

FLUSH: EXAMINING THE EFFICACY OF WATER CONSERVATION IN DUAL FLUSH TOILETS

Masaye Harrison, M.Arch Candidate
University of Oregon at Portland
Department of Architecture
70 Couch Street, Floor 4R
Portland, OR 97210
masaye_h@yahoo.com

ABSTRACT

Toilet flushing typically accounts for the most water consumption in commercial buildings. Dual flush toilet fixture manufacturers credit the smaller flush option with substantive water savings. This paper focuses on the perceived versus actual efficacy of commercial dual flush toilets fixtures to achieve water conservation savings in a LEED certified commercial building. Building occupant survey results and sound pressure datalogger field data were collected and analyzed, revealing that the majority of building occupants were aware of the water conserving functions of dual flush toilets and utilized the small flush option on a consistent basis. This study highlights that post occupancy surveys and ambient room sound level readings may provide a cost-effective, non-invasion testing methodology for building owners to determine the efficacy of dual flush toilet applications in commercial buildings.

1. INTRODUCTION

Today's commercial building owners and facility managers face increasing cost challenges, one of which is reducing water consumption. Toilet flushing typically accounts for the most water consumption in commercial building applications. Commercial building owners are increasingly pursuing Leadership in Energy and Environmental Design (LEED™) Green Building certification via the U.S. Green Building Council effort to demonstrate a commitment to occupant well-being, environmental performance, and economic returns of buildings using established innovative practices, standards, and technologies. To achieve LEED credit points for innovative wastewater technologies and water use reduction, commercial buildings are installing water conservation fixtures at an increasingly rapid pace.

1.1 Brief Background on Dual Flush Toilet Design

Dual flush toilet design may be attributed to Bruce Thompson of Caroma, Australia who in 1980 developed a cistern with two buttons and flush volumes (11.0 litres and 5.5 litres respectively). The shape of the bowl had to be redesigned so that a low water flush could still effectively remove waste. Thompson's Duoset design was installed in a small town trial in South Australia. The trial was successful with regards to water conservation and Australia passed legislation that made dual flush toilets required in almost all new buildings.

Residential dual flush toilet designs continue to utilize buttons mounted on the top of the toilet water tank to control water flush levels. The shape of the button or visual graphics indicate large or small flush volumes. See Figures 1-3 for examples of residential dual flush toilet design.



(Photo Source: M. Harrison)

Fig. 1: Residential dual flush button design



(Photo Source: M. Harrison)

Fig. 2: Residential dual flush button design that uses shape to differentiate between large and small flush volumes



(Photo Source: M. Harrison)

Fig. 3: Residential dual flush button design that uses visual graphics to differentiate between large and small flush volumes

1.2 Dual Flush Toilets Today

This paper examines the efficacy of commercial dual flush valve fixtures mounted with a top spud connection that allow users to flip a flush handle up for smaller flushes involving liquid waste or down for larger flushes involving solid waste. Handle applications are more readily installed in commercial fixtures that lack a water tank and require a design that supports a high volume of public usage.

Pushing the handle down for solid waste yields approximately 1.6 gallons of water per flush (gpf) while pushing the handle up for liquid waste yields a reduced flush of approximately 1.1 gpf. Figure 5 shows a close-up of a typical dual flush toilet handle of this type. Dual flush toilet fixture manufacturers typically credit the smaller flush option with water savings of approximately one half gallon of water per flush. Based on a typical 1:4 flush ratio of large to small, commercial dual flush toilet fixtures are credited

with yielding a 30% reduction in water usage. See Figures 4-5 for examples of a typical commercial dual flush toilet system.



(Photo Source: M. Harrison)

Fig. 4: Typical commercial dual flush toilet



(Photo Source: M. Harrison)

Fig. 5: Usage instructions placed on the toilet handle

1.3 Factors Which May Influence Dual Flush Toilet Usage Behavior

This paper focuses on the perceived versus actual efficacy of commercial dual flush toilets fixtures to achieve substantive water conservation savings. Unlike high-efficiency, pressure-assist toilets or ultra-low flush fixtures, dual flush water conservation benefits require users to make a behavior shift, distinguish between small and large flush requirements and execute the correct handle flip action.

User education, effective signage, handle placement, handle design, gender, age, culture, clothing attire and proclivities

towards cleanliness may all contribute towards the usage or non usage of dual flush valve fixtures.

Dual flush button design has an advantage over typical dual flush handle applications in that the shape of the button educates and re-enforces users to choose a large flush or small flush application. Typically, the shape of commercial dual flush toilet handles does not indicate how flipping the handle up or down will produce a large or small flush volume.

While some dual flush handles have been designed with a green color on the flush handle to help educate users that the toilet has water conservation technology, other commercial dual flush toilet handles do not employ color schemes and instead rely on wall placard with instructions for handle use. See Figure 6 for an example of a dual flush toilet handle design aimed at increasing water conservation awareness.



(Photo Source: www.zurn.com))

Fig. 6: Green dual flush toilet handle to indicate water conservation awareness

The dual flush toilet handle design raises questions regarding ease of use. Age, physical ability, position of the user in either a sitting or standing position and clothing attire may all effect a user’s ability to easily flip up the toilet handle with their hand or foot to achieve a smaller flush action.

Placard placement and clarity may also contribute towards successful user education and behavior shifts. These placards are most easily seen and read in a typical seated position while using restroom facilities but are not typically visible when the user is standing and/or engaged in the act of flushing. See Figure 7 for an example of a dual flush educational placard.

Public restroom users also often have cleanliness concerns and may be apprehensive about touching a handle or button design which their hands. People have been known to use toilet paper, paper towels or handkerchiefs when the need to touch toilet fixtures arises. Traditionally, the rugged commercial handle design allows users to use their foot to push down on the handle to activate the flushing mechanism.



(Photo Source: M. Harrison)

Fig. 7: Placard user instructions for dual flush toilets

2. HYPOTHESIS

To study the perceived vs. actual efficacy of commercial dual flush toilets, the hypothesis tested was: *“The majority of building occupants would use the ‘default’ large flush option which would result in less than a 30% reduction in water flush usage.”*

Let dual flush toilet valve fixtures have two flush positions, F_1 and F_2 with:

F_1 = low flow or liquid waste flush using 1.1 gpf

F_2 = high flow or solid waste flush using 1.6 gpf

f_1 = number of low flow flushes in one 12 hour period

f_2 = number of high flow flushes in one 12 hour period

$(f_1 + f_2)$ = the total number of flushes in one 12 hour period

Total dual flush water usage over a 12 hour time period = $(F_1 \times f_1) + (F_2 \times f_2)$

Let C equal a conventional flush using 1.6 gpf

Total conventional commercial toilet water usage over a 12 hour time period = $C (f_1 + f_2)$

$100\% - (F_1 \times f_1) + (F_2 \times f_2) \div C (f_1 + f_2)$ = percentage of water savings from using dual flush toilets

The hypothesis is thus:

$100\% - (F_1 \times f_1) + (F_2 \times f_2) \div C (f_1 + f_2) < 30\%$

3. METHODOLOGY

To test the hypothesis, a short survey of fifteen (15) questions regarding building occupant restroom behavior was given to 120 occupants of a typical mixed occupancy commercial building in downtown Portland, OR that recently achieved LEED Gold rating from the U.S. Green Building Council (USGBC). Part of the building’s sustainable design features include rain water harvesting used for toilet water usage and low flow urinals and dual flush toilet fixtures.

Sound pressure dataloggers were placed in both the men and women’s restroom facilities (secure and out of view) on one highly trafficked floor to collect dual flush usage data over a 12 hour period or typical building occupancy pattern of 9am – 9pm. See Figure 8 for an example of a sound datalogger.



(Photo Source: www.extech.com)

Fig. 8: Sound datalogger with USB port

4. DATA

Survey Responses: With a survey response rate of 57%, the online survey revealed that 98% of building occupants indicated awareness that their building has dual flush toilets as part of a water conservation strategy. Fifty-five percent (55%) of building occupants indicated that they utilize the small flush option for liquid waste on a consistent basis. Ten percent (10%) of building occupants indicated that they seldom, and in some cases never, utilize the small flush option for liquid waste. Reasons given for not utilizing the small flush option included handle design, difficulty of operation, difficulty to change behavior pattern of always flushing down and lack of perceived difference between the large and small flush options. While some cultures’ proclivities towards cleanliness may dictate using the foot as opposed to the hand to operate the flush handle, survey results indicated that 64% of occupants utilize their hand to operate the flush handle while 31% utilize their foot. Twenty-one percent (21%) of building occupants indicated that it was difficult to somewhat difficult to operate the small flush option.

Field Data: Ambient room sound level readings of men and women restroom facilities on one highly trafficked floor were analyzed over a 12 hour period from 9am-9pm, representing a typical building occupancy day. Figure 9 displays a test measurement to characterize the sound pressure levels of large and small flushes; the sound measurements are unique to the type of flush, ranging between 45dBA – 90dBA and can be visually separated from other types of bathroom activities such as opening and closing stall doors, running the sink water, talking, and utilizing toilet paper products, all of which register in a different dBA range of 50dBA-60dBA. The large flushes consistently showed a longer duration with a slight “hook” shape at the peak of the flush. The small flushes consistently showed a smaller duration with no “hook” shape at the peak. No other sounds generated in the restroom facilities matched the shape and duration of the large and small flushes.

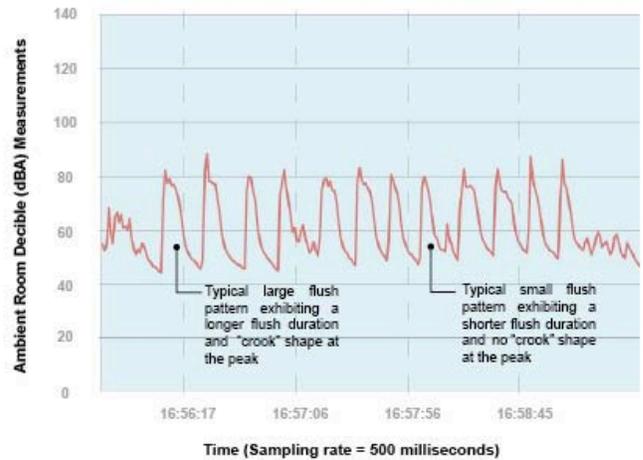


Fig. 9: Placard user instructions for dual flush toilets

Table 1 summarizes the field data generated using the visual analysis method described. Three hundred and seventy (370) total dual flushes were recorded in the men and women’s toilet facilities over a 12 hour period. This translates into 407 gallons of flush water used.

TABLE 1: SUMMARY OF FIELD DATA

| Type of Flush | Number of Flushes | Gallons per flush (gpf) | Total Water Used (gallons) |
|---------------|-------------------|-------------------------|----------------------------|
| Large Flush | 140 | 1.6 | 154 |
| Small Flush | 230 | 1.1 | 253 |
| Total | 370 | | 407 |

Table 2 summarizes the comparative flush water usage if only large or conventional flushing were available in the building. If only large or conventional flushing were available to building occupants, 592 gallons of flush water would have been used.

TABLE 2: COMPARATIVE DATA

| Type of Flush | Number of Flushes | Gallons per flush (gpf) | Total Water Used (gallons) |
|--------------------|-------------------|-------------------------|----------------------------|
| Conventional Flush | 370 | 1.6 | 592 |

The hypothesis that the majority of building occupants would utilize the large flush option and thus limit the water conservation benefits of dual flush toilets to less than 30% was proven wrong.

The hypothesis:

$$100\% - (F_1 \times f_1) + (F_2 \times f_2) \div C (f_1 + f_2) < 30\%$$

The results:

$$100\% - [(154 + 253) \div 592] = 32\%$$

Data analysis indicates that because building occupants utilized the small flush option consistently, a 32% water savings was realized. Though these results were close to the anticipated hypothesis, they were surprising. It may be that the people surveyed were accustomed to such water-saving technologies by having occupied the building for a year. A future study might survey populations at first occupation of a building and after several years to look for short-term and long-term savings-awareness.

5. CONCLUSIONS:

Water conservation in LEED credited buildings continues to play a significant role in post-occupancy cost savings and natural resource management. While we hypothesized that building occupants would not utilize the small dual flush option consistently enough to realize a 30% reduction in water savings, data analysis proved otherwise. The analysis revealed that building occupants are indeed utilizing the smaller flush option and reduced flush water usage by 32%. It is interesting to note that even with these substantive water savings, only fifty-five percent (55%) of building occupants indicated in the survey that they utilize the smaller flush option on a consistent basis. Twenty-one percent (21%) indicated that the flip handle was difficult to

use. This suggests that with increased building occupant education and improved handle design, dual flush water conservation in commercial buildings could be improved.

As the sustainable building industry continues to thrive, the ability to measure post-occupancy building performance against awarded LEED credit points must continue to evolve as well. Hindrances to post-occupancy building studies include cost, disruption to workers and invasiveness to building mechanical systems. The study suggests that post occupancy surveys combined with the placement of sound dataloggers offers a low cost, non-invasion method for determining the efficacy of commercial dual flush toilet usage in LEED commercial buildings.

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