of the testing procedure herein to evaluate the performance of a Chinese range at its rated gas pressure or electric voltage. If an electric unit 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 Chinese range is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the unit, for example, may differ at the two voltages.

10. Procedure

10.1 *General*:

NOTE 2—Prior to starting these test methods, a tester should read the operating manual and fully understand the operation of the appliance.

10.1.1 For gas Chinese range, record the following for each test run:

10.1.1.1 Higher heating value,

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

10.1.1.3 Measured gas temperature,

10.1.1.4 Measured gas pressure,

10.1.1.5 Barometric pressure,

10.1.1.6 Ambient temperature, and

10.1.1.7 Energy input rate during or immediately prior to test.

NOTE 3—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 Chinese range under test. It is recommended that all testing be performed with natural gas having a higher heating value of 1000 to 1075 Btu/ft^3.

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

10.1.3 For an electric Chinese range, record the following for each test run:

10.1.3.1 Voltage while elements are energized,

10.1.3.2 Ambient temperature, and

10.1.3.3 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 Chinese range.

10.2 *Energy Input Rate*:

10.2.1 For a gas Chinese range, operate one of the cooking unit's wells with the control(s) in the full "on" position. Allow the cooking unit to operate for 15 min.

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

10.2.3 If an electrical unit cycles within the 15-min time period required for the test, record only the energy used during the noncycling period starting from the instant that the cooking unit has been turned on.

10.2.4 For an electric Chinese range, operate one of the cooking unit's wells with the control(s) in the full "on" position and record the energy consumption of the cooking unit for the next 15 min.

NOTE 4—When confirming the nameplate rated input for an induction Chinese range, the wok must be in the well/chamber and filled with water to a level which prevents the wok from boiling dry over the 15-min test period. Allowing the wok to boil dry may cause damage to the induction unit, or the wok, or both.

10.2.5 Repeat the procedure in 10.2.1 through 10.2.4 for each cooking well/chamber on the Chinese range and record the energy consumption for the specified time period, as well as the position of the cooking well/chamber, for example, left to right, or left front, left rear etc.

10.2.6 Repeat the procedure in 10.2.1 through 10.2.4 operating all of the Chinese range cooking wells at the same time, recording the energy consumption of the entire Chinese range for the specified time period.

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

NOTE 5—The nameplate rated input of a Chinese range is specified generally as the sum of the nameplate ratings of each of the individual cooking units located on the Chinese range. For example, a Chinese range with two 80 000-Btu/h burners has a nameplate rating of 160 000 Btu/h. Due to this fact, the measured input rate of the entire Chinese range top is sometimes different from the nameplate rating. The nameplate rating is compared (see 10.2.6) against the measured rating for the entire Chinese range. The remainder of the test contained in this test method concentrates on individual cooking units; therefore, it is important that the measured input rates of the individual cooking units fall within the specified variance from their nameplate rating.

10.2.8 Confirm that the measured input rate or power (Btu/h for a gas Chinese range and kW for an electric Chinese range) is within 5 % of the rated nameplate input or power. It is the intent of the testing procedures herein to evaluate the performance of a Chinese range at its rated energy input rate. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the Chinese range or supply another Chinese range for testing.

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

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

10.3.2 Light and adjust pilots according to the manufacturer's instructions.

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

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

10.4 *Testing Capacity*:

10.4.1 Fill the wok with water to the water level mark for the energy efficiency test. The water level mark is determined by filling the wok with water until it is level with the top of the well/chamber (see Fig. 1). This will be the testing capacity.

NOTE 6—The water level mark represents a real-world amount of a testing medium, thereby reflecting traditional cooking styles and usage of a Chinese range/wok.

10.4.2 Weigh and record the weight of the water in the wok. This will be used for the heatup energy efficiency and production capacity test.

10.5 *Heatup Energy Efficiency and Production Capacity*:

10.5.1 This procedure is comprised of one 30-min stabilization run, followed by a minimum of three separate test runs at the full input rate. The reported values of heatup energy efficiency and production capacity shall be the average of at least three test runs. Additional test runs may be necessary to obtain the required precision for the reported test results (Annex A1).

10.5.2 Verify that the wok is at 75 ± 5°F.

10.5.3 Weight and record the weight of the empty wok.

10.5.4 The wok shall have the thermocouple suspended ¾ in. from the bottom center of the wok.

10.5.5 Fill the wok with water to the amount determined in 10.4 with 70 ± 2°F water and record the temperature.

10.5.6 Set the cooking unit controls at 100 ± 5 % of the full-energy input rate and allow the unit to operate for 30 min.

NOTE 7—When performing test in succession(s), it is not necessary to conduct the 30-min stabilization test provided the burners are not turned off between test for more than 2 min; however, if the wok's burners or elements are turned off for more than two min between test, the 30-min stabilization period must be reestablished.

10.5.7 At the end of the 30-min stabilization period, while the burners are still on a 100 ± 5 % of the full-energy input rate, place the wok with the measured amount of water in the well/chamber.

10.5.8 Record the time and energy (including any electric energy used by a gas Chinese range) required to raise the water temperature to 200°F.

10.5.9 Between tests, cool the wok to 75 ± 5°F before running the remaining tests.

10.5.10 Repeat 10.4.5 through 10.4.9 for the remaining test.

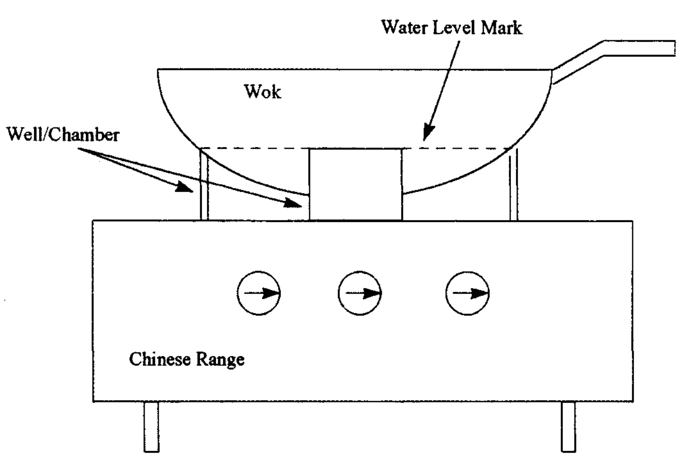

FIG. 1 Water Level Test Mark

10.5.11 Calculate the heatup energy efficiency and production capacity for the cooking unit in accordance with 11.6 and 11.6.2.

10.5.12 Repeat 10.5.5-10.5.11 until each well/chamber burner or element has been tested.

11. Calculation and Report

11.1 *Test Chinese Range*:

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

11.2 *Apparatus and Procedure*:

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

11.2.2 For electric Chinese range, report the voltage for each test.

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

11.3 *Gas Energy Calculations*:

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

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

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

where:

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

where:

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

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

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

P_{cf} = pressure correction factor,

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

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

NOTE 8—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Standard conditions using Practice 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 Chinese range and kW for an electric Chinese range and for the complete Chinese range (see Note 5).

11.4.2 For gas or electric Chinese range, calculate and report the measured energy input rate (Btu/h or kW) based on the energy consumed by each cooking unit and by the entire Chinese range during the period of peak energy input according to the following relationship:

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

where:

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

11.4.3 Calculate and report the percent difference between the manufacturer's nameplate energy input rate and the measured energy input rate.

11.5 *Pilot Energy Rate*:

11.5.1 Calculate and report the pilot energy rate (Btu/h) based on the following:

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

where:

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

11.6 *Heatup Energy Efficiency, and Production Capacity*:

11.6.1 Calculate and report the heatup energy efficiency for the heatup tests based on the following:

$$\eta_{cook} = \frac{E_{water} + E_{wok}}{E_{appliance}} \times 100 \quad (4)$$

where:

η_{heatup} = heatup energy efficiency, %
E_{water} = energy into the water, and
= $W_{water} \times Cp_{water} \times T_2 - T_1$.

where:

W_{water} = weight of water in the wok, which is specified as the water level mark,
Cp_{water} = specific heat of water = 1.0 Btu/lb· °F (418.7 J/kg · °K),
T_1 = ending temperature of the water, that is specified as 200°F (93°C),
T_2 = beginning temperature of the water, that is specified as 70 ± 2°F (21 ± 1°F)
E_{wok} = energy into the wok, and
= $W_{wok} \times Cp_{wok} \times T_2 - T_1$.

where:

W_{wok} = weight of wok, as specified in 6.5,
Cp_{wok} = specific heat of wok, specified as either: aluminum = 0.22 Btu/lb · °F, or steel = 0.11 Btu/lb · °F, and
$E_{appliance}$ = energy consumed by the cooking unit during the test, Btu, including any electric energy consumed by gas wok.

11.6.2 Calculate and report the production capacity (lb/h) for the full-energy input rate based on the following:

$$PC = \frac{W \times 60}{t} \quad (5)$$

where:

PC = production capacity of the Chinese range, lb/h,
W = total weight of the water (excluding pan weights) during test, lb, and
t = total heatup time for the test, min.

12. Precision and Bias

12.1 *Precision*:

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

12.1.1.1 For the heatup 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 Chinese range; energy efficiency; heatup time; performance; production capacity; uniform test procedure; water level mark; well/chamber; wok

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

NOTE A1.1—This procedure is based on the ASHRAE method for determining the confidence interval of the average of several test results (ASHRAE Guideline 2-1986(RA90)). It only should be applied to test results that have been obtained within the tolerances prescribed in this method, for example, thermocouples calibrated, appliance operating within 5 % of rated input during the test run.

A1.1 For the heatup 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 heatup 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. For example, if the production capacity for the appliance is 100 lb/h, the uncertainty must not be greater than ±10 lb/h; thus, the true production capacity is between 90 and 110 lb/h. This interval is determined at the 95 % confidence level, which means that there is only a 1 in 20 chance that the true production capacity could be outside of this interval.

A1.3 Calculating the uncertainty not only guarantees the maximum uncertainty in the reported results, but also is used to determine how many test runs are needed to satisfy this requirement. The uncertainty is calculated from the standard deviation of three or more test results and a factor from Table A1.1, which 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 (heatup-energy efficiency or production capacity) using the results of the first three test runs, as follows:

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

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

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 = $(X_1)^2 \times (X_2)^2 + (X_3)^2$, 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 (⅓in this case).

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

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

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

where:

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

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

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

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

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 heatup-energy efficiency and production capacity, report the average for these parameters along with their corresponding absolute uncertainty, U_3, in the following format:

$$Xa_3 \pm U_3 \quad \text{(A1.5)}$$

If the percent uncertainty is greater than ±10 % for the heatup energy efficiency or production capacity, proceed to Step 5.

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

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

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

$$Xa_4 = (1/4) \times (X_1 + X_2 + X_3 + X_4) \quad \text{(A1.6)}$$

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:

$$S_4 = (1/\sqrt{3}) \times \sqrt{(A_4 - B_4)} \quad \text{(A1.7)}$$

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 results) is as follows:

$$U_4 = C_4 \times S_4 \quad \text{(A1.8)}$$

$$U_4 = 1.59 \times S_4$$

where:

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

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

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

$$\%U_4 = (U_4/Xa_4) \times 100\ \% \quad \text{(A1.9)}$$

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 heatup energy efficiency and production capacity, report the average for these parameters along with their corresponding absolute uncertainty, U_4, in the following format:

$$Xa_4 \pm U_4 \quad \text{(A1.10)}$$

If the percent uncertainty is greater than ±10 % for the heatup 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 in A1.4.10.1 and A1.4.10.2 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:

$$Xa_n = (1/n) \times (X_1 + X_2 + X_3 + X_4 + ... + X_n) \quad \text{(A1.11)}$$

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:

$$S_n = (1/\sqrt{(n-1)}) \times \sqrt{(A_n - B_n)} \quad \text{(A1.12)}$$

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:

$$U_n = C_n \times S_n \quad \text{(A1.13)}$$

where:

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

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

$$\%U_n = (U_n/Xa_n) \times 100\ \% \quad \text{(A1.14)}$$

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 heatup energy efficiency and production capacity, report the average for these parameters along with their corresponding absolute uncertainty, U_n, in the following format:

$$Xa_n \pm U_n \quad \text{(A1.15)}$$

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

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

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

Test	PC
Run No. 1	110 lb/h

Run No. 2	104 lb/h
Run No. 3	101 lb/h

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

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

$$Xa_3 = (1/3) \times (X_1 + X_2 + X_3), \quad \text{(A1.16)}$$

$$Xa_3 = (1/3) \times (110 + 104 + 101),$$

$$Xa_3 = 105 \text{ lb/h}$$

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

$$A_3 = (X_1)^2 + (X_2)^2 \ (X_3)^2, \quad \text{(A1.17)}$$

$$A_3 = (110)^2 + (104)^2 + (101)^2,$$

$$A_3 = 33\,117$$

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

$$B_3 = (1/3) \times [(110 + 104 + 101)^2],$$

$$B_3 = 33\,075$$

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

$$S_3 = (1/\sqrt{2}) \times \sqrt{(33\,117 - 33\,075)}, \quad \text{(A1.18)}$$

$$S_3 = 4.58 \text{ lb/h}$$

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

$$U_3 = 2.48 \times S_3, \quad \text{(A1.19)}$$

$$U_3 = 2.48 \times 4.58,$$

$$U_3 = 11.4 \text{ lb/h}$$

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

$$\%U_3 = (U_3/Xa_3) \times 100\ \%, \quad \text{(A1.20)}$$

$$\%U_3 = (11.4/105) \times 100\ \%,$$

$$\%U_3 = 10.9\ \%$$

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 is 106 lb/h.

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

A1.5.6.1 The new average PC is as follows:

$$Xa_4 = (1/4) \times (X_1 + X_2 + X_3 + X_4), \quad \text{(A1.21)}$$

$$Xa_4 = (1/4) \times (110 + 104 + 101 + 106),$$

$$Xa_4 = 105 \text{ lb/h}$$

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

$$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2, \quad \text{(A1.22)}$$

$$A_4 = (110)^2 + (104)^2 + (101)^2 + (106)^2,$$

$$A_4 = 44\,353$$

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

$$B_4 = (1/4) \times [(110 + 104 + 101 + 106)^2],$$

$$B_4 = 44\,310$$

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

$$S_4 = (1/\sqrt{3}) \times \sqrt{(44\,353 - 44\,310)}, \quad \text{(A1.23)}$$

$$S_4 = 3.79 \text{ lb/h}$$

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

$$U_4 = 1.59 \times S_4, \quad \text{(A1.24)}$$

$$U_4 = 1.59 \times 3.79,$$

$$U_4 = 6.03 \text{ lb/h}$$

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

$$\%U_4 = (U_4/Xa_4) \times 100\ \%, \quad \text{(A1.25)}$$

$$\%U_4 = (6.03/105) \times 100\ \%,$$

$$\%U_4 = 5.74\ \%$$

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

$$\text{PC: } 105 \pm 6 \text{ lb/h} \quad \text{(A1.26)}$$

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

APPENDIX

(Nonmandatory Information)

X1. RESULTS REPORTING SHEETS

Manufacturer______________________________
Model______________________________
Date______________________________
Test Reference Number (optional)____________________

Section 11.1 Test Chinese Range

Description of operational characteristics:______________________________

Section 11.2 Apparatus

Check if testing apparatus conformed to specifications in section 6.
Deviations:______________________________

Section 11.3 Testing Capacity

Testing capacity (pounds) ________

Section 11.3 Maximum Energy Input Rate

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

*Section 11.8 Pilot Energy Rate **(if applicable)***

Gas Heating Value (Btu/ft^3) ________
Pilot Energy Rate (Btu/h) ________

Section 11.9 Heatup Energy Efficiency and Heatup Energy Rate

Test Voltage (V) ________
Gas Heating Value (Btu/ft^3) ________
Heatup Time 70°F to 200°F (min) ________
Production Capacity (lb/h) ________
Energy to Food (Btu/lb) ________
Energy to Appliance (Btu/lb) ________
Heatup Energy Efficiency (%) ________

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