ADDENDUM TO PROJECT REPORT:

Purdue University

Technical Assistance Program

COMPARISON OF CONSUMPTION BETWEEN THE DISHMASTER® FAUCET AND AUTOMATIC DISHWASHING MACHINES

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COMMENTS ON ENERGY CONSUMPTION

This report addendum will show calculations for energy usage and water consumption for automatic dishwashing as compared to using the Dishmaster® faucet system. In discussions with the client, it was agreed to use assumptions of 5 gallons of water usage for handwashing with the Dishmaster® faucet system.

In the original report, column 4 (kWh/Year) in Table 1 gives energy consumption of some dishwasher models. Figure 3 and the third paragraph from the bottom of page 3 give maximum energy consumption (less than or equal to 324 kWh/year). As stated in the paragraph above Figure 3, there are around 215 cycles per year. So, the dishwasher should not use more than energy per cycle:

$$\frac{324\,\frac{kWh}{year}}{215\,\frac{cycles}{year}} = 1.5\,\frac{kWh}{cycle}$$

Earlier, there were 264 cycles/year prescribed, so the limit was:

$$\frac{324\,\frac{kWh}{year}}{264\,\frac{cycles}{year}} = 1.23\,\frac{kWh}{cycle}$$

Dishwashers which are predicted to take cold water are more energy efficient (paragraph 3 from the top of page 3), since more energy is lost during transport of hot water through the pipeline.

Conversion of gallons to Liters (L) and kilograms (kg) is:

$$1\ \textbf{gallon of water} = 3.7854\ \text{L}$$
$$\textbf{Density of water} \approx 1.0\ \frac{\text{kg}}{\text{L}}$$
$$1\ \textbf{gallon of water} \approx 3.7854\ \text{kg}$$

Conversion of ºF to ºC is:

$$^{o}C = (^{\circ}F - 32) \cdot \frac{5}{9}$$

Specific heat of water at 77 ºF is:

$$C_p = 4.187\ \frac{\text{kJ}}{\text{kg}\ ^{\circ}\text{C}} \cdot 3.7854\ \frac{\text{kg}}{\text{gallon}} \approx 15.85\ \frac{\text{kJ}}{\text{gallon}\ ^{o}\text{C}}$$

For rough calculations, C_p can be assumed as constant (not temperature-dependent). It actually decreases slowly with temperature.

Here, energy needed to heat up one gallon from 52 to 107 ºF (from 11.11 to 41.67 ºC) will be calculated. The temperature difference is ΔT = 55 ºF, or ΔT = 30.56 ºC[1].

The energy needed to heat up one gallon for ΔT = 29.44 ºC is:

$$Q_1 = C_p \cdot \Delta T = 15.85\ \frac{\mathbf{kJ}}{\mathbf{gallon\ ^\circ C}} \cdot \mathbf{30.56\ ^\circ C} = \mathbf{484.376}\ \frac{\mathbf{kJ}}{\mathbf{1\ gallon}} = \mathbf{484.376\ kJ\ (per\ 1\ gallon)}$$

This can be converted to kilowatt-hours (1 h = 3600 s; 1 kW = 1 kJ/s):

$$Q_1 = 484.376\ \mathbf{kJ} \cdot \frac{\mathbf{1\ h}}{\mathbf{3600\ s}} = \mathbf{0.1345}\ kWh \approx \mathbf{0.135}\ kWh\ (per\ \mathbf{1}\ gallon)$$

The energy needed to heat up 5 gallons is:

$$Q_5 = 5 \cdot Q_1 = 5 \cdot 0.135\ kWh = 0.675\ kWh\ (per\ 5\ gallons)$$

It is not certain how warm dishwashers heat their water, so in this scenario, it is assumed that the water is heated to approximately 107 ºF. Additionally, each automatic dishwasher has different water and energy usage and this scenario considers an automatic dishwasher that uses 5 gallons of water heated to 107 ºF. Since the maximum power consumption per one automatic dishwasher cycle is 1.5 kWh, there would be an excess of energy per one cycle given the assumptions above:

$$1.5 - Q_5 = 1.5 - 0.675 = 0.825\ \frac{kWh}{cycle}$$

This 0.825 kWh assumingly goes to energy for other electro-mechanical systems in a dishwasher (pumps for water and sprinklers, motor for spinning the sprinkler head...). We note that this is for maximum consumption of both water and electrical energy. As can be seen from Table 4 in the report, many dishwashers consume less water and energy than limited.

Cost per Dishwashing Cycle

As the price and amounts of detergents are unknown, the cost comparison of the two methods are not included in the following calculations. The energy and water cost per one cycle is (either for hand or machine washing):

$$Water\ and\ energy\ cost = Cost\ of\ energy + Cost\ of\ water$$

As of August 2009, in Indiana 1 kWh of electricity costs 7.67 cents. One gallon of tap water cost around 0.281 cents. Note that unit costs vary geographically and over time. So the water and energy cost of one cycle for the automatic dishwasher is:

$$Water\ and\ energy\ cost = 1.5\ kWh \cdot 7.67\ \frac{cents}{kWh} + 5\ gallons \cdot 0.281\ \frac{cents}{gallon} = 12.91\ cents$$

[1] ΔT in degrees Fahrenheit and degrees Celsius are not in linear relationship (it depends on end temperatures in Fahreneits). So degrees Celsius will be held in calculations since literature data is more readily available in degrees Celsius. Calculation of ΔT in degrees Fahrenheit is error prone.

And then for handwashing, this would be:

$$Water\ and\ energy\ cost = 0.135\ \frac{kWh}{gallon} \cdot 5\ gallons\ \cdot\ 7.67 \frac{cents}{kWh} + 5\ gallons \cdot 0.281 \frac{cents}{gallon} = 5.18\ cents$$

So the maximum number of gallons of water that the Dishmaster® can use to have equivalent energy and water usage costs as compared to the automatic dishwasher would be:

$$Water\ and\ energy\ cost = 0.135\ \ kWh/gallon \cdot \#\ of\ gallons\ \cdot\ 7.67\ cents/kWh + \#\ of\ gallons \cdot 0.281\ cents/gall$$

$$= 1.035 \cdot \#\ of\ gallons + 0.281 \cdot \#\ of\ gallon$$

Solving for the # of gallons would provide 9.81 gallons. So if washing with the Dishmaster® uses 9.81 gallons per one cycle, one can say that the cost of its energy and water use is within the cost limit for dishwashers. However, according to the Energy Star standards, Dishmaster® has to use no more than 5 gallons of water to be comparable with dishwashers which meet the Energy Star criteria.

IMPORTANT NOTE 1: All values are obtained under assumption that water is heated from 52 to 107 ºF. To obtain values for other temperature ranges, the same procedure can be repeated. However, for temperature ranges which are close to that used here (which is most likely the case) values will be very close together, so everything can be calculated on the base of proportions. For example, energy required to heat up water from 50 ºF to 110 ºF (for 60 ºF) is very close to:

$$Q_1 = 0.135\ kWh\ (calculated\ for\ 55°F) \cdot \frac{60\ °F}{55\ °F} = 0.147\ kWh$$

IMPORTANT NOTE 2: Calculation presented here does not include thermal and other losses.

Conclusion

Table 1 shows energy and water usage and cost comparisons for both the automatic dishwasher and the Dishmaster® faucet system. From this table, it is evident that handwashing uses much less energy as expected. This table assumes that the Dishmaster® system uses 5 gallons of water heated from 52 to 107 ºF – assumptions from SilverStream. It is difficult to compare the environmental impacts of energy usage to water usage; therefore, it is recommended that both Energy Star limits for energy usage and water usage be met by the Dishmaster® system.

Table 1. Energy and water usage comparison.

	Energy Usage	**Water Usage**	**Energy Cost**
Automatic Dishwasher Via Energy Star	1.5 kWh	5 gallons	$0.13
Handwashing	0.675 kWh [2]	5 gallons [3]	$0.05

[2] Assumes that handwashing with the Dishmaster takes 5 gallons of water heated from 52 ºF to 107 ºF.
[3] Assumes that handwashing with the Dishmaster takes 5 gallons of water.