Standard Test Method for Performance of Rack Conveyor Commercial Dishwashing Machines[1]

This standard is issued under the fixed designation F1920; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method evaluates the energy and water consumption of rack conveyor, commercial dishwashing machines, hereafter referred to as dishwashers. Dishwashers may have remote or self-contained booster heater. This procedure does not address cleaning or sanitizing performance.

1.2 This test method is applicable to both hot water sanitizing and chemical sanitizing rack conveyor machines, which include both single tank and multiple tank machines. Rackless conveyors (i.e. flight type machines) are included. Dishwasher tank heaters are evaluated separately from the booster heater. Machines designed to be interchangeable in the field from high temp and low temp (i.e. Dual Sanitizing Machines) and vice versa, shall be tested at both settings. Machines should be set for factory settings. If a dishwasher includes a prewash tank heater as an option, energy should be submetered separately for the prewash tank heater. This test method may be used for dishwashers with steam coil tank or booster heat, but not dishwashers with steam injection tank or booster heat. 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 (10.5).

1.3.1.2 Maximum energy input rate of the booster heater, if applicable (10.6).

1.3.1.3 Final sanitizing rinse water consumption calibration (10.7).

1.3.1.4 Booster temperature calibration, if applicable (10.2).

1.3.1.5 Wash tank temperature calibration (10.3).

1.3.1.6 Wash tank pump and conveyor motor calibration (10.4).

1.3.2 *Energy Usage and Cycle Rate Performance Tests:*

1.3.2.1 Washing energy performance test (10.8).

1.3.2.2 Tank heater idle energy rate (10.9).

1.3.2.3 Booster idle energy rate, if provided (10.10).

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

F858 Specification for Hot Water Sanitizing Commercial Dishwashing Machines, Single Tank, Conveyor Rack Type

F861 Specification for Commercial Dishwashing Racks

2.2 *NSF Standards:*

NSF/ANSI 3 Commercial Warewashing Equipment[3]

NSF/ANSI 170 Glossary of Foodservice Terms[3]

2.3 *ASHRAE Standard:*

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

[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 25 rack (50 racks for flight type) 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. The temperature averaged over the entire period starting with the first loaded dish rack and ending 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 *batch, n*—a group of five dishloads as described in 3.1.10.

3.1.4.1 *Discussion*—The dishracks are grouped into batches to better simulate typical in-kitchen operation and facilitate consistent application of the washing energy use test.

3.1.5 *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.

3.1.6 *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 *conveyor machine, n*—a dishwashing machine that employs a conveyor or similar mechanism to carry dishes through a series of wash and rinse sprays within the machine.

3.1.9 *cycle rate, n*—maximum production rate of a dishwasher when washing dishloads in accordance with the Cycle Rate Performance test.

3.1.10 *dishload, n*—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 test.

3.1.11 *dishwasher, n—for this test method*, a machine that uniformly washes, rinses, and sanitizes eating and drinking utensils and cookware.

3.1.12 *dual sanitizing machine, n*—a machine designed to operate as either a Chemical Sanitizing or Hot Water Sanitizing machine.

3.1.13 *empty dish rack, n*—dish rack without any dishware placed in the dish rack.

3.1.14 *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.

3.1.15 *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.

3.1.16 *flight type conveyor, n*—a conveyor machine where the dishes are loaded directly on the conveyor rather than transported within a rack. This machine is also referred to as a rackless conveyor.

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

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

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

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

3.1.21 *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.

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

3.1.23 *multiple tank conveyor, n*—a conveyor type machine that includes one or more tanks for wash water and one or more tanks for pumped rinse water, followed by a sanitizing rinse. This type of machine may include a pre-washing section before the washing section and an auxiliary rinse section, for purposes of reusing the sanitizing rinse water, between the power rinse and sanitizing rinse section. Multiple tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

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

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

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

3.1.31 *recovery time, n*—time from the end of washing a dishload to until the wash tank heaters have cycled off.

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 *single tank conveyor, n*—a conveyor machine that includes a tank for wash water followed by a sanitizing rinse (pumped or fresh water). This type of machine does not have a pumped rinse tank. This type of machine may include a prewashing section ahead of the washing section and an auxiliary rinse section, for purposes of reusing the sanitizing rinse water, between the wash and sanitizing rinse sections. Single tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

3.1.36 *tank heater idle energy rate, n*—rate of energy consumed by the dishwasher while "holding" or maintaining the wash 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 *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.

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

3.1.40 *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) is calibrated and verified.

4.2 The maximum energy input rate of the tank heater and the booster heater, if applicable, is measured to confirm that 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 electrical unit is rated dual voltage, that is, designed to operate at either 208 or 240 volts (V) with no change in component, the voltage selected by the manufacturer or the 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, cycle rate, may differ at the two voltages. Therefore the tests may be performed at both voltages and the results reported accordingly.

4.3 Water consumption is adjusted in accordance with manufacturer's rated water consumption per NSF/ANSI 3. Report the measured consumption and confirm that it is within 5 % of the listing on the data plate. 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 tank heater energy rate is determined at idle, that is, when the tank temperature is being maintained, but no washing is taking place.

4.5 Booster heater idle energy rate is determined.

4.6 Dishwasher and booster energy consumption per rack of dishes is determined during a heavy-use scenario by washing racks loaded with a specified quantity of dishes

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 method also will indicate any problems with the electric power supply, gas service pressure, or steam supply flow or pressure.

5.2 Tank and booster temperatures, as well as water consumption, are adjusted to NSF specifications to insure 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(s) are important parts of predicting dishwasher's energy consumption.

5.4 The washing energy performance test determines energy usage per rack. This is useful both as a measure for comparing the energy performance of one dishwasher to another and as a predictor of the dishwasher's 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 *1 or 2 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 accuracy no greater than 1.5 % of the measured value for any demand greater than 100 watts (W). For any demand less than 100 W, the meter shall have a resolution of at least 10 Wh and a maximum accuracy no greater than 10 % of the measured value.

6.2 *1 or 2 Gas Meters,* for measuring the gas consumption of tank heater, or booster heater, if applicable, or both, shall have a resolution of at least 0.1 cubic feet (ft^3) (0.003 m^3), a maximum accuracy no greater than 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 *1 or 2 Steam Flow Meters,* for measuring the flow of steam to tank heaters and or booster heater, if applicable, shall have a resolution of 0.01 ft^3 (0.0003 m^3), a maximum accuracy of 1 % of the measured value, and shall be capable of measuring flows between at least 0 and 50 ft^3/hour and recording data at least as frequently as every second.

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

6.5 *Pressure Gauge,* for water consumption test, shall be capable of measuring at least 0-30 psig with a resolution of at least 1 psig and a maximum uncertainty of 3% of the measured value.

6.6 *Canopy Exhaust Hood or Vent Cowl Exhaust Ducts,* measured in agreement with manufacturers requirements. Vent cowl exhaust ducts shall operate in accordance with the manufacturer's recommendation, if applicable, or at a nominal 200 cubic feet per minute (cfm) (94.4 L/s) on the entrance side of dishwasher and 400 cfm (188.8 L/s) on the exit side if the manufacturer does not provide recommendations. Canopy exhaust hood shall extend at least 1 ft beyond the dishwashing machine footprint operating at the dishwashing machine manufacturer's specified ventilation rate. Report the ventilation rate and ventilation exhaust type.

6.7 *Pressure Gauge,* for monitoring natural gas pressure, shall have a range of 0 to 10 inches water (in. H_2O) (zero to 2.5 kPa), a resolution of 0.1 in. H_2O (125 Pa), and a maximum accuracy 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 degrees Fahrenheit (°F) (0.3°C) and a maximum accuracy of 1% (0.5°C). For dishwashers with steam coil tank or booster heat, the temperature sensor for measuring steam temperatures in the range of 200 °F to 300 °F shall have a resolution of at least 0.5°F and a maximum accuracy of 1%.

6.9 *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, shall have a resolution of 0.2 inches mercury (in. Hg) (670 Pa), and an accuracy of 0.2 in. Hg (670 Pa).

6.10 *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% of 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.

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

6.12 *Analytical Balance Scale,* or equivalent, for measuring weight of dishes and dish racks used in the dishload energy test. It shall have a resolution of at least 0.01 lb (5 g) and an accuracy of 0.01 lb (5 g) or better.

6.13 *Temperature Sensor,* with a range from -20 to 400°F (-30 to 200°C), with a resolution of 0.2°F (0.1°C), an accuracy of 1%, and a response time of less than two seconds for measuring tank temperature, booster and dishwasher inlet temperatures. For dishwashers with steam coil tank or booster heat, the thermocouple probes shall be used for measuring the condensate water outlet temperature. Calibrated K-type 24-GA thermocouple wire with stainless steel sheath and ceramic insulation is the recommended choice for measuring the booster and dishwater inlet temperatures. The thermocouple probe can be fed through a compression fitting so as to submerge exposed junction in booster and dishwasher inlets.

6.14 *Dishracks,* minimum of 30 (60 for flight type machines), 20-inch (in.) × 20-in., peg-type, commercial or acceptable equivalent (e.g.: Metro Mdl P2MO). Each shall weigh 4.4 ± 0.2 lb, and be used in the Washing energy performance test (see 10.8).

6.15 *Plates,* minimum of 300 (600 for flight type machines), 9-in., ceramic glazed plates, weighing 1.3 ± 0.05 lb each.

NOTE 3—Inter-American® mdl #132 are within the specified weight range and are inexpensive.

6.16 *Surface Temperature Thermocouple Probe,* for measuring dish plates and dishracks temperatures. Resolution and accuracy shall be the same as in 6.13.

6.17 *Scale,* for water consumption test, shall be capable of measuring at least 0-100 pounds (lb) with a resolution of at least 0.1 lb and accuracy of ± 0.1 lb or better.

7. Sampling

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

8. Materials

8.1 As specified in 6.14, the dishracks must be made of polypropylene. This material 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.

9. Preparation of Apparatus

9.1 Install the dishwasher in accordance with the dishwasher manufacturer's instructions connected to vent cowl exhaust ducts or a canopy hood extending at least 1 ft beyond the dishwashing machine footprint.. Vent cowl exhaust ducts should operate at a nominal 200 cfm (94.4 L/s) on the entrance side of dishwasher and 400 cfm (188.8 L/s) on the discharge side or in accordance with manufacturer's recommendations, 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.

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, which is within the range of the manufacturer specified input rate, not to exceed 140 ± 2°F. For testing purposes, the dishwasher may be connected to a source of water that is at the manufacturer specified sanitizing rinse temperatures 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(s), motors and controls) is monitored. Connect the booster 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. The dishwasher and booster shall not be monitored as one energy load. Separate monitoring will broaden the usefulness of the data and enhance the accuracy of the results. Internal booster heaters shall be monitored separately and the booster idle energy shall be reported separately from the total idle energy.

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 tank heater (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 electric tank heaters and boosters, confirm, while the elements are energized, that the supply voltage is within ±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. If the machine has several electrical connections, record the voltages separately.

9.7 For gas tank heaters and boosters, during maximum energy input, adjust the gas supply pressure downstream from the appliance's pressure regulator to within ±5 % of the operating manifold pressure specified by the manufacturer. Make adjustments to the dishwasher following the manufacturer's recommendations for optimizing combustion, as applicable.

9.8 Install the flow meter (6.10), such that total water flow to the booster and dishwasher is measured. Install a separate water meter for each water machine connection including tank top-off and auxiliary rinse.

9.9 Install a temperature sensor(s) (6.13) in the tank within ½ in. the factory installed thermostat bulb.

9.10 Install a temperature sensor (6.13) at the inlet to the dishwasher's sanitizing rinse water manifold and in the inlet and outlet the booster heater. Install temperature sensors on each additional water inlet to the machine. The sensors should be installed with the probe immersed in the water.

NOTE 4—Install the thermocouple probes described in 6.13 into sanitizing rinse water manifold for the dishwasher and into the supply water inlet at the booster. The thermocouple probe must be installed so that the thermocouple probe is immersed in the incoming water. A compression fitting should be first installed into the plumbing for both inlets. A junction fitting may need to be installed in the plumbing line that would be compatible with the compression fitting.

9.11 Install dishwashing machine's strip (end) curtains in accordance to manufacturer's recommendations.

9.12 *Preparation of Dishloads:*

9.12.1 This section describes preparation of the 30 (60 for flight type) dishloads (5 stabilization dishloads and 25 test dishloads, 10 and 50 for flight type) and two empty racks to be used in the washing energy performance test.

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

9.12.2.1 The total weight of the dishes,

9.12.2.2 The weight of the (empty) racks, and

9.12.2.3 The initial temperature of the dishes and racks.

9.12.3 The weight of the dry racks is specified in 6.14 as 4.4 ± 0.2 lb per rack. If they weigh greater 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 racks as they will be used during the test. The loading is explained in 9.12.4 and 9.12.5.

9.12.4 Prepare 30 (60 for flight type) dishloads as described in this and the following step (9.12.5). Each dishload must have 13.0 ± 0.5 lb of plates. Ideally, this simply requires ten 9-in plates. If total weight of the ten 9-in. plates does not fall within the range, then change individual plates to achieve the specified weight range.

9.12.5 The plates should be spaced evenly on the racks. The plate spacing shall be the same on all racks.

9.12.6 The bulk temperature of the dishloads before washing must be 75 ± 2°F. This can be accomplished by storing the dishloads in a room with an ambient temperature of 75 ± 2°F. Avoid any circumstances that would result in some dishes being at different temperatures from others, such as being stored in the air path of an HVAC supply register. Determine the bulk temperature using a surface temperature probe (6.16), measuring the temperature of three plates (one front, one center, and one rear) of each dishrack. Average these temperatures to determine the bulk temperature.

9.13 Conveyor and wash pump motor operation may be adjustable. If adjustable calibrate as described in 10.4.

10. Procedure

10.1 *General:*

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

10.1.1.1 Voltage of each electrical connection while elements are energized.

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 of calculation in 11.3.

10.1.2.3 Measure gas temperature.

10.1.2.4 Measured line gas pressure (before pressure regulator).

10.1.2.5 Barometric pressure.

NOTE 5—For a gas appliance, the quality of heat (energy) generated by the compliance 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 6—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 according with accepted laboratory procedures. It is recommended that all testing be performed with gas with a heating value between 1 000 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. Steam condensate temperature and weight should be recorded at the outlet of the machine. 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.).

10.1.5 For each run of every test, confirm that the inlet steam pressure ±5 % of rated "data plate" pressure. If the difference is greater than 5 %, the steam pressure regulator should be adjusted.

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.

10.3 Run two empty dishracks through the machine. 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 the manufacturer's rated sanitizing temperature +15°F. Submerged thermocouple probes may take up to 10 seconds to stabilize during rinse, so the first 10 seconds of rinse temperature data shall be discarded.

10.4 *Wash Tank Pump and Conveyor Motor Calibration:*

10.4.1 Dishwashing machines may be equipped with automatic shut-down that stop the pump(s) and conveyor motors when no racks are being washed. For wash tank pump and conveyor motors that have automatic or adjustable operation time, if user adjustable, set the controls so motors automatically shut off after the manufacturer's recommended (or factory default setting) operating period during washing energy performance testing.

10.4.2 Some dishwasher machines are equipped with a final rinse catch pan (final rinse water saver) to capture the water from the rinse cycle. Set the catch pan drain to manufacturer's recommended setting. Report final rinse catch pan drain setting.

10.4.3 If conveyor speed is user adjustable, set to maximum conveyor speed and report conveyor speed. If not user adjustable, retain factory setting.

10.5 *Tank Heater Maximum Energy Input Rate (i.e. maximum power)*—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(s), follow the steps below. If the tank heater(s) are 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.

10.5.1 For gas and steam powered dishwashers, instruments shall be connected so that the energy (for steam and gas tank heat) consumption of the tank heater is measured separately. Fill the dishwasher tank with water. 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 water. Calculate the total mass of the inlet steam during the test and confirm that it is within 5% of the mass of water measured from the outlet stream. If the difference is greater than 5%, adjust the inlet steam pressure until the difference is less than 5% and rerun the tank heater "maximum energy input rate" (i.e. maximum power) test.

10.5.2 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. In accordance with 11.5, determine the tank heater "maximum energy input rate" (i.e. maximum power) for the dishwasher under test. 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 %, testing shall be terminated.

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

NOTE 7—For some gas appliances, the energy input rate changes as the burner orifices heat up from room temperature to operational temperature. The step described in 10.6.1 is provided to provide a stable test condition. The dishwasher machines sanitizing rinse cycle is run continuously to initiate and keep the booster heater's gas burner(s) on during the booster maximum energy input rate test. 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 rating, follow the steps below while monitoring the total power consumption for all components included in the rating.

10.6.1 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. 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 water 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 booster heater "maximum energy input rate" (i.e. maximum power) test.

10.6.2 Determine the booster "maximum energy input rate" (i.e. maximum power) for the dishwasher under test, in accordance with 11.5. 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 %, testing shall be terminated.

10.7 *Dishwasher Sanitizing Rinse Water Consumption Verification*—The sanitizing and post-sanitizing rinse water consumption test shall be run before the idle energy consumption test. The Dishwasher shall be operated at the same settings (water level, conveyor speed, sanitizing mode, etc.) for both the water consumption test and the idle energy consumption tests. Machines with a post-sanitizing rinse shall separately measure and report the water consumption with the feature turned on and turned off. For fresh water machines, rinse pressure should be set to the manufacturer's rating ±2 psi.

10.7.1 Activate the sanitizing rinse (and the post-sanitizing rinse if the water consumption including post-sanitizing rinse is being measured) for at least one minute. Do not activate any other component(s) of the Dishwasher that consume fresh water. If there is a lever that actuates the sanitizing rinse or post-sanitizing rinse, the lever may be held down to simulate operation, otherwise back to back racks can be sent through the dishwasher continuously. Verify that the pumped sanitizing rinse and post-sanitizing rinse operate correctly. If they do not, terminate testing.

10.7.2 Using a flow meter, measure all water that is sent to the machine 1 min ± 1 second of continuous operation of the sanitizing rinse (and post-sanitizing rinse if the water consumption including post-sanitizing rinse is being measured). Record the exact time. Do not activate any other component(s) of the Dishwasher that consumes water. If there is a lever that actuates the sanitizing rinse or post-sanitizing rinse, the lever may be held down to simulate operation.

10.7.3 Repeat steps 10.7.1 and 10.7.2 three times.

10.7.4 Determine the water consumption, for the dishwasher under test. Report the measured consumption 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.

NOTE 8—Some dishwasher machines are equipped with a final rinse catch pan (final rinse water saver) to capture the water from the rinse cycle. Set the catch pan drain to manufacturer's recommended setting. Report final rinse catch pan drain setting.

10.8 *Washing Energy Performance Test:*

10.8.1 This test will require 30 (60 for flight type) dishloads and two empty dishracks, as described in Sections 6 and 9. Record the weight of the dishes in each dishload and the weight of each of the racks, verify that they meet the weight requirements specified in 9.12.2 and 9.12.3.

10.8.2 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). Each washing energy performance test shall be run in the following sequence:

10.8.2.1 The machine will be conditioned by idling at its operating setpoint for a minimum of 30 minutes followed by running two empty dishracks through the machine.

10.8.2.2 Each washing energy performance test replicate shall consist of six batches of five dishloads per batch. Flight type machines will use ten dishloads per batch. The first batch will be considered a stabilization batch and the remaining five batches will be used to determine dishwasher energy and water consumption and cycle rate.

10.8.2.3 The remaining test replicates shall be run at least 30 minutes after completing the previous test.

10.8.3 Confirm that the minimum wash tank temperature is above the manufacturer's recommended setting.

10.8.4 After the 30 minute minimum idle period, start washing the first empty dishrack.

10.8.5 Commence washing the second empty dishrack as soon as the first dishrack fully exits the dish machine.

10.8.6 After the two empty dishracks have passed completely through the machine, wait for all the tank heaters to cycle off. If the tank heaters are not cycled on at least once after the second empty rack has passed through the machine, then wait for the heaters to cycle on then off again. For multiple tank machines, wait for both wash or power rinse tank heaters to turn off.

10.8.7 Start washing the first batch of dishloads. Load all five dishloads back-to-back with as little space as possible between adjacent racks. For flight type machines ten dishloads will be used per batch; if the conveyor is wider than the dishrack, the racks should be staggered side to side (the first rack should be placed on the left of the conveyor and the next to the right, alternating). Do not push the dishloads through the dishwasher; allow dishwasher to pull the racks through the machine. If the conveyor speed is user adjustable, set to maximum conveyor speed and report the conveyor speed. If it is not user adjustable, retain the factory setting and report the conveyor speed. This is the stabilization batch.

10.8.8 After all 5 (10 for flight type) dishloads (stabilization) completely pass through the machine, wait for the tank heaters to cycle off. If the tank heaters are not cycled on after the fifth full rack has passed through the machine, then wait for the heaters to cycle on then off again.

10.8.9 Commence monitoring elapsed time, energy of the dishwasher and the booster, water consumption, and temperatures of the booster inlet, dishwasher inlet (if using an external booster), sanitizing rinse and wash tank. Temperatures shall be measured at a 30-s interval minimum. Record the minimum tank temperatures experienced during the washing test period at the 30-s intervals. Also record the average rinse temperature while rinse water is flowing as indicated by the water meter. If the rinse temperature decreases before the rinse period is over, the external booster heater is undersized, if a larger booster heater is unavailable, a tank water heater can be used to supply rinse temperature water into the dishwasher.

10.8.9.1 The booster energy shall be logged separately but simultaneously from the dishwasher energy. If possible, submonitor 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.

10.8.10 Load the first test rack of dishes into the machine. Immediately load the remaining four (nine for flight type) dishloads back-to-back with as little space as possible between adjacent racks. Do not push the dishloads through the dishwasher; allow dishwasher to pull the racks through the machine at the manufacturer-specified conveyance speed.

10.8.11 Remove each dishload when the cycle is complete. After the load of five dishracks has exited the machine, wait for all of the tank heaters to cycle off. If all of the tank heaters have not cycled on after the fifth full rack has passed through the machine, then wait for the heaters to cycle on then off again.

10.8.12 Repeat 10.8.8 through 10.8.10 for the remaining batches, for a total of five test batches (25 dishloads total, 50 for flight type).

10.8.13 After removing the last dishload from the last batch, continue monitoring elapsed time, temperature, energy and water consumption until all of the tank heaters have cycled off (all tank heaters must cycle off at least once for a multiple tank machine) after the last rack has passed completely through the machine.

10.8.14 Confirm that the minimum power rinse and auxiliary rinse tank temperatures, if applicable, during the test period are not below the manufacturer's the minimum value specified on the data plate of the machine . If the minimum rinse temperature during the test period was more than 1°F below the data plate tank temperatures, then the test was invalid and must be reported to the manufacturer, if the machine has an external booster heater, its temperature should be readjusted in accordance to 10.8.1. Confirm that the average tank temperature during the entire test (including washing and recovery) is above the minimum value specified on the data plate of the machine plus 5°F. Adjust the thermostat per the manufacturer's instructions if it is user adjustable and repeat the steps in 10.8.1 through 10.8.13. Confirm that the average sanitizing rinse temperature did not go below the data plate minimum while rinse water was flowing. Rinse temperature during the first five seconds shall be discarded due to thermocouple stabilization.

10.8.15 Record the final dishwasher and booster energy, elapsed time, from start of washing the first dishload to when the sanitizing rinse cycled off after the final dishload has passed completely through the machine and the tank heaters have cycled off after the last rack, average dishwasher inlet temperature, average booster inlet temperature, average and minimum tank temperatures, and total water consumption.

10.8.16 Repeat 10.8.4 – 10.8.15 for the remaining replicate tests, waiting 30 minutes between replicate test runs.

10.8.17 In accordance with 11.9, calculate and report the energy consumed per rack. The reported washing energy consumption, water consumption and test cycle rate shall be an average of at least three tests (see Annex A1).

10.9 *Tank Heater Idle Energy Rate (Doors Closed):*

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

10.9.1.1 Allow the Dishwasher to fill and energize the tank heater(s).

10.9.1.2 For single tank machines, with the exterior service door(s) closed, allow the Dishwasher tank to idle for at least one hour for stabilization. Commence monitoring elapsed time, tank temperature, and total energy consumption of the Dishwasher when the tank heater on "cycles" for the first time after the one hour stabilization period.

10.9.1.3 For multiple tank machines, with the exterior service door(s) closed, allow the Dishwasher tanks to idle for at least one hour for stabilization. Commence monitoring the elapsed time and total energy consumption of the Dishwasher and the temperature of all the tanks when one of the tank heaters "off" cycles again after the one hour stabilization period.

10.9.1.4 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.

10.9.1.5 Machines with an automatic "stir feature" (tank pumps engage during idle in order to reduce tank temperature stratification) during idle must have their idle energy recorded separately with the feature enabled and disabled. Machines with an automatic "sleep mode" (the tank heaters shutoff after a certain time has elapsed with no washing) must have idle energy recorded separately with the feature enabled and disabled (if the timer does not exceed 10 consecutive tank cycles or 3 hour idle period). Machines with an automatic "sleep mode" must report the elapsed time for the mode to engage after an empty rack has been washed.

10.9.1.6 Record each tank's minimum tank temperature during the test and confirm that it is at or above the manufacturer's specified minimum tank temperature(s). If the minimum tank temperature(s) during the idle energy test was below the manufacturer's specified tank temperature(s), the test is invalid and the manufacturer needs to be notified. If the tank temperature(s) exceeds 15°F of the measured minimum tank temperature(s), 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 10.9.1.1 through 10.9.1.5. Same tank thermostat setpoints must be used for washing and idle tests. Tank temperatures are lower during washing tests, so the thermostat must be calibrated to meet minimum washing test temperatures before conducting the idle.

10.9.2 If the Dishwasher has an internal booster heater:

10.9.2.1 The booster idle energy rate shall be reported separately from the total idle energy rate.

10.9.2.2 If possible, sub-meter the idle energy rate of the booster heater during the Dishwasher idle energy test described in steps 10.9.1 above.

10.9.2.3 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, the duration of this booster idle energy test must match the duration idle energy test for tank heaters. Repeat steps 10.9.1.1 through 10.9.1.5 above, but record the energy consumption of the booster heater instead of the total Dishwasher energy consumption.

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

10.9.2.5 Booster temperature setpoints during idle tests must be the same as during the washing tests.

10.10 *External Booster Idle Energy Rate:*

10.10.1 The booster idle energy rate test is run using the booster heater thermostat set point used in the washing energy performance test to deliver average temperature of 181 ± 1°F at the final rinse water manifold. If the dishwasher requires higher booster temperatures in order to meet sanitizing rinse criteria in 10.8.9, it must be set for that temperature no greater than 195°F. If the unit has a factory supplied internal booster, the factory setting of the booster must be used. Allow the booster to idle (no water drawn from it) for a minimum of 1 h. Commence monitoring energy consumption and time after the heater cycles "on". Continue for a minimum of 3 h or 10 complete cycles, whichever is longer.

10.10.2 In accordance with 11.7, calculate and report the booster heater idle energy rate.

11. Calculation and Report

11.1 *Test Dishwasher:*

11.1.1 Summarize the physical and operating characteristics of the dishwasher using the Specification F858. Describe the physical and operating characteristics of the booster heater, and if needed, describe other design or operating characteristics of the dishwasher or booster that may facilitate interpretation of the test results. Report final rinse water catch pan drain setting and conveyor speed if adjustable.

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 (10.5).

11.3.2 Calculate the energy consumed based on the following equation.

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

where:

E_{gas} = energy consumed by the appliance,
HV = higher heating value,
= energy content of gas measured at standard conditions, Btu/ft^3

V = actual volume of gas corrected for temperature and pressure at standard conditions, ft^3.

Eq 2 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.

$$V_{measured} \times T_{cf} \times P_{cf} \tag{2}$$

where:

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

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

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

P_{cf} = pressure correction factor,

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

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

NOTE 9—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Standard conditions using Practice D3588 are 14.73 pounds per square inch absolute (psia) (101.5 kPa) and 60°F (519.67 degrees Rankine (°R), (288.71 °K)).

11.4 *Steam Coil Energy Calculations:*

11.4.1 *Inlet Steam Mass Flow Rate:*

11.4.1.1 Find the measured pressure and temperature values for the inlet steam 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.

11.4.1.2 Calculate the mass flow rate for each data point as follows:

$$\dot{M}_{Steam} = \dot{V}_{Steam} \times \rho_{Steam} \tag{3}$$

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.

11.4.2 *Inlet Steam Total Mass:*

$$M_{Total} = \sum_{i=1}^{N} \left(\dot{M}_{Steam,i} \times t_i\right) \times \frac{1\ \text{hour}}{3600\ \text{seconds}} \tag{4}$$

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).

11.4.3 *Inlet Steam Enthalpy:*

11.4.3.1 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.

11.4.4 *Outlet Water Enthalpy:*

11.4.4.1 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.

11.4.4.2 Calculate the enthalpy of the outlet water for each data point as follows:

$$H_{Outlet} = H_{Saturated} - (C_p \times (T_{Saturated} - T_{Measured})) \tag{5}$$

where:

H_{Outlet} = enthalpy of dishwasher outlet stream (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).

11.4.5 *Instantaneous Energy Consumption:*

11.4.5.1 Calculate the energy for each data point as follows:

$$E_i = \dot{M}_{Steam,i} \times (H_{Inlet,i} - H_{Outlet,i+t_{delay}}) \times t_i \times \frac{1\ \text{hour}}{3600\ \text{seconds}} \tag{6}$$

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).

11.4.6 *Total Energy Consumption:*

$$E_{Total} = \sum_{i=1}^{N} (E_i) + E_{Electric} \tag{7}$$

where:

E_{Total} = total energy consumption during test (active or idle) (Btu),

[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.

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}.

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

11.5.1 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.

11.5.2 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:

$$E_{input\ rate} = \frac{E \times 60}{t} \tag{8}$$

where:

$E_{input\ rate}$ = 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.

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

11.6.1 Calculate and report the tank heater idle energy rate and internal booster heater idle energy rate (Btu/h or kW) based on the following equation.

$$E_{idle\ rate} = \frac{E \times 60}{t} \tag{9}$$

where:

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

11.7 *External Booster Heater Idle Energy Rate:*

11.7.1 Calculate and report the booster heater idle energy rate (Btu/h or kW) based on the following equation.

$$E_{idle\ rate} = \frac{E \times 60}{t} \tag{10}$$

where:

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

11.8 *Water Consumption:*

11.8.1 Racks per Hour for Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Conveyor Type (excluding Flight Type) Machines:

$$\text{Racks per Hour} = \frac{CS \times \frac{60\ \text{minutes}}{\text{hour}}}{RL \times \frac{1\ \text{ft}}{12\ \text{in}}} \tag{11}$$

where:

Racks per Hour = number of racks washed per hour, truncated to the next lowest whole number,
RL = rack length (use 20 inches), and
CS = manufacturer specified maximum conveyor speed in feet per minute.

11.8.2 Gallons per Hour for Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Conveyor Type (including Flight Type) Machines:

$$\text{Gallons per Hour} = \frac{\sum_{n=1}^{5} \text{Measured Flow of water for test run n (gal per min)}}{5\ \text{test runs} \times \frac{1\ \text{hour}}{60\ \text{minutes}}} \tag{12}$$

where Measured Flow of water for test run n = flow of water measured by flow meter from one minute of sanitizing rinse activation (and post-sanitizing rinse solenoid activation if the water consumption including post-sanitizing rinse is being measured).

11.8.3 Gallons per Rack for Fresh Water or Pumped Water Sanitizing and Post-Sanitizing Rinse Conveyor Type (excluding Flight Type) Machines:

$$\text{Gallons per Rack} = \frac{\text{Gallons per Hour}}{\text{Racks per Hour}} \tag{13}$$

where:

Gallons per Hour = water use in gallons per hour, as calculated in section 11.8.1, and
Racks per Hour = number of racks washed per hour, truncated to the next lowest whole number, as calculated in section 11.8.2.

11.9 *Washing Energy Performance Test:*

11.9.1 Calculate and report each of the following:

11.9.1.1 Dishwasher electric energy per rack (kWh),

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

11.9.1.3 Total electric energy per rack (kWh),

11.9.1.4 Dishwasher gas energy per rack, if applicable (Btu),

11.9.1.5 Booster gas energy per rack, if applicable (Btu),

11.9.1.6 Total gas energy per rack, if applicable (Btu),

11.9.1.7 Water consumption per rack (gal), and

11.9.1.8 Washing Energy Cycle rate (racks/h).

11.9.2 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 test dishload, until the dishwasher tank heater has cycled off after the final test dishload has passed completely through the machine.

11.9.3 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.

11.9.4 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 Test, Btu,
Q_w	=	the quantity of hot water consumed by the dishwashing machine during the Washing Energy 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 For the washing energy rate, washing water consumption rate, and test cycle rate, the percent uncertainty in each result has been specified to be no greater than ±10 % based on at least three test runs.

12.1.1.2 The repeatability of each remaining parameter is being determined.

12.1.2 *Reproducibility (Multiple Laboratories)*—The interlaboratory precision of the procedure in this test method for measuring each reported parameter is being determined.

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

13. Keywords

13.1 booster; conveyor; dishload; dishrack; dishwasher; hot-water sanitizing; tank heater; warewasher

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DETERMINING THE UNCERTAINTY IN REPORTED TEST RESULTS

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

A1.1 For the 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 must be no greater than ±10 % before any of the parameters for that washing energy performance test run can be reported.

A1.2 The uncertainty in a reported result is a measure of its precision. For example, if the cycle rate for the dishwasher is 30 racks/h, the uncertainty must 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—Section A1.5 shows how to apply this procedure.

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

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

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

TABLE A1.1 Uncertainty Factors

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

where:

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

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

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

where:

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

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

NOTE A1.4—The *"A"* quantity is the sum of the squares of each test result, and the *"B"* quantity is the square of the sum of all test results multiplied by a constant (1/3 in this case).

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

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

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

$$U_3 = 2.48 \times S_3$$

where:

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

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

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

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

where:

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

A1.4.4 *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:

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

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

A1.4.5 *Step 5*—Run a fourth test or the energy per rack or cycle rate results if the percent uncertainty is 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 test results using a calculator or the following formulas:

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

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

where:

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

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

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

where:

S_4 = standard deviation of results for four test runs,
A_4 = $(X_1)^2 + (X_2)^2 + (X_3)^2 + (X_4)^2$, and
B_4 = $(1/4) \times (X_1 + X_2 + X_3 + X_4)^2$.

A1.4.7 *Step 7*—Calculate the absolute uncertainty in the average for each parameter listed in Step 1. Multiply the standard deviation calculated in Step 6 by the Uncertainty Factor for four test results from Table A1.1.

A1.4.7.1 The formula for the absolute uncertainty (four test 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 = the uncertainty factor for four test runs (Table A1.1).

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

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

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

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.

A1.4.10.1 The formula for the average (*n* test runs) is as follows:

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

where:

n = number of test runs,

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

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

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

where:

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

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

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

where:

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

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

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

where:

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

When the percent uncertainty, $\%U_n$, is less than or equal to ±10 % for the energy per rack and cycle rate, report the average for these parameters along with their corresponding absolute uncertainty, U_n, in the following format:

$$Xa_n \pm U_n \quad (A1.15)$$

NOTE A1.5—The researcher may compute a test result that deviates significantly from the other test results. Such a result should be discarded only if there is some physical evidence that the test run was not performed according to the conditions specified in this 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 dishrack was not within specification. To assure 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
Run No. 1	33.8 racks/h
Run No. 2	34.1 racks/h
Run No. 3	31.0 racks/h

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

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

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

$$Xa_3 = (1/3) \times (33.8 + 34.1 + 31.0),$$

$$Xa_3 = 33.0 \text{ racks/h}$$

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

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

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

$$A_3 = 3266$$

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

$$B_3 = (1/3) \times [(33.8 + 34.1 + 31.0)^2],$$

$$B_3 = 3260$$

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

$$S_3 = (1/\sqrt{2}) \times \sqrt{(3266 - 3260)}, \quad (A1.18)$$

$$S_3 = 1.71 \text{ racks/h}$$

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

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

$$U_3 = 2.48 \times 1.71,$$

$$U_3 = 4.24 \text{ racks/h}$$

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

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

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

$$\%U_3 = 12.9\%$$

A1.5.5 Run a fourth test. Since the percent uncertainty for the cycle rate 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 is 32.5 racks/h.

A1.5.6 *Step 4*—Recalculate the average and standard deviation for the CR using the fourth test result:

A1.5.6.1 The new average CR is as follows:

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

$$Xa_4 = (1/4) \times (33.8 + 34.1 + 31.0 + 32.5),$$

$$Xa_4 = 32.9 \text{ racks/h}$$

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

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

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

$$A_4 = 4323$$

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

$$B_4 = (1/4) \times [(33.8 + 34.1 + 31.0 + 32.5)^2],$$

$$B_4 = 4316$$

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

$$S_4 = (1/\sqrt{3}) \times \sqrt{(4323 - 4316)}, \quad (A1.23)$$

$$S_4 = 1.42 \text{ racks/h}$$

A1.5.7 *Step 5*—Recalculate the absolute uncertainty using the new standard deviation and uncertainty factor.

$$U_4 \; 1.59 \times S_4, \tag{A1.24}$$

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

$$U_4 = 2.25 \text{ racks/h}$$

A1.5.8 *Step 6*—Recalculate the percent uncertainty using the new average.

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

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

$$\%U_4 = 6.8\,\%$$

A1.5.9 *Step 7*—Since the percent uncertainty, $\%U_4$, is less than ± 10 %, the average for the cycle rate is reported along with its corresponding absolute uncertainty, U_4 as follows:

$$\text{CR}: 32.9 \pm 2.25 \text{ racks/h} \tag{A1.26}$$

A1.5.9.1 The CR can be reported assuming 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 X.1 Dishwasher (check one for each classification)

ASTM F858-96 Hot Water Sanitizing Commercial Dishwashing Machines, Single Tank, Conveyor Rack Type. Classification.__________

Additional description of operational characteristics:

____

____

____

____

____

____

Report Conveyor Speed ____________ (ft/min)
Final Catch Pan Drain Setting ________

Manufacturer's Nameplate Information

Tank Heater Rated Input __________ (Btu/h, kW or lb_{steam}/h)
Pump Motor Horsepower __________
Voltage _________
Phase _________

Booster:

FIG. X1.1 Sample Results Reporting Sheets

Make ____________
Model ____________
Temp Rise / GPM ____________
Rated Input ______________ (Btu/h, kW or lb_{steam}/h)

Section X.2 Apparatus

____ Check if testing apparatus conformed to specifications in section 9.

Deviations ____

____

____

____

____

____

____

Testing Voltage __________ Volts

For Gas appliances, if applicable:
Gas Heating Value __________ Btu/ft^3
Barometric Pressure __________ psia
Gas Temperature __________ °F
Gas Pressure __________ psia

Section X.3 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) __________

FIG. X1.1 Sample Results Reporting Sheets *(continued)*

Percent Difference between Measured and Rated _______ %

Section X.4 Tank Heater Idle Energy Rate

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

Average idle temperature (°F) _______

Section X.5 Booster Heater Idle Energy Rate

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

Section X.6 Washing Energy Test

Dishwasher Inlet Water Temperature	_______________	(°F)
Booster Heater Inlet Water Temperature	_______________	(°F)
Washing Energy Test Time	_______________	(min)
Dishwasher Energy Consumption	_______________	(Btu or kWh)
Booster Heater Energy Consumption	_______________	(Btu or kWh)
Primary Hot Water Energy	_______________	(Btu)
Average Tank Temperature(s)	_______________	(°F)
Minimum Tank Temperature(s)	_______________	(°F)
Water Consumption	_______________	(gal)
Test Cycle Rate	_______________	(racks/h)
Total Dishwashing Energy Consumption per Rack	_______________	(Btu/rack or kWh/rack)
(including dishwasher, booster heater and primary hot water heating energy)		
Water Consumption per Rack	_______________	(gal/rack)

FIG. X1.1 Sample Results Reporting Sheets *(continued)*