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Targeting the Minimum Practical Toilet Flush Volume

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Thirty years ago, the average American used over 80 gallons of water each day inside their home. The average usage today is closer to 50 gallons per capita per day (gcd), largely – but certainly not exclusively - because of the greatly improved efficiency of toilets and clothes washers. Unfortunately, because almost 90% of the costs associated with operating a water treatment/distribution system are fixed costs, homeowners have not experienced a corresponding reduction in their water bills. But – lowering demands means we can take less water from the natural environment and reduce the cost of chemicals and energy required for water treatment and distribution.

It is difficult to argue against the goal of striving for greater efficiency, not just regarding water demands but for all of our precious natural resources. Is it even possible to be "too efficient"? Can we reduce water demands to such an extent that unforeseen problems begin to materialize? Let's consider the potential impact that reducing toilet flush volumes might have on our internal household drainage piping.

A toilet flush should achieve 3 tasks: 1) remove all waste from the fixture in a single flush, 2) sufficiently clean the toilet bowl, and 3) provide sufficient water to transport the waste through the drain piping out of the building and into the municipal sewage collection system.

Prior to the 1980s, toilets flushed with as much as 5 gallons and, while plungers were still occasionally required to unblock trapways, no one seemed concerned that this tidal wave of water was insufficient to move the waste through the building's drain system. In fact, it might surprise some to know that residential sewage pipes in the USA were actually designed to function with these very high flush volumes. Even though flush volumes have since been reduced to 1.28 gallons or less, the design size of residential drain pipes has not been updated.

It seems obvious that if we continue to reduce toilet flush volumes, at least one – and perhaps all 3 – of the tasks identified above will begin to fail. The plumbing industry has made significant advances in toilet design over the last 25 years, allowing them to drastically reduce flush volumes while at the same time increasing flushing performance. But, in an effort to "err on the side of caution", the industry also wants to avoid reducing flush volumes to such an extent that they begin to lead to unpleasant and costly sewer blockages.

But – how low can we safely go regarding toilet flush volumes? Where is the "tipping point"?

The problem can be approached in a number of ways, ranging from listening to the "gut instincts" of plumbers and industry processionals to undertaking real world studies.

In the early 2000s the authors heard plumbing industry professionals say that it was not physically possible for a 1.6-gallon flush to achieve the 3 tasks identified above. The poor

flushing performance of many 1.6-gallon toilet models at the time seemed to back up this claim. We now know, thanks in part to the development of the MaP testing program, that toilet manufacturers were able to re-engineer their toilet designs to not only flush as well as earlier 3.5-g models but, in the vast majority of cases, to flush much (much!) better. The manufacturers were able to improve toilet flush performance so much that it was actually possible to reduce flush volumes even further and still outperform older 3.5-gallon water-guzzlers. WaterSense, buoyed by this new intelligence, developed their 2007 toilet standard using 1.28 gallons as the maximum allowable flush volume.

Toilet manufacturers, realizing the benefits associated with having a WaterSense certification, began in earnest to develop hundreds of high-performance 1.28-gallon toilet models. Over the first months of 2007, tens of thousands of 1.28-gallon WaterSense-compliant toilets were installed in homes across the USA. The high level of customer satisfaction with the new toilets quickly squashed debate on whether reducing flush volumes from 3.5 gallons to only 1.28 gallons in just over a decade would lead to drainage problems in homes. The answer – based on real world results - was a resounding "No".

In the years since 2007, several manufacturers have developed and produced toilets with even lower flush volumes – some as low as 0.8 gallons. Once again, some industry professionals began sounding the alarm that such extremely low flush volumes would very likely lead to drainage blockages. In an effort to align the competing goals of water efficiency stakeholders (to reduce water demands) and the plumbing industry (to avoid potential health and safety issues resulting from using too little water), the Plumbing Efficiency Research Coalition (PERC) was formed. The first research project undertaken by PERC was to determine the tipping point where flush volumes in commercial buildings were simply too low to reliably transport waste to the sewer. The PERC research project involved flushing realistic waste (the same soybean-based test media developed by the Maximum Performance or MaP program[1], plus toilet paper) into a 135-foot-long drain pipe. The PERC study concluded that waste carry distances were relatively predictable when using flush volumes of 1.28 gallons or more, and more chaotic when using flush volumes of less than 1.28 gallons. Regardless of this unpredictability, flush volumes as low as 0.8 gallons failed to block the study's 135-foot drain pipe. What's more, the PERC study report states, "*It's important to remember that the scope of the PERC research applies exclusively to very long drainlines only. As such, the results from the PERC study do not apply to residential or other applications that employ shorter building drains and other long duration flows of water entering the drain to assist the toilet with the transport of solids to the sewer.*"[2] Based on the results of the PERC study, the tipping point between greater water savings and drainline blockages appeared to be at least slightly less than 0.8 gallons for most residential (domestic) installations. A 2005 drainline laboratory-based study completed by Veritec Consulting Inc.[3] concluded that 0.8 gpf toilet models *"would be expected to meet or exceed the*

[1] https://map-testing.com/
[2] https://plumbingefficiencyresearchcoalition.org/
[3] https://map-testing.com/wp-content/uploads/2022/11/Gauley-Koeller-Drainline-Report-3-11-05.pdf

relatively short waste carry distance requirements typical of household plumbing installations even with no supplemental flows from showers, baths, or clothes washers."

But, how well would 0.8-gallon toilets function outside of the lab, in real life applications? They say "the proof of the pudding is in the taste". Well, over the last decade or so, more than 4 million 0.8-gallon toilets have been installed in North America and the results speak for themselves – a high level of customer satisfaction and no systemic issues with drainline blockages. Clearly the tipping point between flush volumes and blocked drainlines in residential applications is somewhere below 0.8 gallons.

But, how low should we go? The authors are aware there really is a tipping point somewhere between 0 gallons and 0.8 gallons even if we don't currently know exactly what that volume is. And, while we fully support using our natural resources as efficiently as possible, we prefer to err on the side of caution and to not do anything that might lead to consumer dissatisfaction.

As such, we are taking the following position:

1. There is a limited potential for further flush volume savings. Reducing flush volumes from 3.5 gallons to 0.8 gallons results in a 2.7 gallon per flush savings. Any reduction in flush volume below 0.8 gallons would necessarily be far more modest.
2. There is ample evidence that 0.8 gallons is sufficient to: 1) remove all waste from the fixture in a single flush, 2) sufficiently clean the toilet bowl, and 3) transport the waste to the sewer in typical residential applications. There is currently insufficient evidence that flush volumes of *less* than 0.8 gallons could achieve the same results.
3. While we have no reservations about installing 0.8-gallon toilets in residential applications, we hesitate to recommend installing 0.8-gallon toilets in non-residential applications, especially in situations where (1) the drainline is very long, (2) the slope of the drain line is less than that required by code, (3) there are few or no other sources of water (supplemental flows) entering the drain, and (4) there is a history of drain line blockages in the building.

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