

**Evaluation of Reported Results Using the Revised U.S.
Department of Energy Dishwasher Test Procedure**

Natascha Castro
National Institute of Standards and Technology

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U.S. Department of Commerce
Carlos M. Gutierrez, *Secretary*

Technology Administration
Robert Cresanti, *Undersecretary of Commerce for Technology*

National Institute of Standards and Technology
William A. Jeffrey, *Director*

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ABSTRACT

This paper summarizes the main changes to the Department of Energy's test procedure for residential dishwashers and presents the analysis of manufacturers' first-year test results using the new test procedure. The test results, which showed a small increase in energy consumption when using the revised test procedure, are well above the minimum energy standard for most basic models. It is recommended that a standards rulemaking be undertaken to evaluate technological improvements made since 1991, the time of the last standards rulemaking, and adjust the minimum energy standard as appropriate.

BACKGROUND

On August 29, 2003, the Department of Energy (DOE) published a test procedure revision for residential dishwashers to enable better testing of soil-sensing models and the measurement of standby power for all models [1]. Soil-sensing dishwashers measure operational values (e.g., turbidity, pressure, temperature) and adapt the wash cycle based on the information collected. Because of the dishwasher's responsiveness to different soil levels, the previous DOE test method for dishwashers, using clean dishes, was inaccurate for the purpose of rating energy consumption. Moreover, the energy consumption results using clean dishes were believed to be significantly lower than the levels consumers would likely experience. The new test procedure reflects the soil level found on consumers' dishware in a reliable energy consumption test procedure. It also incorporates standby power, energy consumed when the dishwasher was not performing a cleaning cycle, which was previously not factored into the energy consumption value reported to consumers.

The revised test procedure became effective September 29, 2003, allowing manufacturers to begin to make representations with results obtained using the revised test procedure. Since February 25, 2004, all manufacturers are required to use the revised test procedure. Although the revised test procedure was expected to increase the energy consumption values for some models, the Department of Energy retained the same minimum energy standard because industry stated that there were no marginally compliant models that would fail to comply using the new test procedure[1]. The minimum energy efficiency standard, revised on May 14, 1991, set the minimum energy factor of at least 0.46 cycles/kW·h for standard-size dishwashers and 0.62 cycles/kW·h for compact models [2]. It is also important to note that although the test procedure uses soiled test loads to obtain the energy values needed to calculate energy use, cleaning performance is not rated by the DOE test procedure; the energy factor is based on machine energy and water energy.

This current dishwasher test procedure is posted at
http://www.eere.energy.gov/buildings/appliance_standards/residential/dishwashers.html

THE REVISED DOE DISHWASHER TEST PROCEDURE

This section describes the four major changes instituted by the August 2003 final rule. More information on the basis for these changes can be found in the International Appliance Technical Conference (IATC) report on the New U.S. Department of Energy Dishwasher Test Procedure, which describes both the development process and verification testing [3]. This material is provided here in a condensed format to provide an overview of the significant changes made to the DOE dishwasher test procedure.

Revised calculations in this test procedure provide consumers with more realistic and accurate estimates of the complete operating cost and energy use of each dishwasher. The revisions also provide a better approximation of the actual energy consumption of soil-sensing models as consumers use them. The original test used clean dishes and did not engage the action of the soil-sensing mechanisms to take a dishwasher beyond the lightest wash cycles.

Under the revised test procedure, standby energy consumption is combined with the energy consumed during the wash cycle for a more complete annual operating cost estimate. Manufacturers or private labelers must now determine if the dishwasher is soil-sensing or non-soil-sensing, depending on whether it has the ability to adjust any energy-consuming aspect of a wash cycle based on the soil load of the dishes, and then follow instructions specific to that type of model. Soil-sensing dishwashers must be evaluated using a weighted, three-point test method.

Soil Load

By introducing a soiled test load, manufacturers now have a test procedure that assesses the cycle responses that are controlled by the sensing technology. The revised test procedure references the American National Standards Institute/Association of Home Appliance Manufacturers (ANSI/AHAM) DW-1 [4] standard for specifications on the size and composition of the place settings and the quantities and types of soils which must be applied to the dishes for the series of three soil tests: heavy, medium and light.

After running a preconditioning cycle, a standard-sized dishwasher's heavy response is tested, using four soiled place settings and four clean place settings; second, the medium response is tested, using two soiled place settings and six clean place settings; and third, the light response is tested, using one-half the soil load for a single place setting and seven clean place settings. The energy consumption for each of these tests is calculated by combining the electrical energy needed to run the machine and the water energy needed to heat the water that is supplied to the dishwasher. The combined energy for each test is represented as (Test #1 Energy (Heavy), Test #2 Energy (Medium), and Test #3 Energy (Light)). This testing order was selected to obtain a more realistic energy response than those control algorithms that use the previous wash cycle as an input to determining the wash intensity for the next cycle. Tests of compact models are the same except that for the heavy and medium tests soil loads are reduced by half. For each of these tests only half the detergent in the ANSI/AHAM DW-1 performance test is used and the rinse agent is omitted.

The Energy Factor Calculation

The dishwasher final rule established a weighted, three-point test method using soiled dishware for energy and water consumption measurements of soil-sensing dishwashers. The energy consumption for each of the three tests is measured and calculated in the same way as the original test method. However, the energy factor for a soil-sensing dishwasher is now based on a weighted average of the three energy consumption tests. The weighting factors are the percentages for the distribution of U.S. households in the three soil level categories – 62 % Light level of soil, 33 % Medium, and 5 % Heavy.

Incorporating the weighting factors with the energy consumed in each test yields an energy factor for soil-sensing dishwashers as defined in Equation 1.

Equation 1 – Energy Factor (EF) for Soil-Sensing Dishwashers

$$EF_{\text{soil-sensing}} = 1 / [(.62 \times \text{Test \#1 Energy}) \quad \text{Light} \\ + (.33 \times \text{Test \#2 Energy}) \quad \text{Medium} \\ + (.05 \times \text{Test \#3 Energy})] \quad \text{Heavy}$$

Standby Power

Many soil-sensing dishwashers and selected non-soil-sensing dishwashers consume standby power, a constant low level of power to retain information necessary for their operation. With the revised DOE test procedure, the standby mode is defined, along with the required measurement equipment and method for calculating standby energy consumption.

Two options are available for measuring standby energy consumption, depending on whether the stability criteria are met. If the standby power consumption is stable and the variation in the power levels is less than 5 % of max, then manufacturers or private labelers can measure the instantaneous power level using a wattmeter. However, if the stability criteria are not met, manufacturers or private labelers must measure the energy consumption using a watt-hour meter over a period of at least 5 min and calculate the average standby power by dividing the energy measured using the watt-hour meter by measurement time. The estimated annual standby power use, S , is expressed in kilowatt-hours per year and defined in Equation 2.

Equation 2 – Estimated Annual Standby Power Use, S

$$S = S_m \times ((H_s)/1000)$$

where,

$$S_m = \text{average standby power measured in watts}$$

$$H_s = \text{number of standby hours per year (calculated in the test procedure)}$$

These changes provide the means to obtain a quantitative value for the level of standby energy that the dishwasher consumes. Manufacturers or private labelers must add this standby energy amount to the machine energy and water energy computed for the normal cycle and representative normal cycle for soil-sensing models. This combined energy consumption is used to determine the Estimated Annual Operating Cost (EAOC) and the Estimated Annual Energy Use (EAEU).

Non-Soil-Sensing Dishwashers

For non-soil-sensing dishwashers, manufacturers or private labelers will still use clean dishes to determine the energy factor as the average of the test results from the normal and truncated normal cycles. In addition, manufacturers or private labelers must calculate the standby power consumption for any dishwasher using energy in standby mode and add that figure to the EAOC and EAEU totals, but not to the energy factor.

Only dishwashers that are both non-soil-sensing and non-water-heating are tested without a test load.

MANUFACTURER DATA AND ANALYSIS

By February 2004, all manufacturers began testing their products using the revised DOE test procedure and were required to certify compliance with the federal minimum energy standard in their annual report. The National Institute of Standards and Technology (NIST) obtained copies of energy consumption data submitted to the Federal Trade Commission (FTC) [5], along with several reports from manufacturers for 2005. The 2005 data was not yet available on the FTC website and therefore was extracted directly from the available manufacturers reports. Table 1 lists the manufacturer and models reported in 2004 along with data available to date for 2005. Because the 2005 data is incomplete, this report will focus on the 2004 data, which represents over 500 basic models.

Table 1: List of Manufacturer Reported Models for 2004-2005¹

Manufacturer	2004 All Models²		New for 2005³
BSH Home Appliances	Bosch Thermador Gaggenau	Kueppersbusch Siemens	Bosch Thermador
Dacor	Dacor		
Electrolux	Frigidaire Kenmore Multiflex	White-Westinghouse Gibson	
Fisher Paykel	Fisher & Paykel		Fisher & Paykel
General Electric Camco (Canada)	GE --		-- GE
Haier			Haier
Maytag	Maytag Magic Chef Crosley Amana Jenn-Air	Performa Admiral Samsung Jade Julien	

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² The data in this column represents all models manufactured in 2004.

³ The data in this column represents all new model reports for 2005 and includes any increase in the 2005 annual report relative to 2004 annual report values. Discontinued models are not shown.

Miele	Miele	
Whirlpool	Estate Kenmore KitchenAid	Roper Kirkland Ikea Ingles Roper
Asko	Asko	Eurotech
Viking	Viking	
Equator Corporation	Equator	

Comparison to Federal Minimum Energy Efficiency Standard

The energy factor, the unit selected to set the minimum energy efficiency standard, is simply the inverse of the energy consumption for the normal cycle. It does not take into account standby power consumption because it is a measure of the per-cycle energy efficiency.

Figure 1 shows the reported energy consumption for all standard dishwashers in the 2004 model year. Here it is evident that of the 500 models reported, 4 models fail to meet the minimum energy standard of 0.46 (these models are no longer being produced). The graph in Figure 1 shows a plateau at an energy factor of approximately 0.6 cycles/kW·h.

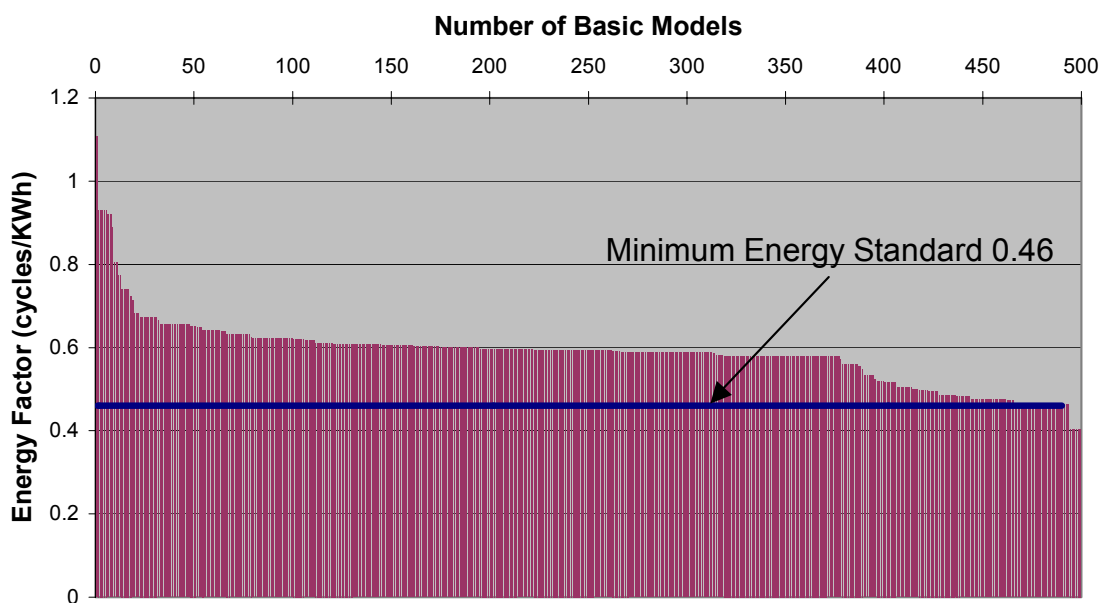


Figure 1: Reported Energy Efficiency for Standard Residential Dishwashers

Further examination of Figure 1 shows the following breakdown of percentages and the Energy Factor that the group meets or exceeds. Of the 500 models, only 5 % are 'borderline' with the minimum energy standard. Table 2 shows the Energy Factor statistics for the 2004 dishwasher data.

Table 2: Energy Factor Statistics for 2004 Dishwasher Data

Percentile	Energy Factor
75 %	0.58 (25 % above minimum energy standard)
85 %	0.50 (9 % above minimum energy standard)
95 %	0.47 (2 % above minimum energy standard)

In the last decade since the minimum energy efficiency standards were set, there have been tremendous advances in dishwasher technology, including the development and strong market penetration of soil-sensing dishwashers. Although a very expensive feature at its introduction, sensor prices have brought down manufacturing costs and resulted in an increase to both the number of manufacturers that offer this feature, as well as the number of soil sensing models that individual manufacturers produce.

Although manufacturers are not required to state whether the dishwashers use soil-sensing technology, it is estimated that one-third to one-half of the models are soil-sensing dishwashers. In fact, the prevalence of pretreatment practices (Castro et al. 2004) result in lower energy consumption values for the dishwashers because the light, medium, and heavy soil loads are based upon ‘normal use’. This has provided a benefit to soil sensing dishwashers because the ‘normal cycle’ is calculated using a weighting factor of 0.62 % for the light cycle, which is typically significantly less energy intensive than the ‘normal cycle’ of a conventional dishwasher.

Figure 2 shows the reported energy consumption for all compact dishwashers in the 2004 model year. In 2004 there were only three compact dishwashers, all of which exceeded the minimum energy standard of 0.62 by at least 40 %.

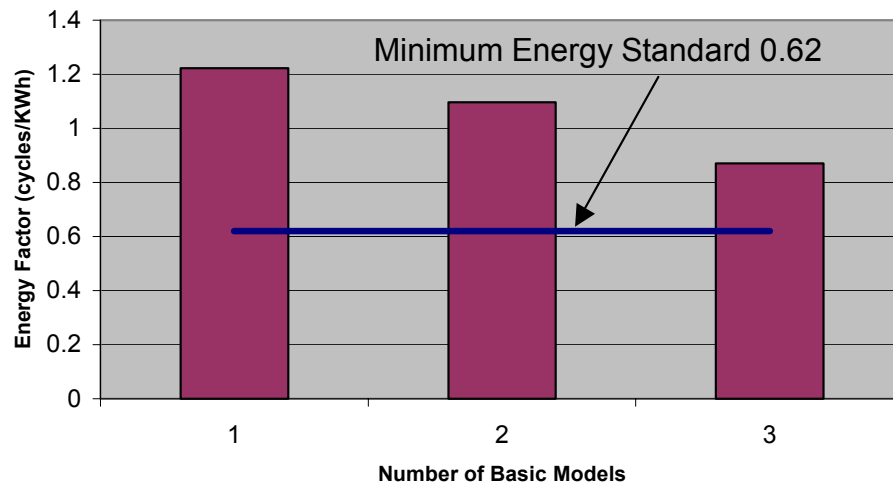


Figure 2: Reported Energy Efficiency for Compact Residential Dishwashers

ENERGY STAR

Earning the Energy Star means a product meets the energy efficiency guidelines set by the U.S. Environmental Protection Agency and the U.S. Department of Energy. The current Energy Star criteria became effective January 1, 2001 and apply only to models manufactured after January 1, 2001. The new criteria raised the requirements from 13 % above the federal standard to at least 25 % above the federal standard as listed in Table 3, the maximum according to Energy Star. Additionally, only standard capacity dishwashers are eligible to qualify for Energy Star, where standard capacity is defined as greater than or equal to eight place settings and six serving pieces; compact dishwashers are not eligible to earn the Energy Star [6].



Table 3: Key Energy Star Criterion (source: www.energystar.gov)

Equipment	Criteria	
Dishwashers	At least 25 % more energy efficient than the minimum federal government standards	

Product Type	Federal Standard (Energy Factor)	Energy Star Requirement (Energy Factor)
Standard (\geq place settings + six serving pieces)	≥ 0.46	≥ 0.58
Compact (< 8 place settings + six serving pieces)	≥ 0.62	NA

ENERGY STAR seeks out partnerships to manufacture or promote Energy Star labeled products and homes, promote or sponsor programs, and work with Energy Star qualified new homes. Partners include:

- Manufacturers - who label products eligible for the Energy Star designation and receive product differentiation and increasing market share.
- Retailers - who stock and promote Energy Star products and benefit with increased sales and customer loyalty.
- Utilities & Regional Energy Efficiency Program Sponsors - who sponsor energy efficiency programs and are instrumental to delivering the Energy Star message at the local level.
- Builders, Lenders, Raters, & Sponsors of New Homes - who partner with and encourage the use of Energy Star in new homes and as a result see increased profits, satisfied customers, and environmental benefits.

This Energy Star criteria, applied to the 2004 product set, results in the Energy Star qualification for 370 out of the 490 standard dishwasher models. That is, even with the tightening of requirements in January 01, 2001, 75 % of the dishwashers qualified for Energy Star status. At present, the top performer, with an energy factor of 1.11 (140 % above the federal standard) receives the same Energy Star rating as dishwashers with an energy factor of 0.58 (25 % above the federal standard).

The criteria for qualification are intended to be strict and to present a challenge for energy efficiency. It provides incentives for manufacturers to earn the right to label and market their

products as Energy Star products, and to gain the benefit of product differentiation and increasing market share. Energy Star was a program designed to highlight the best energy efficient products and to aid consumers in making their purchasing decisions. However, due to improvements in dishwasher technology, the requirement to be at least 25 % more efficient than the minimum federal government energy standard is generally attainable. Manufacturers with the most energy efficient models do not see the benefit of product differentiation when 75 % of the products qualify. Utilities & Regional Energy Efficiency Program Sponsors have difficulty offering incentives for the purchase of qualifying products when the average dishwasher on the market qualifies. This suggests the need to review the minimum energy standard to determine whether the federal standard should be raised, as well as a subsequent review of the Energy Star criterion.

SUMMARY AND RECOMMENDATIONS

The August 29, 2003 changes to the DOE test procedure provided a new method of test for soil-sensing dishwashers and added a test method for incorporating standby power into the estimated annual operating cost. The revised test procedure, which became effective September 29, 2003, requires manufacturers to make representations (i.e., energy labels) with results obtained using the revised test procedure as of February 25, 2004. The introduction of a soil-based test presented a more realistic test of the sensor operation on which consumers can base purchasing decisions. However, because no soil-sensing models would fail to comply when tested with the revised test procedure, the Department was not required to change the minimum energy efficiency standards.

The current Federal standards for minimum energy efficiency, established in 1991, are 0.46 cycles/kW·h for standard dishwashers and 0.62 cycles/kW·h for compact dishwashers. Since that time, soil-sensing dishwashers have penetrated the market and well exceeded the initial forecast of 10 % market share of dishwasher models.

Analysis of test results of dishwashers for model year 2004 was presented along with a subset of 2005 data. The data showed that the energy factor was well above the minimum energy standard for most models. In addition, data for the three compact models manufactured in 2004 show that all are at least 40 % above the minimum energy standard for compact dishwashers. Furthermore, the Energy Star program, which highlights the top performers in terms of energy efficiency, shows that on a national basis, 75 % of the models on the market earn the Energy Star rating. This is even after the Energy Star program raised its qualification criteria from 13 % above the Federal energy standard to 25 % above the Federal energy standard.

It is recommended that a standards review be undertaken to determine an appropriate increase to the minimum energy standard followed by a review of the Energy Star criterion. The intent is not to provide a moving target to manufacturers, but rather to evaluate whether technological developments have advanced to a point that lower performers should be required to meet higher standards. It is also desirable that the Energy Star program continues to provide an incentive to manufacturers for new models such that top performers receive the recognition and distinction among other models. With that, Energy Star partners can develop incentives directed to those areas where sales are lagging and the marketplace needs some help.

REFERENCES

1. DOE, Title 10 Code of Regulations (CFR) Part 430, Appendix C to Subpart B “Uniform Test Method for Measuring the Energy Consumption of Dishwashers,” August 29, 2003.
2. Federal Register Volume 56, No. 93, p. 22250, May 14, 1991.
3. Castro, N.S. et al, 2004. “The New U.S. Department of Energy Dishwasher Test Procedure: Development and First Results” in proceedings of IATC.
4. ANSI/AHAM DW-1-1992, “Household Electric Dishwashers,” 1992.
5. Federal Trade Commission data on residential appliances energy use is available at <http://www.ftc.gov/bcp/conline/edcams/eande/appliances/index.htm>
6. Energy Star requirements are available at <http://www.energystar.gov/>