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An American National Standard

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. Dishwasher tank heaters are evaluated separately from the booster heater.

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 (10.2).

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

1.3.1.3 Final sanitizing rinse water consumption calibration (10.4).

1.3.1.4 Booster temperature calibration, if applicable (10.5).

1.3.1.5 Wash tank temperature calibration (10.6).

1.3.1.6 Wash tank pump and conveyor motor calibration (10.7).

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:*

3.1.1 *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.

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

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

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

3.1.4.1 *Discussion*—The machine shall be capable of removing physical soil from properly racked and prescraped items, and sanitizing multiple-use eating and drinking utensils.

[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.

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

3.1.5.1 *Discussion*—Two empty dish racks are run through the dishwasher prior to washing the first dishload to condition the dishwasher for testing as specified in the Washing Energy Test (see 10.8).

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

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

3.1.7.1 *Discussion*—All tank heaters must cycle off at least once for a multiple tank machine.

3.1.8 *tank heater idle 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.

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

4. Summary of Test Method

4.1 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, all further testing ceases, and the manufacturer shall be contacted. The manufacturer may make appropriate changes or adjustments to the dishwasher.

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 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 must be performed at both voltages and the results reported accordingly.

4.2 Wash tank and booster temperatures are retained at the manufacturer's factory settings.

4.3 Water consumption is adjusted in accordance with 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 of the NSF rating or the manufacturer's rating if not listed to NSF standards, then the manufacturer shall be contacted.

4.4 The tank heater energy rate is determine 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 by washing ten racks loaded with a specified quantity of dishes.

4.7 Water consumption (gal/h (L/h)) 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 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 dishwashers energy consumption.

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

6. Apparatus

6.1 *1 or 2 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 % of the measured value for any demand greater than 100 W. For any demand less than 100 W, the meter shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 10 %.

6.2 *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 0.01 ft^3 (0.0003 m^3), and a maximum uncertainty no greater than 1 % of the measured value for any demand greater than 2.2 ft^3/h (0.06 m^3/h). If the meter is used for measuring the gas consumed by pilot lights, it shall have a resolution of a least 0.01 ft^3 (0.0003 m^3) and have a maximum uncertainty of at least 0.01 ft^3 (0.0003 m^3) and have a maximum uncertainty no greater than 2 % of the measured value.

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), and a maximum uncertainty of 1 % of the measured value.

6.4 *Pressure Gage*, for measuring pressure of steam to steam coils and steam injector, shall have a resolution of 0.5 psig (3.4 kPa), and a maximum uncertainty of 1 % of the measured value.

6.5 *Canopy Exhaust Hood or Vent Cowl Exhaust Ducts*, measured in agreement with manufacturers requirements. Vent cowl exhaust ducts shall operate at a nominal 200 cfm (94.4 L/s) on entrance side of dishwasher and 400 cfm (188.8 L/s) on exit side or in accordance with manufacturer's recommendation, if applicable. Canopy exhaust hood shall use a 3-ft by 6-ft configuration operating at the dishwashing machine manufacturer's specified ventilation rate. Report the ventilation rate and ventilation exhaust type.

6.6 *Pressure Gage*, for monitoring natural gas pressure, shall have a range of 0 to 10 in. H_2O (zero to 2.5 kPa), a resolution of 0.1 in. H_2O (125 Pa), and a maximum uncertainty of 1 % of the measured value.

6.7 *Temperature Sensor*, for measuring natural gas temperature in the range of 50 to 100°F (10 to 40°C), with a resolution of 0.5°F (0.3°C) and an uncertainty of ±1 °F (0.5°C).

6.8 *Barometer*, for measuring absolute atmospheric pressure, to be used for adjustment of measured natural gas volume to standard conditions, shall have a resolution of 0.2 in. Hg (670 Pa), and an uncertainty of 0.2 in. Hg (670 Pa).

6.9 *Flow Meter*, for measuring water consumption of the dishwasher. Shall have a resolution of 0.01 gal (40 mL), and an uncertainty of 0.01 gal (40 mL), at flow rate as low as 0.2 gpm (13 mL/s).

6.10 *Stop Watch*, with a 0.1-s resolution.

6.11 *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 0.01 lb (5 g) and an uncertainty of 0.01 lb (5 g).

6.12 *Calibrated Exposed Junction Thermocouple Probes*, with a range from -20 to 400°F (-30 to 200°C), with a resolution of 0.2°F (0.1°C) and an uncertainty of 1.0°F (0.5°C), for measuring tank temperature, booster and dishwater inlet temperatures. 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.

6.13 *Dishracks*, minimum of 12, Metro Mdl P2MO, 20-in. × 20-in., peg-type, commercial or acceptable equivalent. Each shall weigh 4.6 ± 0.1 lb, and used in the Washing Energy Test (see 10.8).

6.14 *Plates*, minimum of 150, 9-in., ceramic glazed plates, weighing an average of 1.3 ± 0.05 lb each. If plates meeting this criteria cannot be obtained, then it will be necessary to acquire saucers, as specified in 6.15. See 9.11 prior to obtaining these plates.

NOTE 2—Inter-American® mdl #132 are within the specified weight range and are inexpensive.

6.15 *Saucers*, minimum of 30, glazed saucers, weighing less than 0.5 lb each. See 9.12 for an explanation of why these may be required.

6.16 *Surface Temperature Thermocouple Probe*, for measuring dish plates and dishracks temperatures. Resolution and uncertainty shall be the same as in 6.12.

7. Sampling

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

8. Materials

8.1 As specified in 6.13, 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 (and the letters "PP" below it).

9. Preparation of Apparatus

9.1 Install the dishwasher in accordance with the dishwasher manufacturer's instructions under a 3-ft by 6-ft canopy exhaust hood or connect to vent cowl exhaust ducts. 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 exit 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 ±3°F of its input temperatures, not to exceed 140 ± 3°F.

9.4 Connect the dishwasher (including tank heater, motors and controls) and booster to calibrated energy test meters. 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.

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.

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

9.7 For gas tank heaters and boosters, during maximum energy input, adjust the gas supply pressure downstream from the appliance's pressure regulator to within ±2.5 % of the operating manifold pressure specified by the manufacturer. Make adjustments to the dishwasher following the manufacturer's recommendations for optimizing combustion, as applicable.

9.8 Install the flow meter (6.9), such that total water flow to the booster and dishwasher is measured.

9.9 Install a temperature sensor(s) (6.12) in the wash tank near the thermostat bulb.

9.10 Install a temperature sensor (6.12) at the inlet to the dishwasher's final rinse water manifold and in the inlet to the booster heater. The sensors should be installed with the probe immersed in the water.

NOTE 3—Install the thermocouple probes described in 6.12 into final 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 ten dishloads and two empty racks to be used in the washing energy test.

NOTE 4—Though the washing energy test requires 40 dishloads, the test may be conducted with ten dishloads as long as each load is cooled to 75 ± 2°F prior to being loaded into the dishwasher.

9.12.2 An important feature of the washing energy test is that every dishwasher be subjected to the same thermal load. To accomplish this feature, the tested 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 racks is specified in 6.13 as 4.6 lb or greater. If they weigh greater than 4.7 lb, trim away material until they weigh 4.6 ± 0.1 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 ten dishloads as described in this and the following step (9.12.5). The ten dishloads must have 19.5 ± 0.75 lb of plates. Ideally, this simply requires fifteen 9-in plates. If total weight of the fifteen 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.

9.12.5 The plates and saucers should be spaced evenly on the 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 at least 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 10.7.

10. Procedure

10.1 *General*:

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

10.1.1.1 Voltage while elements are energized.

10.1.1.2 Measure peak input rate during or immediately prior to test, which does not include motor starting load.

10.1.2 For dishwashers with a gas powered tank heater or booster the following shall be obtained and recorded for each run of every test.

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.

10.1.2.6 Measured peak input rate according to 10.2.

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 or steam injectors for tank heat, the supplied steam pressure, steam temperature at dishwasher inlet, steam temperature at dishwasher outlet, and average flow rate shall be recorded for each run of every test.

10.1.5 For each run of every test, confirm that the peak input rate is within ±5 % of rated "nameplate" input. If the difference is greater than 5 %, testing shall be terminated and contact the manufacturer. The manufacturer shall make appropriate changes or adjustments to the dishwasher.

10.2 *Tank Heater Maximum Energy Input Rate*:

10.2.1 *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 and proceed with 10.2.2.

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 10.2.1 is provided to minimize this effect.

10.2.2 Fill the dishwasher tank with 70 ± 10°F water, and energize the tank heaters. Commence monitoring time and energy consumption. When the heaters cycle off, note the time and total energy consumption. For electric tank heaters, a direct measurement of power may be substituted for the monitoring of time and energy consumption.

10.2.3 In accordance with 11.4, determine the tank heater maximum energy input rate for the dishwasher under test. Report the measured input rate and confirm that it is within 5 % of the nameplate rated input. If the difference is greater than 5 %, testing shall be terminated and the manufacturer contacted. The manufacturer may make appropriate changes or adjustments to the dishwasher.

10.3 *Booster Maximum Energy Input Rate*:

NOTE 8—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 10.3.1 is provided to provide a stable test condition. The dishwasher machines final 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.

10.3.1 Open the dishwasher drain. Close the door(s) and initiate the final rinse. For electric booster heaters, after the booster cycles on, monitor 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 time and energy consumption.

10.3.2 Determine the booster maximum energy input rate for the dishwasher under test, in accordance with 11.4. Report the measured input rate and confirm that it is within 5 % of the nameplate rated input. If the difference is greater than 5 %, testing shall be terminated and the manufacturer contacted. The manufacturer shall make appropriate changes or adjustments to the booster.

10.4 *Dishwasher Final Sanitizing Rinse Water Consumption Verification*:

10.4.1 Adjust pressure regulator in water supply line for final sanitizing rinse to 20 ± 1 psi while final rinse water is flowing. Cold water (70 ± 10°F) shall be used for the dishwasher water consumption verification.

10.4.2 Measure water consumption using the flowmeter specified in 6.9. Run final rinse cycle for one minute and record water consumption (gal/min).

10.4.3 Confirm that the water consumption in gallons per minute is within ±3 % of the NSF-rated water consumption or the manufacturer's rating if not listed to NSF standards. If it is not, testing shall be terminated and the manufacturer contacted. The manufacturer shall make appropriate changes or adjustments to the dishwasher.

10.5 *Booster Temperature Calibration (External Booster Heaters)*:

10.5.1 While monitoring the water inlet of the booster heater and dishwater (rinse manifold) temperature, initiate a dishwasher cycle. 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 manifold (measured only during the rinse) is 181 ± 1°F on five consecutive cycles. If the machine is supplied with an internal booster heater, retain the factory setting of the thermostat.

10.6 *Wash Tank Temperature Verification*:

10.6.1 Fill the dishwasher tank and activate the tank heaters. Set the tank heater thermostat to the manufacturer's recommended setting.

10.7 *Wash Tank Pump and Conveyor Motor Calibration*:

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

10.7.2 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.

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

10.8 *Washing Energy Performance Test*:

10.8.1 This test will require 40 dishloads and two empty dishracks, as described in Sections 3, 6, and 9. Record the weight of the dishes and the weight of the racks. Record the make and model of the dishracks and dishes.

10.8.2 The bulk temperature of the dishloads must be 75 ± 2°F. Determine the bulk temperature using a surface temperature probe (6.16) and measuring the temperature of at least three plates (one front, one center, and one rear). Average these temperatures to determine the bulk temperature.

10.8.3 Allow the dishwasher to idle (no washing taking place) for 1 h.

10.8.4 Using the surface temperature probe measure the temperature of a dish in the front, middle, and rear of each dishload. Record the average of these temperature and confirm that it is 75 ± 2°F.

10.8.5 After the 1-h idle period, observe the tank heaters and tank temperature. After the tank heater cycles off, start washing the first empty dishrack. Immediately after completion of the final rinse cycle (do not remove rack before dishwasher is finished conveying the rack), remove the first empty dishrack.

10.8.6 Commence washing the second empty dishrack as soon as the first dishrack enters the dish machine. After the two dishracks have passed completely through the machine, wait for the tank heaters to cycle off. If the tank heaters are not cycled on after the second empty rack has passed through the machine, then wait for the heaters to cycle on then off again.

10.8.7 Commence monitoring time, energy of the dishwasher and the booster, water consumption, and temperatures of the booster inlet, final rinse and wash tank. Temperatures shall be measured at a 30-s interval minimum between measurements. Note the minimum tank temperature experienced during the washing period.

10.8.8 Load the first full rack of dishes into the machine. Immediately load the remaining racks back-to-back.

10.8.9 Remove each dishload when the cycle is complete. If less than 40 individual dishloads are used for the testing, then cool each dishload down to 75 ± 2°F before it is loaded into the machine.

10.8.10 After removing the last dishload, continue monitoring time, temperature, energy and water consumption until the final rinse turns off after the last dishload has been cycled through the machine. Monitor the time until the tank heaters have cycled off (all tank heaters must cycle off at least once for a multiple tank machine). Note the time for the tank heaters to recover after the last dishload has been cycled through the machine.

10.8.11 Confirm that the minimum wash, power rinse and auxiliary rinse tank temperatures, if applicable, during the test are above the manufacturer's rated tank temperature as listed on the nameplate. If the minimum tank temperature during the washing energy test was below the manufacturer's nameplate rated tank temperature, then the test was invalid and must be reported to the manufacturer. After the manufacturer makes adjustments, repeat 10.8.1 through 10.8.10. Confirm that the final rinse temperature did not go below the nameplate minimum.

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

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

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

10.9.1 Tank heater idle energy rate test is to run using tank heater thermostat set point from washing energy performance test. Allow the dishwasher to fill, and energize the tank heaters.

10.9.2 With the exterior service door(s) closed, allow the dishwasher tank to idle for at least two tank heater "on" cycles. Commence monitoring elapse time, temperature, and energy consumption as the tank heater "on" cycles for the second time. Allow the dishwasher to idle for 3 h. Record final time and energy consumption.

10.9.3 Confirm that the minimum wash tank temperature during the test is above the manufacturer's rated wash tank temperature as listed on the nameplate. If the average tank temperature during the washing energy test was below the manufacturer's nameplate rated wash tank temperature, then the test was invalid and must be repeated. Adjust the thermostat per the manufacturer's instructions and repeat 10.9.1 and 10.9.2.

10.9.4 In accordance with 11.5, calculate and report the tank heater idle energy rate.

10.10 *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 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. Continue for a minimum of 5 h.

10.10.2 In accordance with 11.6, 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 (10.2).

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.

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

where:

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

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

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

P_{cf} = pressure correction factor,

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

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

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 psia (101.5 kPa) and 60°F (519.67 °R, (288.71 °K)).

11.4 *Booster and Tank Heater Energy Input Rate*:

11.4.1 Report the manufacturer's nameplate energy input rate in Btu/h for a gas booster or tank heater and in kW for an electric booster or tank heater.

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

$$E_{input\ rate} = \frac{E \times 60}{t} \tag{3}$$

where:

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

11.5 *Tank Heater Idle Energy Rate*:

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

$$E_{idle\ rate} = \frac{E \times 60}{t} \tag{4}$$

where:

$E_{idle\ rate}$ = idle energy rate, Btu/h or kW,