ENERGY STAR Commercial Dishwasher Test Method Webinar

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Christopher Kent, U.S. Environmental Protection Agency
Ashley Armstrong, U.S. Department of Energy

ENERGY STAR Program

Agenda

- Introduction
- Validation Testing Overview
- Test Method
  - Definitions
  - Idle Energy Test
  - Flight Type
  - Post-sanitizing Rinse
  - Calculations
- Timeline
- Additional Information
  - Definition Revisions
  - Calculations
  - Test Data

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Webinar Goals

- Provide validation testing overview
- Discuss proposed changes to referenced test methods
- Discuss other test method issues

EPA–DOE Memorandum of Understanding (MOU)

- On September 30, 2009, EPA and DOE signed a memorandum of understanding (MOU) designed to enhance and strengthen the ENERGY STAR program

EPA: Brand Manager	DOE: Technical Support
• New Products • Performance Levels • Marketing & Outreach • Product Database • Monitoring & Verification	• Test Methods • Metrics • Monitoring & Verification

EPA-DOE ENERGY STAR Team

- As part of the MOU, DOE is the lead for writing and updating ENERGY STAR test methods
- Navigant is contracted by DOE to write new test methods and validate and/or update existing test methods
- DOE team will provide overview of support and findings related to the test method

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Test Method Validation

- DOE conducted testing to validate:

ASTM F1696-07	*Standard Test Method for Performance of Single-Rack, Door-Type Commercial Dishwashing Machines*
ASTM F1920-11	*Standard Test Method for Performance of Rack Conveyor, Commercial Dishwashing Machines*
ENERGY STAR Draft 1 Test Method (Rev. May 2011)	*Final Rinse Water Consumption*

Test Method Validation

- Testing conducted at NSF International in Ann Arbor, MI
- Testing scope:
  - Idle energy rate (i.e. power) consumption
  - Rinse water consumption
- Evaluated issues that arose during testing
- Resolutions incorporated into *ENERGY STAR Commercial Dishwashers Draft Test Method (Rev. Jan-2012)*

Test Method Scope

	Tested	Not Tested
Types	Under Counter	Flight Type
	Single Tank, Door Type	
	Single Tank Conveyor	
	Multiple Tank Conveyor	
Sub Types	Glasswashing	
	Pot, Pan, and Utensil Washer	
Rinse	Pumped	Post-sanitizing Rinse
	Fresh Water	
Tank Heat Type	Electric	Steam Injection
	Gas	
	Steam Coil	

Units Tested

	Tank Temperature	Tank Heat Type	Subcategory
Undercounter	High	Electric	Glasswashing
	Low	Electric	Chemical Dump Type
Stationary Single Tank Door Type	High	Electric	--
	Convertible	Gas	Dual Rated as Pot, Pan, Utensil
Single Tank Conveyor	Low	Steam	--
	Low	Electric	--
Multiple Tank Conveyor	Convertible	Electric	--
	High	Electric	--

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Definitions - Changes

- "Final" removed from "Final sanitizing Rinse" to include Post-sanitizing Rinse
- Mode Definitions
  - Wash, Rinse, and Dwell Modes
    - For stationary rack machines only
  - Idle Energy Mode
    - Added "ready to wash dishes at the required temperature"
  - Energy Saver Mode:
    - "A dishwasher is in energy saver mode if, after inactivity, the dishwasher converts to a setting that consumes less energy than it does in idle mode (not all dishwashers include this feature)."

Definitions - New Terms

- Water heater
- Booster heater
- Sanitization
- Sanitizing Solution
- Washing
- Fresh Water
- Sanitizing Rinse
- Chemical Sanitizing Rinse
- Hot Water Sanitizing Rinse
- Pumped Rinse
- Auxiliary Rinse
- Recirculating Sanitizing Rinse
- Non-recirculating Pumped Sanitizing Rinse
- Post-sanitizing Rinse
- Prewashing Unit
- Rack
- Ambient Temperature
- Flow Pressure
- Line Pressure
- Rated Temperature
- Tank Heater Idle Rate
- Uncertainty

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Maximum Energy Input Rate

- ASTM tests
  - Did not ensure dishwasher operating within 5% of manufacturer specified input rate
  - Overly burdensome
- ENERGY STAR proposed revisions:
  - No required starting temperature
  - More detailed test steps
  - Specific directions for:
    - Electric
    - Gas
    - Steam coil

Booster Calibration

	ASTM	ENERGY STAR (proposed)
Setting for units without recommended temperature	Average of 181°F	Minimum of 181°F
Temperature verification	Average temperature verified over five cycles	Stabilized flowing rinse temperature greater than manufacturer specified temperature -1°F

Wash Tank Temperature

	ASTM	ENERGY STAR (proposed)
Temperature verified	Average	Minimum
Maximum temperature	None	15°F higher than minimum temperature

Idle Energy Measurement

- Account for differences between single and multiple tank machines
  - All tanks cycle twice before start of test
- Run longer than 3 hours if 10 cycles have not occurred
- Minimum temperature verified (instead of average)
- Maximum temperature limit: 15°F above manufacturer specified tank temperature

Internal Booster Heaters

- ASTM procedures are for external boosters
- Internal booster heater machines unfairly penalized if internal booster heat included in idle energy
- Sub-monitor or separately monitor internal booster heater idle energy
  - Similar to method for measuring tank heater idle energy
- Some internal booster heaters cannot physically be separately monitored
  - Include internal booster heat in idle energy

Energy Saver Mode

- Draft test method requires disabling Energy Saver Mode prior to testing
  - Ensures ENERGY STAR specifications achieved with most conservative set-up
  - Reward efficient Idle Mode designs
  - "As shipped" settings vary
    - Typical durations before Energy Saver Mode turns on
    - User ability to override or change setting
  - Energy to convert from:
    - Idle Mode to Wash Mode
    - Energy Saver Mode to Wash Mode

Steam Coil Test Method

- At inlet, record:
  - Steam Temperature
  - Steam Pressure
  - Steam Volumetric Flow Rate
- At outlet, record:
  - Water Temperature
  - Water Pressure
- Record at least every second
- Record time delay between inlet and outlet
- Confirm majority non-condensed steam used at inlet

Steam Coil Calculations

- For each data point:
  - Inlet Stream and Outlet Stream Enthalpies
    - Based on mass calculations and steam tables
  - Instantaneous Energy Consumption
- Total energy consumption:
  - Sum of:
    - Instantaneous energy consumption for each data point
    - Electric energy consumption

Steam Coil Test Method

- Is the test method generally applicable to all dishwashers with steam coil tank heat?
- What are typical ranges of steam “quality” (i.e. how much steam vs. water) of the inlet and outlet streams?

Steam Injection Test Method

- Steam injection unit not tested
- Test method not developed
- Test method would be similar to steam coil test method
  - Enthalpy of inlet stream measured
  - Steam injected directly into water
  - Outlet stream would be tank overflow?
  - Other energy losses?

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Flight Type Machines

- Conveyor test method applicable:
  - Water consumption
  - Idle energy
- Are any modifications to conveyor test method necessary to accommodate flight types?

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Post-sanitizing Rinse - Water Consumption

- Water from Post-sanitizing Rinse included in water consumption value
- Setup and verification for Post-sanitizing Rinse similar to Sanitizing Rinse
- Known design:
  - Stationary rack
  - Fresh Water
  - Same spray system for Sanitizing and Post-sanitizing Rinses
- Test methods developed for other possible designs

Post-sanitizing Rinse - Water Consumption

- Would machines with a fresh water Sanitizing Rinse always have a fresh water Post-sanitizing Rinse?

Post-sanitizing Rinse - Water Consumption

- Would machines with a fresh water Sanitizing Rinse always have a fresh water Post-sanitizing Rinse?
- Would machines with a pumped water Sanitizing Rinse always have a pumped water Post-sanitizing Rinse?

Post-sanitizing Rinse - Water Consumption

- Would machines with a fresh water Sanitizing Rinse always have a fresh water Post-sanitizing Rinse?
- Would machines with a pumped water Sanitizing Rinse always have a pumped water Post-sanitizing Rinse?
- Would fresh water Sanitizing Rinse Stationary Rack type machines always use the same spray system for the Sanitizing Rinse and Post-sanitizing Rinse?

Post-sanitizing Rinse - Water Consumption

- Would machines with a fresh water Sanitizing Rinse always have a fresh water Post-sanitizing Rinse?
- Would machines with a pumped water Sanitizing Rinse always have a pumped water Post-sanitizing Rinse?
- Would fresh water Sanitizing Rinse Stationary Rack type machines always use the same spray system for the Sanitizing Rinse and Post-sanitizing Rinse?
- For conveyor machines, would the Post-sanitizing Rinse always have a solenoid for activation?

Post-sanitizing Rinse - Idle Energy

- Post-sanitizing Rinse feature does not consume idle energy
- No modifications to idle energy test necessary to accommodate Post-Sanitizing Rinse

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Calculations

- Racks per Hour
  - NSF Metric
  - Truncated to next lowest whole number
- Gallons per Hour
  - NSF Metric
  - Includes number of racks for stationary type machines
- Gallons per Rack
  - ENERGY STAR Metric

Stakeholder Discussion

- Other questions or comments?

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Version 2.0 Revision Timeline

January 9, 2012	Draft Test Method Published
January 25, 2012	**Test Method Webinar**
January 30, 2012	Stakeholder Comments Due
February 2012	Final Draft Specification Published
March 2012	Draft 2 or Final Draft Test Method Published* Final Version 2.0 Specification Published with Final Test Method
December 2012	Version 2.0 Specification Effective

* Pending need for additional drafts

Contact Information

Please send any additional comments to commercialdishwashers@energystar.gov or contact:

Christopher Kent
EPA ENERGY STAR Program
Kent.Christopher@epa.gov

Becky Duff
ICF International
RDuff@icfi.com

Ashley Armstrong
DOE ENERGY STAR Program
Ashley.Armstrong@ee.doe.gov

Julie Pierce
Navigant Consulting, Inc.
Julie.Pierce@navigant.com

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Definition Revisions

- Single Tank, Door Type: A stationary rack machine designed to accept a standard nominal 20 inch x 20 inch dish rack which requires the raising of a door to place the rack into the wash/rinse chamber. Closing of the door typically initiates the wash cycle. Subcategories of single tank, stationary door type machines include: single rack, double rack, pot, pan and utensil washers, chemical dump type and hooded wash compartment ("hood type"). Single tank, door type models can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

Definition Revisions

- Single Tank Conveyor: A conveyor machine that includes a tank for wash water followed by a ~~final~~ sanitizing rinse. This type of machine does not have a pumped rinse tank. This type of machine may include a prewashing section ahead of the washing section and an auxiliary rinse section for purposes of reusing the sanitizing ~~final~~ rinse water between the power rinse and sanitizing ~~final~~ rinse sections. Single tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

Definition Revisions

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

Definition Revisions

- Chemical Dump Type Machine: A low temp, stationary rack machine with a pumped recirculated ~~final~~ sanitizing rinse.
- Product Family: Variations of one model offered within a single product line with design differences limited to: finish/color; length of pre-wash section, voltage, and orientation (e.g., corner, straight through models). Individual models represented by a product family must have the same ~~final~~ sanitizing and post-sanitizing rinse water and idle energy consumption.

Definition Revisions

- Wash Mode: For stationary rack machines, the dishwasher is in wash mode when it ~~Machine~~ is actively running a cycle and is spraying wash water (i.e., water that is neither part of the ~~final~~ sanitizing rinse, post-sanitizing rinse, nor the prewashing unit).

- Rinse Mode: For stationary rack machines, the dishwasher is in rinse mode when it ~~Machine~~ is at the end of the actively running cycle and is spraying ~~final~~ hot water or chemical sanitizing rinse water or a post-sanitizing rinse.

- Dwell Mode: For stationary rack type, the dishwasher is in dwell mode when it ~~machine~~ is actively running a cycle but is not in wash or rinse modes.

Definition Revisions

- Idle Mode: For all dishwasher types, the dishwasher is in idle mode when it ~~machine~~ is not actively running ~~a cycle~~ but is still powered on and ready to wash dishes at the required temperature.

- Idle Energy Rate: The rate of energy consumed by the dishwasher ~~tank heater~~ while "holding" or maintaining wash tank water at the thermostat(s) set point during the time period specified in ASTM Standards F1920-11 and F1696-07.

- Energy Saver Mode: A dishwasher is in energy saver mode if, after inactivity, the dishwasher converts to a setting that consumes less energy than it does in idle mode (not all dishwashers include this feature).

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Calculations - Racks per Hour

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

Where:

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

- 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)

Calculations - Racks per Hour

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

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

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

Calculations - Gallons per Hour

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

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

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

Calculations - Gallons per Hour

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

$$Gallons\ per\ Hour = \frac{\sum_{n=1}^{5} \frac{Measured\ Weight\ of\ water\ for\ test\ run\ n\ (lbs)}{Rinse\ Activation\ Duration\ for\ test\ run\ n\ (seconds)}}{5\ test\ runs\ x\ \frac{8.34\ lbs}{gal}\ x\ \frac{1\ hour}{3600\ seconds}}$$

Where:

- Measured Weight of water for test run n = Weight of water sent to capture vessel from one minute of sanitizing rinse and post-sanitizing rinse solenoid activation
- Rinse Activation Duration = Measured duration of sanitizing rinse and post-sanitizing rinse solenoid activation (one minute +/- one second)

Calculations - Water Consumption

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

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

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

Calculations - Water Consumption

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

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

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

Calculations - Water Consumption

- Pot, Pan, and Utensil Type Machines

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

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^2 for machine tested

Calculations - Steam Coil

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

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

Where:

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

Calculations - Steam Coil

- Inlet Steam Total Mass

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

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)

Calculations - Steam Coil

- Inlet Stream Enthalpy
  - 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.

Calculations - Steam Coil

- Outlet Water Enthalpy
  - 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.
  - Calculate the enthalpy of the outlet water for each data point as follows:

Where:

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

- 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)

Calculations - Steam Coil

- Instantaneous Energy Consumption
  - Calculate the energy for each data point as follows:

Where:

$$E_i = \dot{M}_{steam,i} \; x \; \left(H_{inlet,i} - H_{outlet,i+t_{delay}}\right) x \; t_i \; x \; \frac{1 \; hour}{3600 \; seconds}$$

- 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)

Calculations - Steam Coil

- Total Energy Consumption

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

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}

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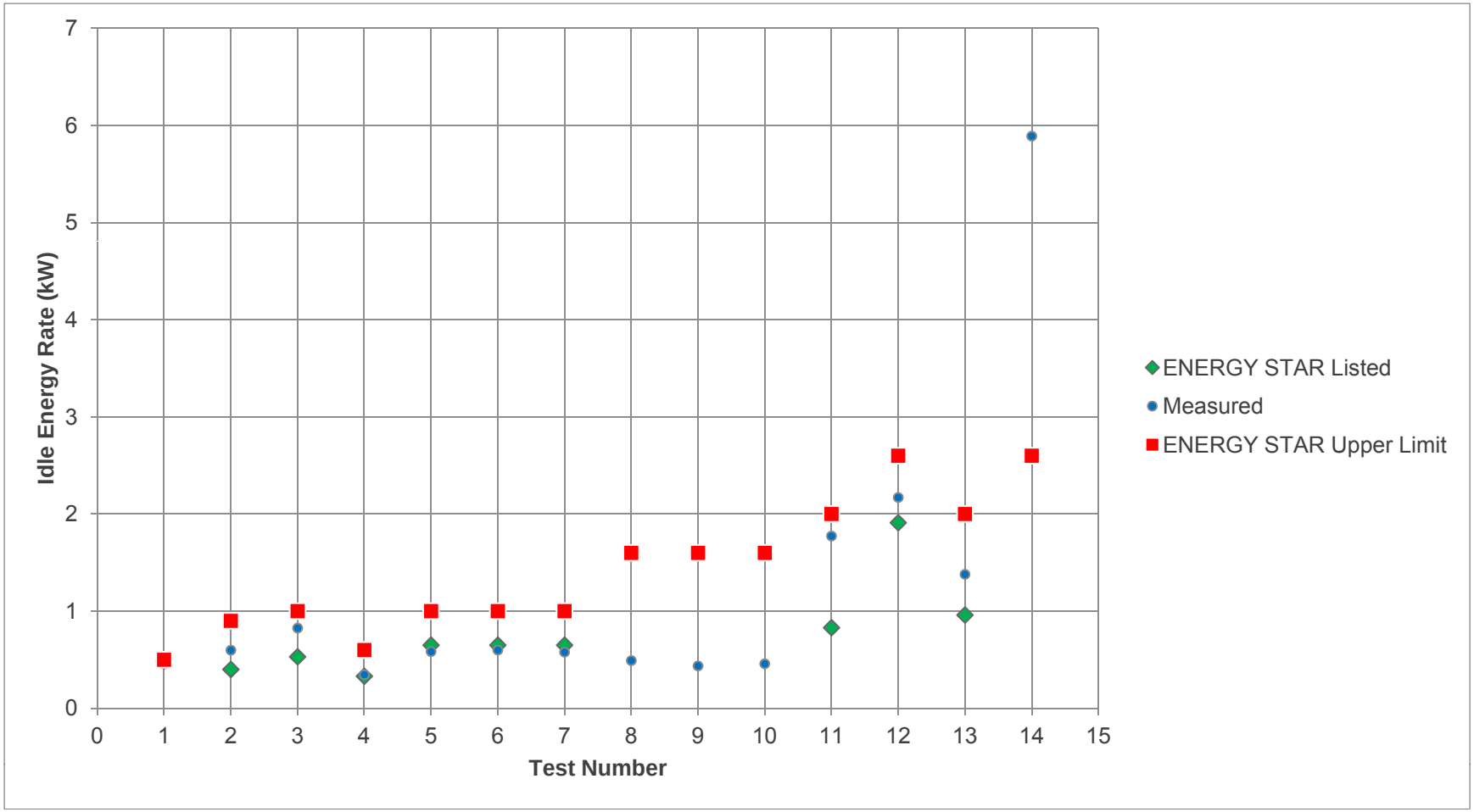
Test Unit Summary

Test Number	Unit Number	Test Type	Machine Type	Tank Temperature	Tank Heat Type
1	1	Initial	Undercounter	Low	Electric
2	2	Initial	Undercounter	High	Electric
3	3	Initial	Door Type	High	Gas
4	3	Alternate Temperature	Door Type	Low	Gas
5	4	Initial	Door Type	High	Electric
6	4	Repeatability	Door Type	High	Electric
7	4	Repeatability	Door Type	High	Electric
8	5	Initial	Single Tank Conveyor	Low	Electric
9	5	Repeatability	Single Tank Conveyor	Low	Electric
10	5	Repeatability	Single Tank Conveyor	Low	Electric
11	6	Initial	Single Tank Conveyor	High	Steam
12	7	Initial	Multiple Tank Conveyor	High	Electric
13	7	Alternate Temperature	Multiple Tank Conveyor	Low	Electric
14	8	Initial	Multiple Tank Conveyor	High	Electric

Validation Test Data Summary

- Measured Idle Energy and Rinse Water Consumption values are compared to:
  - Values listed in ENERGY STAR database (if applicable)
  - ENERGY STAR Commercial Dishwashers Version 1.2 Specification

Idle Energy Validation Test Data



Rinse Water Consumption Validation Test Data