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An American National Standard

Standard Test Method for Energy Performance of ~~Single-Rack,~~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,~~pan and utensil machines, fresh water rinse ~~machines,~~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 ~~10.2~~10.3).

1.3.1.2 Maximum energy input rate of the booster heater, if applicable (see ~~10.3~~10.4).

1.3.1.3 Water consumption calibration (see ~~10.4~~10.5).

1.3.1.4 Booster temperature calibration, if applicable (see ~~10.5~~10.2).

1.3.1.5 Tank temperature calibration (see ~~10.6~~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

[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.

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:*

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~~Washing Energy Performance test.

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

[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.

~~3.1.3.1 *Discussion*—~~

~~The machine shall be capable of removing physical soil from properly racked and prescraped tableware, and sanitizing multiple-use tableware.~~

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,*~~*loads: n*—

3.1.22.1 *dishload, n*—a peg type, polypropylene dishrack of a specified weight, loaded with ~~fifteen~~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,~~ 6 glasses, polypropylene glass rack of a specified weight, loaded with eighteen ~~8-oz (237 mL) water~~ 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 ~~nameplate~~ 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 ~~in.~~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.

~~3.1.8.1 *Discussion*—~~

~~Undercounter 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 ~~Specification~~ F953 Type I (straight through model) and Type II (corner model) machines, stationary rack machine designed to accept a standard 20 ~~by~~ inch × 20 ~~in.~~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.

~~3.1.9.1 *Discussion*—~~

~~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 %~~ 5 % of the rated ~~input, all further testing ceases and the manufacturer is contacted. The manufacturer may make appropriate changes or adjustments to the dishwasher.~~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 ~~V~~ 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 ~~must~~may be performed at both voltages and results reported accordingly.

~~4.2 The wash tank and booster temperature are retained at the manufacturer's factory settings.~~

4.3 The water consumption is adjusted to the manufacturer's rated water consumption per NSF/ANSI ~~3. The pressure regulator valve is adjusted to 20 ± 1 psi and the water consumption measured. If this is not within ±0.15 GPM~~Standard 3. Report the measured consumption and confirm that it is within 5 % of the NSF ~~rating or the manufacturer's rating if not listed to NSF standards, then the manufacturer shall be contacted.~~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 ~~both~~ with the door(s) closed ~~and with the door(s) left open~~ (see 10.8).

4.5 The booster heater idle energy rate is determined (see ~~10.8~~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 ~~Wh~~ 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 ~~of at least~~ 10 Wh ~~and a maximum uncertainty no greater than 1.5 %~~ 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 ~~W,~~ watts (W), the meter shall have a resolution of ~~at least~~ 10 Wh ~~and a maximum uncertainty no greater than 10 % of~~ or better and a minimum accuracy of 10 % of the measured value.

6.2 ~~*One or Two Gas Meters,*~~*Gas Meter(s),* for measuring the gas consumption of tank heater or booster heater, or both, shall have a resolution of at least ~~0.01 ft~~0.1 cubic feet (ft^3 ~~(0.0003~~) (0.003 m^3), a ~~maximum uncertainty no greater than 1 % of~~ minimum

accuracy of 1 % of the measured value for any demand greater than 2.2 ft^3/h /hour (h) (0.06 m^3/h), and shall be capable of measuring flows between at least 0.00 and 250 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/hour. Pilot light gas consumption should ^{3} (0.0003 m^3), have a maximum uncertainty no greater than 2 % of the measured value, and shall be capable of measuring flows between at least 0.0 and 10.0 ftbe measured for at least an 8 hour period.^{3}/h.

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

6.4 *Pressure Gage,Gauge,* for measuring the pressure of steam to steam coils. coils and steam injector. It shall have a resolution of at least 0.5 psig pounds per square inch gage (psig) (3.4 kPa), a maximum uncertaintyminimum accuracy of 1±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'smanufacturer's requirements and operating at the dishwasher manufacturer's recommended ventilation rate, if applicable, or a nominal 300 to 500 cfm cubic feet per minute (cfm) ventilation rate if the manufacturer foesdoes not provide a recommended ventilation rate. Report the ventilation rate used for the tests.

6.6 *Pressure Gage,Gauge,* for monitoring natural gas pressure. It shall have a range of 0 to 10 in. inches water (in. H_2OO) (0 to 2.5 kPa), a resolution of at least 0.1 in. H_2O (125 Pa), and a maximum uncertaintyaccuracy of 1 % 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 maximum uncertainty of ±1°F (±0.5°C).minimum accuracy of 1 %.

6.9 *Temperature Sensor,* for measuring steam temperatures, 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 uncertaintyaccuracy of ±1°F.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. 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. Hg mercury (in. Hg) (670 Pa) and a maximum uncertaintyaccuracy of 0.2 in. Hg (670 Pa).

6.11 *Flow Meter,* for measuring water consumption of the dishwasher. It The calibrated flow meters shall have a resolution of at least 0.01 gal (40 mL), and an uncertainty of 0.01 gal (40 mL), at 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-s resolution.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 *Calibrated Exposed Junction Thermocouple Probes, 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,* 12, Metro Mdl P2MO, 20 in. minimum of 10 20 inch (in.) by 20 in., peg type, commercial, or acceptable equivalent. They equivalent (e.g.: Metro Mdl P2MO). Each shall weigh 4.64.4 ± 0.10.2 lb and are used in the washing energy performance test.

6.16 *Glassracks,* Six, minimum of 6, 36 glass compartment medium plus, 19¾ by 19¾ in. Six ⅜ in. high with compartments measuring 2⅞ by 2⅞ by 4 13⁄16 in., commercial, or acceptable equivalent. TheyEach shall weigh 4.8 ± 0.2 lb and are used in the washing energy performance test. Polypropylene holding 36 glasses (height).

6.17 *Plates,* 180, minimum of 100, 9 in., ceramic-glazed, weighing an average of 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 6.186.19. See 9.11 prior to obtaining these plates.

6.18 *Glasses,* minimum of 108, 8 oz (237 ~~mL)~~ml) double bulge milk glasses 3⅝ in. in height and 2⅝ in. in diameter (for example: Libbey 618, Anchor/Oneida 7708U), weighing ~~an average of 0.35~~0.35 lb (159 g) each. If glasses meeting ~~this~~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,* ~~30,~~ 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 ~~6.13~~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 ~~6.14~~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.~~ Btu/(lb × °F). One verification that a rack is polypropylene is if it has the recycling symbol ~~±x5~~ No. 5 on it ~~(and~~with the letters "PP" below ~~it).~~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-ft~~ 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 ~~should be removed.~~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 ~~±3°F of its rated input temperature~~the range of the manufacturer specified input temperatures (not to exceed 140 ± ~~3°F).~~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 ~~final~~sanitizing rinse temperature ~~±1°F~~ in lieu of an external booster heater.

9.4 Connect the dishwasher ~~and booster~~ to a calibrated energy test ~~meters~~meter so that all energy (including tank heater, motors, and controls) is monitored. ~~For machines with internal booster heaters, the booster heater energy use shall separately submetered from the machine tank heater, motors and controls. Separate monitoring will broaden the usefulness of the data and enhance the accuracy of the result.~~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.~~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 %~~ ±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 %~~ ±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 ~~6.10~~6.11) such that total water flow to the booster and dishwasher is ~~measured.~~measured Install a separate water meter for each water machine connection including any cold water connections.

9.9 Install a temperature sensor (see ~~6.13~~6.14) in the wash tank ~~near~~within ½~~the~~ in. of the factory installed thermostat bulb.

9.10 Install a temperature sensor (see ~~6.13~~6.14) in the ~~final~~sanitizing rinse at the inlet to the rinse ~~manifold,~~ manifold (usually rinse agent injection port), and in the inlet ~~to the~~ 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 ~~18~~10 dishloads and ~~two~~an empty ~~racks~~rack to be used in the washing energy ~~test~~ 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 ~~racks~~ dry dishracks is specified in ~~6.14~~6.15 as ~~4.6 lb or greater.~~4.4 ± 0.2 lb per rack. If they weigh more than 4.6 lb, trim away material until they weigh ~~4.6~~4.4 ± ~~0.1~~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 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 ~~19.5 ± 0.75~~ 13.0 ± 0.5 lb of plates. Ideally, this simply requires ~~fifteen~~ten 9-in. plates. If the total weight of the ~~fifteen~~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.~~ 75 ± 2°F. This can be accomplished by storing the dishloads together in a room with an ambient temperature of ~~75 ± 2°F.~~ 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 (~~6.19~~6.21), measuring the temperature of ~~at least~~ 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 ~~glass loads~~ glassloads and ~~two~~an empty ~~racks~~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 ~~racks~~ dry glassracks is specified in ~~6.14~~6.16 as ~~4.6 lb or greater.~~4.8 ± 0.2 lb per rack. If they weigh more than ~~4.6~~5.0 lb, trim away material until they weigh ~~4.6~~4.8 ± ~~0.1~~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 ~~6.17~~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 ~~in each opening of the rack.~~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 (~~6.19~~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 and electric~~ (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~~ gas powered tank heater or booster, the following shall be obtained and recorded for each run of every ~~test:~~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, and~~

10.1.2.5 ~~Measured peak input rate during or immediately prior to test.~~Barometric pressure.

~~NOTE 3—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 4—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.~~

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 ~~supplied~~ steam ~~pressure, steam temperature at dishwasher inlet, steam temperature at dishwasher outlet, and average flow rate~~ temperature, pressure, and instantaneous or average volumetric flow rate at dishwasher inlet shall be recorded ~~for each run~~ 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 ~~each run of every test, confirm~~ 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} ~~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 dishwasher. (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.

NOTE 5—When the test procedure specifies to use the manufacturer's recommendations, instructions, specifications, or requirements, the information source should be used in the following order of preference: nameplate data, user manual, specification sheet, communication with manufacturer.

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:~~ 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 ~~*Gas Tank Heaters*—Fill the dishwasher tank with 70 ± 10°F water, initiate the tank heaters, and when the burners cycle off, immediately drain the tank. Re-fill the dishwasher tank with 70 ± 10°F water and energize the tank heaters. Commence monitoring~~ 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 ~~heaters cycle on. When the heaters cycle off, note the time and total energy consumption.~~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.

~~NOTE 6—For some gas appliances, the input rate changes as the burner orifices heat up from room temperature to operational temperature. Section 10.2.1 is provided to minimize this effect.~~

~~10.2.2 *Electric Tank Heaters*—Directly measure the power during a complete heater "on" cycle~~

10.3.3 ~~Determine the tank heater maximum energy input rate in accordance with~~For electric tank heaters, the input rate should be measured ~~11.4, for the dishwasher under test. Report the measured input rate and confirm that it is within 5 % of the nameplate rated input or manufacturer specification. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the dishwasher.~~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 ~~booster~~tank heater ~~maximum~~"maximum energy input ~~rate~~ rate" (i.e. maximum power) in accordance with ~~11.4~~10.4, for the dishwasher under test. Report the measured input rate and confirm that it is within 5 % of the ~~nameplate or~~

~~manufacturer specification rated input.~~ 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:~~ 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 ~~Open the dishwasher drain. Close the door(s) and initiate a tank fill. After the booster cycles on, monitor~~ 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 ~~for 10 min. For gas boosters, commence the 10 min monitoring period 15 min after the burners cycle on (to allow the burners to stabilize). For electric boosters, a direct measurement of power may be substituted for the monitoring of~~ 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.~~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~~"maximum energy input ~~rate~~ 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 %~~ 5 % of the ~~nameplate rated input.~~ data plate rated input or 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 booster.~~5 %, terminate testing.

10.5 *Dishwasher Water Consumption Verification:*

~~10.4.1 Ensure final rinse water for door type machines is supplied at 20 ± 5 psi. Cold water (70 ± 10°F) shall be used for the dishwasher water consumption verification.~~

~~10.4.2 If multiple cycle times are available, the dishwasher shall be tested at the shortest time setting.~~

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 ~~postsanitizing~~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 ~~1~~2 psig of the manufacturer's specified value. If they are not, make adjustments and operate the machine through additional cycles until they are ~~(that is,~~ (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 ~~10.4.3~~10.5.1 – ~~10.4.6~~10.5.4 ~~for a total of five times.~~three times. Completely dry the vessel after each cycle.

~~10.4.8 Confirm that the water consumption per rack of dishes or glasses is within ±3 % of the NSF rated water consumption or the manufacturer's rating if not listed to NSF standards. If it is not, the rinse water pressure should be adjusted to provide the NSF rated water consumption. If the adjusted rinse water pressure is outside the manufacturer's recommendations, testing shall be terminated and the manufacturer contacted. The manufacturer may make appropriate changes or adjustments to the dishwasher. Record the final water consumption per rack.~~

10.6 ~~*Booster Temperature Calibration (External Booster Heaters)—*~~*Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Rack Type Machines:* ~~While monitoring the inlet and outlet temperature of the booster, initiate a dishwasher cycle every 2 min. Adjust the booster heater to the manufacturer's recommended final rinse temperature. 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 inlet (measured only during the rinse) is 181 ± 1°F.~~