Appendix A — WaterSense Drainline Carry Testing Results

The U.S. EPA's water-efficient product labeling program, WaterSense, includes High-Efficiency Toilets (HETs), i.e., toilet models that flush with an effective flush volume of 1.28 gallons[2] or less.

The effective flush volume is the average flush volume of the toilet fixture under typical residential conditions. Two types of toilet fixtures meet this criteria: single-flush models that flush with 1.28 gallons or less, and dual-flush models that offer the user a choice between a "full flush" of 1.6 gallons to remove solid waste and a "reduced flush" of no more than 1.1 gallons to remove liquid-only waste. Studies have shown that dual-flush toilets can save at 20% or more water compared to single-flush 1.6-gallon models and, as such, are considered HETs.

After reviewing the WaterSense Toilet Testing Protocol, Dr. Larry Galowin (a guest researcher with NIST), commented that he was very pleased the EPA had decided to use a realistic test media (extruded soybean paste and toilet paper) for evaluating toilet flushing performance and that the testing protocol called for a complete evacuation of the media from the fixture in a single flush. Dr. Galowin has several criticisms of current ASME A112.19.2 certification requirements that he would like to see addressed by the EPA's WaterSense program, including:

1. ASME requires toilets to evacuate only 79 percent of test media (sponges and paper wads) to pass, whereas consumers want and expect toilets to evacuate virtually 100 percent of the waste. As such, a toilet model that leaves 20 percent of the waste behind may pass existing certification requirements but would certainly fail to meet consumer expectations.
2. Flushing performance testing is completed using sponges and paper wads; drainline carry testing is completed using three-quarter-inch plastic balls. Neither test media is even vaguely realistic (i.e., similar to human feces and toilet paper) and therefore test results may not be indicative of what would be expected in the field.
3. Totally different test media is used to evaluate flushing performance and drainline carry performance. His contention is that in the "real world" the same "media" is both flushed out of the toilet and transported through the drainline.
4. Flushing performance testing and drainline carry testing are completed as separate tests (and with different test media). His contention is that in the "real world" waste is evacuated from the bowl and transported down the drainline as part of the same event. Dr. Galowin proposes that to more accurately reflect "real world" conditions toilet fixtures be connected to a length of drainline via a floor flange and turning fitting, and a passing score require a minimum mass of test media to be evacuated from the toilet and transported a minimum distance through the drainline.

It is the intention of the EPA that WaterSense labeled toilet fixtures not only provide superior water savings but also meet consumer expectations for flushing and drainline carry

[2] Value equates to 80 percent of current maximum flush volume by code.

performance. For example, all WaterSense labeled toilet fixtures must be tested to ensure they can fully evacuate at least 350 grams of realistic test media in a single flush, and the results of the *Evaluation of Water-Efficient Toilet Technologies to Carry Waste in Drainlines*[3] project indicated that there should be no problem achieving sufficient drainline carry distances when using 3-inch diameter pipe installed at a 2 percent slope. However, Dr. Galowin's comments prompted EPA to consider the potential for drainage problems if a more *severe* installation was used, i.e., a 4-inch diameter pipe installed at a 1 percent slope.

As such, a number of tests were completed to evaluate the flushing and drainline carry conditions by flushing realistic media in several HET models connected to a 4-inch diameter drainline installed at a 1 percent slope.

Dr. Galowin: *"The toilet sample being tested should be connected to a drainline via a floor flange and turning fitting. The drainline should be of suitable diameter and of adequate length to provide meaningful data. While the test setup should not necessarily reflect the worst possible field conditions, it should reflect 'more difficult than average' conditions."*

The following is a description of the test set-up used to evaluate flushing/drainline performance.

Pipe Diameter: 4 inches

- Most building/plumbing codes call for a 3-inch diameter drain to be used for a single toilet fixture. The use of a 4-inch diameter drain will result in shorter overall carry distances and, therefore, meets the "more difficult than average conditions" condition.

Pipe Slope: 1 percent

- Most building/plumbing codes call for toilet drains to be installed at a 2-percent slope. The use of a 1-percent slope will result in shorter overall carry distances and, therefore, meets the "more difficult than average" condition.

Pipe Length: 4 meters

- Most residential toilet drainlines run only for a short distance before they connect to other pipes. In most cases there are supplemental flows (e.g., from showers, baths, sinks, clothes washers, etc.) in the drainline to help move solid waste through the line.

    Dr. Galowin suggested that toilet models be connected to a 3 meter to 5 meter (9.8 feet to 16.4 feet) length of drainline during performance / drainline testing completed in the lab. Personal discussions between one of EPA's sub-consultants[4] and a plumbing inspector for new homes suggested that he rarely sees horizontal drains.

- Lines of greater than 12 feet (3.7 meter) for toilets before they connect to other pipes or supplemental flows are introduced.
- A carry distance of 4 meters was selected as a suitable carry distance.

[3] Gauley and Koeller, March 2005
[4] Bill Gauley, Veritec Consulting Inc.

Supplemental Flows: None

- It is common for drainlines that service toilet fixtures to also service other fixtures or appliances, i.e., the flows from these other fixtures and appliances help to transport solid waste through the pipes.
- To be conservative, and to keep in line with the “more difficult than average” requirement, no simulated supplemental flows (i.e., from showers, baths, laundry, etc.) were introduced to the drainline during testing.

Following Flushes: A single liquid-only flush

- Toilets are normally subjected to multiple liquid-only flushes for every “solids” flush. Estimates of the ratio of liquid-to-solid flushes typically range from 3:1 to 5:1.
- To be conservative, and to keep in line with the “more difficult than average” requirement, the testing program used only a single liquid following flush.

Pipe Material: Clear plastic pipe

- Plastic drain piping is commonly used in new home construction. In older homes drain pipes were often made of cast iron. It is expected that drainline carry would be: a) less in cast iron pipes than in plastic pipes, and b) less in older pipes than in new pipes.
- Because it is important to be able to observe the waste flowing through the pipe (to properly assess performance levels) and because many of the other test parameters are “more difficult than average,” e.g., the testing is being done using 4-inch diameter pipe installed at 1 percent slope with no supplemental flows and only a single following flush, it was considered suitable that the testing be completed using clear plastic piping.

Pipe Layout: Straight and true

- Because of building or ground settling or heaving, or because of improper installation, some drainlines in the field do not have the proper slope or may have a number of “dips and sags” along their length. Some older drain pipes may be partly blocked with grease, grit, tree roots, or other materials that would reduce the pipe’s ability to transport waste.
- Because it is not possible or even necessary to assess every possible “negative” drainline condition, a laser level and string-line were used to install the test drainline in a straight line and at a constant slope.

Although dual-flush fixtures with a “full flush” volume of 1.6 gallons qualify as an HET, there is no concern regarding the ability of 1.6-gallon models to transport the waste and, as such, there was no need to include testing on 1.6-gallon flushes. Tests were completed on the following types of models:

- 1.2-gallon gravity washdown
- 1.28-gallon gravity siphonic
- 1.0-gallon pressure-assist

Although a carry distance of 4 meters (13 feet) was established as the benchmark for this study, a total of 9 meters (30 feet) of piping was installed. A “pass” was achieved if the waste from a toilet sample was transported at least 4 meter after 350 grams of solids flush followed by one liquid only flush[5].

Tests were performed using two types of media: sinking and floating. The soybean paste used in MaP testing has a density greater than that of water and therefore sinks. To make the test media float, a small amount of powdered styrofoam was blended into the soybean paste. Four balls of six sheets of toilet paper were also added to each test. Five tests flushes were conducted for each scenario—a total of 60 tests were conducted. Carry distances identified in the following table are the average of the five tests.

Average Carry Distances

350g Sinking Waste

1.20-gallon Washdown		**1-gallon Pressure-Assist**		**1.28-gallon Gravity**	
1st Flush	2.9 m (9.4 ft)	1st Flush	1.3 m (4.2 ft)	1st Flush	3.7 m (12.2 ft)
2nd Flush	**7.4 m (24.1 ft)**	**2nd Flush**	**4.4 m (14.4 ft)**	**2nd Flush**	**6.2 m (20.3 ft)**

350g Floating Waste

1.20-gallon Washdown		**1-gallon Pressure-Assist**		**1.28-gallon Gravity**	
1st Flush	5.8 m (19.2 ft)	1st Flush	2.0 m (6.4 ft)	1st Flush	4.5 m (14.8 ft)
2nd Flush	**9.0 m (29.5 ft)**	**2nd Flush**	**4.9 m (16.1 ft)**	**2nd Flush**	**9.0 m (29.5 ft)**

Test Location

The above tests were conducted by Veritec Consulting, Inc., at their test facility in Mississauga, Ontario.

Conclusion

Although only a limited number of tests were conducted, the results above indicate that HETs (even 1-gallon models) should be able to exceed 4 meters in drainline carry under the adverse conditions described here. It is expected that carry distances under more typical conditions, e.g., 3-inch diameter pipe, 2 percent slope, with the inclusion of supplemental flows and more than one liquid-only following flush, would be greater than the average values identified above.

[5] The liquid-only flush occurred 60 seconds after the solids from the first flush came to a rest.