The Formation of PERC and the Drainline Carry Research Project

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Over the course of the past 25 years, manufacturers of plumbing products and appliances have been under strong market pressure to develop water-consuming products that consume less and less water. Prior to 1992, the overwhelming majority of toilets in North America were manufactured to flush at 3.5 U.S. gallons per flush (gpf). Urinals flushed at 1.5 gpf and showerheads and faucets were flowing at 3.0 gallons per minute (gpm). Those values changed drastically in 1992 when President George H.W. Bush signed the Energy Policy Act of 1992 (EPAct 92) into law.

While EPAct 92 mandated significantly lower flush volumes and flow rates for urinals, faucets and showerheads, toilet consumption was reduced most drastically down to 1.6 gpf, about a 54 percent reduction. Further complicating market dynamics, new building rating system programs were introduced in the late 1990s such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program and the Green Globes Green Building Initiative (GBI). These programs, along with municipal and utility-based purchase incentive programs for toilets and other products, motivated manufacturers to develop models that consumed even less water than the levels mandated by EPAct 92. Reacting to these programs, by the mid-2000s, the market for toilets had already begun transitioning from 1.6 gpf models to high-efficiency toilets with flush volumes of 1.28 gpf. Manufacturers ultimately began developing toilets with consumption levels as low as 0.8 gpf.

EPAct 92, the building rating systems and the purchase incentive programs were all spectacularly successful in terms of delivering improved water efficiency. Large utilities across the country reported water use reductions or flat usage in spite of significant population growth in their distribution areas, which from a water-efficiency perspective was great news indeed.

However, from a health and safety perspective, all the flow rate and consumption level reductions discussed above carried with them a new and unique set of unintended consequences. Reductions in showerhead flow rates create increased potential for scalding bathers, reduced flush volumes in urinals increase the likelihood for struvite buildup and drain blockages in public bathrooms, and reduced flow rates in general extend hot water delivery times and can create severe water quality concerns, including the development of opportunistic pathogens in premise plumbing systems.

While all of these issues were apparent to the plumbing industry and academic researchers alike, little was being done in terms of applied research to address them. The need to align plumbing industry and water efficiency stakeholders to address these needs was clear. It was in this environment that the idea to form the Plumbing Efficiency Research Coalition (PERC) was conceived.

The PERC concept was originally the brainchild of the International Association of Plumbing and Mechanical Officials (IAPMO). After about a year of discussions and negotiations with other premiere plumbing and water efficiency associations, PERC was officially formed in December of 2008 with great fanfare at a Memorandum of Understanding (MOU) signing ceremony at U.S. EPA Headquarters, with then-Administrator Stephen L. Johnson presiding.

The founding signatories to the PERC MOU were the Alliance for Water Efficiency (AWE), IAPMO, the International Code Council (ICC), the Plumbing, Heating, Cooling Contractors – National Association (PHCC), and Plumbing Manufacturers International (PMI). In 2010, PERC signed another MOU at EPA Headquarters with AS-Flow, an Australian coalition formed to conduct similar research on reduced flows. The MOU with AS-Flow called for PERC and AS-Flow to share information and research results so that redundant efforts could be avoided. The American Society of Plumbing Engineers (ASPE) joined PERC in 2011.

Shortly after PERC was formed, the coalition decided to make drainline transport the first research project to be undertaken. This decision was not made lightly. PERC members canvassed their memberships, and the consensus from water efficiency experts, plumbing engineers, contractors and manufacturers alike was that the reduced flows going into building drains would have the most obvious and profound implications on the continuing efficacy of our plumbing systems. A PERC Technical Committee (TC) was formed and I was selected by the coalition to act as the technical director of the project.

The first order of business was to do a literature search in order to review past research efforts. The most comprehensive was conducted at Heriot Watt University in Scotland by the late Professor John Swaffield, perhaps the world's most celebrated and prolific researcher in the field of plumbing. There were also a few studies conducted in North America that investigated the impacts of flow reductions in building drains in the late 1990s and early 2000s. However, in reviewing the available body of research, it became clear that, while extremely valuable findings resulted from the research, the plumbing community was not being adequately advised regarding the continued efficacy of long building drains in commercial buildings, which PERC stakeholders identified as the application most at risk for blockage-related problems. Thus, an opportunity existed to substantially add to the available body of knowledge by developing a work plan focusing on very long drainlines.

By the time that PERC set forth on developing a work plan, there was enough field experience to establish that 1.6 gpf toilets provided enough water to keep the great majority of building drains functioning properly. However, somewhere between 1.6 gpf and 0 gpf a tipping point existed where there simply would not be not enough water to reliably transport solid wastes through the building drain to the sewer. It was also determined that the most important deliverable of a research project on drainline transport would be to identify where that tipping point would likely occur, signaling the potential for an onset of chronic blockages, and which system variables would either mitigate or exasperate the potential for those blockages to occur.

A great deal of thought and planning went into the development of the drainline transport work plan. The first obstacle was to identify where the research would be conducted. The PERC TC sought an area that could accommodate a test apparatus of approximately 150 linear feet in length. We considered conducting the research at the Port Hueneme Naval facility in Southern California, as the Navy was interested in the PERC drainline work. However, a suitable indoor location to house the test apparatus was never identified.

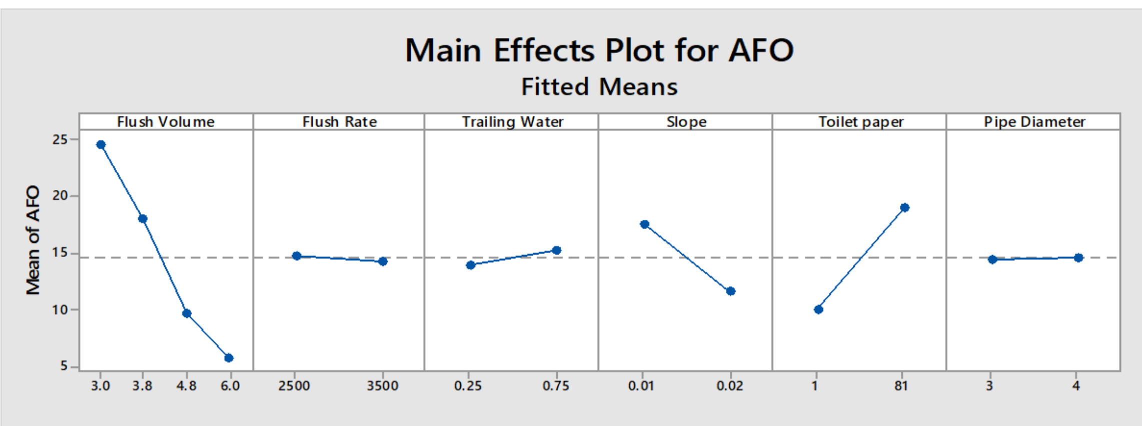
Shortly thereafter, I had a chance to discuss the PERC research with my colleagues at American Standard, Inc. (now American Standard Brands), my employer prior to joining IAPMO. American Standard graciously offered to donate the floor space needed, enough for a 135-foot-long apparatus at its New Product Design Center facility in Piscataway, N.J. Without the cost savings provided by American Standard's generous contributions, the PERC research would have been considerably delayed in order to raise the additional funds needed to rent the required floor space.

Raising the funds needed to support the research proved to be quite a challenge. Doing applied research on the issue of drainline transport is inherently expensive, due primarily to the amount of time and labor involved. The PERC TC ultimately decided to cut back on the original plan of work and focus on a two-phase approach to the research. The price tag associated with the Phase One portion of the research was approximately $70,000. That amount was ultimately raised and PERC was able to begin its research in 2012. Phase Two had a significantly higher price tag of $160,000, as additional test variables were added to the test plan. Phase Two commenced in 2015. All work testing was completed in 2016, and the final PERC report was issued in March 2016.

As for the technical aspects of the test plan, the identification of the test variables, the associated test procedures, the test apparatus materials, test media and media loadings that were selected, those aspects of PERC's research are highly nuanced and would require far more space to even briefly characterize than this article affords. However, I would like to highlight a few of the research's key findings.

Refer to Figure 1 below. This plot shows the test variables that were incorporated into the PERC test plan. The significance of the test variables is illustrated by how vertical the plot line is. Plot lines that are horizontal indicate that the test variable is non-significant.

Figure 1, Main Findings of the PERC Research



The flush volume tipping point: Results indicated that drainline performance stays relatively orderly and predictable with flush volumes as low as 1.28 gpf. Below that level, performance drops off and becomes increasingly chaotic, especially on drainlines sloped less than 2 percent. (1/4 inch per foot). There was a big drop-off in performance between the 1.28 gpf and 1.0 gpf flush volumes.

The importance of toilet paper selection: Perhaps the most surprising result from the research was learning the significance of the wet tensile strength of toilet paper. Based on the MOU with AS-Flow, PERC was able to conduct testing, building on AS-Flow research that illustrated a very strong inverse correlation between drainline transport distances and the wet tensile strength of the toilet paper. The higher the wet tensile strength of the paper, the lower the resulting drainline transport distance. This factor was shown to be significant in terms of drainline transport. In fact, the testing found that the selection of toilet paper was much more significant than the selection of a toilet, based on the toilet flush attributes of flush rate and percent trailing water.

The non-significance of pipe diameter: This was another surprising result. Prior research had proved that smaller pipe diameters provided deeper flood levels inside the pipe from surges of water, such as a flush from a toilet. As a result, the surge wave attenuates more slowly and travels farther. Thus, it was thought that a smaller pipe diameter would provide superior hydraulics to support drainline transport. However, the research showed that, here again, toilet paper would play an important role. Toilet paper tends to bunch together and expand in the drainline, especially high-wet-tensile-strength toilet paper, inhibiting airflow in the drainline (see photo 4). The airflow blockages inhibited drainline transport and overcame the hydraulic advantages provided by the smaller pipe diameter. As a result, pipe diameter was shown to be non-significant as illustrated by the horizontal plot line in Figure 1.

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.

This article provides only a glimpse into the PERC research and cannot substitute for reading the full PERC reports should you wish to have a full understanding of the research. If you would like to read the full reports, they may be downloaded for free at www.plumbingefficiencyresearchcoalition.org.

Photo 1 – PERC representatives meet at EPA headquarters with then-Administrator Stephen Johnson in December 2008 to sign the Memorandum of Understanding forming PERC.

Photo 2 - IAPMO's Pete DeMarco signs an MOU with Jeffrey Clark representing the Australian research coalition AS-Flow, at EPA headquarters in 2010. AWE's Mary Ann Dickinson is to Clark's right.

Photo 3 – The 135-foot-long PERC test apparatus

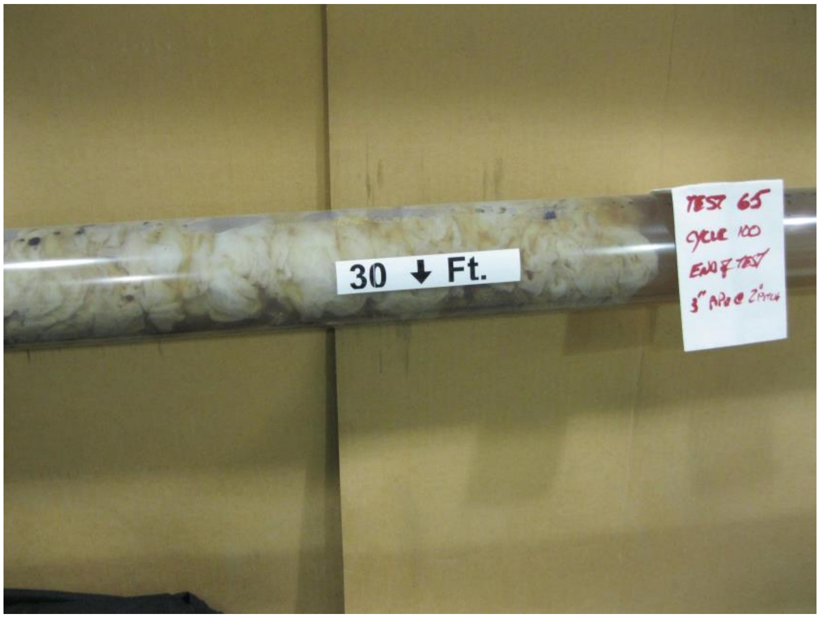


Photo 4 – Toilet paper bunches up to block airflow in 3-inch-diameter pipe.