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Down the Drain

PERC I study demonstrates pipe slope, flush volumes AND toilet paper determine what goes down the drain.

The Energy Policy Act of 1992, where water use reduction in plumbing fixtures became a reality at the national level, unknowingly began a debate of drain line transport efficacy. Fast forward to today, the plumbing market transitions towards 4.8 Lpf / 1.28 gpf toilets, and continues to push the envelope by reducing consumption levels (to 1.1 gpf for example)…and the debate continues.

Although reducing the water usage of plumbing fixtures prompts the emergence of low-flow, high efficiency toilets that support water conservation, unintentional consequences such as the lack of water pressure is negatively affecting the drain line function. Recognizing that ongoing efforts to make plumbing systems as efficient as possible are a certainty, the PERC I (The Plumbing Efficiency Research Coalition) study sought to apply a scientific approach towards a better understanding of drain line function under lower flow conditions so that the plumbing industry can work proactively to prevent widespread blockages from becoming a reality.

By carefully controlling certain variables, the PERC I study sought to learn how drain lines react and which of these variables impact performance significantly and which variables do not.

As it turns out, the PERC I study uncovered that toilet paper – along with the pipe slope and flush volume – are key variables in determining whether drain lines might be predisposed to a clog. It is important to keep in mind that the study points out that the test is not real world conditions -- it purposely did not use toilets. Thus, toilet hydraulics was judged as not a factor when, in fact, it is a factor in real world conditions.

While it is only the first study conducted by PERC (PERC II is currently being conducted) and other types of studies have preceded it, their conclusions are important for facility managers, engineers, architects and others in the construction industry to understand that as manufacturers continue to innovate by using less and less water, the potential exists for clogged drains. In fact, the impact of lower flush volumes and pipe slope were already well documented. By confirming the impact of toilet paper into the equation through their test, PERC has moved forward toward a more comprehensive understanding to help manufacturers and building owners conserve water, our most precious resource, without sacrificing performance and user satisfaction.

This white paper is being presented by Sloan Valve Company to review the PERC I study (which is a must read for any plumbing professional) in relationship to what a building owner or engineer faces when dealing with the issue of commercial drain line transport of waste. Its findings will be reviewed in relationship to real-life building conditions in the United States – conditions that Sloan, as the premier manufacturer of flushometers, has faced for over one hundred years. The goal is to help owners and engineers understand that the combination of slope, flush volume and toilet paper are only part of a larger drain line transport equation; that actual building conditions – which is repeatedly pointed out in the PERC study itself – must be factored into any specification or application of plumbing systems to assure proper performance – conditions Sloan experience has factored into product performance. In fact, Sloan strongly recommends an onsite visit by a plumbing engineer as part of the entire process in ANY retrofit project. Such a hands-on survey of the building's entire plumbing system can help identify potential issues and affect the outcome for the best possible solutions, which may not support ultra-low water flows. At the end of this white paper you will read Sloan's recommendations for using lower flushing fixtures and flushometers, particularly the growing use of ultra-high efficiency models that flush down to 1.1 gallons per flush (gpf).

Who is PERC?

Let's begin by briefly reviewing who is behind the study. PERC was formed on January 6, 2009 when five organizations signed a Memorandum of Understanding to meet the needs of the critical topic of what happens when you lower the volume of water in plumbing systems to control waste. These organizations are:

- AWE – Alliance for Water Efficiency
- IAPMO – International Association of Plumbing & Mechanical Officials
- ICC – International Code Council
- PHCC – Plumbing-Heating-Cooling Contractors—National Association
- PMI – Plumbing Manufacturers International
- ASPE – American Society of Plumbing Engineers

Today, these six organizations now form the leading edge thinking that seeks to make plumbing systems as efficient as possible.

Manufacturers such as Sloan helped fund the group's initial efforts. Sloan, as do other companies and owners of the plumbing systems, stands to benefit from this type of research. As PERC seeks to apply a scientific approach toward a better understanding of issues such as the drain line function under lower flow conditions, everyone in the value chain benefits. In fact, as water volumes started dropping after the Energy Act of 1992 just a little over 20 years ago, the stories of drain line blockages started rising. Even today, debates rage on with the plumbing trades and drain cleaning service companies reporting increases of drain line blockages. Yet, there is no "real" data available to determine to what extent these events are happening. Nor is there any authoritative evidence existing that high-efficiency toilets have been responsible for blockages in building drain lines or municipal sewer systems. So, what is all the fuss about?

Where There's Clogging, There's…

The fact of the matter is that there is clogging going on. Simply recall what happened when the Energy Act lowered the volume initially to 1.6 gpf in the city of Las Vegas. Reports of clogging at the fixture were rampant. In fact, legend has it that hoteliers had maintenance people with plungers in violin cases roaming the halls "on call." Since then, of course, water volumes have continued to drop. That, coupled with the aging infrastructure of buildings, created an atmosphere for potential concern.

"The Drain line Transport of Solid Waste in Buildings" study by PERC was published in November 2012 to address this issue (testing commenced on March 12, 2012 and concluded on July 11, 2012), and outlines details of the testing methodologies, analyses and findings in its 64 pages. The PERC coalition sought to have the results improve the understanding of sanitary plumbing system performance, inform future system design and policy decisions, and spur further testing and research into these systems.

The study already has that effect (it is quoted extensively in the professional journals). Not only has it spawned more discussion and brought to light the importance of drain line transport, the study – because it was done specifically NOT as "another toilet study" – brought to light an important element that while **slope** and **flush volume** play a critical role in what goes and does not go down the drain**, toilet paper** has a significant effect on that performance. While previous literature covered some of these variables (see Appendix), it was the PERC study that brought about a truly timely and independent testing procedure to document the profound impact that the combination of slope-flush volume-toilet paper has on drain line performance.

Drain Line Science

The topic of drain line carry is not without an abundance of reports. For example, ranging from the PERC study to the earlier L. B. Jack "Overview of investigations addressing the issue of low water use sanitary appliances and associated drainage network design," published in 2000, this topic of what happens to waste when water volumes are lowered in a drain line is covered by at a minimum 27 professional and scientific articles (see Appendix). Yet, until the PERC document (which again did NOT utilize any fixtures, keeping the science as pure as possible for the variables and allowing the issue of toilet paper to arise itself), no one organization has brought together this kind of comprehensive overview found in PERC.

Toilet paper testing was not a part of the original work plan, having been added mid-way through the study. As a result, toilet paper was shown to be an important variable in the transport of solid wastes in building drain lines – something that would have been missed if the flexibility of the test procedure did not exist.

For example, slope studies have been done before and their results are reflected and reinforced by the PERC study. A 2005 study by Gauley & Koeller confirmed the positive correlation between flush volumes and carry distance, and drain line slope and carry distance – two of the key variables in drain line performance found in PERC. The 2005 study found that carry distances in a 3" diameter drain line were 50% greater than a 4" drain line at a 2% slope for both 1.6 and 1.28 gpf. They also concluded that where extremely long drainage distances exist (i.e., shopping malls, industrial facilities), evaluation on a site-by-site basis would probably be required, especially if no supplemental flows are available. Even in these earlier studies, onsite inspection is brought out as essential to proper performance.

Such performance variables are what the PERC study seemed to reinforce – and more. The word "seem" is used because the PERC I testing was done *emulating* fixtures – not using them. As stated, the committee did not want another "toilet" study. Instead they created a procedure that included an apparatus called a Surge Injector. This is what makes the PERC study so interesting – and so valid: it was studying pure dynamics of the behavior of water and waste in drain lines-(aka, a near perfect discharge down a controlled drain pipe).

Test Procedure

The test procedure used in the PERC study was comprised of 40 test runs, each run consisting of 100 flushes from the Surge Injector, a 3" (75 mm) diameter clear pipe, sectioned off by ball valves at the 25 percent and 75 percent volumetric heights. The Surge Injector contained a PVC cap with an orifice drilled into the top. That orifice controlled the flow of air into the pipes, thus controlling the flush rate (see below).

The Surge Injectors were installed onto a typical closet flange on the drain line test apparatus flush stand that was created. The injectors were **manually activated** by opening a "release valve" at the bottom of the injector (see page 18 of the PERC report for a visual). Air flowing into the injector from the drilled orifice allowed water to flow **from** the injector into the test apparatus at a **controlled flush rate** in gallons per flush.

Each test run required the Surge Injector **specifically set up to provide a required flush volume** (3.0, 4.8, or 6.0 liters – 0.8, 1.28, or 1.6 gallons), a flush rate, and a percent of trailing water. The test procedure called for a higher volume of clear water discharge being introduced at the end of each test run. This was done in order to observe the clearing potential of the clear water discharge. This "clearing flush" was used at the end of each 100-cycle test run, set and evaluated at 3.0 gallons (11.4 L) and 5.0 gallons (18.9 L) volumes.

The test media used was uncased MaP[2] test media (soybean paste extruded into approximately ¾" diameter cylinders, each 4" in length and weighing 12 oz.) – media that is widely used in industry test protocols to test the flush performance.

For toilet paper, PERC selected a brand of toilet paper that was found to have a very high wet tensile strength through testing. Also, a very low wet tensile strength brand was selected, and both single and double-ply paper was evaluated. The committee doubled the amount of sheets of single-ply paper to normalize the amount between the high tensile strength brand and the low tensile strength brand. As a result, each test run incorporating the single-ply low tensile strength paper used eight (8) balls of six (6) sheets each, a total of 48 sheets, as opposed to four (4) balls, 24 total sheets of the 2-ply high tensile strength paper.

The PERC Test Plan was constructed to incorporate the variables of drain line diameter, slope, volume, percent trailing water, flush rate, and toilet paper selection (based on wet tensile strength).

PERC I Conclusions

The conclusions of the tests are interesting. While additional research is not only suggested, but encouraged, what PERC uncovered provides a deeper understanding of drain line behaviors. For example, as far as a "clearing flush" is concerned – the flush intended to clear the drain line at the end of a 40 test run – it cleared the drain line in 32 of 40 test runs. Prior international studies have concluded that toilet hydraulics is a significant factor in drain line transport, specifically pointing to the amount of trailing water as a key factor. The PERC performance brought about the following conclusion from the committee*: this potential solution to a drain line blockage proved to be unreliable and cannot be suggested as a building drain clearing solution.* At a success rate of 80%, the solution may still be viable but will require additional evaluation.

Prior to PERC, **toilet hydraulics** was believed to be important. In PERC, it was found to be a non-significant variable. That is, toilet discharge characteristics, or how fast the volume of water is introduced in combination with the fixture as a result of the hydraulics, had no significant effect on drain line transport. Therefore, the committee concluded that *toilet fixture designs have a minimal effect on drain line transport in long building drains. However,* Sloan acknowledges that there may be more to it than just "how fast" the water is presented. In fact, the flush curve and toilet design is important – certainly for bowl evacuation and potentially for drain line carry. Drain line carry aside, fixture design must contend with user and housekeeping issues: cleanliness and scrubbing action of bowl, splashing and noise, all while contending with ever-lowering flush volumes. If toilet paper is a significant variable, the commercial environment in which much more is commonly flushed underscores the importance of fixture design.

This is not to say that manufacturers abandon hydraulic design. On the contrary, toilet hydraulics will always be important to the overall behavior of waste transport and evacuation, but not necessarily to drain line performance! On the contrary, a real-world test is called for and should be considered before final judgment is rendered.

Slope

Prior studies have reviewed new construction strategies such as decreasing pipe diameter, increasing slope, and shortening horizontal runs to increase the effectiveness of high-efficiency toilets to transport of solid waste (Gauley & Koeller, 2005; Gormley & Campbell, 2006). In comparison, the PERC I study was conducted at one percent and two percent drain line slopes.

To approximate the kinds of distances encountered in commercial applications, the test piping, made mostly of clear 4" PVC sloped downward for 65-ft., took a wide-sweep 90-degree turn for 5 ft., took another wide-sweep 90-degree turn and continued for an additional 65' or 135' total. Researchers found that slope was the most significant variable in drain line transport, with 2% being better. The committee acknowledged that in the real world, since the building drain slope will be somewhere between 1% and 2%, and the toilet paper used will fall somewhere between the best case and worst case examples used in the test. Slope, however, is the "first factor" to consider in commercial buildings experiencing clogging problems. This is another reason for "a walk through" by a plumbing engineer at the site for a plumbing survey, which Sloan recommends. However, evaluating the slope is often difficult if the pipes are behind the wall or beneath the floor.

There was a correlation between drain line slope and drain line carry, i.e., the carry distance increases as the pipe slope increases. For example, a 1% slope with 3" piping had the carry distance of about 33 ft. (10 m). Whereas, a 2% slope with 3" piping had a carry distance of about 72 ft. (22 m).

Flush Volume

The PERC study found that at the 0.8 gpf / 3.0 Lpf flush volume, there was a demonstrated major difference in performance compared to the other volumes tested. In 5 of the 16 test runs conducted at this low volume, the test media compressed together to form large plugs in the drain line that resulted in full-pipe or near full-pipe conditions. The committee determined that at this flush volume, a "chaotic, unpredictable condition" to the extent that the data at the 0.8 gpf / 3.0 Lpf volume was mostly noise and not useable in the analysis.

The 1.28 gpf (4.8 Lpf) and 1.6 gpf (6.0 Lpf) test runs, on the other hand, resulted in an "orderly and predictable movement in the test apparatus." The committee anticipated no problems in new construction, **BUT IN RETROFIT**, recommended (again) the drain lines be inspected. This is important to remember: **there is a difference between new and retrofit construction for drain line transport behavior. Emerging water conservation standards generally seem to miss this subtlety even though manufacturers continue to highlight its impact on water conservation mandates.**

But, this is not entirely new. In existing building retrofits, the importance of evaluation of current conditions of plumbing infrastructure in order to align the flow rate of high-efficiency toilets was demonstrated in several studies (Alliance for Water Efficiency, 2011; Gauley & Koeller, 2005; Gormley & Campbell, 2006). In these documents, pipe diameter, slope, length of horizontal runs, as well as presence of drain line defects were pointed out to be considerations, and in some cases modeling was suggested using computer software.

Furthermore, the combination of flush volume with the other two variables (slope and toilet paper) MUST be evaluated properly in construction, especially retrofit applications. The conclusions at the end of this white paper, Sloan cites specific recommendations on such an approach.

Toilet Paper

Toilet Paper was the third variable that along with pipe slope and flush volume had a significant effect on the drain line transportability of waste. Unfortunately in the real world, let alone in the laboratory it is very difficult to control all the variables that result from the material properties of different brands of toilet paper. For example, a major manufacturer of toilet paper announced plans to roll out a new line of tissues that incorporates wheat straw and bamboo. While the goal is to provide a rapidly renewable and environmentally friendly source of fiber for its products, what will the effect be on drain line transport?

The reason these are valid questions now is because of what PERC I uncovered about toilet paper. That is, a definite correlation existed between the wet tensile strength of toilet paper and transport distances. Therefore, toilet paper selection has the potential to be as significant in terms of drain line performance. PERC I goes so far as to say that, "the selection of toilet paper is definitely more significant than other toilet flush characteristics (flush rate and trailing water)."

Specification of toilet paper would perhaps have never been a consideration in the past. Yet, as a result of PERC I, shouldn't it be? If manufacturers continue to test the limits of flush volumes and study slopes, is it not wise to begin to address the specification of the tensile strength of a toilet paper specifically designed to enhance the performance of drain line carry?

Other Blockage

This PERC I study centers on toilet paper. Sloan suggests other blockage media should be considered for future research and papers, for example, wet wipes, toilet seat covers or sanitary napkins. Currently, wet wipes are having a profound effect on plumbing systems across the country including New York, Wisconsin, California, Hawaii and Alaska. Consider New York's class action suit against wet wipe manufacturers as wet wipes are considered "flushable" but do not disintegrate the way traditional toilet paper does. http://goo.gl/SA3Vhb

While the PERC I study provides important insights, it also raises new questions, providing an opportunity for further research. PERC Phase 2 will focus on the following research areas: pipe size reduction, additional flush volume levels, toilet discharge and toilet paper characteristics.

Recommendations

Plumbing systems are part art, part science. Sloan commends PERC I for this outstanding study, and hopes it is the first of many that continue to explore plumbing performance and human comfort. Water conservation, one of Sloan's core values since the company was founded in 1906, continues to be a driving force of a great many of the company's decisions.

With the PERC study in mind, Sloan recommends the following:

1. Consideration of slope, flush volume and type of toilet paper in all retrofit applications.
2. Whenever possible, physically inspect drain lines of existing buildings prior to specification or recommendations.
3. Encourage the manufacturers of toilet paper to begin consideration of publishing tensile strength characteristics to better inform engineers and end users (since the data clearly suggests that the selection of toilet paper is definitely more significant than other toilet flush characteristics, i.e., flush rate and trailing water).
4. Stabilize performance of the flush volumes being recommended in light of the 0.8 gpf / 3.0 Lpf volume tests. Sloan encourages 1.1 gpf/4.2 Lpf where the design characteristics of the drain line are appropriate.
5. Whenever possible, test install a floor or set of particularly heavy traffic restrooms with high-efficiency fixtures in order to evaluate a complete change out of the retrofit site. Some progressive contractors actually recommend this, especially if the retrofit is going from a very large Pre-EPAct water closets of 3.5 gpf down to 1.28 gpf or below.

Sloan also encourages ongoing discussion and education. For example, toilet manufacturers are sometimes asked by customers for results of the MaP However, as the PERC I study demonstrated, in a long drain line, when toilet paper and a more realistic test media are used, and in long duration (100 flush) flush sequences, percent trailing water and flush rate (i.e.: toilet flush discharge characteristics) are non-significant factors in drain line performance. Therefore, customers are asking for results that are by themselves, incomplete.

Also, care should be exercised when discussing the results of PERC or any other study. For example, some reviews stated about PERC I that "1.28 and 1.6 gpf toilets were found to perform well under test conditions, resulting in an orderly and predictable movement in the test drain line" (this was stated in the "Water Conservation Synthesis Report & Article Summaries" published by the Institute for the Built Environment at Colorado State University) . The PERC test never involved toilet fixtures (see Surge Injector discussions). In fact, PERC made clear to its members and study sponsors that this effort would not be another toilet study. Care, therefore, must be exercised when reporting results, and while projection "to toilets" is acceptable, it must be made clear that the PERC study did NOT test toilet fixtures per se. As in any discipline, proper statements of fact and definitions of terms play a large role in avoiding confusion.

Along these lines, when faced with human behaviors or real-life conditions (i.e., use of toilet paper and existing building slopes), performance in drain lines can and will suffer unless variables are properly evaluated. Therefore, as an example, Sloan has made the decision to put on all the specifications for their 1.1 flushometer/fixture combinations:

> ***Note: 1.1 gpf flushometer only recommended in new construction installations or those where sufficient drain line carry can be assured. Alternatives include 1.28 gpf or 1.6 gpf flushometers.***

This clearly alerts the specifier to explore such variables. The good news is that the 1.1 gpf valve/fixture combinations meet the happy medium (and remember, the PERC I study NOT use toilet fixtures in the test). That is, efficient 1.1 toilet systems are likely to mirror the 1.28 gpf/4.8 Lpf and 1.6 gpf/6.0 Lpf flush volumes, which the committee found "no problems with" in new commercial construction. (Note, again, the language on the Sloan specification sheets.)

In fact, the committee cautioned users to **inspect** drain line defects in existing buildings, including root intrusions, sagging or other physical conditions that could result in clogging with lower flush volumes.

But, that seems like common sense, especially with older buildings. Sloan agrees, too, with the committee's findings that the U.S. EPA WaterSense® Program should expand their toilet specifications to include commercial flushometer-valve operated HETs (the specification is expected to be released later this year).

Overall, PERC I provides a thorough understanding of what can impact drain line transport. The questions are, what is the tensile strength of the squares you are using, what is the slope of the drain line you are about to flush into, and finally, what is the flush volume you are using to begin the whole process? Ignoring any one of those questions puts your building at risk.

Beyond PERC

The PERC I study presents results that can be easily implemented in an ideal building environment that can be best compared to new construction situations. In a new facility, for example, the water supply system and the drainage pipes can be designed to accommodate the higher operating pressures, reduced flows and slope recommendations of these new water-efficient plumbing products. Using a 1.1 gpf toilet system within the plumbing design would be an effective solution.

However, the PERC I study does not address or recognize the larger base of existing buildings and their existing plumbing infrastructure. When incorporating high efficiency fixtures in an existing building such as in a retrofit or a remodel, it often requires greater consideration of the existing conditions and capacities of the drainage and supply systems. Anything below 1.28 gpf are circumspect – there are variables that can negatively impact drain line carry. Above 1.28 gpf has so far proven itself in the commercial marketplace.

When dealing with an older plumbing system, Sloan’s experience suggests there are additional important factors than studied in PERC I that must be taken into consideration to ensure that the use of these lower flushing valves-and-fixtures will not impact fixture and system performance, negating the benefit of the water savings that is trying to be achieved. Water conservation **IS** still possible in older buildings. However, accommodation must be made for factors such as bowl performance, drainage, water supply and other variables that directly impact the goals of water conservation.

If there is a concern about the efficacy of an existing drain line, then it is in the best interest to engage a plumbing engineer to evaluate and ensure the system is capable of performing adequately on the reduced flows. It is often recommended to upgrade one restroom with high-efficiency fixtures and flushometers first as a "test" and evaluate the system performance for a period of time to see if there are any adverse effects on the drain line carry before changing the whole building.

In a building where there may be drainage concerns, using a 1.6/1.1 gpf (6.0/4.2 Lpf) dual flush instead of a 1.28 gpf (4.84 Lpf) single flush is another often viable solution in Sloan’s experience. The 1.6/1.1 gpf (6.0/4.2 Lpf) dual flush is recognized in most codes as a high efficiency flushing device, equivalent to a 1.28 gpf (4.84 Lpf) single flush. The additional water delivered for the full flush (the ‘solids’ flush) is often, but not always, enough to overcome these adverse conditions in an old drainage system. The reduced ‘liquid’ flush offsets the extra water used for the solid flush, particularly as liquid flushing (often with light solids like tissue paper) typically occurs twice as often as a ‘solids’ flush.

If these factors are not an issue, then using low flow fixtures such as 1.1 gpf toilet systems are an option to consider in select locations.

Appendix

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