Considerations for Reduced Water Consumption Rates of Urinal Fixtures

From product standards to the model plumbing codes, plumbing fixtures are generally assumed to need water to function. For years, water closets and urinals were designed without a lot of forethought about the amount of water that was needed to remove both solid and liquid waste. They were designed to use as much water as needed to get the job done.

These plumbing fixtures were always considered water-consuming fixtures by both the product standards and the plumbing codes. This water consumption was represented in a gallons per flush (gpf) or liters per flush (lpf) consumption rate.

The Federal Policy Act of 1992 (EPAct), scarce water supply, environmental awareness, social awareness of the value of water, LEED and other green building programs, and various state and local initiatives have all led to substantial reductions in water use for various plumbing fittings and fixtures. Plumbing manufacturers have responded with a wide array of products that perform equally to—or, in most instances, better than—these inefficient older products. As **Figure 1** on the following page indicates, over the past 35 years the consumption rates of various plumbing fixtures and fittings have been significantly reduced, sometimes by as much as 80 percent.

Plumbing system design has not always kept up with these reduced consumption rates, however, either in terms of water supply (inlets) or sanitary drainage (outlets). While there has been documentation and general acceptance that overall reduction in consumption rates has not negatively impacted residential sanitary drainage systems because of substantial supplemental flows from larger appliances such as washing machines and dishwashers[1], there continues to be concern about the impact that these reductions are having and will have on sanitary drainage systems in commercial buildings.[2]

[1]Koeller and Gauley (revised 2009). High Efficiency Flushometer Toilets in Non-Residential Applications.
[2]Plumbing Research and Efficiency Coalition (PERC) (November 2012). Drainline Transport of Solid Waste in Buildings.

FIGURE 1. WATER CONSUMPTION BY WATER-USING PLUMBING PRODUCTS AND APPLIANCES — 1980-2012

Water-using Fixture or Appliance	1980s Water Use	1990 Water Requirement	EPAct 1992 Requirement	2009 Baseline Plumbing Code	2012 “Green Code” Requirement	% Reduction in Avg Water Use since 1980s
Residential Bathroom Lavatory Faucet	3.5+ gpm	2.5 gpm	2.2 gpm	2.2 gpm	1.5 gpm	57%
Showerhead	3.5+ gpm	3.5 gpm	2.5 gpm	2.5 gpm	2.0 gpm	43%
Toilet – Residential	5.0+ gpf	3.5 gpf	1.6 gpf	1.6 gpf	1.28 gpf	74%
Toilet – Commercial	5.0+ gpf	3.5 gpf	1.6 gpf	1.6 gpf	1.6 gpf[1]	68%
Urinal	1.5 to 3.0+ gpf	1.5 to 3.0 gpf	1.0 gpf	1.0 gpf	0.5 gpf	67%
Commercial Lavatory Faucet	3.5+ gpm	2.5 gpm	2.2 gpm	0.5 gpm	0.5 gpm	86%
Food Service Pre-rinse Spray Valve	5.0+ gpm	No requirement	1.6 gpm (EPAct 2005)	No requirement	1.3 gpm	74%
Residential Clothes Washer	51 gallons/load	No requirement	26 gallons/load (2012 standard)	No requirement	16 gallons/load	67%
Residential Dishwasher	14 gallons/cycle	No requirement	6.5 gallons/cycle (2012 standard)	No requirement	5.0 gallons/cycle (ASHRAE S191P)	64%

gpm: gallons per minute
gpf: gallons per flush

Source: John Koeller and Bill Gauley

Urinals represent one of the best opportunities to achieve increased efficiency in commercial buildings. There is also a wide range of efficient products to choose from. While EPA Watersense has identified 0.5 gallons per flush (gpf) as the maximum consumption rate eligible for certification in their flushing urinal specification, more efficient water-consuming options such as 0.25 gpf or as low as 0.125 gpf are also available. Within this range of water-consuming urinals, it is possible to save between 50 percent and 88 percent when compared to a 1.0 gpf urinal. Another type of urinal, which requires no water to function, is also available. These urinals save 100 percent compared to any water-consuming urinal and only require periodic maintenance to operate properly.

To date, however, little information or research is available to determine if these greatly reduced consumption rates negatively impact the drainage systems of commercial buildings when considered along with all the other reduced consumption factors.

This paper will discuss the applicable standards, impacts and successful strategies involved when considering urinals that utilize a reduced rate of water to operate.

> Efficient water-consuming urinal options such as 0.25 gpf or as low as 0.125 gpf make it possible to save between 50 percent and 88 percent when compared to a 1.0 gpf urinal.

Plumbing Fixtures and Plumbing System Design Technical Overview

In order to understand how reductions in water consumption for fittings and fixtures may impact drain lines, it is important to first understand the purpose of plumbing codes and standards as they relate to both plumbing fixtures and plumbing systems.

Section 101.3. International Plumbing Code
"The purpose of this code is to provide minimum standards to safeguard life or limb, health, property and public welfare by regulating and controlling the design, construction, installation, quality of materials, location, operation and maintenance or use of plumbing equipment and systems."

There are two ANSI-approved, nationally recognized product standards that apply to urinals. For water-consuming urinals, there is the ASME A112.19.2 standard; for nonwater urinals, ANSI/ASME A112.19.19 applies. The development, adoption, publishing and renewal of these standards follow a rigorous consensus process as required by ANSI. These standards provide the necessary requirements and testing criteria to ensure that these plumbing fixtures are safe, sanitary and adequate for use in any properly installed plumbing system.

Section 101.3 of the International Plumbing Code spells out very clearly the intent of the entire code: "The purpose of this code is to provide minimum standards to safeguard life or limb, health, property and public welfare by regulating and controlling the design, construction, installation, quality of materials, location, operation and maintenance or use of plumbing equipment and systems." It is critical to recognize that both installation and maintenance are included within the general scope of the Plumbing Code.

The Plumbing Code is then organized into various sections including definitions, fixtures, water supply and distribution, sanitary drainage, and traps and interceptors. All sections of the Plumbing Code, taken in sum, lay out the types of equipment and systems that are permitted for use.

In a manner similar to the product fixture standards, the Plumbing Code is also developed, adopted and renewed utilizing consensus processes. All three model plumbing codes in the United States currently reference the product standards for both water-consuming and nonwater urinals. Plumbing codes also provide specific requirements for the design and installation of proper sanitary drainage, which includes the requirement that horizontal drain lines with a diameter of 3 inches or less have a minimum of 1/4 inch per foot or 2 percent downhill slope (International Plumbing Code 704.1 and Uniform Plumbing Code 708.0).

The proper pitch of these drain lines has been a long-standing requirement of the Plumbing Code. Wastewater carries both liquid and solid waste, and it is necessary for pipes to be sloped properly in order for all items to be cleared from the building or structure. As stated previously, both plumbing fixtures and plumbing systems have, until recently, assumed much larger consumption levels of water.

PLUMBING CODE FIXTURE STANDARDS

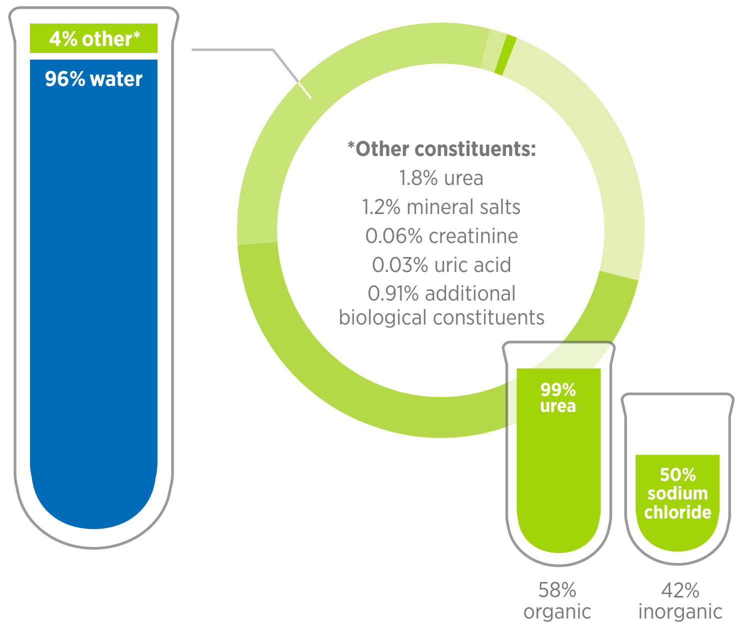
Water-consuming:
ASME A112.19.2

Nonwater:
ANSI/ASME A112.19.19

Urine Composition

Human urine (see **Figure 2**) is comprised of approximately 96 percent water and 4 percent other constituents, which include 1.8 percent urea, 1.2 percent mineral salts, 0.06 percent creatinine, 0.03 percent uric acid, and 0.91 percent additional biological constituents. Urine contains organic and inorganic constituents, with organic constituents representing 58 percent and inorganic constituents representing 42 percent of the total "other" 4 percent volume. The principal organic constituent in urine is urea, representing 99 percent of the organic volume. The principle inorganic constituent in urine is sodium chloride, representing 50 percent of the inorganic volume.

FIGURE 2. COMPOSITION OF URINE



What Happens in the Drain Pipes of Water-Flushing Urinals?

Mineral Constituents Found in Water-Flushing Urinal Drain Pipes

The inorganic mineral sediments found in water-flushing urinal plumbing drain pipes were identified using X-ray diffraction (XRD) and were found to be composed primarily of calcite ($CaCO_3$). Other inorganic mineral sediments were found—such as hydroxyapatite, $Ca_5(PO_4)3(OH)$, and struvite, $MgNH_4PO_4 \cdot 6H_2O$—but at much lower concentrations.[3]

Note: Hydroxyapatite, also known as hydroxylapatite or HAP, is a form of calcium apatite with the formula $Ca_5(PO_4)3(OH)$ but is usually written $Ca_{10}(PO_4)6(OH)_2$ to denote that the crystal unit cell comprises two molecules.

Water-Flushing Urinal Drain Pipe Buildup and Maintenance

Water-flushing urinals produce calcite buildup in the urinal trapway and drain pipes. Calcite buildup is solid in consistency, bonds to the pipe wall, and can only be removed by accessing the drain pipe through a cleanout plug using a drain machine with cutter heads to remove the hard deposits.

If no cleanout plug exists, the urinal must be removed from the wall for access to any portion of the drain pipe. In most cases, the urinal must be removed from the wall to clean the horizontal connection nipple because the nipple cannot be accessed through cleanouts. In some instances, buildup can become so severe that pipes may need to be replaced.

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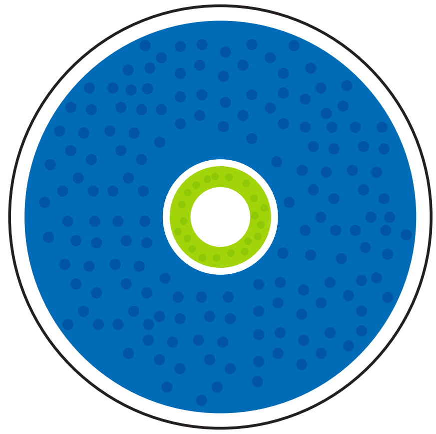
[3]Putnam, D. (1971, July). Composition and Concentrative Properties of Human Urine. Retrieved August 29, 2008, from http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/.

The cause of this hard buildup in water-flushing urinals is the bonding of the mineral ions in the flushing water with the sediment in the urine. The chemical bond between the flushing water minerals and the urine sediment forms a hard calcite buildup inside the drain pipe. The addition of flushing water to urine sediment is similar to adding a catalyst or hardener to a resin or glue. These buildups occur in water-consuming urinals of each type, from 1.0 gpf down to 0.125 gpg. The frequency and amount of buildup can vary based on usage of the fixture.

FIGURE 3. MINERAL SEDIMENTS IN NONWATER URINAL DRAIN PIPES



Struvite – $MgNH_4PO_4{\cdot}6H_2O$ (magnesium ammonium phosphate hexahydrate)

Hydroxyapatite – $Ca_5(PO_4)3(OH)$
Calcite – $CaCO_3$

What Happens in Nonwater Urinal Drain Pipes?

Mineral Constituents Found in Nonwater Urinal Drain Pipes

The inorganic mineral sediments (see **Figure 3**) found in nonwater urinal plumbing drain pipes were identified using X-ray diffraction (XRD) and found to be composed primarily of struvite ($MgNH_4PO_4{\cdot}6H_2O$) or magnesium ammonium phosphate hexahydrate, also known as MAP. Other inorganic mineral sediments were found, such as hydroxyapatite $Ca_5(PO_4)3(OH)$ and calcite ($CaCO_3$), but at much lower concentrations.

Nonwater Urinal Drain Pipe Buildup and Maintenance

Manufacturer-specified maintenance procedures for waterfree urinals include pouring a bucket of water into the drainage system on a periodic basis. This practice removes loose and soft sediment from the housings, drain nipples and main drainage pipes. Sediment from undiluted urine in the drain pipe remains soft and does not form the hard buildup encountered in water-flushing urinals. This is because flush water and urine sediment are not regularly mixed. Without a supply of frequent flush water as a catalyst or hardener, the sediment remains soft and is rinsed away by flushing water through the empty drain housing or trapway into the drain pipe. Nonwater urinal drain pipes can be rinsed clean by the action of flowing water.

New Insights and Lessons Learned

The Plumbing Efficiency Research Coalition (PERC) was formed in 2009 to bring together plumbing and water efficiency experts in the United States to study critical topics related to the impacts of reducing water consumption in plumbing systems. The Coalition consists of:

- Alliance for Water Efficiency (AWE)
- International Association of Plumbing and Mechanical Officials (IAPMO)
- International Code Council (ICC)
- American Society of Plumbing Engineers (ASPE)
- Plumbing Manufacturers International (PMI)
- Plumbing Heating Cooling Contractors of America (PHCC)

While the first PERC research effort focused on drain line carry and performance of reduced flows for solid waste, the Coalition also stated that reduced flows are occurring in the plumbing systems overall due to the subsequent decrease in water consumption for all plumbing fixtures and fittings. After the first phase of testing was completed, a number of conclusions were drawn. Among other insights, PERC concluded that localized supplemental flows are beneficial to the overall performance of plumbing systems.

Australia also has decades-long experience with drought and with using the reduction of water consumption in both plumbing fixtures and fittings as an important conservation tool. ASFlow (a consortium of plumbing experts in Australia) conducted research on the impact that these reductions have on drain line performance, both for solid waste and overall. ASFlow conclusions parallel those of PERC, encouraging localized supplemental flows in order to maintain sufficient water volume for drain pipes to remain functional.

ASFlow compared drain line accumulation from nonwater urinals with an upstream water source (in this case, a single commercial lavatory) to those without any supplemental water source. The conclusions drawn from more than three years of research in a laboratory setting were that struvite buildup over time and use will occur in drain line systems connected to nonwater and very low-consumption urinals, and that buildup can potentially cause complete blockage of the drain line.

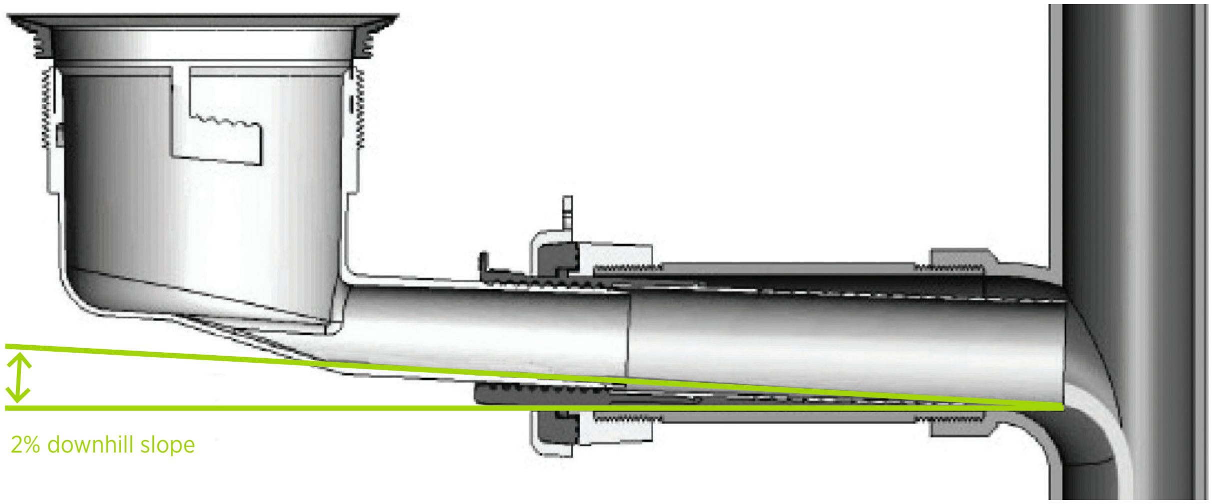
ASFlow's laboratory research also concluded that struvite buildup in the drain lines of nonwater urinals can be significantly reduced through the introduction of a single upstream water-using fixture. This additional research from ASFlow supports the use of localized supplemental flows as a means to keep drain lines flowing properly.

In addition to the referenced product standards for nonwater urinals, UPC, IGC and NSPC model codes now require a water-supplied fixture (such as a flushing urinal or a lavatory faucet) "to be installed upstream on the same drain line to facilitate drain line flow and rinsing." IPC is considering this as well. These plumbing code provisions have been added over the past five years to address the issue of localized supplemental flows that are beneficial to the overall performance of existing drain lines.

Water and plumbing experts encourage supplemental flows in order to maintain sufficient water volume for drain pipes to remain functional.

Supplemental flows are beneficial to the overall performance of plumbing systems.

FIGURE 4. WATERFREE DRAIN LINE CONNECTION SYSTEM



Conclusion

While manufacturers have responded to the need for lower water consumption with superior and better-performing products such as ultra-high-efficiency water and nonwater urinals, the impact on existing plumbing drainage systems with greatly reduced volumes remains a concern. However, the studies referenced above indicate that there are clear actions that plumbers, engineers and building maintenance personnel can take to maximize the performance of these fixtures and minimize issues.

Ensuring that the required 2 percent slope is maintained throughout the plumbing drainage system (see **Figure 4**), including the short drain nipple from the urinal outlet to the main horizontal drain, is especially important. Even in this short distance, struvite and calcite can develop from stagnant waste and eventually cause urinal backups.

In addition, increased attention to preventive maintenance is more important than ever. Cleaning the trapways, drain lines and cartridges of urinals on a regular basis will provide users with a trouble-free experience while saving building maintenance staff the trouble, expense and potential damage associated with clogged urinals. Finally, whenever possible, plumbing system designs should take advantage of supplemental flows from other water-using fixtures upstream of urinals to meet building codes and help slow the buildup of solids that cause premature clogs.

Maximizing Fixture Performance

These actions are most important for slowing the buildup of solids that can cause clogs:

- Ensuring the 2 percent slope is maintained
- Paying attention to preventive maintenance
- Using plumbing system designs that take advantage of supplemental flows