Test Plan Proposal to Investigate Drainline Transport in Buildings

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Background:

With the enactment of the Energy Policy Act of 1992, all water closets (toilets) manufactured in or imported into the United States were required to flush no more than a maximum average of 1.6 US gallons, effective January 1, 1994 for residential models and January 1, 1997 for all models. At that time, concern for drainline transport efficacy was voiced by many in the plumbing trade and those in various professional associations. However, early reporting and research on 1.6 gallon per flush (gpf) water closet models focused primarily on the flush efficacy of the various water closet models on the market in response to significant consumer complaints about poor flush performance. Since then, water closet manufacturers have made great strides in improving flushing performance. Intermittent and anecdotal complaints of drainline carry transport problems were not thoroughly researched and largely attributed to older or faulty sanitary drainlines.

Recently, the need to find additional efficiencies on water-consuming plumbing fixtures has resulted in the creation of voluntary specifications that eliminate another 20% from the flush discharge volume of water closets, bringing consumption down to a maximum average of 1.28 gpf. These toilets are known as High Efficiency Toilets (HETs). The States of California and Texas have passed legislation to require all toilets sold in those states to be HET's by the year 2014. There are other provisions in California that will significantly accelerate this transition and it is anticipated that other areas of the country will soon enact similar requirements. Some water closet manufacturers are now voluntarily offering models that flush at 1.0 gpf. One manufacturer is actively marketing a model that flushes at 0.8 gpf. This activity has rightfully raised the debate of drainline carry efficacy anew. Many plumbing experts are concerned that we are at or approaching a "tipping point" where a significant number of sanitary waste systems will be adversely affected by drainline transport problems, especially in larger commercial systems that have long horizontal runs to the sewer. Recently, drainline transport problems in Europe and Australia have been reported, further raising concerns here in North America.

Looking forward, newer technologies, such as non-water consuming and High Efficiency urinals (HEUs), lower flow rate faucets and increasingly efficient water consuming appliances will further reduce the amount of water discharged into sanitary waste systems. Equally significant are Graywater Reuse Systems that collect discharged water from lavatory basins, clothes washers, bathtubs and shower fixtures in a residence for reuse, usually for irrigation purposes. This is another emerging technology that significantly reduces waste water in residential sanitary drainage systems. On the commercial side, the emphasis upon water and energy use reduction has resulted in a proliferation of products in the medical and food service sectors that substantially reduce flows to the drain. Yet, to date, an extensive research project of sufficient scope has yet to be conducted that would to determine if significant problems could arise regarding drainline transport in these "efficient buildings".

The Need for Research:

The Plumbing Efficiency Research Coalition seeks funding to conduct scientific research to determine the effect of reduced flows into our domestic and commercial plumbing systems. Due to the complexity associated with the number of variables in "real world" plumbing systems, we believe that a multi–factorial designed experiment is required to properly measure the impact of the toilet fixture toward drainline transport relative to other plumbing system variables, such as pitch, and flush volume.

Emerging Technologies with Potential to Mitigate Drainline Blockages

Based on the casual observations of previous drainline transport research efforts, it is known that intermittent injections of clear water surges of sufficient volumes can transport solids in the drainline great distances and, theoretically, clear a building drain out to the connection to the sewer. For commercial installations, flushometer-valves that employ hands-free electronic activation can now be programmed to flush at pre-designated times and at user-selected volumes.

For example, consider a commercial office building with restrooms employing a bank of High Efficiency flushometer-valve toilets that flush at 1.28 gpf (4.8 Lpf). For example, at pre-determined intervals, the toilets furthest upstream (on the drainline) can be programmed to flush once or twice per day with a higher flush volume that clears the building drain of all solids and transports the solids to the sewer.

These new programmable features have the potential to offer a very low-cost solution for many commercial installations. As such, PERC is recommending that this potential solution be worked into the test plan.

Laboratory Testing

The focus of this effort will be to verify the feasibility of using programmable flushometer valves or other sources of clear water to clear long drainlines of deposited solids and to measure the relative importance of other systemic variables. This work would best be conducted on an apparatus employing 4" diameter pipe set at both minimum slope (1%) and standard code-compliant slope (2%). The study would involve investigating various flush volumes so as to intentionally deposit test media along the length of the test apparatus. The data from the resulting transport distances will allow for determining the relative importance of the test variables. At the end of each test run, a higher volume clear water discharge will be introduced into the drainline apparatus (simulating a discharge from a pre-programmed flushometer-valve) in order to observe the clearing potential of the clear water discharge.

A 200 foot long (~60 meters) test apparatus is recommended to conduct this test. This will allow for adequate distance to show resolution in drainline transport at the various test flush volumes. In addition, the long distance simulates worst case commercial building drain installations and will allow us to determine if the high volume clearing has potential to clear very long commercial building drains.

To minimize costs, PERC will seek to conduct this test program on a suitable existing test apparatus. PERC is currently in the process of executing a MoU with the AS-Flow committee in Australia. Once the MoU is executed, PERC plans to review this test proposal with the AS-Flow Committee to determine the most cost effective location to conduct this work.

Test Plan Details

The PERC Technical Committee has developed a proposed test plan to accomplish this work.

Below are the variables that need to be considered for the test plan. (Also see the associated Excel file that details the designed experiment test plan.)

- Flush volume: Discharge levels of 1.6 gpf (6.0 Lpf), 1.28 gpf (4.8 Lpf) and 0.8 gpf (3.0 Lpf) will be evaluated

- Pipe Diameter and Material: 4" (100mm) diameter clear PVC only. It would be preferable to also evaluate 3" and 6" diameter pipe, but to minimize costs; only 4" (100mm) diameter will be used for this initial work.
- Toilet Discharge Flow Rate / Velocity: Needed to simulate fast acting and slow acting toilets. The PERC Committee will use a "surge generator" type device to simulate those flow rates (rather than actual toilet fixtures). This device (see photo) will allow for more consistent discharge and will maintain the test plan variable pertaining to the discharge more accurately than can be achieved by using actual toilets.
- Trailing water: The surge generator will be constructed to allow injection of the solids at various points that result in a high volume of trailing water (70%), typical of fast acting toilets, and a lower volume trailing water (20%) typical of slower acting toilets.
- Test Media: Soy bean paste (miso paste) will be used to simulate solid human waste. This test media has been used extensively to test toilets to various flush performance tests, including the current US EPA WaterSense specification for gravity flush toilets in the United States and has achieved good acceptance in the industry as an appropriate test media. Two-ply toilet paper will also be used.
- The following assumptions pertaining to flush discharges into the test apparatus will be applied:

    - A 3:1 ratio for solid and liquid waste flushes
    - 50 / 50 "male to female" ratio
    - All males use urinals, not toilets for liquid waste.*
    - No other long duration flows are available to assist the toilet. Urinals do not provide any transport assist (waterless or .125 gpf).
    - Males: 33.3% solid waste flushes using miso and toilet paper (4 balls @ six sheets each), 0% liquid flushes.
    - Females 33.3% solid waste flushes using miso and toilet paper and 66.7% liquid waste using toilet paper only (4 balls at 6 sheets).*
    - Essentially, this equates to 50% of the flushes having miso and paper and the other 50% having a lesser amount of paper only.
    - The miso loadings will randomly vary between 300 grams, 200 grams and 100 grams for all solid flushes for each round of testing.
    - Frequency and volume of clearing flush: The test plan will start using a 1% frequency for the clearing flush set a 3 gallons (11.4 Liters). If successful at clearing the 300 foot (90 Meter) test apparatus at these levels no additional testing will be required. If not, evaluation at 2% frequency or at higher flush volume may be required. It will be up to the test engineer to determine if those values need to be revised once we begin testing, based on observation.

*The above assumptions are not provided to simulate reality in all cases, but rather to provide an assumed worst case scenario.

Study Variables:

Diameter (in)	4"			
Pitch (%)	1.0%	2.0%		
Flush Volume (Lpf/gpf)*	6.0/1.6	4.8/1.3	3.0/0.8	
Velocity - Peak Flow (ml/sec)	3500	2000		
Trailing water (% water after solids)	70%	20%		
Flush Contents	Miso/Paper	Paper		
Loadings (grams miso)	300	200	100	0
Clearing Flush Volume (Lpf/gpf)	11.4/3.0	15.1/4.0*	18.9/5.0*	
Frequency of clearing flush	1%	2%*		

*only if necessary

Deliverables from test plan:

1. Prior international studies and some field failures reported recently in Australia, indicate that flush volumes consistent with High Efficiency toilets may result in systemic drainline transport related failures in building drains or sewer lines. This study will evaluate the viability of a low-cost building drain clearing solution: Determine if we can clear over 200 ft of 4” diameter plastic pipe with a flushometer valve or other device set to deliver higher volume discharges at intermittent intervals (1 or 2% of flushes).
2. Prior international studies have concluded that toilet hydraulics are a significant factor in drainline transport, specifically pointing to the amount of trailing water as a key factor. This study will determine the role that toilet discharge curves play in drainline transport efficacy in a multi flush sequence and will rank the hydraulic characteristics (percent trailing water and flow rate) of the toilet relative to other variables beyond the control of the toilet design (flush volume and drainline slope).

Lacking from this plan:
1. The impact of various plumbing system geometries. While we may be able to incorporate elbows, junctions, etc. into the test apparatus, this test plan will ultimately only evaluate one simulated system.
2. The impact of systems imperfections (bellies, varying slopes)
3. Some usage and abuse factors, such as paper seat covers and paper towels
4. A determination of where the use of intermittent high volume flush valve would be recommended. This test plan will investigate the viability of the clearing flush solution, but will not provide insight as to specific systems where such a solution may need to be deployed.

Specifically, this effort will allow PERC to issue design recommendations to the construction community regarding the transport potential of single event, high volume clear water surges, thus allowing the use of high efficiency fixtures in long drainline commercial installations and realizing overall water conserving efficiencies. In addition, this work will determine the significance of toilet design as it pertains to multi-flush, real world drainline transport potential. It will do this by evaluating the interactions between the toilet and other system variables and measuring the relative impact of these variables.

Cost: PERC estimates a cost of $170,000 US to conduct this work, as detailed below:

<u>UPDATE</u>: Due to an offer extended to PERC by American Standard Brands, the estimated cost of conducting the above scope of work has been reduced to $73,700.00.

Apparatus / Equipment			
Labor to build apparatus supports and platform		$ -	Supplied by American Standard Brands
Labor to install piping	135' 4" PVC	$ -	Supplied by American Standard Brands
Material costs (PVC pipe, adjustable support fixtures to allow for slope adjustment)		$ -	Supplied by American Standard Brands
Electronic scale (1) for water discharge		$ -	Supplied by American Standard Brands
Electronic balance (1) for media		$ -	Supplied by American Standard Brands
Shipping costs - equipment and test media		0	
Surge Injectors (3)	$400 each	$ 1,200.00	
Misc. (tools, supplies, clean up costs)		$ -	Supplied by American Standard Brands
Disassembly (labor)		$ -	n/a
Test Media			
Miso (12 each 20 Kg buckets)	240 @ $20/kg	$ 4,800.00	
Toilet paper	10 @ $100/case	$ 1,000.00	http://www.globalindustrial.com/p/janitorial/bathroom/paper-cleaning-supply/scott-embossed-premium-bathroom-tissue-605-sheets-roll
Misc. (extruder, disp. gloves, hoses, rags)		$ -	
Test Personnel Costs			
2 Test Engineer (75 days)	600 hr @$50/hr per technician	$ 60,000.00	Note: Includes 10 days for assembly and disassembly of apparatus test runs, etc.; 60 full days total, of which 50 days (8 weeks) for actually running the tests
Per Diem expenses (travel, meals, lodging, etc.)		n/a	
Document search - review		$ -	24 hrs at $150
Report development and preparation		$ 3,000.00	Final report & publication/distribution: 20 hrs @ $150
Sub Total		**$ 70,200.00**	
Contingency costs (~5%)		$ 3,500.00	
Grand Total		**$ 73,700.00**	