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An American National Standard

Standard Test Method for Energy Performance of Stationary-Rack, Door-Type Commercial Dishwashing Machines[1]

This standard is issued under the fixed designation F1696; 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 and water consumption of single-rack, door-type commercial dishwashers (hereafter referred to as dishwashers). Dishwashers may have a remote or self-contained booster heater. This test method does not address cleaning or sanitizing performance.

1.2 This test method is applicable to both hot water sanitizing and chemical sanitizing stationary rack machines, which includes undercounter single rack machines, upright door-type machines, pot, pan and utensil machines, fresh water rinse machines and fill-and-dump machines. Dishwasher tank heaters are evaluated separately from the booster heater. Machines designed to be interchangeable in the field from high temp and low temp (that is, Dual Sanitizing Machines) and vice versa, shall be tested at both settings. Machines should be set for factory settings. If a dishwasher includes a booster heater as an option, energy should be sub metered separately for the booster heater. When the test method specifies to use the data plate or manufacturer's recommendations, instructions, specifications, or requirements, the information source shall be used in the following order of preference and documented in the test report: data plate, user manual, communication with manufacturer.

1.3 The following procedures are included in this test method:

1.3.1 *Procedures to Confirm Dishwasher is Operating Properly Prior to Performance Testing:*

1.3.1.1 Maximum energy input rate of the tank heaters (see 10.3).

1.3.1.2 Maximum energy input rate of the booster heater, if applicable (see 10.4).

1.3.1.3 Water consumption calibration (see 10.5).

1.3.1.4 Booster temperature calibration, if applicable (see 10.2).

1.3.1.5 Tank temperature calibration (see 10.7.6.1 and 10.7.6.2).

1.3.2 *Energy Usage and Cycle Rate Performance Tests:*

1.3.2.1 Washing energy test (see 10.7).

1.3.2.2 Idle energy rate (door(s) open and door(s) closed) (see 10.8).

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

F857 Specification for Hot Water and Chemical Sanitizing Commercial Dishwashing Machines, Stationary Rack Type

F861 Specification for Commercial Dishwashing Racks

F953 Specification for Commercial Dishwashing Machines (Stationary Rack, Dump Type) Chemical Sanitizing

2.2 *NSF Standards:*[3]

NSF/ANSI 3 Commercial Warewashing Equipment

NSF/ANSI 170 Glossary of Foodservice Terms

2.3 *ASHRAE Document:*[4]

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

3. Terminology

3.1 *Definitions:*

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

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

[3] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140, http://www.nsf.org.

[4] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

3.1.1 *ambient temperature, n*—defined in NSF/ANSI 170-2014; Section 3.3.

3.1.2 *auxiliary rinse, n*—defined in NSF/ANSI 170-2014; Section 3.5.

3.1.3 *average tank temperature, n*—temperature of the wash tank measured within ½ in. of the factory installed thermostat bulb. The temperature is measured and averaged during the 10 rack (6 racks for pot and pan or for undercounter) loaded room temperature washing test. The time interval for averaging includes washing, rinsing, dwell, energy recovery (for heat recovery dishwashers), wash tank temperature recovery and loading. For upright machines, the temperature averaged over the entire period starting with the first loaded dish rack and ending with the elapsed interval period after the last rack is washed. For undercounter machines, the measurement period ends when both wash tank and booster elements cycled off after the last load is washed. Stabilization loads should not be included in the average wash tank temperature.

3.1.4 *booster heater, n*—water heater for taking supply hot water (typically 140°F) up to 180°F for sanitizing rinse; the booster heater may be separate from dishwasher or integral. Booster heater is defined in NSF/ANSI 170-2014; Section 3.224.1.

3.1.5 *chemical dump type machine, n*—a low temp, stationary rack machine with a pumped recirculated sanitizing rinse.

3.1.6 *chemical sanitizing (low temp) machine, n*—a machine that applies a chemical sanitizing solution to the surfaces of dishes to achieve sanitization.

3.1.7 *chemical sanitizing rinse, n*—defined in NSF/ANSI 170-2010; Section 3.170.

3.1.8 *cycle rate, n*—the number of loaded dishracks washed per hour during the Washing Energy Performance test.

3.1.9 *dishwasher, n*—a machine that uniformly washes, rinses, and sanitizes eating and drinking utensils and cookware.

3.1.10 *dual sanitizing machine, n*—a machine designed to operate as either a high temp or low temp machine.

3.1.11 *dwell mode, n*—for stationary rack machines, the dishwasher is in dwell mode when it is actively running a cycle but is not in wash or rinse modes.

3.1.12 *energy saver mode, n*—operational setting that is designed to reduce energy during idle mode through temporary shut-down of certain machine components (pumps or belt motors) or reduction of certain temperature set points.

3.1.13 *factory settings, n*—a setting that has been programmed or adjusted at the factory and is representative of the way that model is set up initially. These settings are the default settings for the machine and may or may not be user adjustable.

3.1.14 *flow pressure, n*—defined in NSF/ANSI 170-2014; Section 3.76.

3.1.15 *fresh water, n*—defined in NSF/ANSI 170-2014; Section 3.85.

3.1.16 *glasswashing, n*—a stationary rack, under counter machine specifically designed to clean and sanitize glasses.

3.1.17 *hot water sanitizing (high temp) machine, n*—a machine that applies hot water to the surfaces of dishes to achieve sanitization.

3.1.18 *hot water sanitizing rinse, n*—defined in NSF/ANSI 170-2010; Section 3.171.

3.1.19 *idle mode, n*—for all dishwasher types, the dishwasher is in idle mode when it is not actively running but is still powered on and ready to wash dishes while maintaining the tank or tanks at the required temperature.

3.1.20 *idle rate, n*—rate of energy consumed by the dishwasher while "holding" or maintaining the heated tank water at the thermostat(s) set point during the time period specified.

3.1.21 *line pressure, n*—defined in NSF/ANSI 170-2014; Section 3.115.

3.1.22 *loads:*

3.1.22.1 *dishload, n*—a peg type, polypropylene dishrack of a specified weight, loaded with ten 9-in. plates of a specified weight, used to put a thermal load on the dishwasher during the washing energy performance test.

3.1.22.2 *glassload, n*—6 glasses by 6 glasses, polypropylene glass rack of a specified weight, loaded with eighteen 8-fl oz (237 ml) glasses, used to put a thermal load on the dishwasher during the washing energy performance test.

3.1.23 *non-recirculating pumped sanitizing rinse, n*—defined in NSF/ANSI 170-2014; Section 3.131.

3.1.24 *post-sanitizing rinse, n*—defined in NSF/ANSI 170-2014; Section 3.174.

3.1.25 *pot, pan, and utensil, n*—a stationary rack, door type machine designed to clean and sanitize pots, pans, and kitchen utensils.

3.1.26 *prewashing unit, n*—defined in NSF/ANSI 170-2014; Section 3.150.

3.1.27 *pumped rinse, n*—defined in NSF/ANSI 170-2014; Section 3.154.

3.1.28 *rack, n*—defined in NSF/ANSI 170-2014; Section 3.157.

3.1.29 *rated temperature, n*—dishwasher's rated data plate minimum operating tank temperature as determined by NSF/ANSI 3.

3.1.30 *recirculating final sanitizing rinse, n*—defined in NSF/ANSI 170- 2014; Section 3.162.

3.1.31 *rinse mode, n*—for stationary rack machines, the dishwasher is in rinse mode when it is at the end of the actively running cycle and is spraying hot water or chemical sanitizing rinse water or a post-sanitizing rinse. If there is a post-sanitizing rinse, it shall be included in rinse mode.

3.1.32 *sanitization, n*—defined in NSF/ANSI 170-2014; Section 3.178.

3.1.33 *sanitizing rinse, n*—defined in NSF/ANSI 170-2010; Section 3.173.

3.1.34 *sanitizing solution, n*—defined in NSF/ANSI 170-2014; Section 3.179.

3.1.35 *stationary rack machine, n*—a dishwashing machine in which a rack of dishes remains stationary within the machine while subjected to sequential wash and rinse sprays. This definition also applies to machines in which the rack revolves on an axis during the wash and rinse cycles.

3.1.36 *tank heater idle energy rate, n*—rate of energy consumed by the dishwasher while "holding" or maintaining the heated tank water at the thermostat(s) set point during the time period specified.

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

3.1.38 *undercounter dishwasher, n*—Specification F953 Type III machines, a stationary rack machine with an overall height of 38 inches or less, designed to be installed under food preparation workspaces. Under counter dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

3.1.39 *upright door-type dishwasher, n*—Specification F857 Type I (straight through model) and Type II (corner model) and F953 Type I (straight through model) and Type II (corner model) machines, stationary rack machine designed to accept a standard 20 inch × 20 inch dish rack, which requires the raising of a door to place the rack into the wash/rinse chamber. Closing of the door typically initiates the wash cycle. Subcategories of single tank, stationary door type machines include: single rack, double rack, pot, pan and utensil washers, chemical dump type and hooded wash compartment ("hood type"). Single tank, door type models can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

3.1.40 *user adjustable, n*—a setting that can be adjusted by the operator without tools and can be adjusted without removal of panels. These settings cannot be accessed through password protected service menus that are described in the service manual. These settings can be accessed through menus without passwords and are described in user manuals. Password protection that allows the manager to access the settings is considered user adjustable. Button combinations not described in the user manual are considered passwords.

3.1.41 *washing, n*—defined in NSF/ANSI 170-2014; Section 3.222.

3.1.42 *wash mode, n*—for stationary rack machines, the dishwasher is in wash mode when it is actively running a cycle and is spraying wash water (that is, water that is neither part of the sanitizing rinse, nor post sanitizing rinse).

3.1.43 *water heater, n*—defined in NSF International/American National Standards Institute (NSF/ANSI) 170-2014: Glossary of Food Equipment Terminology; Section 3.224.

4. Summary of Test Method

4.1 The booster temperature (for high temperature machines) and wash tank temperature are calibrated and verified.

4.2 The maximum energy input rate of the tank heater and the booster heater is determined to check whether the dishwasher is operating at the manufacturer's rated input. If the measured input rate is not within 5 % of the rated input or the rating printed on the heating element, all further testing ceases.

NOTE 1—It is the intent of the testing procedure herein to evaluate the performance of a dishwasher 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 volts (V) with no change in components), the voltage selected by the manufacturer or tester, or both, shall be reported. If a dishwasher is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the unit (for example, recovery time) may differ at the two voltages. Therefore the tests may be performed at both voltages and results reported accordingly.

4.3 The water consumption is adjusted to the manufacturer's rated water consumption per NSF/ANSI Standard 3. Report the measured consumption and confirm that it is within 5 % of the NSF rating. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the dishwasher or provide another unit for testing.

4.4 The dishwasher energy rate is determined at idle, that is, when the tank temperature(s) is being maintained, but no washing is taking place. This test is run with the door(s) closed (see 10.8).

4.5 The booster heater idle energy rate is determined (see 10.9).

4.6 The dishwasher and booster energy consumption per rack of dishes or glasses is determined by washing racks loaded with a specified quantity of dishes or glasses (see 10.7).

4.7 Water consumption is monitored during testing to determine the rate of water usage.

5. Significance and Use

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

5.2 The tank and booster temperature are verified and water consumption is adjusted to NSF specifications to ensure that the test is applied to a properly functioning dishwasher.

5.3 Because much of a dishwasher's operating period is spent in the idle condition, tank heater and booster idle energy consumption rate is an important part of predicting an end user's energy consumption. The test is run with the door(s) open and with the door(s) closed, so that the energy use of both end-user behaviors can be characterized.

5.4 A washing energy test generates an energy per rack usage. This is useful both as a measure for comparing the energy performance of one dishwasher to another and as a predictor of an end users energy consumption.

5.5 Water-consumption characterization is useful for estimating water and sewage costs associated with dishwashing machine operation.

6. Apparatus

NOTE 2—For all instruments, the specifications may be better than specified. Values provided are intended to be the minimum or maximum (depending on which is the worst case for the parameter) allowable.

6.1 *One or Two watt-hour (Wh) Meters,* for measuring the electrical energy consumption of the tank heaters, pump motor, and booster heater (if applicable), shall have a resolution 10 Wh or better and a minimum accuracy 1.5 % of the measured value for any demand greater than 100 W. For any demand less than 100 watts (W), the meter shall have a resolution of 10 Wh or better and a minimum accuracy of 10 % of the measured value.

6.2 *Gas Meter(s),* for measuring the gas consumption of tank heater or booster heater, or both, shall have a resolution of at least 0.1 cubic feet (ft^3) (0.003 m^3), a minimum accuracy of 1 % of the measured value for any demand greater than 2.2 ft^3/hour (h) (0.06 m^3/h), and shall be capable of measuring flows between at least 0 and 250 ft^3/hour. Pilot light gas consumption should be measured for at least an 8 hour period.

6.3 *One or Two Steam Flow Meters,* for measuring the flow of steam to tank heaters and or booster heater, if applicable. They shall have a resolution of at least 0.01 ft^3 (0.0003 m^3), a maximum accuracy no greater than 1 % of the measured value, and shall be capable of measuring flows between at least 0.0 and 50 ft^3/hour and recording data at least as frequently as every second.

6.4 *Pressure Gauge,* for measuring the pressure of steam to steam coils and steam injector. It shall have a resolution of at least 0.5 pounds per square inch gage (psig) (3.4 kPa), a minimum accuracy of ±1 % of the measured value, and shall be capable of measuring flows between at least 0 and 100 psig.

6.5 *Canopy Exhaust Hood,* mounted in agreement with manufacturer's requirements and operating at the dishwasher manufacturer's recommended ventilation rate, if applicable, or a nominal 300 to 500 cubic feet per minute (cfm) ventilation rate if the manufacturer does not provide a recommended ventilation rate. Report the ventilation rate used for the tests.

6.6 *Pressure Gauge,* for monitoring natural gas pressure. It shall have a range of 0 to 10 inches water (in. H_2O) (0 to 2.5 kPa), a resolution of at least 0.1 in. H_2O (125 Pa), and a maximum accuracy of 3 % of the measured value.

6.7 *Pressure Gauge,* for water consumption test. It shall be capable of measuring at least 0 to 30 pounds per square inch gage (psig) with a resolution of at least 1 psig and a maximum uncertainty of 3% of the measured value.

6.8 *Temperature Sensor,* for measuring natural gas and ambient air temperatures in the range of 50 to 100°F (10 to 40°C), with a resolution of at least 0.5°F (0.3°C) and a minimum accuracy of 1 %.

6.9 *Temperature Sensor,* for measuring steam temperatures for dishwashers with steam coil tank or booster heat, in the range of 200 to 300°F, with a resolution of at least 0.5°F and a maximum accuracy of 1 %.

6.10 *Barometer,* for measuring absolute atmospheric pressure, to be used for adjustment of measured natural gas volume to standard conditions, if the gas flow meter does not correct for pressure, or for calculating absolute pressure from gage pressure if the pressure gauge does not correct for atmospheric pressure for steam coil tank or booster heat. It shall have a resolution of at least 0.2 in. mercury (in. Hg) (670 Pa) and a maximum accuracy of 0.2 in. Hg (670 Pa).

6.11 *Flow Meter,* for measuring water consumption of the dishwasher. The calibrated flow meters shall have a resolution of at least 0.01 gal (40 mL), a maximum accuracy of 1 % full scale and shall be capable of measuring flow rates as low as 0.2 gpm (13 mL/s). The maximum flowrate of the machine should not exceed 90 % of the meter's upper measurement range. If using a data acquisition system, water meters should have the capability of outputting a minimum of 100 pulses per gallon.

6.12 *Stop Watch,* with a 0.1 second (s) resolution and an accuracy of ± 2% of the time period being measured.

6.13 *Analytical Balance Scale,* or equivalent, for measuring weight of dishes or glasses and dish- or glassracks used in the dish load or glassload energy test. It shall have a resolution of at least 0.01 lb (5 g) and a accuracy of 0.01 lb (5 g) or better.

6.14 *Temperature Sensor,* with a range from –20 to 400°F (–30 to 200°C), a resolution of at least 0.2°F (0.1°C), a maximum accuracy of 1 %, and a response time of less than 2 seconds, for measuring tank temperature and booster and dishwasher inlet temperature. For tankless dishwashing machines, the temperature should be measured in the sump. For dishwashing machines with steam coil tank or booster heat, the thermocouple probes shall be used for measuring the condensate water outlet temperature. Calibrated Type K Z4 GA thermocouple wire with stainless steel sheath and ceramic insulation is the recommended choice for booster and dishwasher inlet temperature. The thermocouple probe can be fed through a compression fitting so as to submerse the exposed junction in the booster and dishwasher inlets.

6.15 *Dishracks,* minimum of 10 20 inch (in.) by 20 in., peg type, commercial, or acceptable equivalent (e.g.: Metro Mdl P2MO). Each shall weigh 4.4 ± 0.2 lb and are used in the washing energy performance test.

6.16 *Glassracks,* minimum of 6, 36 glass compartment medium plus, 19¾ by 19¾ in. Six ⅜ in. high with compartments measuring 2⅞ by 2⅞ by 4¹³⁄₁₆ in., commercial, or acceptable equivalent. Each shall weigh 4.8 ± 0.2 lb and are used in the washing energy performance test. Polypropylene holding 36 glasses (height).

6.17 *Plates,* minimum of 100, 9 in., ceramic-glazed, weighing 1.3 ± 0.05 lb each. If plates, meeting these criteria cannot be obtained, then it will be necessary to acquire saucers, as specified in 6.19. See 9.11 prior to obtaining these plates.

6.18 *Glasses,* minimum of 108, 8 oz (237 ml) double bulge milk glasses 3⅝ in. in height and 2⅝ in. in diameter (for example: Libbey 618, Anchor/Oneida 7708U), weighing 0.35 lb (159 g) each. If glasses meeting these criteria cannot be obtained, then add or remove no more than one glass per rack that will together equal the required total weight of 5.75 ± 0.25 lb for the glasses alone (i.e., excluding the rack weight).

6.19 *Saucers,* ceramic-glazed, weighing less than 0.5 lb each. See 9.11 for an explanation of why these may be required.

6.20 *Pans,* minimum of 18 aluminum, solid 23 gauge pans, weighing 3.2 lb each with a total weight of 9.6 ± 0.2 lb for 3 pans.

6.21 *Surface Temperature Thermocouple Probe,* for measuring the plate or glass temperature. Resolution and uncertainty shall be the same as in 6.14.

6.22 *Vessel,* for capturing the sanitizing and post-sanitizing rinse water, shall be large enough (depending on the tank volume) to capture the water consumed during the entire water consumption test.

6.23 *Scale,* for water consumption test, shall be capable of measuring at least 0-50 pounds (lb) with a resolution of at least 0.1 lb and an accuracy of ± 0.1 lb or better.

7. Materials

7.1 As specified in 6.15 and 6.16, the dishracks or glassracks must be made of polypropylene. This is required because the test method assumes a specific heat of 0.39 Btu/(lb × °F). One verification that a rack is polypropylene is if it has the recycling symbol No. 5 on it with the letters "PP" below the symbol.

8. Sampling

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

9. Preparation of Apparatus

9.1 Install the dishwasher in accordance with the manufacturer's instructions under a 3-feet (ft) by 3-ft canopy exhaust hood, operating at a nominal ventilation rate of 100 cfm per linear foot of hood space or in accordance with manufacturer's recommendation, if applicable. Record the ventilation rate used for the testing. The associated heating or cooling system shall be capable of maintaining an ambient temperature of 75 ± 5°F within the testing environment when the exhaust ventilation system is working and the appliance is being operated. All packing material and protective packaging shall be removed. Drain connections shall be accessible with sufficient space to allow capture vessel to be positioned beneath.

9.2 Install the booster heater (if it is not integral to the dishwasher) in accordance with the manufacturer's recommendations. The pipe from the booster outlet to the dishwasher inlet shall be minimized, and shall be wrapped with ½-in. insulation along its entire length.

9.3 Connect the booster to a supply of water that is within the range of the manufacturer specified input temperatures (not to exceed 140 ± 2°F). For condensing heat recovery machines, connect the supply to 70 ± 3°F water. For testing purposes, the dishwasher may be connected to a source of water that is at the manufacturer specified sanitizing rinse temperature in lieu of an external booster heater.

9.4 Connect the dishwasher to a calibrated energy test meter so that all energy (including tank heater, motors, and controls) is monitored. Connect the external booster heater to a separate calibrated energy test meter. For steam coil or gas dishwashers, electric energy consumption shall be simultaneously monitored with steam or gas energy consumption. Internal booster heaters shall be monitored separately and the booster i energy shall be reported separately from the total energy. If it is not possible to measure booster heater energy separately, it shall be included in the total energy consumption.

9.5 For gas installations, install a pressure regulator (downstream from the meter) to maintain a constant (manifold) pressure of gas supplied to the dishwasher and booster heater (if applicable) for all tests. Install instrumentation to record both the pressure and temperature of the gas supplied to the dishwasher and the barometric pressure during each test so that the measured gas flow can be corrected to standard conditions if the gas flow meter does not already correct for pressure and temperature. For steam coil tank or booster heat installations, install instruments to provide dry superheated steam to the dishwasher. Adjust the steam supply pressure to within ±2.5 % of the operating pressure specified by the manufacturer. Install instrumentation to record the pressure, temperature, and volumetric flow rate of the steam supplied to the dishwasher tank heater (and booster heater separately, if applicable), the pressure and temperature of the condensate exiting the dishwasher (and booster heater separately, if applicable), and the barometric pressure during each test so that the measured gage pressures can be corrected to absolute pressure.

9.6 For an electric tank or booster heater, confirm (while the elements are energized) that the supply voltage is within ±2.5 % of the operating voltage specified by the manufacturer. If it is not, a voltage regulator may be required during the tests. Record the test voltage for each test.

9.7 For a gas tank or booster heater, 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, as applicable.

9.8 Install the flow meter (see 6.11) such that total water flow to the booster and dishwasher is measured Install a separate water meter for each water machine connection including any cold water connections.

9.9 Install a temperature sensor (see 6.14) in the wash tank within ½ in. of the factory installed thermostat bulb.

9.10 Install a temperature sensor (see 6.14) in the sanitizing rinse at the inlet to the rinse manifold (usually rinse agent injection port), and in the inlet and outlet of the external booster heater. The sensors should be installed with the probe immersed in the water. If the machine has an internal booster heater and it is not possible to measure rinse temperature directly, a thermocouple should be installed on the outer surface of the booster heater.

NOTE 3—Install the thermocouple probes described in 6.21 into the water inlets for dishwasher rinse and booster. The thermocouple probe shall be installed so that the thermocouple is immersed in the incoming water. A compression fitting should be installed first into the plumbing for both inlets. A junction fitting may be installed in the plumbing line that would be compatible with the compression fitting.

9.11 *Preparation of Dish-Loads (for upright door machines):*

9.11.1 This section describes preparation of 10 dishloads and an empty rack to be used in the washing energy performance test washing energy performance test for upright door machines.

9.11.2 An important feature of the washing energy performance test is that every dishwasher is subjected to the same thermal load. To accomplish this, the tester must control some of the factors that affect the thermal load. These factors are:

9.11.2.1 The total weight of the dishes,

9.11.2.2 The weight of the (empty) racks, and

9.11.2.3 The initial temperature of the dishes and racks.

9.11.3 The weight of the dry dishracks is specified in 6.15 as 4.4 ± 0.2 lb per rack. If they weigh more than 4.6 lb, trim away material until they weigh 4.4 ± 0.2 lb. To see what parts of the rack are not needed for the test and may therefore be trimmed, it may be desirable to load the rack as they will be used during the test. The loading is explained in 9.11.4 and 9.11.5.

9.11.4 Prepare ten dishloads as described in this and the following step (9.11.5). The ten dishloads must have 13.0 ± 0.5 lb of plates. Ideally, this simply requires ten 9-in. plates. If the total weight of the ten 9-in. plates does not fall within the range, then use the saucers to adjust the total weight. A maximum of three saucers can be added per rack.

9.11.5 Space the plates and saucers evenly on the racks. The plate and saucer spacing shall be the same on all racks.

9.11.6 The bulk temperature of the dishloads must be 75 ± 2°F. This can be accomplished by storing the dishloads together in a room with an ambient temperature of 75 ± 2°F. Avoid any circumstances that would result in some dishes being at different temperature from others, such as being stored in the air path of an HVAC supply register. Determine the bulk temperature using a surface temperature probe (6.21), measuring the temperature of three plates (one front, one center, and one rear) of each dishrack. Average these temperatures to determine the bulk temperature.

9.12 *Preparation of Glass-Loads (for undercounter machines):*

9.12.1 This section describes preparation of six glassloads and an empty rack to be used in the washing energy performance test for undercounter dishmachines.

9.12.2 An important feature of the washing energy performance test is that every dishwasher is subjected to the same thermal load. To accomplish this, the tester must control some of the factors that affect the thermal load. These factors are:

9.12.2.1 The total weight of the glasses,

9.12.2.2 The weight of the (empty) racks, and

9.12.2.3 The initial temperature of the glasses and racks.

9.12.3 The weight of the dry glassracks is specified in 6.16 as 4.8 ± 0.2 lb per rack. If they weigh more than 5.0 lb, trim away material until they weigh 4.8 ± 0.2 lb. To see what parts of the rack are not needed for the test and may therefore be trimmed, it may be desirable to load the rack as they will be used during the test. The loading is explained in 9.12.4 and 9.12.5.

9.12.4 Prepare six glassloads as described in this and the following step (9.12.5). The six glassloads must have 5.75 ± 0.25 lb of glasses. Ideally, this simply requires eighteen glasses described in 6.18. If the total weight of the eighteen glasses does not fall within the range, then add or remove no more than one glass per rack.

9.12.5 Insert the glasses inverted and spaced evenly in the rack. The glass spacing shall be the same on all racks.

9.12.6 The bulk temperature of the glassloads must be 75 ± 2°F. This can be accomplished by storing the glassloads together in a room with an ambient temperature of 75 ± 2°F. Avoid any circumstances that would result in some glasses being at different temperature from others, such as being stored in the air path of an HVAC supply register. Determine the bulk temperature using a surface temperature probe (6.21), measuring the temperature of at least three glasses (one front, one center, and one rear) of each glassrack. Average these temperatures to determine the bulk temperature.

9.13 *Preparation of Pan-Loads (for pot and pan machines):*

9.13.1 This section describes preparation of six pan loads and an empty rack to be used in the washing energy performance test for pot and pan machines.

9.13.2 An important feature of the washing energy performance test is that every dishwasher is subjected to the same thermal load. To accomplish this, the tester must control some of the factors that affect the thermal load. These factors are:

9.13.2.1 The total weight of the pans,

9.13.2.2 The weight of the (empty) racks, and

9.13.2.3 The initial temperature of the pans and racks.

9.13.3 The same racks should be used for pot and pan dishwashers as the dish racks. The weight of the dry pan rack is specified in 6.15 as 4.4 ± 0.2 lb per rack. If they weigh more than 4.6 lb, trim away material until they weigh 4.4 ± 0.2 lb. To see what parts of the rack are not needed for the test and may therefore be trimmed, it may be desirable to load the rack as they will be used during the test. The loading is explained in 9.13.4 and 9.13.5.

9.13.4 Prepare six pan loads as described in this and the following step (9.13.5). The six pan loads must have 9.6 ± 0.2 lb of sheet pans. Ideally, this simply requires three aluminum sheet pans described in 6.20.

9.13.5 Insert the three pans vertically and spaced evenly in the rack. The pan spacing shall be the same on all racks.

9.13.6 The bulk temperature of the pans must be 75 ± 2°F. This can be accomplished by storing the pan load together in a room with an ambient temperature of 75 ± 2°F. Avoid any circumstances that would result in some pans being at different temperature from others, such as being stored in the air path of an HVAC supply register. Determine the bulk temperature using a surface temperature probe (6.21), measuring the temperature of each pan per rack. Average these temperatures to determine the bulk temperature.

10. Procedure

10.1 *General:*

10.1.1 Obtain and record the following for each run of every test (gas, electric, and steam coil units).

10.1.1.1 Voltage while elements are energized, and

10.1.1.2 Measured peak input rate during or immediately prior to test (does not include motor starting load).

10.1.2 For dishwashers with a gas powered tank heater or booster, the following shall be obtained and recorded for each run of every test if the gas meter does not already correct the gas volume based on temperature and pressure:

10.1.2.1 Higher heating value,

10.1.2.2 Standard gas conditions for calculation in 11.3,

10.1.2.3 Measured gas temperature,

10.1.2.4 Measured line gas pressure (before pressure regulator), and

10.1.2.5 Barometric pressure.

NOTE 4—For a gas appliance, the quantity of heat (energy) generated by the complete combustion of the fuel is known as the heating value, heat of combustion, or calorific value of that fuel. For natural gas, this heating value varies according to the constituents of the gas. It is measured in Btu/ft^3. The heating value should be obtained during testing and used in the determination of the energy input to the appliance.

NOTE 5—The preferred method for determining the heating value of gas supplied to the dishwasher under testing is by using a calorimeter or gas chromatograph in accordance with accepted laboratory procedures. It is recommended that all testing be performed with gas with a heating value between 1000 and 1075 Btu/ft^3 (37 300 to 40 100 kJ/m^3). The use of "bottle" natural gas with a certified heating value within the specified 1000 to 1075 Btu/ft^3 (37 300 to 40 100 kJ/m^3) range is an acceptable alternative.

10.1.3 For gas dishwashers, energy calculations shall be in accordance with 11.3.

10.1.4 For dishwashers that use steam coils for tank or booster heat, the steam temperature, pressure, and instantaneous or average volumetric flow rate at dishwasher inlet shall be recorded at intervals no greater than one second of every test. Cumulative flow rate and average temperatures and pressures can be measured and recorded at an interval of 5 seconds or less. Barometric pressure has to be recorded for every run or idle performed on the dishwasher. Make any necessary corrections to the measurements as required by the instruments (i.e. correction for elevation of pressure gauge above pressure line, etc.).

NOTE 6—When the test procedure specifies to use the data plate or manufacturer's recommendations, instructions, specifications, or requirements, the information source should be used in the following order of preference: data plate, user manual, specification sheet, communication with manufacturer.

10.1.5 For dishwashers with steam coil tank or booster heat, with the exterior service door(s) closed, allow the dishwasher tank to idle for one "on" cycle. As the tank or booster heater cycles on for the second time, record the amount of time between steam entering the volumetric flow meter and exiting as condensate with a stopwatch as t_{delay} (seconds). This time delay is used to compare the data from the inlet to the corresponding data from the outlet. Adjust testing times so that there is enough data to account for this delay. Alternately, if the time delay cannot be determined using this method, it may be estimated by dividing the volume of the heat exchanger by the average flow during the first complete heater "on" cycle.

10.2 *Booster Temperature Calibration (High Temperature Machines):*

10.2.1 For external booster heaters, while monitoring the water inlet of the booster heater or water source and dishwasher (rinse manifold) temperature, initiate a dishwasher cycle. Adjust the booster heater or water source to the manufacturer's recommended sanitizing rinse temperature ± 2°F, if user adjustable. If the manufacturer does not have a recommended external booster heater setting, then set the booster heater thermostat such that the average temperature of water at the dishwasher manifold (measured only during the rinse) is between 180°F and 195°F. If the machine is supplied with an internal booster heater, retain the factory setting of the thermostat.

10.2.2 Run two machine cycles with an empty dishrack placed in the machine to confirm that the stabilized flowing sanitizing rinse temperature is above the manufacturer's rated sanitizing rinse temperature minus 1°F (or above 180°F if the manufacturer does not provide a rated sanitizing rinse temperature). If the stabilized flowing sanitizing rinse temperature is below the manufacturer's data plate rated sanitizing rinse temperature minus 1°F (or below 180°F if the manufacturer does not provide a rated sanitizing rinse temperature), adjust the thermostat per the manufacturer's instructions if it is user adjustable not to exceed manufacturer's rated temperature +15°F. Submerged thermocouple probes may take up to 5 seconds to stabilize during rinse, so the first 5 seconds of rinse temperature data may be discarded.

10.3 *Tank Heater Maximum Energy Input Rate (i.e. maximum power):*

10.3.1 The maximum energy input rate determination is used to verify that the dishwasher is operating within manufacturer specifications. If there is a data plate rating or a rating printed on the heating element for the tank heater, follow the steps below. If the tank heater is included as part of a total power consumption data plate rating, follow the steps below while monitoring the total power consumption for all components included in the rating. Tankless dishwashing machines do not have tank heating elements.

10.3.2 Instruments shall be connected so that only the energy (for steam and gas tank heat) or power (for electric tank heat) consumption of the tank heater is measured. Fill the Dishwasher tank with water. For electric tank heaters, commence monitoring the power of the tank heater when the tank heater cycles on. Stop monitoring the power when the tank heater cycles off. Record the maximum power value as the "maximum energy input rate". For gas tank heaters, allow the tank heater to idle for one "on" cycle to allow the burner orifices to heat up. Commence monitoring the elapsed time and energy consumption of the tank heater when the tank heater cycles on for the second time. Stop monitoring the elapsed time and energy consumption of the tank heater when the tank heater cycles off. Record the time and energy consumption of the tank heater during the complete "on" cycle. For steam coil tank heaters, commence monitoring the elapsed time and energy consumption of the tank heater when the tank heater cycles on. Stop monitoring the elapsed time and energy consumption of the tank heater when the tank heater cycles off. Record the time and energy consumption of the tank heater during the complete "on" cycle. For machines with steam coil tank heat, using an appropriately sized vessel that is completely dry, catch all condensate from the outlet during the test. Weigh the filled vessel, subtracting the weight of the capture vessel to calculate the weight of the condensate. Measure the temperature of the condensate in order to obtain the steam condensate density. Calculate the total mass of the inlet steam during the test and confirm that it is within 5% of the mass of condensate measured from the outlet stream. If the difference is greater than 5%, adjust the pressure of the inlet steam until the difference is less than 5% and rerun the tank heater "maximum energy input rate" (i.e. maximum power) test.

10.3.3 For electric tank heaters, the input rate should be measured only when the heater element is engaged (no pumps or motors working) if there is one meter installed on the machine, otherwise the tank heater needs to be submetered. Commence monitoring the energy to the tank heater when the tank heater cycles on. Stop monitoring the energy when the tank heater cycles off.

10.3.4 Determine the tank heater "maximum energy input rate" (i.e. maximum power) in accordance with 10.4, for the dishwasher under test. Report the measured input rate and confirm that it is within 5 % of the data plate rated input or the rating printed on the heating element. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the dishwasher.

10.4 *Booster Maximum Energy Input Rate (i.e. maximum power):*

10.4.1 If there is a data plate rating or a rating printed on the heating element for the booster heater, follow the steps below. If the booster heater is included as part of a total power consumption data plate rating, follow the steps below while monitoring the total power consumption for all components included in the rating.

10.4.2 Instruments shall be connected so that only the energy (for gas or steam booster heat) or power (for electric booster heat) consumption of the booster heater is measured. Fill the booster heater with water.

10.4.3 For electric booster heaters, commence monitoring the power of the booster heater when the booster heater cycles on. Stop monitoring the power when the booster heater cycles off. Record the maximum power value as the "maximum energy input rate". For gas booster heaters, allow the tank heater to idle for one "on" cycle to allow the burner orifices to heat up. Commence monitoring the elapsed time and energy consumption of the booster heater when the booster heater cycles on for the second time. Stop monitoring the elapsed time and energy consumption of the booster heater when the booster heater cycles off. Record the time and energy consumption of the booster heater during the complete "on" cycle. For steam coil booster heaters, commence monitoring the elapsed time and energy consumption of the booster heater when the booster heater cycles on. Stop monitoring the elapsed time and energy consumption of the booster heater when the tank heater cycles off. Record the time and energy consumption of the booster heater during the complete "on" cycle. For machines with steam coil booster heat, using an appropriately sized vessel that is completely dry, catch all condensate from the outlet during the test. Weigh the filled vessel, subtracting the weight of the capture vessel to calculate the weight of the condensate. Measure the temperature of the condensate in order to obtain the steam condensate density. Calculate the total mass of the inlet steam during the test and confirm that it is within 5% of the mass of condensate measured from the outlet stream. If the difference is greater than 5%, adjust the inlet pressure of the steam until the difference is less than 5% and rerun the booster heater "maximum energy input rate" (i.e. maximum power) test.

10.4.4 Determine the booster "maximum energy input rate" (i.e. maximum power) for the dishwasher under test in accordance with 11.4. Report the measured input rate and confirm that it is within 5 % of the data plate rated input or rating printed on the heating element. If the difference is greater than 5 %, terminate testing.

10.5 *Dishwasher Water Consumption Verification:*

10.5.1 Completely dry and weigh the capture vessel.

10.5.2 Verify that the wash tank is completely filled. Operate the machine through three cycles. Verify that the wash, rinse (including post-sanitizing rinse if this feature is included), and dwell times are within 1 second of the manufacturer's specified values and that the water pressure is within 2 psig of the manufacturer's specified value. If they are not, make adjustments and operate the machine through additional cycles until they are (i.e. steady state is achieved). If the specified times are not reached, terminate testing.

10.5.3 Using the weighed capture vessel, catch all water that is sent to the drain during a complete cycle, including any water from a post-sanitizing rinse if the water consumption including post-sanitizing rinse is being measured. Record the exact wash, rinse, and dwell times. It may take longer than the duration of the cycle for all of the water to drain; thus the vessel shall remain in place until the water flow from the cycle ceases.

10.5.4 Weigh the filled vessel after the cycle, subtracting the weight of the capture vessel to calculate the weight of the water.

10.5.5 Repeat 10.5.1 – 10.5.4 three times. Completely dry the vessel after each cycle.

10.6 *Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Rack Type Machines:*

10.6.1 Completely dry and weigh the capture vessel. Operate the machine through three cycles. Verify that the wash, rinse, and dwell times are within one second of the manufacturer's specified values and that the water is within 0.25 inch (in.) of the water fill line.

10.6.2 Using the weighed capture vessel, catch all water that is sent to the drain during a complete cycle, including any water from a post-sanitizing rinse if the water consumption including post-sanitizing rinse is being measured. Record the exact wash, rinse, and dwell times. It may take longer than the duration of the cycle for all of the water to drain; thus the vessel shall remain in place until the water flow from the cycle ceases.

10.6.3 Weigh the filled vessel after the cycle, subtracting the weight of the capture vessel to calculate the weight of the water.

10.6.4 Repeat steps 10.6.1 through 10.6.4 three times. Completely dry the vessel after each cycle.

10.6.5 Determine the water consumption, for the dishwasher under test. Report the measured input rate and confirm that it is within 5 % of the data plate rating. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the dishwasher or provide another unit for testing.

10.7 *Washing Energy Performance Test:*

NOTE 7—Glassloads are used for undercounter machines and dishloads are used for upright door machines, panloads should be used for pot and pan machines.

10.7.1 This test will require ten dishloads or six glassloads or six panloads and an empty rack (as described in Sections 3, 6 and 9). Record the weight of the dishes or glasses or pans in each dishload or glassload or panloads, respectively, and the weight of each of the racks. Record the make and model of the dishracks or glassracks and dishes or glasses or pans.

10.7.2 The washing energy performance tests are to be run a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results (see Annex A1).

10.7.3 The bulk temperature of the dishloads or glassloads or panloads shall be 75 ± 2°F. Determine the bulk temperature using a surface temperature probe (see 6.21) and measure the temperature of three plates or glasses or pans (one front, one center, and one back). Average these temperatures to determine the bulk temperature.

10.7.4 Allow the dishwasher to idle (no washing taking place) for 30 minutes with the door closed.

10.7.5 Using the surface temperature probe, measure the temperature of a dish or glass or pan in the front, middle, and rear of each dishload or glassload or panload. Record the average of these temperatures and confirm that it is 75 ± 2°F.

10.7.6 *For Upright Door Machines*—The following steps outline the procedures for testing a door type dishwasher including the stabilization and test runs. The washing test consists of washing 10 loaded racks with 10 dishes as specified in 9.11.3 and 9.11.4. The average temperature plates must be within 75 ± 2°F before entering the dishwasher.

10.7.6.1 To begin stabilizing the dishwasher, load the dishwasher with an empty rack and initiate five consecutive wash cycles without opening the door. Once the tank heaters cycle off after the 5 cycles, remove the empty rack from the dishwasher and insert the first loaded rack engaging the wash cycle. Start recording energy and water consumption, wash and rinse temperatures as soon as the cycle engages. Verify that the rated data plate minimum operating tank temperature is met during the first wash cycle of dishes, contact the manufacturer and make appropriate changes if it does not and repeat the test. When the wash cycle is complete, leave the loaded rack inside the machine for an amount of time that ensures the average wash tank temperature (3.1.3) will not fall below the data plate minimum tank temperature throughout the test. Allow 10 s to unload the washed rack and load the dishwasher with the next room-temperature load before starting the next wash cycle.

10.7.6.2 Engage the next wash cycle for a total of 10 racks of plates (or 6 racks of pans for pot and pan machines) washed while maintaining the same interval between cycles as determined in 10.7.6.1. During the test in 10.7.6.2: record wash and booster energy, elapsed time, total water consumption, inlet water temperature, tank (or sump temperature for tankless machines) and rinse temperature during the test. Tank temperatures shall be measured at a 30-s interval minimum. Stop recording data once all 10 racks of plates or 6 panloads for pot and pan machines are washed and the cycle interval time as determined in 10.7.6.1 elapses after the last rack. For tankless, machines end recording data once the last cycle ends including the rinse and heat recovery cycle if applicable. Verify that the average tank temperature throughout the test including recovery is above the data plate minimum rated temperature. (For dump and fill machines, the average sump tank temperature should be above the data plate minimum rated temperature.)

10.7.6.3 The booster energy shall be reported separately from the dishwasher energy. If possible, sub-monitor the energy of the booster heater during the washing energy performance test. If the booster heater cannot be sub-monitored, the booster heater energy shall be included as part of the dishwasher energy.

10.7.7 *For Undercounter Machines*—The following steps outline the procedures for testing a door type dishwasher including the stabilization and test runs. The washing test consists of washing six racks loaded with 18 glasses specified in 9.12.3 and 9.12.4, and allowing the wash tank elements to cycle off.

10.7.7.1 To begin stabilizing the dishwasher, wait for the tank heaters to cycle off, load and wash the first empty rack. Wait for the dishwasher to recover and for the tank heaters to cycle off leaving the door closed with the empty rack inside. Allow 10 seconds for rack reloading. Remove the empty rack and load the first loaded rack engaging the wash cycle. Leave the loaded rack inside the machine without opening the door and allow the wash tank temperature to recover.

10.7.7.2 Start recording energy consumption, wash and rinse temperatures as soon as the next cycle engages. Repeat washing another five racks of glasses, allowing the tank heaters to recover and cycle off between each load. Stop recording data once all 6 racks are washed and both booster and wash tank heating elements cycle off. A total of 6 racks will be washed, but the first rack is for stabilization and its data is not used, resulting in 5 racks of glasses used for the washing test. During the test in 10.7.7.2: record total energy, elapsed time, average water inlet temperature, average tank temperature during the test and water consumption of the dish machine.

10.7.7.3 The booster energy shall be reported separately from the dishwasher energy. If possible, sub-monitor the energy of the booster heater during the washing energy performance test. If the booster heater cannot be sub-monitored, the booster heater energy shall be included as part of the dishwasher energy.

10.7.8 Confirm that the average wash tank temperature (3.1.3) during the entire washing cycle including recovery is above the minimum value specified on the data plate of the machine . If the average tank heater temperature during the heater cycle was below the data plate rated tank temperature,, then the test was invalid. After the appropriate adjustments, then repeat 10.7.1 through 10.7.7. Confirm that the average sanitizing rinse temperature did not go below the data plate minimum while rinse water was flowing.

10.7.9 Repeat 10.7.4 – 10.7.8 for the remaining replicate test runs.

10.7.10 In accordance with 11.7, calculate and report the energy consumed per rack.

10.8 *Closed Door Idle Energy Rate:*

10.8.1 If the Dishwasher does not have an internal booster heater:

10.8.1.1 Allow the Dishwasher to fill and energize the tank heater.

10.8.1.2 With the door(s) closed, allow the Dishwasher tank to idle for at least 30 minutes for stabilization. Commence monitoring elapsed time, tank temperature, and total energy consumption of the Dishwasher when the tank heater "off" cycles for the first time after the one hour stabilization period.

10.8.1.3 Allow the dishwashing machine to idle for 3 hours. If there have not been 10 distinct tank heater cycles for all tank heaters during the 3 hour period, continue to run the test and record data. Stop the test when the tank heaters (use the same tank heater that initiated the 1st cycle for data recording) cycles off again after all tank heaters have "on" cycled ten times. This 3 hour or more idle period must start on a tank heater off cycle and end when the same tank heater turns off. Record the final elapsed time and energy consumption of the Dishwasher.

10.8.1.4 Machines with an automatic "stir feature" (tank pumps engage during idle in order to reduce tank temperature stratification) during idle must be tested at factory settings.

10.8.1.5 Record the minimum tank temperature during the test and confirm that it is at or above the data plate listed minimum tank temperature. If the minimum tank temperature during the idle energy test is below the manufacturer's specified tank temperature, the test is invalid and the manufacturer needs to be notified. If the tank temperature exceeds 15°F of the measured minimum tank temperature, the test is invalid and the manufacturer needs to be notified. Adjust the thermostat per the manufacturer's instructions if it is user adjustable and repeat the steps in 10.8.1.1 through 10.8.1.4. Same tank thermostat setpoints should be used for washing and idle tests. Tank temperatures are lower during washing tests, so the thermostat should be calibrated to meet minimum washing test temperatures before conducting the idle.

10.8.2 If the Dishwasher has an internal booster heater:

10.8.2.1 Repeat the procedure in 10.8.1. If the booster heater cannot be disconnected during the test, the booster idle energy consumption shall be reported separately from the total idle energy consumption.

10.8.2.2 If possible, sub-monitor the idle energy consumption of the booster heater during the Dishwasher idle energy test described in steps 10.8.1.2 through 10.8.1.5 above.

10.8.2.3 If the booster heater idle energy cannot be simultaneously measured with the Dishwasher idle energy, the booster heater idle energy may be monitored at a different time; however, duration of this booster idle energy test should match the duration idle energy test for tank heaters. Repeat steps 10.8.1.2 through 10.8.1.5 above, but record the energy consumption of the booster heater instead of the total Dishwasher energy consumption.

10.8.2.4 If the booster heater cannot be separately monitored or sub-monitored, the booster heater idle energy consumption shall be included as part of the total idle energy consumption.

10.8.2.5 Booster temperature setpoints during idle tests should be the same as during the washing tests.

10.9 *Closed Door Energy Saver Mode Idle Energy Rate:*

10.9.1 Machines with an automatic "sleep mode" (the tank heaters shutoff after a certain time has elapsed with no washing) must have idle energy and temperature recorded separately with the feature enabled as set from the factory. Machines with an automatic "sleep mode" must report the elapsed time for the mode to engage after an empty rack has been washed. Repeat procedure from section 10.8 in Energy Saver Mode.

11. Calculation and Report

11.1 *Test Dishwasher:*

11.1.1 Summarize the physical and operating characteristics of the dishwasher using Specification F857. Describe the physical and operating characteristics of the booster heater. If needed, describe other design or operating characteristics of the dishwasher or booster 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 9. Describe any deviations from those specifications. Report the ventilation rate.

11.2.2 Report the voltage for each test.

11.2.3 Report the higher heating value of the gas used during each test for gas booster or tank heaters.

11.3 *Gas Energy Calculations:*

11.3.1 For gas dishwashers, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (see 10.3).

11.3.2 Calculate the energy consumed based on:

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

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,
= $_{meas} \times T_{cf} \times P_{cf}$

where:

V_{meas} = measured volume of gas, ft^3,
T_{cf} = temperature correction factor,
$= \dfrac{\text{absolute standard gas temperature °R}}{\text{absolute actual gas temperature °R}}$

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

P_{cf} = pressure correction factor

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

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

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 in Practice D3588 are 519.67 degrees Rankine (°R) and 14.73 pounds per square inch absolute (psia).

NOTE 9—Eq 1 shall only be used to calculate V if the gas meter does not already correct the gas volume based on temperature and pressure using the same standard values for temperature and pressure that were used to calculate the higher heating value.

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

11.3.3.1 *Inlet Steam Mass Flow Rate:*

(1) Find the measured pressure and temperature values for the inlet stream for each data point in the superheated or saturated steam tables[5] (depending on the state of the steam) and record the listed density (ρ_{Steam}). If the exact pressure and temperature are not listed in the table, interpolate between the two closest pressure and temperature values to calculate the density.

(2) Calculate the mass flow rate for each data point as follows:

$$\dot{M}_{Steam} = \dot{V}_{Steam} \times \rho_{Steam} \tag{2}$$

where:

$\dot{M}_{Steam}$ = mass flow rate of steam (pounds (lb)/h),
$\dot{V}_{Steam}$ = measured volumetric flow rate of steam (ft^3/h), and
ρ_{Steam} = density of steam (lb/ft^3), calculated from steam tables.

11.3.3.2 *Inlet Steam Total Mass:*

$$M_{Total} = \sum_{i=1}^{N} \left(\dot{M}_{Steam,i} \times t_i\right) \times \frac{1 \text{ hour}}{3600 \text{ seconds}} \tag{3}$$

where:

M_{Total} = total steam consumption during time period (lb),
$\dot{M}_{Steam,i}$ = instantaneous steam mass flow rate for each data point (lb/h),
N = total number of data points during time period, excluding extra data to account for t_{delay}, and
t_i = time interval of each data point (seconds).

11.3.3.3 *Inlet Steam Enthalpy:*

(1) Find the measured pressure and temperature values for the inlet steam for each data point in the superheated or saturated steam tables (depending on the state of the steam) and record the listed enthalpy (H_{Inlet}). If the exact pressure and temperature are not listed in the table, interpolate between the two closest pressure and temperature values to calculate the enthalpy.

11.3.3.4 *Outlet Water Enthalpy:*

(1) Find the pressure value for the outlet water for each data point in the saturated steam tables. Record the listed saturated liquid enthalpy value ($H_{Saturated}$) and saturated temperature value ($T_{Saturated}$). If the exact pressure is not listed in the table, interpolate between the two closest pressure values to calculate the enthalpy.

(2) Calculate the enthalpy of the outlet water for each data point as follows:

$$H_{Outlet} = H_{Saturated} - \left(C_p \times \left(T_{Saturated} - T_{Measured}\right)\right) \tag{4}$$

where:

H_{Outlet} = enthalpy of dishwasher outlet steam (British thermal units (Btu)/lb),
$H_{Saturated}$ = saturated liquid enthalpy value listed in steam tables (Btu/lb),
C_p = heat capacity of water (1 Btu/lb °F),
$T_{Saturated}$ = saturated liquid temperature value listed in steam tables (°F), and
$T_{Measured}$ = recorded temperature of liquid water outlet stream during test (°F).

11.3.3.5 *Instantaneous Energy Consumption:*

(1) Calculate the energy for each data point as follows:

$$E_i = \dot{M}_{Steam,i} \times \left(H_{Inlet,i} - H_{Outlet,i+t_{delay}}\right) \times t_i \times \frac{1 \text{ hour}}{3600 \text{ seconds}} \tag{5}$$

where:

E_i = instantaneous energy consumption for each data point (Btu),
$\dot{M}_{Steam,i}$ = calculated mass flow rate of steam for each data point (lb/h),
$H_{Inlet,i}$ = enthalpy of dishwasher inlet steam for each data point (Btu/lb),
$H_{Outlet,i+t_{delay}}$ = enthalpy of dishwasher outlet water for each data point (Btu/lb),
t_{delay} = measured time between steam entering the flow meter and exiting as water (seconds), and
t_i = time interval of each data point (seconds).

11.3.3.6 *Total Energy Consumption:*

$$E_{Total} = \sum_{i=1}^{N} (E_i) + E_{Electric} \tag{6}$$

where:

E_{Total} = total energy consumption during test (active or idle) (Btu),
E_i = instantaneous energy consumption for each data point (Btu),
$E_{Electric}$ = electric energy consumption during test (Btu), and
N = total number of data points, excluding extra data to account for t_{delay}.

11.4 *Booster and Tank Heater Energy Input Rate (i.e. maximum power):*

11.4.1 Report the manufacturer's data plate energy input rate in Btu/h for a gas or steam booster or tank heater and in kilowatts (kW) for an electric booster or tank heater.

11.4.2 Calculate and report the measured energy input rate (Btu/h or kW) of the booster heater and the tank heaters based on the energy consumed during the period of peak energy input according to the following relationship:

[5] "Steam tables" throughout this test procedure refers to any steam table source based on the International Association for the Properties of Water and Steam Formulation 1997 for the Thermodynamic Properties of Water and Steam for Industrial Use.

$$q_{input} = \frac{E \times 60}{t} \quad (7)$$

where:

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

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

11.5 *Idle Energy Rate (i.e. power):*

11.5.1 Calculate and report the closed door idle energy rate and internal booster heater idle energy rate (Btu/h or kW) based on:

$$q_{idle} = \frac{E \times 60}{t} \quad (8)$$

where:

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

11.5.2 Report the average tank temperature(s) during the 3-h idle period.

11.6 *Water Consumption:*

11.6.1 Racks per Hour for Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Type Machines:

$$\text{Racks per Hour} = \frac{3600 \text{ seconds} \times NR}{(WT + RT + DT + LT)(\text{seconds})} \quad (9)$$

where:

Racks per Hour = number of racks washed per hour, truncated to the next lowest whole number,
NR = number of racks washed per cycle,
WT = wash time (i.e. amount of time spent in wash mode) in seconds as recorded during test,
RT = rinse time (i.e. amount of time spent in rinse mode, including a post-sanitizing rinse) in seconds as recorded during test,
DT = dwell time (i.e. amount of time spent in dwell mode) in seconds as recorded during test, and
LT = load time (30 seconds for under counter dishwashers, 5 seconds for straight through door-type dishwashers, 7 seconds for corner door-type dishwashers, 30 seconds for front load/unload door-type dishwashers).

11.6.2 Gallons per Hour for Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Type Machines:

$$\text{Gallons per Hour} = \frac{\sum_{n=1}^{5} \frac{\text{Measured Weight of water for cycle n (lbs)}}{\text{5 cycles}}}{\frac{\text{8.34 lbs}}{\text{gal}}} \times \frac{\text{Racks per Hour}}{NR} \quad (10)$$

where:

Racks per Hour = number of racks washed per hour, truncated to the next lowest whole number, as calculated in section 11.6.1, and
NR = number of racks washed per cycle.

11.6.3 Gallons per Rack for Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Rack Type Machines:

$$\text{Gallons per Rack} = \frac{\text{Gallons per Hour}}{\text{Racks per Hour}} \quad (11)$$

where:

Gallons per Hour = water use in gallons per hour, as calculated in section 11.6.2, and
Racks per Hour = number of racks washed per hour, truncated to the next lowest whole number, as calculated in section 11.6.1.

11.6.4 Pot, Pan, and Utensil Type Machines:

$$\text{Gallons per Square Foot} = \frac{\text{Gallons per Rack}}{\text{Square foot of Rack}} \quad (12)$$

where:

Gallons per Rack = water use in gallons per hour, as calculated in section 11.6.2, and
Square foot of Rack = manufacturer specified rack area in ft^2 for machine tested.

11.7 *Washing Energy Performance Test:*

11.7.1 Calculate and report each of the following:

11.7.1.1 Dishwasher electric energy per rack (kWh),

11.7.1.2 Booster electric energy per rack, if applicable (kWh),

11.7.1.3 Total electric energy per rack (kWh),

11.7.1.4 Dishwasher gas energy per rack, if applicable (Btu (kJ)),

11.7.1.5 Booster gas energy per rack, if applicable (Btu (kJ)),

11.7.1.6 Total gas energy per rack, if applicable (Btu (kJ)), and

11.7.1.7 For gas dishwashers, report the electric energy rate separately in kW. For direct steam or steam coil dishwashers, report the washing energy in both Btu (kJ) and $lb(kg)_{steam}$.

11.8 *Cycle* rate (racks/hr). See 11.7.3.

11.8.1 Use the following relationship:

$$E_{rack} = \frac{E_{test}}{10} \tag{13}$$

where:

E_{rack} = one of the energy per rack values listed above, and
E_{test} = energy consumed during the dishload or glassload run test, specific to the parameter being expressed (for example, for dishwasher energy per rack, E_{test} = the total energy consumed by the dishwasher during the tenrun test).

11.8.2 Report the elapsed time for the washing energy performance test. The elapsed time is measured from the time the dishwasher has commenced washing the first dishload or glassload, until the dishwasher tank heater has cycled off after the last dishload or glassload has been removed. Calculate the cycle rate (racks per hour) by dividing the number of dishloads or glass loads by the elapsed time.

11.8.3 Report the total dishwasher and booster energy consumed during the washing energy performance test, the average dishwasher inlet temperature, average booster inlet temperature, average and minimum tank temperatures, and total water consumption.

11.8.4 Calculate and report the primary hot water energy use during the washing energy rate test based on: Eprimary = (Vwater × 8.334 × (Tinput – Tcold)) ÷ 0.65.

$$E_{DHW} = \frac{Q_w c_p \rho \Delta T}{\eta} \tag{14}$$

where:

E_{DHW} = the calculated domestic hot water energy use during the Washing energy performance test, Btu,
Q_w = the quantity of hot water consumed by the dishwashing machine during the Washing energy performance test, gal,
c_p = the specific heat of water, Btu/lb·°F = 1.00 Btu/lb·°F,
ρ = the density of water, lb/gal = 8.33 lb/gal,
η = the assumed system efficiency of the commercial domestic hot water heating system, % = 65%,
ΔT = the temperature rise of the hot water °F = $T_{hot} - T_{cold}$,
T_{hot} = the average temperature of the hot water supplied to the dishwashing machine during the Washing energy performance test, measured at the inlet to the booster heater, °F, and
T_{cold} = the assumed cold water supply temperature for the commercial domestic hot water heating system, °F = 60°F.

12. Precision and Bias

12.1 *Precision:*

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

12.1.1.1 The repeatability of each 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:*

12.2.1 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 booster; dishload; dishrack; dishwasher; glassload; glassrack; tank heater

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

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

A1.1 For the energy per rack (*ER*) and cycle rate (*CR*) results, the uncertainty in the averages of at least three test runs is reported. For each test run, the uncertainty of the energy per rack and cycle rate shall be no greater than ±10 % before any of the parameters for that washing energy test run can be reported.

A1.2 The uncertainty in a reported result is a measure of its precision. If, for example, the cycle rate for the dishwasher is 30 racks/h, the uncertainty shall not be greater than ±3 racks/h. Thus, the true cycle rate is between 27 and 33 racks/h. This interval is determined at the 95 % confidence level, which means that there is only a 1 in 20 chance that the true cycle rate 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—See A1.5 for an example of applying this procedure.

A1.4.1 *Step 1*—Calculate the average and the standard deviation for the test results (energy per rack and cycle rate) using the results of the first three test runs, as follows:

NOTE A1.3—The formulas that follow may be used to calculate the average and sample standard deviation. However, it is recommended that a calculator with statistical function be used. If one is used, be sure to use the sample standard deviation function. Using the population standard deviation function will result in an error in the uncertainty. The formula for the average (three test runs) is as follows:

TABLE A1.1

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

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

where:

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

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

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

where:

S_3 = standard deviation of results for three test runs,
A_3 = $(X_1)^2 + (X_2)^2 + (X_3)^2$, and
B_3 = $(1/3) \times (X_1 + X_2 + X_3)^2$.

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

A1.4.2 *Step 2*—Calculate the absolute uncertainty in the average for each parameter listed in Step 1. Multiply the standard deviation calculated in Step 1 by the Uncertainty Factor corresponding to three test results from Table A1.1. The formula for the absolute uncertainty (three test runs) is as follows:

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

$$U_3 = 2.48 \times S_3$$

where:

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

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

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

where:

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

A1.4.4 *Step 4*—If the percent uncertainty, % U_3, is not greater than ±10 % for energy per rack and cycle rate, report the average for these parameters along with their corresponding absolute uncertainty, U_3, in the following format:

$$Xa_3 \pm U_3 \quad (A1.5)$$

If the percent uncertainty is greater than ±10 % for energy per rack or cycle rate, proceed to Step 5.

A1.4.5 *Step 5*—Run a fourth test for the energy per rack or cycle rate results if the percent uncertainty was greater than ±10 %.

A1.4.6 *Step 6*—When a fourth test is run for a given energy per rack and cycle rate, calculate the average and standard deviation for DER and CR using a calculator or the following formulas: The formula for the average (four test runs) is as follows:

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

where:

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

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

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

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. The formula for the absolute uncertainty (four test runs) 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 = uncertainty factor for four test runs (see Table A1.1).

A1.4.8 *Step 8*—Calculate the percent uncertainty in the parameter averages using the averages from Step 6 and the absolute uncertainties from Step 7. The formula 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 energy per rack and cycle rate, 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 energy per rack or cycle rate, 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. The formula for the average (*n* test runs) is as follows:

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

where:

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

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

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

where:

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

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

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

where:

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

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.

When the percent uncertainty, % U_n, is less than or equal to ±10 % for the energy per rack and cycle rate, 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 test method. For example, a thermocouple was out of calibration, the dishwasher's input capacity was not within 5 % of the rated input, or the glassrack 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 washing energy performance yielded the following cycle rate (CR) results:

Test	CR, racks/h
Run No. 1	33.8 %
Run No. 2	34.1 %
Run No. 3	31.0 %

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

Xa_3 = $(1/3) \times (X_1 + X_2 + X_3)$
Xa_3 = $(1/3) \times (33.8 + 34.1 + 31.0)$
Xa_3 = 33.0 racks/h

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

$A_3 = (X_1)^2 + (X_2)^2 + (X_3)^2$
$A_3 = (33.8)^2 + (34.1)^2 + (31.0)^2$
$A_3 = 3266$
$B_3 = (1/3) \times [(X_1 + X_2 + X_3)^2]$
$B_3 = (1/3) \times [(33.8 + 34.1 + 31.0)^2]$
$B_3 = 3260$

The new standard deviation for the CR is as follows:

$$S_3 = \left(1 / \sqrt{2}\right) \times \sqrt{(3266 - 3260)}$$

$S_3 = 1.71$ racks/h

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

$U_3 = 2.48 \times S_3$
$U_3 = 2.48 \times 1.71$
$U_3 = 4.24$ racks/h

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

$\% U_3 = (U_3/Xa_3) \times 100 \%$
$\%U_3 = (4.24/33.0) \times 100 \%$
$\% U_3 = 12.9 \%$

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

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

$Xa_4 = (1/4) \times (X_1 + X_2 + X_3 + X_4)$
$Xa_4 = (1/4) \times (33.8 + 34.1 + 31.0 + 32.5)$
$Xa_4 = 32.9$ racks/h

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

$A_4 = (X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$
$A_4 = (33.8)^2 + (34.1)^2 + (31.0)^2 + (32.5)$
$A_4 = 4323$
$B_4 = (1/4) \times [(X_1 + X_2 + X_3 + X_4)^2]$
$B_4 = (1/4) \times [(33.8 + 34.1 + 31.0 + 32.5)^2]$
$B_4 = 4316$

The new standard deviation for the CR is as follows:

$$S_4 = \left(1 / \sqrt{3}\right) \times \sqrt{(4323 - 4316)}$$

$S_4 = 1.42$ racks/h

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

$U_4 = 1.59 \times S_4$
$U_4 = 1.59 \times 1.53$
$U_4 = 2.25$ racks/h

A1.5.8 *Step 7*—Recalculate the percent uncertainty using the new average, as follows:

$\% U_4 = (U_4/Xa_4) \times 100 \%$
$\%U_4 = (2.25/32.9) \times 100 \%$
$\% U_4 = 6.8 \%$

A1.5.9 *Step 8*—Since the percent uncertainty, % *U*4, is less than ±10 %, the average for the CR is reported along with its corresponding absolute uncertainty, U_4, as follows:

$$CR: 32.9 \pm 2.43 \text{ racks/h}$$

The CR can be reported assuming that the ±10 % precision requirement has been met for the corresponding washing energy per rack value. The washing energy per rack 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 Dishwasher

Specification F 857 Classification (check one for each classification)

Additional description of operational characteristics:

____

____

____

____

____

____

Manufacturer's Nameplate Information

Tank Heater Rated Input_______ (Btu/h, kW, or lb_{steam}/h)

Pump Motor Horsepower_______

Voltage_______

Phase _______

Booster:

Make _______

Model _______

Temp Rise/GPM _______

Rated Input _______ (Btu/h, kW, or lb_{steam}/h)

Section 11.2 Apparatus

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

Deviations ______________________________

____

____

____

____

____

____

Testing Voltage __________ Volts

Gas Heating Value, if applicable __________ Btu/ft^3

Section 11.4 Maximum Energy Input Rate

Tank Heaters

Measured (Btu/h (kJ/h) or kW) __________

Rated (Btu/h (kJ/h) or kW) __________

Percent Difference between Measured and Rated __________ %

Booster

Measured (Btu/h (kJ/h) or kW) __________

Rated (Btu/h (kJ/h) or kW) __________

Percent Difference between Measured and Rated __________ %

Section 11.5 Tank Heater Idle Energy Rate

Door Open

(Btu/h (kJ/h) or kW) __________

Door Closed

(Btu/h (kJ/h) or kW) __________

Section 11.6 Booster Heater Idle Energy Rate

(Btu/h (kJ/h) or kW) __________

Section 11.7 Washing Energy Test

	Dishwasher	Booster	Total
Electric energy per rack (kWh)	__________	__________	__________
Gas energy per rack (Btu)	__________	__________	__________
Cycle rate (Racks per hour)	__________		