APPLIANCE ENGINEER®

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A New Federal Test Procedure for Dishwashers

The following discusses a new test method for dishwashers developed by DOE, NIST, AHAM, TIAX, and stakeholders and presents the results from tests of two soil-sensing dishwasher models.*

Soil-sensing models represent a group of innovative dishwashers that measure operational values (e.g., turbidity, pressure, and temperature) and adapt the wash cycle based on the information collected. Because of the responsiveness of these dishwashers to the presence or absence of a soil load, the Department of Energy (DOE) test method for dishwashers, using clean dishes, was inaccurate for the purpose of rating energy consumption. The energy consumption results using clean dishes were believed to be significantly lower than the levels consumers would likely experience. In addition, standby power consumed when the dishwasher was not performing a cleaning cycle was previously not factored into the energy consumption reported to consumers.

This paper summarizes the main changes to the test procedure for residential dishwashers and quantifies energy consumption differences through tests of two soil-sensing dishwashers. The tests presented herein were an important step in validating the DOE test procedure as a means to obtain efficiency factors that consumers can rely on for making purchase decisions.

Revised DOE Test Procedure

The Energy Conservation Program for Consumer Products requires the evaluation of energy consumption for each basic model for each covered product. On Aug. 29, 2003 a revised test procedure for residential dishwashers was published. The goal of this rulemaking was to enable better testing of soil-sensing models and the measurement of standby power for all models [1].

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. Currently, almost all dishwashers on the market are water-heating dishwashers, providing internal water heating to more than 120°F in at least one wash phase of the normal cycle, and are tested using 50°F or 120°F inlet water, though provisions are made for testing non-water-heating dishwashers.

The DOE test procedure prescribes the test conditions, including those listed in Table 1. It requires a test load for water-heating dishwashers, while tests of non-water-heating dishwashers are conducted without a test load. Under the revised test procedure, manufacturers must test soil-sensing dishwashers using a three-level (heavy, medium, and light), soil-based test that will yield an energy factor (EF) that is based on a range of challenges to the machines' automatic sensing systems. For non-soil-sensing dishwashers, manufacturers or private labelers will still use the original test procedure with clean dishes to determine the EF 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 estimated annual operating cost (EAOC) and estimated annual energy usage (EAEU) totals, but not to the EF.

Table 1: DOE Test Procedure Test Conditions

Dishwasher Type	Water Heating	Non-Water-heating
Water Temperature	(50±2)°F or (120±2)°F	140±2°F
Test Load	8 place settings	none
Machine & Room Temp.	75°F to 85°F	75°F to 85°F
Water Pressure	(35±2.5) psi	(35±2.5) psi

The ANSI/AHAM DW-1 [2] standard is referenced in the test procedure for specifications on the size and composition of the place settings and the quantities and types of soils that 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.

For each of these tests, only half the detergent in the ANSI/AHAM DW-1 performance test is used and a rinse agent is omitted. Because some control algorithms use the previous wash cycle as an input to determining the wash intensity for the next cycle, this test sequence was selected to obtain a more realistic energy response. Tests of compact models are the same, except that in the heavy and medium tests, soil loads are reduced by half. For each of the three test runs, manufacturers or private

labelers must calculate the machine energy consumption, drying energy consumption, water consumption, and water energy consumption. For soil-sensing dishwashers, the EF will be determined as a weighted average of the three tests, using 0.05, 0.33, and 0.62 to represent the frequency that consumers use the heavy, medium, and light response, respectively. These weighting factors are discussed in a report from TIAX, Inc. [3].

The test procedure also defines standby mode 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 power usage is stable. If the stability criteria are met, manufacturers or private labelers can measure the standby power directly using a wattmeter. If the standby power consumption is not stable and there is significant variation in the power levels, the manufacturers or private labelers must measure the energy consumption using a watt-hour meter over a period of at least 5 min. They then calculate the average standby power by dividing the energy measured using the watt-hour meter by measurement time. 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 and water energy computed for the normal cycle and representative normal cycle for soil-sensing models, and include those amounts in the EAOC and EAEU.

By combining standby energy consumption with the energy consumed by the wash cycle, this test procedure will calculate information that will provide consumers with more realistic and accurate estimates of the complete operating cost and energy use of each dishwasher. With the soil test, soil-sensing dishwashers have a test procedure that challenges the cycle responses that the sensing technology controls. It will provide a better approximation of the actual energy consumption of soil-sensing models as consumers use them than did the original test which used clean dishes and did not engage the action of the soil-sensing mechanisms to take a dishwasher beyond the lightest wash cycles.

The minimum energy standard, not affected by the 2003 rulemaking, specifies an EF of at least 1.65 cycles/MJ (0.46 cycles/kWh) for standard-size dishwashers to be in compliance. This factor is the basis of comparison for all models.

As part of the test procedure development process, verification studies were conducted before publishing the final rule. These tests were carried out to determine whether the test procedure could effectively measure the energy and water consumption of models using different soil-sensing technologies.

Verification Testing and Analysis

Two types of soil-sensing dishwashers were tested using the revised test procedure. The first, Dishwasher A, uses an optical sensor to gauge the turbidity level of the water as a measure of soil load. The second dishwasher, Dishwasher B, uses a pressure sensor to measure the level of soil collected at the food filter. Both of these models then use their sensor readings as inputs to the wash algorithm to determine the appropriate wash intensity for the cycle.

Tests of the heavy, medium, and light response for each dishwasher were carried out. The number of tests required for each dishwasher was determined using the 95-percent confidence level required for reporting results. Due to the variations in test results for the two dishwashers, a total of nine tests were required for each model to reach a 95-percent confidence level. The sections below present the measurements taken for water and energy consumption and discuss the calculations needed to obtain the EF and standby power consumption.

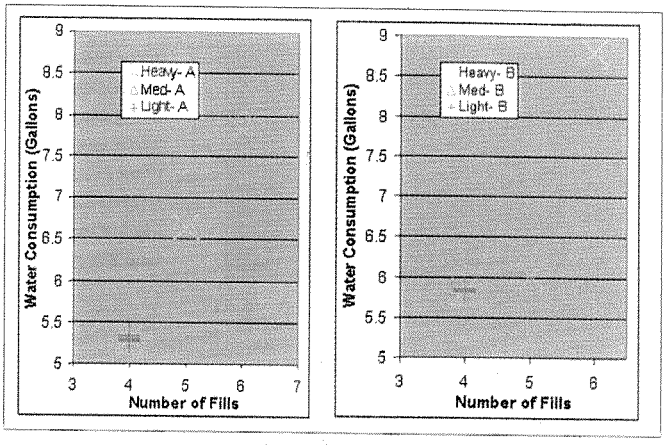

Figure 1a and 1b: Plot of Water Consumption Results for Dishwashers A & B

Water Consumption

The energy attributed to heating the water supply from 50°F to the supply temperature of 120°F represents the most significant factor on energy consumption. For this reason, the variability of the fill size and repeatability of fill patterns directly impact the resulting EF.

The test results show an average fill size of 1.33 gal for Dishwasher A and 1.43 gal for Dishwasher B. Although the AHAM DW-1 soiling procedure is designed for repeatability, both dishwashers have some variation in the fill data. Water consumption data for Dishwasher A and Dishwasher B are plotted in Figure 1a and Figure 1b, respectively.

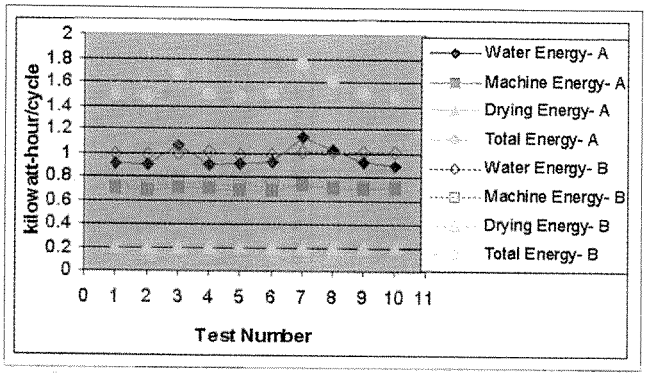

Figure 2: Plot of Energy Consumption Results

For Dishwasher A, the light-soil load invariably triggered a four-fill cycle while both medium and heavy loads had responses that varied from four to six fills. This individual variation of fill size is a result of the system's response to turbidity measurements. In Figure 1a, the data at four fills represent the response six times out of ten tests conducted while the remaining four tests varied between five and six fills.

Dishwasher B had more consistent responses to the standard soil loads with a four-fill cycle response for all tests using the light- and medium-soil loads. The only variation (shown in Figure 1b) came from the heavy load that triggered the six-fill response six times out of ten, the five-fill response three times out of ten, and the four-fill response once. However, Dishwasher B does not have uniform fill sizes. Using the pressure measurement across the food filter as an input, the dishwasher runs a small fill of approximately 0.2 gal to clean the filter. This is the reason that the water consumption for the five-fill cycle is only slightly higher than that of the four-fill cycle.

Energy Consumption Tests

The per-cycle energy consumption for a dishwasher is a composite of the machine energy, the water energy, and the drying energy. First, the values recorded for water consumption are combined using the weighting factors to obtain a representative water use for the sensor's normal cycle. Water energy consumption is then calculated as the product of water use, the increase in nominal water heater temperature, and the specific heat of water. Next, the representative machine energy consumption for the sensor normal cycle is determined by multiplying the recorded energy consumption for the heavy, medium, and light response by the weighting factors and adding the resulting values. Finally, the drying energy consumption is calculated as the average energy consumed during the drying portion of the three-level test. In order to give manufacturers credit for machines that provide consumers with the ability to dry dishes without heat, the total energy consumption is calculated as the water energy plus the machine energy, minus half of the drying energy. This represents the energy use for consumers that use the air-dry option 50 percent of the time.

Figure 2 shows the energy consumption values for both dishwashers. The results are comparable for the two dishwashers, though it is evident that the higher water consumption for Dishwasher B results in a higher total energy consumption.

Energy Factor Calculation

The energy factor 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. The DOE sets the Minimum Energy Efficiency Standard at 0.46 cycles/kWh for standard dishwashers and 0.62 cycles/kWh for compact dishwashers. The EF calculated for each test is shown in Figure 3.

In Figure 3, error bars mark three standard deviations from the mean. It is evident that Dishwasher A has much more variation in its cycle responses. Because manufacturers must report the energy performance of each model, it is useful to determine the number of tests required to meet the confidence interval for reporting results. This is computed using the following equation:

$$n = t^2 s^2 / d^2$$

where,

d is the allowable margin of error, s is the standard deviation, n is the number of tests, and t is the percentile of a one-sided t-distribution. [4]

Setting d equal to 5 percent of the minimum energy standard (as is used in the sampling plan for enforcement testing), one can determine if additional tests need to be conducted to satisfy the confidence requirements.

Due to the variation in the test results, more than 10 tests are required to reach the 97.5-percent confidence for Dishwasher A. However, testing was stopped at 10 tests because the purpose of this test is to validate the procedure and not to obtain the confidence levels needed to make representations for the energy efficiency of these models. For Dishwasher B, because there was very little variation in the results, the sample size for 97.5-percent confidence was ascer-

tained to be nine tests. The results show an EF of 0.65 for Dishwasher A and 0.61 for Dishwasher B, both of which well surpass the minimum energy standard of 0.46.

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 instantaneous power level is measured using a wattmeter for dishwashers with stable power levels (variations less than 5 percent of max) or averaged over time using a watt-hour meter and dividing the accumulated energy consumption by the duration of the measurement period. Measurement results were 2.2 W for Dishwasher A and 2.0 W for Dishwasher B. This represents a small, but not insignificant level of energy consumption.

The estimated annual standby power use, S, expressed in kilowatt-hours per year (kW/year) is calculated as the average standby power multiplied by the number of hours that the appliance is in standby mode. This value is used as an input to the EAOC.

Conclusions

The changes to the DOE test procedure provide a new method of test for soil-sensing dishwashers and add a test method for incorporating standby power into the EAOC. Results from tests of two dishwashers using the revised test procedure show promising results for the comparison of energy performance.

The introduction of a soil-based test presents a more realistic test of the sensor operation on which consumers can base purchasing decisions. The resulting EF are 0.65 and 0.61 for dishwashers A and B, respectively. However, it is important to note that although these values report energy use, cleaning performance is not rated by the DOE test procedure.

The revised test procedure, which was effective as of Sept. 29, 2003, is posted at *www.eere.energy.gov/buildings/appliance_standards/residential/dishwashers.html*. Manufacturers may already begin to make representations with results using the revised test procedure, and all manufacturers must use the revised test procedure by Feb. 25, 2004.

Acknowledgements

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References

1. DOE 10 CFR Part 430, Appendix C to Subpart B, *Uniform Test Method for Measuring the Energy Consumption of Dishwashers*, 2003.

2. ANSI/AHAM DW-1-1992, *Household Electric Dishwashers*, 1992.

3. TIAX, Inc., *Review of Survey Data to Support Revisions to DOE's Dishwasher Test Procedure* and *Addendum*, 2002.

4. Natrella, Mary G., *Experimental Statistics*, National Bureau of Standards Handbook 91, 1963.

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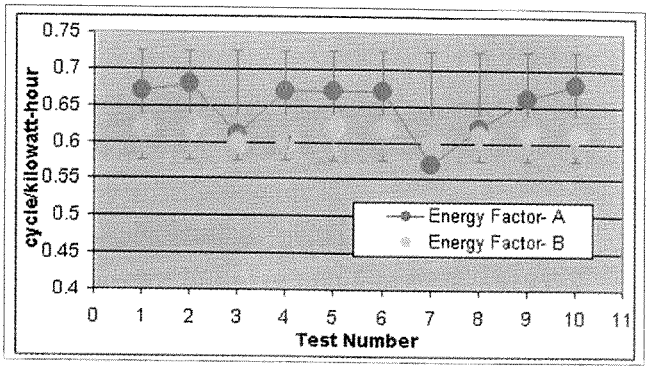
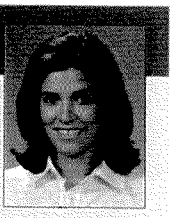


Figure 3: Plot of Energy Factor Results

About the Author



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