



# ENERGY STAR® Program Requirements Product Specification for Commercial Dishwashers

## Final Test Method (Rev. May-2012)

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### 1 OVERVIEW

The following test method shall be used for determining product compliance with requirements in the ENERGY STAR Eligibility Criteria for Commercial Dishwashers.

*Note: Throughout this test method, “may” refers to an action that is voluntary and “shall” refers to an action that is mandatory.*

### 2 APPLICABILITY

This test method is applicable to commercial dishwashers, specifically: under counter; glasswashing; single tank, door type; pot, pan and utensil; dual sanitizing rinse; single tank conveyor; multiple tank conveyor and flight type machines. This test method may also be used to test machines that include a post-sanitizing rinse. This test method is applicable to machines with electric, gas, or steam coil tank heat and electric, gas, or steam booster heat but not for machines with steam injection tank or booster heat.

*Note: This test method has not been validated for flight type machines, machines with a post-sanitizing rinse, or machines with steam coil booster heaters.*

### 3 DEFINITIONS

Unless otherwise specified, all terms used in this document are consistent with the definitions in the ENERGY STAR Eligibility Criteria for Commercial Dishwashers Version 2.0.

*Note: Dishwashing Machines are referred to as Dishwashers throughout this Test Method.*

#### A) Acronyms, Abbreviations, and Units:

- 1) ANSI: American National Standards Institute
- 2) ASTM: American Society for Testing and Materials
- 3) Btu: British Thermal Units
- 4) cfm: Cubic feet per minute
- 5) DOE: U.S. Department of Energy
- 6) EPA: U.S. Environmental Protection Agency
- 7) °F: Degrees Fahrenheit
- 8) ft: Feet

- 9) ft<sup>3</sup>: Cubic feet
- 10) h: Hour(s)
- 11) in: Inch(es)
- 12) in. H<sub>2</sub>O: Inches water
- 13) in. Hg: Inches mercury
- 14) kW: Kilowatt(s)
- 15) kWh: Kilowatt-hour(s)
- 16) lb: Pound(s)
- 17) min: Minute(s)
- 18) NSF: NSF International
- 19) psi: Pounds per square inch
- 20) psia: Pounds per square inch absolute
- 21) psig: Pounds per square inch gauge
- 22) °R: Degrees Rankine
- 23) s: Second(s)
- 24) UUT: Unit Under Test
- 25) V: Volt(s)
- 26) W: Watt(s)
- 27) Wh: Watt-hour(s)

B) General:

- 1) Warewashing Machine Terminology
  - a) Water heater: Water Heater is defined in NSF International/American National Standards Institute (*NSF/ANSI 170-2010: Glossary of Food Equipment Terminology; Section 3.223*).
  - b) Booster Heater: Booster Heater is defined in *NSF/ANSI 170-2010; Section 3.223.1*.
  - c) Sanitization: Sanitization is defined in *NSF/ANSI 170-2010; Section 3.176*.
  - d) Sanitizing Solution: Sanitizing Solution is defined in *NSF/ANSI 170-2010; Section 3.177*.
  - e) Washing: Washing is defined in *NSF/ANSI 170-2010; Section 3.221*.
  - f) Fresh Water: Fresh Water is defined in *NSF/ANSI 170-2010; Section 3.83*.

- g) Sanitizing Rinse: Sanitizing Rinse is defined in *NSF/ANSI 170-2010; Section 3.173*.
- h) Chemical Sanitizing Rinse: Chemical Sanitizing Rinse is defined in *NSF/ANSI 170-2010; Section 3.170*.
- i) Hot Water Sanitizing Rinse: Hot Water Sanitizing Rinse is defined in *NSF/ANSI 170-2010; Section 3.171*.
- j) Pumped Rinse: Pumped Rinse is defined in *NSF/ANSI 170-2010; Section 3.152*.
- k) Auxiliary Rinse: Auxiliary rinse is defined in *NSF/ANSI 170-2010; Section 3.5*.
- l) Recirculating Sanitizing Rinse: Recirculating Sanitizing Rinse is defined in *NSF/ANSI 170-2010; Section 3.160*.
- m) Non-recirculating Pumped Sanitizing Rinse: Non-recirculating Pumped Sanitizing Rinse is defined in *NSF/ANSI 170-2010; Section 3.129*.
- n) Post-sanitizing Rinse: Post-sanitizing Rinse is defined in *NSF/ANSI 170-2010; Section 3.172*.
- o) Prewashing Unit: Prewashing Unit is defined in *NSF/ANSI 170-2010; Section 3.148*.
- p) Rack: Rack is defined in *NSF/ANSI 170-2010; Section 3.155*.
- q) User Adjustable: A feature is user adjustable if it may be adjusted by the machine operator without aid from a technician or manufacturer.

2) Test Method Terminology

- a) Ambient Temperature: Ambient Temperature is defined in *NSF/ANSI 170-2010; Section 3.3*.
- b) Flow Pressure: Flow Pressure is defined in *NSF/ANSI 170-2010; Section 3.74*.
- c) Line Pressure: Line Pressure is defined in *NSF/ANSI 170-2010; Section 3.113*.
- d) Rated Temperature: Rated Temperature is defined in *American Society for Testing and Materials (ASTM) F1920-11: Standard Test Method for Performance of Rack Conveyor, Commercial Dishwashing Machines; Section 3.1.7*.
- e) Tank Heater Idle Rate: Tank Heater Idle Rate is defined in *ASTM F1920-11; Section 3.1.9*.
- f) Uncertainty: Uncertainty is defined in *ASTM F1920-11; Section 3.1.10*.

## 4 TEST CONDUCT

- A) Testing Order: 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, cycle times, sanitizing mode, etc.) for both the water consumption test and the idle energy consumption tests.
- B) Machines with a post-sanitizing rinse shall separately measure and report the water consumption with the feature turned on and turned off.

- C) 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.
- D) Machines designed to be used either as a Dishwasher or a pot, pan, and utensil washer shall be tested at both settings.
- E) If a machine includes an Energy Saver Mode, it shall be turned off or disabled whether or not it is user adjustable. DOE shall be contacted if this feature cannot be turned off or disabled.
- F) If a Dishwasher includes a prewash tank heater as an option, the model must be tested and reported separately from the same model without the prewash tank heater.
- G) When the test method or referenced test procedures specify to use the nameplate 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: nameplate data, user manual, communication with manufacturer.
- H) Since this test method will be used to qualify and/or verify products for ENERGY STAR, any issues that result in a termination of testing will require the test lab to obtain a replacement unit or replacement part. Field servicing of components by technicians is allowed. Component replacements are limited to direct replacements with identical model numbers in cases where the component is rendered defective. If the manufacturer elects to have a unit repaired by servicing or replacing a component, the manufacturer may not request that a new unit be tested unless the unit is inoperable subsequent to the repair. For features that are user adjustable, adjustments may not occur once data collection has started.
- I) Power and energy data may be recorded for longer than the time periods specified. However, data that are used for calculations shall be obtained from as close to the specified time periods or events (e.g. tank heater "on" cycle) as possible.

## 5 TEST SETUP

### A) Water Consumption Test Instrumentation

- 1) Pressure Gauge: The pressure gauge shall be capable of measuring at least 0-60 pounds per square inch gage (psig) with a resolution of at least 1 psig and a maximum uncertainty of 1% of the measured value.
- 2) Scale: The scale shall be capable of measuring at least 0-100 pounds (lb) with a resolution of at least 0.1 lb and an accuracy of at least +/- 0.1 lb.
- 3) Stopwatch: The stopwatch shall have a resolution of at least 0.1 seconds (s) and an accuracy of at least +/- 2% of the time period being measured.
- 4) Vessel: The vessel for capturing the sanitizing and post-sanitizing rinse water shall be large enough (depending on the tank volume) to capture the water consumed during the entire water consumption test.

### B) Idle Energy Consumption Test Instrumentation

- 1) 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.

## 2) Meters

- a) Watt-hour Meters: For Dishwashers with electric tank or booster heat, the watt-hour meters for measuring the energy consumption of the Dishwasher and booster heater separately shall meet the requirements in *ASTM F1920-11; Section 6.1* with the following revisions.
  - i. The maximum uncertainty shall be no greater than 10% of the measured value.
- b) Gas Meters: For Dishwashers with gas tank or booster heat, the gas meters for measuring the gas consumption of the Dishwasher and booster heater separately shall meet the requirements in *ASTM F1920-11; Section 6.2* with the following revision and additions.
  - i. The requirement that the pilot light gas meter shall have a maximum uncertainty of at least 0.01 cubic feet (ft<sup>3</sup>) shall be excluded.
  - ii. The tank heater gas meters shall be capable of measuring flows between at least 0 ft<sup>3</sup>/hour (h) and 250 ft<sup>3</sup>/h and the pilot light gas meters shall be capable of measuring flows between at least 0 ft<sup>3</sup>/h and 10 ft<sup>3</sup>/h.
- c) Steam Flow Meters: For Dishwashers with steam coil tank or booster heat, the steam flow meters shall meet the requirements in *ASTM F1920-11; Section 6.3* with the following addition.
  - i. The steam flow meters shall be capable of measuring flows between at least 0 ft<sup>3</sup>/h and 50 ft<sup>3</sup>/h and shall be capable of recording data at least as frequently as every second.
- d) Water Flow Meters: For conveyor Dishwashers, the calibrated flow meters shall have a resolution of at least 0.1 gallons per minute, an accuracy of +/- 1.5% of the flow rate being measured, and shall be capable of measuring flows between at least 0 gallons per minute and 6 gallons per minute.

## 3) Pressure Gauges

- a) Gas Pressure Gauge: For Dishwashers with gas tank heat, the gas pressure gauges shall meet the requirements in *ASTM F1920-11; Section 6.6*.
- b) Steam Pressure Gauge: For Dishwashers with steam coil tank or booster heat, the steam pressure gauges shall meet the requirements in *ASTM F1920-11; Section 6.4* with the following addition.
  - i. The steam pressure gauges shall be capable of measuring pressures between at least 0 psig and 100 psig.

## 4) Ventilation

- a) Stationary Rack: For Dishwashers that are classified as stationary rack types, ventilation shall meet the requirements in *ASTM F1696-07: Standard Test Method for Energy Performance of Single-Rack, Door-Type Commercial Dishwashing Machines; Section 6.5*.
- b) Conveyors: For Dishwashers that are classified as conveyor types, ventilation shall meet the requirements in *ASTM F1920-11; Section 6.5* with the following revision.
  - i. 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) on the

entrance side of the Dishwasher and 400 cfm on the exit side if the manufacturer does not provide recommendations.

5) Thermocouple Probes and Temperature Sensors

- a) Thermocouple Probes: For all Dishwashers, the thermocouple probes shall meet the requirements in *ASTM F1920-11; Section 6.12* with the following revision and additions.
  - i. "Dishwater" shall be replaced with "Dishwasher".
  - ii. The thermocouple probes shall have a response time of less than 2 seconds.
  - iii. For Dishwashers with steam coil tank or booster heat, the thermocouple probes shall be used for measuring the condensate water outlet temperature.
- b) Ambient Air: For all Dishwashers, the temperature sensor for measuring ambient air temperatures in the range of 50 degrees Fahrenheit (°F) to 100 °F shall have a resolution of at least 0.5 °F and a maximum uncertainty of +/- 1 °F.
- c) Gas: For Dishwashers with gas tank heat, the temperature sensor for measuring natural gas temperatures shall meet the requirements in *ASTM F1920-11; Section 6.7*.
- d) Steam: 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 uncertainty of +/- 1 °F.

6) Additional Requirements

- a) Stop Watch: For all Dishwashers, the stop watch shall meet the requirements in *ASTM F1920-11; Section 6.10*. The stop watch shall have an accuracy of +/- 2% of the time period being measured.
- b) Barometer: For Dishwashers with natural gas tank heat, a barometer shall be used if the gas flow meter does not correct for pressure. For Dishwashers with steam coil tank or booster heat, a barometer shall be used for calculating absolute pressure from gage pressure if the pressure gauge does not correct for atmospheric pressure. The barometer shall meet the requirements in *ASTM F1920-11; Section 6.8*.
- c) Dishrack: Metro Mdl P2MO, 20 in. x 20 in., peg-type, commercial or acceptable equivalent.

C) Commercial Dishwasher Installation

- 1) Commercial Dishwashers shall be installed per manufacturer's installation instructions. All packing material and protective packaging shall be removed.
- 2) Drain connections shall be accessible with sufficient space to allow capture vessel to be positioned beneath.
- 3) For steam coil tank or booster heat Dishwashers, 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.

- 4) Stationary Rack Type: For Dishwashers that are classified as stationary rack types, the Dishwasher setup shall meet the requirements in *ASTM F1696-07; Sections 9.1-9.10* with the following revisions and additions.
  - a) In Section 9.3, the supply of water shall be within the range of the manufacturer-specified input temperatures (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 temperature in lieu of an external booster heater.
  - b) In Section 9.4, the watt-hour meters shall be connected so that all idle energy (including tank heater, motors, and controls) is monitored. 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. For the idle energy test, internal booster heaters shall be monitored separately and the booster idle energy shall be reported separately from the total idle energy.
  - c) In Section 9.5, instrumentation to record both the pressure and temperature of the gas supplied to the Dishwasher and the barometric pressure is only necessary if the gas flow meter does not already correct for pressure and temperature.
- 5) Conveyors: For Dishwashers that are classified as conveyors, the Dishwasher setup shall meet the requirements in *ASTM F1920-11; Sections 9.1-9.11* with the following revisions and additions.
  - a) In Section 9.3, the supply of water shall be within the range of the manufacturer-specified input temperatures (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 temperature in lieu of an external booster heater.
  - b) In Section 9.4, the watt-hour meters shall be connected so that all idle energy (including tank heater(s), motors, and controls) is monitored. 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. For the idle energy test, internal booster heaters shall be monitored separately and the booster idle energy shall be reported separately from the total idle energy.
  - c) In Section 9.5, instrumentation to record both the pressure and temperature of the gas supplied to the Dishwasher and the barometric pressure is only necessary if the gas flow meter does not already correct for pressure and temperature.

#### D) Test Settings

##### 1) Water Consumption Test Settings:

- a) Fresh Water Sanitizing or Post-Sanitizing Rinse Stationary Rack Type Machines
  - i. If multiple cycle times are available, the Dishwasher shall be tested at the shortest time setting.
  - ii. If the water consumption including post-sanitizing rinse is being measured, turn on the post-sanitizing rinse feature and ensure it remains on during testing.

- iii. Based on manufacturer instructions, set the sanitizing or post-sanitizing rinse flow pressure based on the following:
  - For machines marked for sanitizing or post-sanitizing rinse pressure ratings of 20 +/- 5 psig, the test shall be run at 20 +/- 1 psig.
  - For machines marked for sanitizing or post-sanitizing rinse pressure ratings other than 20 +/- 5 psig, and a marked pressure range of greater than 5 psig, the test shall be run with the sanitizing or post-sanitizing rinse pressure set at both the minimum and maximum ratings marked on the unit +/- 1 psig.
  - For machines marked for sanitizing or post-sanitizing rinse pressure ratings other than 20 +/- 5 psig, and a marked pressure range of less than or equal to 5 psig, the test shall be run with the sanitizing or post-sanitizing rinse pressure set at the minimum rating marked on the unit +/- 1 psig.
- b) Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Rack Type Machines
  - i. If multiple cycle times are available, the Dishwasher shall be tested at the shortest time setting.
  - ii. If the water consumption including post-sanitizing rinse is being measured, turn on the post-sanitizing rinse feature and ensure it remains on during testing.
  - iii. The machine shall be filled to the manufacturer's recommended level. The same water level shall be used for the water consumption and idle energy tests for consistency.
- c) Fresh Water Sanitizing or Post-Sanitizing Rinse Conveyor Type Machines
  - i. 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.
  - ii. If the water consumption including post-sanitizing rinse is being measured, turn on the post-sanitizing rinse feature and ensure it remains on during testing.
  - iii. Based on manufacturer instructions, set the rinse flow pressure based on the following:
    - For machines marked for sanitizing or post-sanitizing rinse pressure ratings of 20 +/- 5 psig, the test shall be run at 20 +/- 1 psig.
    - For machines marked for sanitizing or post-sanitizing rinse pressure ratings other than 20 +/- 5 psig, and a marked pressure range of greater than 5 psig, the test shall be run with the sanitizing or post-sanitizing rinse pressure set at both the minimum and maximum ratings marked on the unit +/- 1 psig.
    - For machines marked for sanitizing or post-sanitizing rinse pressure ratings other than 20 +/- 5 psig, and a marked pressure range of less than or equal to 5 psig, the test shall be run with the sanitizing or post-sanitizing rinse pressure set at the minimum rating marked on the unit +/- 1 psig.
- d) Pumped Water Sanitizing or Post-Sanitizing Rinse Conveyor Type Machines

- i. 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.
- ii. If the water consumption including post-sanitizing rinse is being measured, turn the post-sanitizing rinse feature on and ensure it remains on during testing.

## **6 TEST METHODS FOR ALL PRODUCTS**

### **6.1 Sanitizing and Post-Sanitizing Rinse Water Consumption**

#### **1) Fresh Water Sanitizing or Post-Sanitizing Rinse Stationary Rack Type Machines**

- a) Completely dry and weigh the capture vessel.
- b) Operate the machine through three cycles. Verify that the wash, rinse (including post-sanitizing rinse if this feature is included), and dwell times are within 1 second of the manufacturer's specified values and that the water pressure is within 1 psig of the manufacturer's specified value. If they are not, make adjustments and operate the machine through additional cycles until they are (i.e. steady state is achieved). If the specified times are not reached, terminate testing.
- c) Using the weighed capture vessel, catch all water that is sent to the drain during a complete cycle, including any water from a post-sanitizing rinse if the water consumption including post-sanitizing rinse is being measured. Record the exact wash, rinse, and dwell times. It may take longer than the duration of the cycle for all of the water to drain; thus the vessel shall remain in place until the water flow from the cycle ceases.
- d) Weigh the filled vessel after the cycle, subtracting the weight of the capture vessel to calculate the weight of the water.
- e) Repeat steps a) through d) five times. Completely dry the vessel after each cycle.

#### **2) Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Rack Type Machines**

- a) Completely dry and weigh the capture vessel.
- b) Operate the machine through three cycles. Verify that the wash, rinse, and dwell times are within one second of the manufacturer's specified values and that the water is within 0.25 inch (in.) of the water fill line. If it is not, adjust the water pressure until the water is within 0.25 in. of the water fill line. If the water is still not within 0.25 in. of the water fill line, the wash, rinse, and dwell times may be adjusted, but the new times shall be recorded. If the specified times and/or water fill level are not reached, terminate testing.
- c) Using the weighed capture vessel, catch all water that is sent to the drain during a complete cycle, including any water from a post-sanitizing rinse if the water consumption including post-sanitizing rinse is being measured. Record the exact wash, rinse, and dwell times. It may take longer than the duration of the cycle for all of the water to drain; thus the vessel shall remain in place until the water flow from the cycle ceases.
- d) Weigh the filled vessel after the cycle, subtracting the weight of the capture vessel to calculate the weight of the water.
- e) Repeat steps a) through d) five times. Completely dry the vessel after each cycle.

3) Fresh Water Sanitizing or Post-Sanitizing Rinse Conveyor Type Machines

- a) Activate the sanitizing rinse solenoid (and the post-sanitizing rinse solenoid if the water consumption including post-sanitizing rinse is being measured) for 5 minutes (min). Do not activate any other component(s) of the Dishwasher that sends water to the drain. If there is a lever that actuates the sanitizing rinse solenoid or post-sanitizing rinse solenoid, the lever may be held down to simulate operation. Verify that the water pressure is within 1 psig of the manufacturer's specified value. If it is not, make adjustments and operate the machine until it is (i.e. steady state is achieved).
- b) Using a flow meter, measure all water that is sent to the drain during 1 min +/- 1 second of continuous operation of the sanitizing rinse solenoid (and post-sanitizing rinse solenoid 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 sends water to the drain. If there is a lever that actuates the sanitizing rinse solenoid or post-sanitizing rinse solenoid, the lever may be held down to simulate operation.
- c) Repeat steps a) and b) five times.

4) Pumped Water Sanitizing or Post-Sanitizing Rinse Conveyor Type Machines

- a) Activate the sanitizing rinse (and the post-sanitizing rinse if the water consumption including post-sanitizing rinse is being measured) for 5 min. Do not activate any other component(s) of the Dishwasher that sends water to the drain. If there is a lever that actuates the sanitizing rinse or post-sanitizing rinse, the lever may be held down to simulate operation. Verify that the pumped sanitizing rinse and post-sanitizing rinse operate correctly. If they do not, terminate testing.
- b) Using a flow meter, measure all water that is sent to the drain during 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 sends water to the drain. If there is a lever that actuates the sanitizing rinse or post-sanitizing rinse, the lever may be held down to simulate operation.
- c) Repeat steps a) and b) five times.

## 6.2 Idle Energy Consumption for Stationary Rack Type Machines

- 1) General measurements shall be taken and recorded as specified in *ASTM F1696-07; Section 10.1* with the following revisions and additions.
  - a) Steam coil units shall also be included in Section 10.1.1.
  - b) Section 10.1.1.2 shall be disregarded.
  - c) The higher heating value shall be measured for all tests with a gas powered tank heater or booster. The other measurements specified in Section 10.1.2 shall only be taken if the gas meter does not already correct the gas volume based on temperature and pressure. Section 10.1.2.6 shall be disregarded.
  - d) Section 10.1.4 shall be replaced with "For Dishwashers that use steam coils for tank or booster heat, the steam temperature, pressure, and volumetric flow rate at Dishwasher inlet, water temperature and pressure at Dishwasher outlet, and barometric pressure

shall be recorded at no greater than 1 second of every test. Make any necessary corrections to the measurements as required by the instruments (i.e. correction for elevation of pressure gauge above pressure line, etc.).”

- e) Section 10.1.5 shall be disregarded.
- 2) For Dishwashers with steam coil tank or booster heat, allow the Dishwasher tank or booster heater to idle for one “on” cycle, with the exterior service door(s) closed. As the tank or booster heater cycles on for the second time, record the amount of time between steam entering the volumetric flow meter and exiting as condensate with a stopwatch as  $t_{delay}$  (seconds). This time delay is used to compare the data from the inlet to the corresponding data from the outlet. Adjust testing times so that there is enough data to account for this delay. Alternately, if the time delay cannot be determined using this method, it may be estimated by dividing the volume of the heat exchanger by the average flow during the first complete heater “on” cycle.
- 3) If there is a booster heater for high temperature machines, the booster temperature shall be calibrated as follows:
  - a) *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  $\pm 2$  °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.
  - b) *Run two machine cycles with an empty dishrack placed in the machine to confirm that the stabilized flowing sanitizing rinse temperature is above the manufacturer's rated sanitizing rinse temperature minus 1 °F (or above 180 °F if the manufacturer does not provide a rated rinse temperature). If the stabilized flowing sanitizing rinse temperature is below the manufacturer's nameplate 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.*
- 4) The wash tank temperature shall be set as specified in *ASTM F1920-11; Section 10.6* with the following revisions and additions.
  - a) “Dishwater” shall be replaced with “Dishwasher”. Verify that the minimum tank heater temperature during the three consecutive heater cycles is above the manufacturer's recommended setting minus 1 °F and the maximum temperature is not more than 15 °F higher than the minimum measured temperature. Repeat for all actively heated tanks.
  - b) Run two machine cycles with an empty dishrack placed in the machine to confirm that the minimum tank temperature(s) during the test is above the manufacturer's recommended setting minus 1 °F and the maximum temperature is not more than 15 °F higher than the minimum measured temperature. If the tank temperature(s) is not correct, adjust the thermostat per the manufacturer's instructions if it is user adjustable.
- 5) The tank heater “maximum energy input rate” (i.e. maximum power) shall be measured and reported as specified in *ASTM F1696-07; Section 10.2* with the following revisions and additions.
  - a) The maximum energy input rate determination is used to verify that the dishwasher is operating within manufacturer specifications. If there is a nameplate rating or a rating printed on the heating element for the tank heater, follow the steps below. If the tank

heater is included as part of a total power consumption nameplate rating, follow the steps below while monitoring the total power consumption for all components included in the rating.

- b) Section 10.2.1 shall be disregarded.
  - c) Section 10.2.2 shall be replaced with the following:
    - i. Instruments shall be connected so that only the energy (for steam and gas tank heat) or power (for electric tank heat) consumption of the tank heater is measured. Fill the Dishwasher tank with water.
    - ii. For electric tank heaters, commence monitoring the power of the tank heater when the tank heater cycles on. Stop monitoring the power when the tank heater cycles off. Record the maximum power value as the “maximum energy input rate”.
    - iii. 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.
    - iv. 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.
  - d) Section 10.2.3 shall be followed as written with the following revision.
    - i. The tank heater “maximum energy input rate” (i.e. maximum power) for the Dishwasher under test shall be determined in accordance with Section 7.6 of this test method.
    - ii. If the difference between the recorded value and the nameplate rating or rating printed on the heating element is greater than 5%, testing shall be terminated.  
  
*Note: ASTM F1696-07 specifies that the manufacturer may make appropriate changes or adjustments to the dishwasher. See Test Conduct Section 4H) for ENERGY STAR requirements.*
  - e) For machines with steam coil tank heat, using an appropriately sized vessel that is completely dry, catch all water 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 quality of the steam until the difference is less than 5% and rerun the tank heater “maximum energy input rate” (i.e. maximum power) test.
- 6) If there is a booster heater, the booster heater maximum energy input rate shall be measured and reported as specified in *ASTM F1696-07; Section 10.3* with the following revisions and additions.

- a) If there is a nameplate 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 nameplate rating, follow the steps below while monitoring the total power consumption for all components included in the rating.
- b) Section 10.3.1 shall be replaced with the following:
  - i. 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.
  - ii. 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”.
  - iii. 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.
  - iv. 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.
- c) Section 10.3.2 shall be followed as written with the following revision.
  - i. The booster heater “maximum energy input rate” (i.e. maximum power) for the Dishwasher under test shall be determined in accordance with Section 7.6 of this test method.
  - ii. If the difference between the recorded value and the nameplate rating or rating printed on the heating element is greater than 5%, testing shall be terminated.

*Note: ASTM F1696-07 specifies that the manufacturer may make appropriate changes or adjustments to the dishwasher. See Test Conduct Section 4H) for ENERGY STAR requirements.*
- d) For machines with steam coil booster heat, using an appropriately sized vessel that is completely dry, catch all water 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 quality of the steam until the difference is less than 5% and rerun the booster heater “maximum energy input rate” (i.e. maximum power) test.

7) The idle energy rate (i.e. power) shall be measured as follows:

- a) If the Dishwasher does not have an internal booster heater:
  - i. Allow the Dishwasher to fill and energize the tank heater.

- ii. With the door(s) closed, allow the Dishwasher tank to idle for at least *1 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 1 hour stabilization period*.
- iii. Allow the Dishwasher to idle for 3 hours. *If there have not been ten distinct heater cycles during the 3 hour period, continue to run the test and record data. Stop the test the tenth time that the heater cycles off.* Record the final *elapsed* time and energy consumption *of the Dishwasher*.
- iv. Record the minimum tank temperature during the test and confirm that it is at or above the *manufacturer’s specified* minimum tank temperature minus 1 °F, as applicable. If the minimum tank temperature during the idle energy test is below the manufacturer’s specified tank temperature *minus 1 °F*, the test is invalid and must be repeated. *If the tank temperature exceeds 15 °F of the measured minimum tank temperature, the test is invalid and must be repeated.* Adjust the thermostat per the manufacturer’s instructions *if it is user adjustable* and repeat the steps in i through iii.

b) If the Dishwasher has an internal booster heater:

- i. Allow the Dishwasher to fill and energize the tank heater and booster heater.
- ii. With the door(s) closed, allow the Dishwasher tank and booster heater to idle for at least 1 hour for stabilization. Commence monitoring elapsed time, tank temperature, and total energy consumption of the Dishwasher when the tank heater cycles “on” for the first time after the 1 hour stabilization period.
- iii. Allow the Dishwasher to idle for 3 hours. *If there have not been ten distinct heater cycles during the 3 hour period, continue to run the test and record data. Stop the test the tenth time that the heater cycles off.* Record the final elapsed time and energy consumption of the Dishwasher.
- iv. The booster idle energy consumption shall be reported separately from the total idle energy consumption.
  - If possible, sub-monitor the idle energy consumption of the booster heater during the Dishwasher idle energy test described in steps i through iii above.
  - 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 number of booster heater “on” cycles in the separate test must be equivalent to the number of booster heater “on” cycles in the Dishwasher idle energy. Repeat steps i through iii above, but record the energy consumption of the booster heater instead of the total Dishwasher energy consumption.
  - If the booster heater cannot be separately monitored or sub-monitored, the booster heater idle energy consumption shall be included as part of the total idle energy consumption.
- v. Record the minimum tank temperature during the test(s) and confirm that it is at or above the manufacturer’s specified minimum tank temperature minus 1 °F, as

applicable. If the minimum tank temperature during the idle energy test is below the manufacturer's specified tank temperature minus 1 °F, then the test is invalid and must be repeated. If the tank temperature exceeds 15 °F of the measured minimum tank temperature, the test is invalid and must be repeated. Adjust the thermostat per the manufacturer's instructions if it is user adjustable and repeat the steps in i through iv.

### 6.3 Idle Energy Consumption for Conveyor Type Machines

- 1) General measurements shall be taken and recorded as specified in *ASTM F1920-11; Section 10.1* with the following revisions and additions.
  - a) Steam coil units shall also be included in Section 10.1.1.
  - b) Section 10.1.1.2 shall be disregarded.
  - c) The higher heating value shall be measured for all tests with a gas powered tank heater or booster. The other measurements specified in Section 10.1.2 shall only be taken if the gas meter does not already correct the gas volume based on temperature and pressure. Section 10.1.2.6 shall be disregarded.
  - d) Section 10.1.4 shall be replaced with "For Dishwashers that use steam coils for tank or booster heat, the steam temperature, pressure, and volumetric flow rate at Dishwasher inlet, water temperature and pressure at Dishwasher outlet, and barometric pressure shall be recorded at no greater than 1 second of every test. Make any necessary corrections to the measurements as required by the instruments (i.e. correction for elevation of pressure gauge above pressure line, etc.)."
  - e) Section 10.1.5 shall be disregarded.
- 2) For Dishwashers with steam coil tank or booster heat, with the exterior service door(s) closed, allow the Dishwasher tank or booster to idle for one "on" cycle. As the tank or booster heater cycles on for the second time, record the amount of time between steam entering the volumetric flow meter and exiting as condensate with a stopwatch as  $t_{delay}$  (seconds). This time delay is used to compare the data from the inlet to the corresponding data from the outlet. Adjust testing times so that there is enough data to account for this delay. Alternately, if the time delay cannot be determined using this method, it may be estimated by dividing the volume of the heat exchanger by the average flow during the first complete heater "on" cycle.
- 3) If there is a booster heater for high temperature machines, the booster temperature shall be calibrated as follows:
  - a) *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  $\pm 2$  °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.
  - b) *Run two empty dishracks through the machine to confirm that the stabilized flowing sanitizing rinse temperature is above the manufacturer's rated sanitizing rinse temperature minus 1 °F (or above 180 °F if the manufacturer does not provide a rated*

sanitizing rinse temperature). If the stabilized flowing sanitizing rinse temperature is below the manufacturer's nameplate rated sanitizing rinse temperature minus 1 °F (or below 180 °F if the manufacturer does not provide a rated rinse temperature), adjust the thermostat per the manufacturer's instructions if it is user adjustable.

- 4) The tank temperature(s) shall be calibrated as specified in *ASTM F1920-11; Section 10.6* with the following revisions and additions.
  - a) "Dishwater" should be replaced with "Dishwasher". Verify that the minimum tank heater temperature during the three consecutive heater cycles is above the manufacturer's recommended setting minus 1 °F and the maximum temperature is not more than 15 °F higher than the measured minimum temperature. Repeat for all actively heated tanks.
  - b) Run two empty dishracks through the machine to confirm that the minimum tank temperature(s) during the test is above the manufacturer's recommended setting minus 1 °F and the maximum temperature is not more than 15 °F higher than the measured minimum temperature. If the tank temperature(s) is not correct, adjust the thermostat per the manufacturer's instructions if it is user adjustable.
- 5) The wash tank pump and conveyor motor shall be calibrated as specified in *ASTM F1920-11; Section 10.7* with the following revision.
  - a) Section 10.7.1 is applicable to all pumps (not just the wash pump).
- 6) The tank heater "maximum energy input rate" (i.e. maximum power) shall be measured and reported as specified in *ASTM F1920-11; Section 10.2* with the following revisions and additions.
  - a) The maximum energy input rate determination is used to verify that the dishwasher is operating within manufacturer specifications. If there is a nameplate 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 nameplate rating, follow the steps below while monitoring the total power consumption for all components included in the rating.
  - b) Section 10.2.1 shall be replaced with the following:
    - i. Instruments shall be connected so that only the energy (for steam and gas tank heat) or power (for electric tank heat) consumption of the tank heater(s) is measured. Fill the Dishwasher tank with water.
    - ii. For electric tank heaters, commence monitoring the power of the tank heater when the tank heater cycles on. Stop monitoring the power when the tank heater cycles off. Record the maximum power value as the "maximum energy input rate".
    - iii. 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.
    - iv. 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.

- c) Section 10.2.2 shall be followed as written with the following revision.
  - i. The tank heater “maximum energy input rate” (i.e. maximum power) for the Dishwasher under test shall be determined in accordance with Section 7.6 of this test method.
  - ii. If the difference between the recorded value and the nameplate rating or rating printed on the heating element is greater than 5%, testing shall be terminated.

*Note: ASTM F1696-07 specifies that the manufacturer may make appropriate changes or adjustments to the dishwasher. See Test Conduct Section 4H) for ENERGY STAR requirements.*

- d) For machines with steam coil tank heat, using an appropriately sized vessel that is completely dry, catch all water 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 quality of the steam until the difference is less than 5% and rerun the tank heater “maximum energy input rate” (i.e. maximum power) test.
- 7) If there is a booster heater, the booster heater maximum energy input rate shall be measured and reported as specified in *ASTM F1920-11; Section 10.3* with the following revisions and additions.
- a) If there is a nameplate 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.
  - b) Section 10.3.1 shall be replaced with the following:
    - i. 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.
    - ii. 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.
    - iii. 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.
    - iv. 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.

- c) Section 10.3.2 shall be followed as written with the following revision.
- i. The booster heater “maximum energy input rate” (i.e. maximum power) for the Dishwasher under test shall be determined in accordance with Section 7.6 of this test method.
  - ii. If the difference between the recorded value and the nameplate rating or rating printed on the heating element is greater than 5%, testing shall be terminated.

*Note: ASTM F1696-07 specifies that the manufacturer may make appropriate changes or adjustments to the dishwasher. See Test Conduct Section 4H) for ENERGY STAR requirements.*

- d) For machines with steam coil booster heat, using an appropriately sized vessel that is completely dry, catch all water 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 quality of the steam until the difference is less than 5% and rerun the booster heater “maximum energy input rate” (i.e. maximum power) test.

8) The idle energy rate (i.e. power) shall be measured as follows:

- a) If the Dishwasher does not have an internal booster heater:
- i. Allow the Dishwasher to fill and energize the tank heater(s).
  - ii. *For single tank machines, with the exterior service door(s) closed, allow the Dishwasher tank to idle for at least 1 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 1 hour stabilization period.*
  - iii. *For multiple tank machines, with the exterior service door(s) closed, allow the Dishwasher tanks to idle for at least 1 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 “on” cycles again after the 1 hour stabilization period.*
  - iv. Allow the Dishwasher to idle for 3 hours. *If there have not been ten 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 one of the tank heaters cycles off again after all tank heaters have “on” cycled ten times. Record the final elapsed time and energy consumption of the Dishwasher.*
  - v. *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) minus 1 °F, as applicable. If the minimum tank temperature(s) during the idle energy test was below the manufacturer’s specified tank temperature(s) minus 1 °F, the test is invalid and must be repeated. If the tank temperature(s) exceeds 15 °F of the measured minimum tank temperature(s), the test is invalid and must be repeated. Adjust the thermostat per the manufacturer’s instructions if it is user adjustable and repeat the steps in i through iv.*

- b) If the Dishwasher has an internal booster heater:
- i. Allow the Dishwasher to fill and energize the tank heater(s).
  - ii. For single tank machines, with the exterior service door(s) closed, allow the Dishwasher tank to idle for at least 1 hour for stabilization. Commence monitoring elapsed time, tank temperature, and total energy consumption of the Dishwasher when the tank heater cycles “on” for the first time after the 1 hour stabilization period.
  - iii. For multiple tank machines, with the exterior service door(s) closed, allow the Dishwasher tanks to idle for at least 1 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 “on” cycles again after the 1 hour stabilization period.
  - iv. Allow the Dishwasher to idle for 3 hours. If there have not been ten 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 one of the tank heaters cycles off again after all tank heaters have “on” cycled ten times. Record the final elapsed time and energy consumption of the Dishwasher.
  - v. The booster idle energy rate shall be reported separately from the total idle energy rate.
    - If possible, sub-monitor the idle energy rate of the booster heater during the Dishwasher idle energy test described in steps i through iv above.
    - 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 number of booster heater “on” cycles in the separate test must be equivalent to the number of booster heater “on” cycles in the Dishwasher idle energy test. Repeat steps i through iv above, but record the energy consumption of the booster heater instead of the total Dishwasher energy consumption.
    - 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.
  - vi. Record each tank’s minimum tank temperature during the test(s) and confirm that it is at or above the manufacturer’s specified minimum tank temperature(s) minus 1 °F, as applicable. If the minimum tank temperature(s) during the idle energy test is below the manufacturer’s specified tank temperature(s) minus 1 °F, then the test is invalid and must be repeated. If the tank temperature(s) exceeds 15 °F of the measured minimum tank temperature(s), the test is invalid and must be repeated. Adjust the thermostat per the manufacturer’s instructions if it is user adjustable and repeat the steps in i through v.

## 7 CALCULATIONS

### 7.1 Racks per Hour

#### A) Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Type Machines

### Equation 1: Racks per Hour for Stationary Type Machines

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

Where:

Racks per Hour = Number of racks washed per hour, truncated to the next lowest whole number

NR = Number of racks washed per cycle

WT = Wash time (i.e. amount of time spent in wash mode) in seconds as recorded during test  
RT = Rinse time (i.e. amount of time spent in rinse mode, including a post-sanitizing rinse) in seconds as recorded during test

DT = Dwell time (i.e. amount of time spent in dwell mode) in seconds as recorded during test

LT = Load time (30 seconds for under counter Dishwashers, 5 seconds for straight through door-type Dishwashers, 7 seconds for corner door-type Dishwashers, 30 seconds for front load/unload door-type Dishwashers)

- B) Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Conveyor Type (excluding Flight Type) Machines

### Equation 2: Racks per Hour for Conveyor Type Machines

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

Where:

Racks per Hour = Number of racks washed per hour, truncated to the next lowest whole number

RL = Rack length (use 20 inches)

CS = Manufacturer specified maximum conveyor speed in feet per minute

## 7.2 Sanitizing and Post-Sanitizing Rinse Water Consumption (Gallons per Hour, GPH)

- A) Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Type Machines

### Equation 3: Gallons per Hour for Stationary Type Machines

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

Where:

Racks per Hour = Number of racks washed per hour, truncated to the next lowest whole number, as calculated in Section 7.1

NR = Number of racks washed per cycle

- B) Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Conveyor Type (including Flight Type) Machines

**Equation 4: Gallons per Hour for Conveyor Type Machines**

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

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).

**7.3 Sanitizing and Post-Sanitizing Rinse Water Consumption**

- A) Fresh Water or Pumped Water Sanitizing or Post-Sanitizing Rinse Stationary Rack Type Machines

**Equation 5: Gallons per Rack for Stationary Type Machines**

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

Where:

Gallons per Hour= Water use in gallons per hour, as calculated in Section 7.2  
Racks per Hour= Number of racks washed per hour, truncated to the next lowest whole number, as calculated in Section 7.1

- B) Fresh Water or Pumped Water Sanitizing and Post-Sanitizing Rinse Conveyor Type (excluding Flight Type) Machines

**Equation 6: Gallons per Rack for Conveyor Type Machines**

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

Where:

Gallons per Hour= Water use in gallons per hour, as calculated in Section 7.2  
Racks per Hour= Number of racks washed per hour, truncated to the next lowest whole number, as calculated in Section 7.1

- C) Pot, Pan, and Utensil Type Machines

**Equation 7: Gallons per Square Foot for Pot, Pan, and Utensil Type Machines**

$$\text{Gallons per Square Foot} = \frac{\text{Gallons per Rack}}{\text{Square foot of rack}}$$

Where:

Gallons per Rack= Water use in gallons per hour, as calculated in Section 7.3A)  
Square foot of rack= Manufacturer specified rack area in ft<sup>2</sup> for machine tested

## 7.4 Gas Energy Consumption

- A) The gas energy consumption rate shall be calculated as specified in *ASTM F1920-11; Section 11.3* with the following revision.
- 1) Equation (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 in *ASTM F1920-11; Section 10.1.2*.

## 7.5 Steam Coil Energy Consumption

- A) Inlet Steam Mass Flow Rate
- 1) Find the measured pressure and temperature values for the inlet stream for each data point in the superheated or saturated steam tables<sup>1</sup> (depending on the state of the steam) and record the listed density ( $\rho_{Steam}$ ). If the exact pressure and temperature are not listed in the table, interpolate between the two closest pressure and temperature values to calculate the density.
  - 2) Calculate the mass flow rate for each data point as follows:

### Equation 8: Inlet Steam Mass Flow Rate for Steam Coil Machines

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

Where:

$\dot{M}_{Steam}$  = Mass flow rate of steam (pounds (lb)/h)  
 $\dot{V}_{Steam}$  = Measured volumetric flow rate of steam (ft<sup>3</sup>/h)  
 $\rho_{Steam}$  = Density of steam (lb/ft<sup>3</sup>), calculated from steam tables

- B) Inlet Steam Total Mass

### Equation 9: Inlet Steam Total Mass for Steam Coil Machines

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

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  $t_{delay}$   
 $t_i$  = Time interval of each data point (seconds)

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<sup>1</sup> "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.

C) Inlet Stream Enthalpy

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

D) Outlet Water Enthalpy

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

**Equation 10: Outlet Water Enthalpy for Steam Coil Machines**

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

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)

$T_{Measured}$  = Recorded temperature of liquid water outlet stream during test (°F)

E) Instantaneous Energy Consumption

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

**Equation 11: Instantaneous Energy Consumption for Steam Coil Machines**

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

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)

$t_i$  = Time interval of each data point (seconds)

F) Total Energy Consumption

**Equation 12: Total Energy Consumption for Steam Coil Machines**

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

Where:

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

$E_i$  = Instantaneous energy consumption for each data point (Btu)

$E_{Electric}$  = Electric energy consumption during test (Btu)

$N$  = Total number of data points, excluding extra data to account for  $t_{delay}$

## 7.6 Booster and Tank Heater Maximum Power

- A) The idle energy input rate (i.e. maximum power) shall be calculated as specified in *ASTM F1920-11; Section 11.4* if a direct measurement of power was not taken.
- 1) The value 60 provided in the equation is a conversion factor from minute to hours.
  - 2) This calculation shall also be used for steam.

## 7.7 Idle Energy Rate (Power)

- A) The idle energy rate (i.e. power) shall be calculated as specified in *ASTM F1920-11; Section 11.5* with the following clarification, and additions.
- 1) The value 60 provided in the equation is a conversion factor from minute to hours.
  - 2) This calculation shall also be used for steam.
  - 3) If the idle energy rate (i.e. power) is reported in Btu/h, convert it to kilowatts (kW) based on the following equation:

### Equation 13: Idle Energy Rate Conversion

$$E_{Idle\ rate} (kW) = E_{Idle\ rate} \left( \frac{Btu}{h} \right) \times \frac{kW}{3412\ Btu/h}$$

## 7.8 Internal Booster Heater Idle Energy Rate (Power)

- A) The booster heater idle energy rate (i.e. power) shall be calculated using the same equation as specified in *ASTM F1920-11; Section 11.5* for the tank heater idle energy rate with the following clarification and addition.
- 1) The value 60 provided in the equation is a conversion factor from minute to hours.
  - 2) This calculation shall also be used for steam.
  - 3) If the internal booster heater idle energy rate (i.e. power) is reported in Btu/h, convert it to kW based on the following equation:

### Equation 14: Internal Booster Heater Idle Energy Rate Conversion

$$E_{Idle\ rate} (kW) = E_{Idle\ rate} \left( \frac{Btu}{h} \right) \times \frac{kW}{3412\ Btu/h}$$

## 8 REFERENCES

- A) ASTM F857-07. Standard Specification for Hot Water Sanitizing Commercial Dishwashing Machines, Stationary Rack Type. Published April 2007.
- B) ASTM F858-07. Standard Specification for Hot Water Sanitizing Commercial Dishwashing Machines, Single Tank, Conveyor Rack Type. Published April 2007.
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- E) NSF/ANSI 3-2010. Commercial Warewashing Equipment. November 2, 2010. NSF/ANSI 170-2010. Glossary of Food Equipment Terminology. April 6, 2011.
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