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Dual Flush Savings—An Analysis of Field Data

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Recent research affirms that dual-flush fixtures offer significant water savings, but also tell a slightly different story about the effects of flush frequency and volume.



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Introduction

High-efficiency toilets (HET) are the next generation in low-volume bathroom plumbing fixtures. Defined as toilets that flush using 4 liters of water (1.28 gallons) per flush or less, these fixtures are generally divided into two categories—single-flush models and dual-flush models that offer a partial flush for urine.

Some have suggested that dual-flush models offer a greater potential water savings than their single-flush HET counterparts. This belief may have originated from common understanding of biology, because people typically use the toilet more frequently for urinating, hence it seems logical that the partial-flush feature would be invoked more frequently than the full flush, resulting in lower water use. Empirical data from recent research conducted by Aquacraft confirm that dual-flush fixtures offer significant savings over older, higher-volume fixtures, but offer a slightly different story about the frequency of partial versus full flushes (Aquacraft 2004).

In results from field studies using a popular dual-flush toilet with a 0.8 gallon-per-flush (gpf) and 1.6 gpf options at single-family residences, it was found that the overall average flush volume for this fixture was approximately 1.24 gpf. This volume is virtually identical to the 1.28 gpf volume rating of single-flush HETs. One of these studies, *“Water and Energy Savings from High Efficiency Fixtures and Appliances in Single Family Homes,”* measured the individual flush volumes of homes retrofit with dual-flush toilets in the East Bay Municipal Utility District (EBMUD) and Seattle Public Utilities (SPU) customer homes. The combined results for EBMUD (1.34 gpf) and SPU (1.23 gpf) resulted in an average flush volume of 1.29 gpf with a standard deviation of 0.41 (Aquacraft 2004). Neither this combined mean, nor the individual mean flush volumes for EBMUD and SPU was statistically different from a single-flush HET mean volume of 1.28 gallon per flush at the 95% confidence level. **Given the currently available empirical data, there is not evidence to support the contention that a dual-flush HET will save more water than a single-flush HET.**

This analysis uses field studies by Aquacraft (2004) in EBMUD and SPU to highlight the overall statistical similarities in toilet water use patterns between dual-flush toilets and single-flush HETs. A comparison is then drawn between these findings and those of other studies of dual-flush toilet water consumption, to estimate a ratio of small- to large-flush and average-flush volume in single-family residences. Estimates of water consumption of dual-flush toilets (0.8/1.6 gpf) are based on actual field measurements. It is important to note that, even though no statistical difference in the gallons per flush between studies of dual-flush toilets and single-flush HET was found, these findings are suggestive, but not definitive. Studies with larger sample size would be needed to more confidently assess the water usage patterns of one toilet design over the other.

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Research Methodology

During the period of 2000 to 2003, Aquacraft Inc. used a grant from the US EPA to conduct several studies on residential water use patterns and the impact of best available technology practices on water conservation in single-family homes (Aquacraft 2004, p. 8). EBMUD and SPU were the lead participating agencies in this research. A systematic random sampling procedure was used to select homes whose water use patterns were representative of the entire single-family customer base for those areas. Baseline end use data were obtained from each home, and then a full indoor retrofit of all toilets, showerheads, faucets, and clotheswashers was implemented. After the retrofit, additional end use data were collected allowing for a comparison of water use before and after the retrofit of efficient fixtures.

To determine the end uses of water in home, flow trace data were collected from each participating household by attaching a data logger to the register of the water meter serving domestic and outdoor uses. These flow trace data were disaggregated into individual water use events at 10-second intervals using Aquacraft Inc.'s Trace Wizard software. This is the same methodology utilized in the AWWA *Residential End Uses of Water* study (Mayer, P.W., et al. 1999). The resulting high-resolution end use information provided insights to how much water was being used when, where, and for what purpose. These data enabled a determination of what type of appliance or fixture was using water, and how much for each event, throughout the day.

One of the toilet models tested was a dual-flush toilet, designed to use 1.6 or 0.8 gpf, depending upon user selection. (In this study, the Caroma Caravelle dual-flush toilet model was used.) A total of 26 EBMUD homes and 33 Seattle homes were retrofit with new toilets. The homes were all owner-occupied, single-family residences. The average household consisted of 2.7 residents, 1.5 baths, and was less than 2,000 square-feet.

The original study, completed in 2004, analyzed the water savings of low water consumption toilets, but did not assess the flush ratio of the dual-flush toilet fixtures. To address this gap, Aquacraft Inc. was contracted to reanalyze the data from the EPA retrofit study and provide these results to Kohler Co.

For dual-flush toilets, the delineation between a large flush and small flush is not always clear-cut. For the purpose of data analysis in this study, an arbitrary boundary was used to separate small flushes from large ones. A flush volume less than 1.1 gallons was deemed a small flush and a flush greater than or equal to 1.1 gallons was deemed to be a large flush. All of the toilet water consumption data was reanalyzed to understand water consumption and usage for each type of toilet. The data collection method does not determine what particular toilet in the household was flushed, only that a toilet was flushed and how much water flowed to the toilet. To keep these results accurate, households that were retrofitted with more than one type of toilet, or did not have all of the toilets retrofitted, were discarded from this analysis. As a result, the number of households included in the analysis for this study was fewer than in the original EPA retrofit study report.

Research Results

The data from EBMUD and SPU were reanalyzed to look more closely at flush volumes and dual-flush ratios, among other factors. The results for this reanalysis of the data are summarized in Table 1 below, along with results from several other studies conducted during same time period. The results of the Canada, Oregon, and Utah studies are included to round out the comparison of dual-flush performance. Data from these three studies was taken directly from those study reports, although some different data collection methodologies were used.

Discussion of Results

In Seattle and EBMUD study homes, the ratio of small flush to large flush was 0.8, which is significantly less than commonly expected ratios of two or more. On average, the dual flush toilets in EBMUD and Seattle consumed 1.29 gpf.

The Oregon SWEEP study stated that the average water use per flush with the 0.8/1.6 gpf dual-flush toilet was 1.3 gpf. It also stated that the ratio of small flush to large flush was 1.86. Unless the Caroma was using roughly 1 gallon for the small flush and 1.8 gallons for the large flush, these results do not correlate (Sullivan, G.P., et al. 2001).

The Utah results indicated a flush ratio of 1.47 small flush to large flush. These dual-flush toilets were measured to use 0.88 gallons for the small flush, and 1.68 gallons for the large flush. The average volume of water used was 1.20 gpf, which correlates well with the flush ratio (Mohadjer, P. 2003).

The study performed by Aquacraft provided training for the residents in use of the dual-flush toilet. In total, 65 dual-flush toilets were included in this analysis. The range of results was similar to the range between Oregon and Utah

studies. Among the EBMUD homes, the average gallon per flush was 1.34 gallons, while in Seattle the average was 1.23 gpf. The standard deviation for each test was 0.4 and 0.42, indicating that, at the 95% confidence level, the results in EBMUD and Seattle are not statistically different from each other. The standard deviation was calculated by comparing the average flush volumes of each house in the study. It is not the standard deviation of individual flushes.

Taking these results in combination with other studies that have been performed in the last few years, the estimated average water consumption of a dual-flush toilet is approximately 1.24 gpf. The average small-to-large flush ratio is approximately 1.4.

The flush ratio from the EBMUD study at 0.51 is quite different from the average ratio of 1.41, and on the opposite end of the spectrum of the Oregon study with a flush ratio of 1.86. It is not clear why there may be such a diversity of flush ratios since both studies used the same model of dual flush toilet in similar applications.

Conclusion Had the dual-flush toilets used in these studies all performed at the exact level of 0.8 gpf and 1.6 gpf, the average flush volume would have been 1.15 gpf.

According to a reanalysis of Aquacraft (2004) field research data, alongside other study findings, dual-flush toilet performance is quite similar to the rated flush volume of a single-flush HET. It is important to note that even though there appears to be no statistical difference in the overall average gallons per flush between dual-flush toilets and single-flush HETs, these findings are not definitive. Studies with larger sample size would be needed to more confidently assess the water usage patterns of one toilet design over the other.

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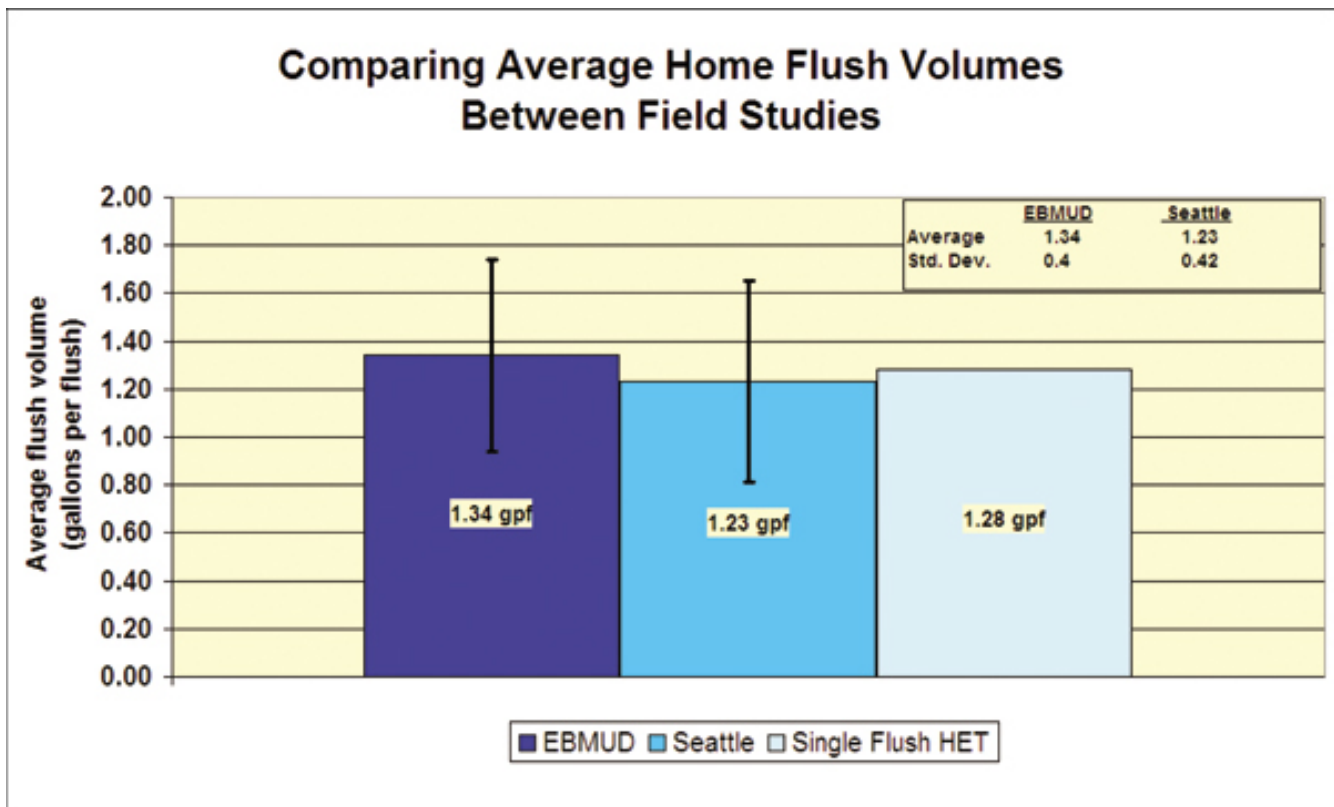
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TABLE 1

Table 1. Dual-flush toilet performance from recent research studies.					
Dual-Flush Toilet Studies	# of Toilets in Study	Flush Ratio (small/large)	Small Flush Volume (gpf)	Large Flush Volume (gpf)	Avg Flush Volume (gpf)
(Aquacraft 2004) —EBMUD ^a	33	0.51	0.8 ^e	1.6 ^e	1.34
(Aquacraft 2004) —Seattle ^a	32	1.19	0.8 ^e	1.6 ^e	1.23
(Veritec, 2002) —Canada ^d	56	1.6	0.9	1.59	1.16 ^a
(Sullivan, G.P., et al. 2001) —Oregon	50+ ^b	1.86	0.9	1.6	1.3
(Mohadjer, P. 2003) —Utah	61	1.47	0.88	1.68	1.20 ^a
Weighted average ^c		1.41	0.89	1.63	1.24
Unweighted average		1.33	0.89	1.62	1.25
Notes:					
a) Calculated value based on ratio and small/large flush volumes published in study					
b) House count included in study. Actual number of toilets not reported					
c) Assumes one toilet per house (50 total) in Oregon study					
d) Only single-family residential data used from study					
e) Nominal values. Value not included in averages. Actual volumes not published					

CHART 1



Aquacraft, 2004. Water and Energy Savings from High Efficiency Fixtures and Appliances in Single Family Homes.

Mayer, P.W., et al, 1999. Residential End Uses of Water, Denver, CO.

Mohadjer, P., 2003. Residential Ultra-Low-Flush Toilet Replacement Program.

Sullivan, G.P., et al, 2001. Save Water and Energy Education Program:

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