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An American National Standard

Standard Test Method for Energy Performance of Single-Rack Hot Water Sanitizing, Door-Type Commercial Dishwashing Machines[1]

This standard is issued under the fixed designation F 1696; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the evaluation of the energy consumption of single-rack, hot water sanitizing, door-type commercial dishwashers (hereafter referred to as dishwashers). This includes under the counter single rack, hot water sanitizing, door type commercial dishwashing machines. This test method excludes single temperature door-type machines. Dishwasher tank heaters are evaluated separately from the booster heater. Dishwashers may have a remote or self-contained booster heater. This test method does not address cleaning or sanitizing performance.

1.2 The following procedures are included in this test method:

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

1.2.1.1 Maximum energy input rate of the tank heaters (see 10.2).

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

1.2.1.3 Water consumption calibration (see 10.4).

1.2.1.4 Booster temperature calibration, if applicable (see 10.5).

1.2.1.5 Wash tank temperature calibration (see 10.6).

1.2.2 *Energy Usage and Cycle Rate Performance Tests*:

1.2.2.1 Washing energy test (10.7).

1.2.2.2 Tank heater idle energy rate (door(s) open and door(s) closed) (see 10.8).

1.2.2.3 Booster idle energy rate, if provided (see 10.9).

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

1.4 *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:*

F 857 Specification for Hot Water Sanitizing Commercial Dishwashing Machines, Stationary Rack Type[2]

2.2 *NSF Standards:*[3]

NSF, Listings Food Equipment and Related Products, Components and Materials

Standard Number 3 Commercial Spray-Type Dishwashing Machines

2.3 *ASHRAE Document:*[4]

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

3. Terminology

3.1 *Definitions:*

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

3.1.3 *dishwasher*, *n—for this test method*, a heat-sanitizing commercial, single rack, door-type dishwasher.

3.1.4 *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 is determined to check whether the dishwasher is operating at the manufacturer's rated input. If the measured input rate is not within 5 % of the rated input, all further testing ceases and the manufacturer is contacted. The manufacturer may make appropriate changes or adjustments to the dishwasher.

[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] *Annual Book of ASTM Standards*, Vol 15.08.

[3] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140.

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

NOTE 1—It is the intent of the testing procedure herein to evaluate the performance of a dishwasher at its rated gas pressure or electric voltage. If an electric unit is rated dual voltage (that is, designed to operate at either 208 or 240 V with no change in components), the voltage selected by the manufacturer or tester, or both, shall be reported. If an dishwasher is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the unit (for example, recovery time) may differ at the two voltages.

4.2 The wash tank and booster temperature are calibrated to the manufacturer's recommendations.

4.3 The water consumption is adjusted per the manufacturer's recommendations. 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 determined at idle, that is, when the tank temperature is being maintained, but no washing is taking place. This test is run both with the door(s) closed and with the door(s) left open.

4.5 The booster heater idle energy rate is determined.

4.6 The dishwasher and booster energy consumption per rack of dishes is determined by washing 10 racks loaded with a specified quantity of dishes.

5. Significance and Use

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

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

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

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

6. Apparatus

6.1 *One or Two 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 *One or Two Gas Meters*, for measuring the gas consumption of tank heater or booster heater, 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 the pilot lights, it shall have a resolution of a least 0.01 ft^3/(0.0003 m^3) and have a maximum error of at least 0.01 ft^3(0.0003 m^3) and have a maximum error no greater than 2 % of the measured value.

6.3 *One or Two Steam Flow Meters*, for measuring the flow of steam to tank heaters and or booster heater. They 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 the pressure of steam to steam coils. It 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*, mounted in agreement with manufacturer's requirements and operating at a nominal 300 to 500 cfm ventilation rate or in accordance with the manufacturer's recommendation, if applicable. Report the ventilation rate.

6.6 *Pressure Gage*, for monitoring natural gas pressure. It shall have a range of 0 to 10 in. H_2O (0 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°F 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. It 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. It 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°F 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 and booster and dishwasher inlet temperature. Calibrated Type K Z4 GA thermocouple wire with stainless steel sheath and ceramic insulation is the recommended choice for booster and dishwasher inlet temperature. The thermocouple probe can be fed through a compression fitting so as to submerse the exposed junction in the booster and dishwasher inlets.

6.13 *Dishracks*, 12, Metro Mdl P2MO, 20 in. by 20 in., peg type, commercial, or acceptable equivalent. They shall weigh 4.6 ± 0.1 lb and are used in the washing energy test.

6.14 *Plates*, 100, 9 in., ceramic-glazed, 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[5] are within the specified weight range and are inexpensive.

[5] Available from Keystone Restaurant Supply, 491 W. San Carlos St., San Jose, CA 95110.

6.15 *Saucers*, 20, ceramic-glazed, weighing less than 0.5 lb each. See 9.11 for an explanation of why these may be required.

6.16 *Surface Temperature Thermocouple Probe*, for measuring the plate temperature. Resolution and uncertainty shall be the same as in 6.12.

7. Materials

7.1 As specified in 6.13, the dishracks must be made of polypropylene. This is required because the test method assumes a specific heat of 0.39 Btu/lb°F. One verification that a rack is polypropylene is if it has the recycling symbol ±x5 on it (and the letters "PP" below it).

8. Sampling

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

9. Preparation of Apparatus

9.1 Install the dishwasher in accordance with the manufacturer's instructions under a 3-ft by 3-ft canopy exhaust hood, operating at a nominal ventilation rate of 300 to 500 cfm or in accordance with manufacturer's recommendation, if applicable. 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 that is within ±3°F of its rated input temperature (not to exceed 140 ± 3°F).

9.4 Connect the dishwasher and booster to calibrated energy test meters. The dishwasher and booster may be monitored as one energy load, but it is preferable to monitor them separately. Separate monitoring will broaden the usefulness of the data and enhance the accuracy of the result.

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

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

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

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

9.10 Install a temperature sensor (see 6.12) in the dishwasher rinse water inlet, and in the booster inlet. The sensors should be installed with the probe immersed in the water.

NOTE 3—Install the thermocouple probes described in 6.12 into the water inlets for dishwasher rinse and booster. The thermocouple probe shall be installed so that the thermocouple is immersed in the incoming water. A compression fitting should be installed first into the plumbing for both inlets. A junction fitting may be installed in the plumbing line that would be compatible with the compression fitting.

9.11 *Preparation of Dish-Loads*:

9.11.1 This section describes preparation of ten dishloads and two empty racks to be used in the washing energy test.

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

9.11.2.1 the total weight of the dishes,

9.11.2.2 the weight of the (empty) racks, and

9.11.2.3 the initial temperature of the dishes and racks.

9.11.3 The weight of the racks is specified in 6.13 as 4.6 lb or greater. If they weigh more than 4.6 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 rack as they will be used during the test. The loading is explained in 9.11.4 and 9.11.5.

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

9.11.5 Space the plates and saucers evenly on the racks.

9.11.6 The bulk temperature of the dishloads must be 75 ± 2°F. This can be accomplished by storing the dishloads together in a room with an ambient temperature of 75 ± 2°F. Avoid any circumstances that would result in some dishes being at different temperature from others, such as being stored in the air path of an HVAC supply register. Determine the bulk temperature using a surface temperature probe (6.16), 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.

10. Procedure

10.1 *General*:

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

10.1.1.1 Voltage while elements are energized, and

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

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

10.1.2.1 Higher heating value,

10.1.2.2 Standard gas conditions for calculation in 11.3,

10.1.2.3 Measured gas temperature,

10.1.2.4 Measured line gas pressure (before pressure regulator),

10.1.2.5 Barometric pressure, and

10.1.2.6 Measured peak input rate during or immediately prior to test.

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

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

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

10.1.4 For dishwashers that use steam coils for tank 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 the rated "nameplate" input. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the dishwasher.

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

10.2.2 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 Determine the tank heater maximum energy input rate in accordance with 11.4, 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 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the dishwasher.

10.3 *Booster Maximum Energy Input Rate*:

10.3.1 Open the dishwasher drain. Close the door(s) and initiate a tank fill. 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 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the booster.

10.4 *Dishwasher Water Consumption Calibration*:

10.4.1 Ensure final rinse water is supplied at 20 ± 1 psi.

10.4.2 Measure water consumption using the flowmeter specified in 6.9 and run the dishwasher through five complete cycles. Determine the average water consumption per rack.

10.4.3 Confirm that the water consumption per rack of dishes 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 may make appropriate changes or adjustments to the dishwasher. Record the final water consumption per rack.

10.5 *Booster Temperature Calibration*:

10.5.1 While monitoring the inlet and outlet temperature of the booster, initiate a dishwasher cycle every 2 min. Adjust the booster heater such that the average temperature of water at the dishwasher inlet (measured only during the rinse) is 181 ± 1°F.

10.6 *Wash Tank Temperature Calibration*:

10.6.1 Fill the dishwasher tank and activate the tank heaters. When the tank heaters cycle off, start the wash pump (door closed) and commence monitoring temperature. Observe the temperature at which the tank heaters cycle on. Allow the tank temperature to recover, cycle off, and again observe the cycle-on temperature. Observe the cycle-on temperature a third time and confirm that for each run the cycle-on temperature was 151 ± 1°F. If it falls outside of this range on any run, adjust the thermostat accordingly and repeat the three runs.

NOTE 7—The wash tank temperature calibration may need to be changed again during the washing energy test (10.9) to achieve the "ready" temperature required for this test. The reasoning for changing the wash tank temperature thermostat setting is explained in Note 8. The "ready" temperature is an approximate starting point for the determination of when to start washing the next dishload. The "ready" temperature is the dishwasher tank temperature that is hot enough to start washing the next room temperature dishload and not drop the tank temperature below the recommended 151 ± 1°F.

10.7 *Washing Energy Performance Test*:

10.7.1 This test will require ten 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.

10.7.2 The bulk temperature of the dishloads shall be 75 ± 2°F. Determine the bulk temperature using a surface temperature probe (see 6.16) and measure the temperature of at least three plates (one front, one center, and one back). Average these temperatures to determine the bulk temperature.

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

10.7.4 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 temperatures and confirm that it is 75 ± 2°F.

10.7.5 After the 1-h idle period, observe the tank heaters and tank temperature. When the tank temperature is on the rise (tank heaters energized), and the temperature reaches 156°F (from now on referred to as the "ready" temperature), start washing the first empty dishrack. Immediately after completion of the cycle, remove the first empty dishrack. Close the door(s), but not far enough to activate the wash cycle.

NOTE 8—The condition required to start washing the first empty dishrack may not occur immediately following the 1-h idle period. For example, when 1 h has elapsed, the tank temperature may already be above the ready temperature, with the tank heaters already energized. In this case, allow the elements or burners to cycle off, then on again, and wait for the temperature to reach the ready temperature.

NOTE 9—The specification of 156°F as the "ready" temperature is an approximate starting point. It may be different from dishwasher to dishwasher and from dishload to dishload, and is precisely determined though an iterative process. The goal of the iteration is to determine the lowest possible "ready" temperature that does not result in any dishload dropping the tank temperature below the NSF required minimum 150°F (that is, 151 ± 1°F). There is one period during the washing energy test where the lowest tank temperature might occur, that is, during the washing of the first dishload. Therefore, this test requires that the tank temperature falls within the range from 151 ± 1°F during the first dishload. If it doesn't, then the "ready" temperature is adjusted (up, if it fell to below 150°F, down, if it fell to above 152°F), and the test is rerun. The tank heater thermostat may require adjusting up if element(s) or burner(s) cut out before the tank temperature reaches the "ready" temperature and down if the tank temperature is always above the "ready" temperature. The "ready" temperature may be changed during the test in order to maximize the cycle rate (racks washed per hour), provided the minimum tank temperature meets the qualifications of tank temperature fall to 151 ± 1°F with the first dishload and 151 ± 1°F or higher with each subsequent dishload.

10.7.6 Commence washing the second empty dishrack as soon as the same "ready" temperature from the previous empty rack has been reached. Immediately after completion of the cycle remove the second empty dishrack. Close the door(s), but not far enough to activate the wash cycle. When the tank temperature reaches the "ready" temperature needed to ensure that the first dishload will cause the tank temperature to fall to 151 ± 1°F, commence washing the first dishload. Commence monitoring time, energy of the dishwasher and the booster, water consumption, and temperature of the booster inlet, final rinse and wash tank. Note the minimum tank temperature experienced during this washing period. Confirm that, at some point during this dishload this tank temperature is 151 ± 1°F. Remove the dishload when the cycle is complete. Close the door(s), but not far enough to activate the wash cycle.

10.7.7 If the minimum tank temperature during the washing of this first dishload did not fall into the range of 151 ± 1°F, adjust the" ready" temperature (up, if it fell to below 150°F, down, if it fell to above 152°F), and repeat the test, starting at 10.7.1.

10.7.8 If the minimum tank temperature during the washing of this first dishload did fall into the range of 151 ± 1°F, record the tank temperature and proceed to washing subsequent dishloads. When the tank temperature reaches the next "ready" temperature, commence washing the next dishload. Remove the dishload when the cycle is complete, and leave the door(s) open. Repeat this step eight more times (resulting in a total of twelve loads, two with the empty racks and ten with dishloads). Note the minimum tank temperature that occurs during any of these dishloads does not have to fall in the range of 151 ± 1°F (that requirement only pertains to the washing of the first dishload). It does however have to remain above the NSF required minimum 150°F at all times. If the temperature does fall below 150°F at any time, increase the "ready" temperature by 1°F and repeat the test starting at 10.7.1.

10.7.9 After removing the last dishload, close the door(s) (but not far enough to activate another cycle) and when the tank temperature reaches the "ready" temperature, turn off the tank heaters. The last "ready" temperature that signifies the end of the washing energy test should be the same "ready" temperature as the tenth dishload's "ready" temperature (that is, if the tenth dishload's" ready" temperature was 155°F after the tenth dishload has been washed, wait until the tank temperature has recovered to 155°F before ending test).

10.7.10 Record the final dishwasher and booster energy, elapsed time (from start of washing the first dishload to when the final "ready" temperature is reached in 10.7.9), average dishwasher inlet temperature, average booster inlet temperature, minimum tank temperature, and total water consumption, and "ready" temperatures. If at anytime the booster supplying the dishwasher does not maintain the average final rinse temperature of 180 ± 1°F during washing energy performance test, the test shall be considered a failure.

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

10.8 *Closed Door and Open Door Tank Heater Idle Energy Rate*:

10.8.1 Allow the dishwasher to fill, and energize the tank heaters.

10.8.2 With the 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.

10.8.3 Repeat 10.8.1 and 10.8.2, but this time leave the door(s) open.

10.8.4 Calculate and report the closed door(s) and open door(s) tank heater idle energy rate in accordance with 11.5.

10.9 *Booster Idle Energy Rate*:

10.9.1 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.

10.9.2 Calculate and report the booster heater idle energy rate, in accordance with 11.6.

11. Calculation and Report

11.1 *Test Dishwasher*:

11.1.1 Summarize the physical and operating characteristics of the dishwasher using Specification F 857. Describe the physical and operating characteristics of the booster heater. If needed, describe other design or operating characteristics of the dishwasher or booster that may facilitate interpretation of the test results.

11.2 *Apparatus and Procedure*:

11.2.1 Confirm that the testing apparatus conformed to all of the specifications in Section 9. Describe any deviations from those specifications. Report the ventilation rate.

11.2.2 Report the voltage for each test.

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

11.3 *Gas Energy Calculations*:

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

11.3.2 Calculate the energy consumed based on:

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

where:

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

where:

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

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

P_{cf} = pressure correction factor
= $\frac{\text{absolute actual gas pressure psia}}{\text{absolute standard pressure psia}}$

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

NOTE 10—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. PG&E standard conditions are 519.67°R and 14.73 psia.

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:

$$E_{input\ rate} = \frac{E \times 60}{t} \tag{2}$$

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 open door and the closed door tank heater idle energy rate (Btu/h or kW) based on:

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

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.

11.6 *Booster Heater Idle Energy Rate*:

11.6.1 Calculate and report the booster heater idle energy rate (Btu/h or kW) based on:

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

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 *Washing Energy Test*:

11.7.1 Calculate and report each of the following:

11.7.1.1 Dishwasher electric energy per rack (kWh),

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

11.7.1.3 Total electric energy per rack (kWh),

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

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

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

11.7.1.7 *Cycle* rate (racks/hr).

11.7.2 Use the following relationship:

$$E_{rack} = \frac{E_{test}}{10} \tag{5}$$

where:

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

11.7.3 Report the elapsed time for the washing energy test. The elapsed time is measured from the time the dishwasher has commenced washing the first dishload, till the dishwasher tank temperature has reached the tenth dishload's ready temperature after the last dishload has been removed. Calculate the cycle rate (racks per hour) by dividing ten racks (ten dishloads) by the elapsed time.

12. Precision and Bias

12.1 *Precision*:

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

12.1.1.1 The repeatability of each reported parameter is being determined.

12.1.2 *Reproducibility* (multiple laboratories):