High-Efficiency Toilets

by Leigh Marymor

New 1.28-gallon toilets do a surprisingly good job of clearing the bowl

As a plumbing contractor, I remember the response when the first generation of 1.6-gallon-per-flush (gpf) toilets hit the market in 1994: People hated them. They didn't clear the bowl of solids and often left dirty porcelain. In the years since, plumbing manufacturers have redesigned their products so they are now less likely to clog.

The 1.6-gpf standard was a step forward, but in the face of drought and population growth, it has not been enough to eliminate water shortages, which are a serious problem in western states like California, Arizona, and Texas. Florida and other southeastern states are grappling with water problems as well. As a result, there has been an ongoing movement to enact even stricter conservation standards.

WaterSense Program

The EPA has established a program called WaterSense, which sets water conservation goals for a variety of plumbing products, including toilets, urinals, and faucets. Showerheads are expected to follow in the near future. The goal for toilets is to reduce usage by 20 percent, to a maximum of 1.28 gpf. A fixture that meets this standard is considered to be a high-efficiency toilet (HET) and is eligible to receive a WaterSense label (**see Figure 1, page 2**).

Although the WaterSense program is voluntary, it's just a matter of time before its provisions find their way into state laws and plumbing codes. This has already started happening in California and Texas, where it will be illegal as of January 1, 2014, to sell toilets that require more than 1.28 gpf. In anticipation of such standards, manufacturers have begun rolling out a new generation of HETs.

Comparing Performance

The poor performance of early water-saving toilets gave plumbing manufacturers a black eye, and they've made a concerted effort to avoid a repeat of that with newer models. A recent print ad from one major manufacturer bragged about the number of its toilets that belong to the "1,000 gram club." This refers to the

Kohler

weight of solids that can be cleared from the bowl in a single flush as measured in a standardized Maximum Performance test, or MaP (for an explanation of MaP testing, see sidebar, page 5). To qualify for a WaterSense label, a toilet must be able to flush 350 grams of solids.

The best performers in the MaP ratings can clear 500 to 1,000 grams of solids. Comparing a toilet that flushes 500 grams with one that flushes 1,000 grams is like comparing an "A" product to an "A+" product: Few users will ever need a 1,000-gram flush, so the difference is more or less academic.

Other factors. Though important, raw flushing power is not the only consideration. The focus on MaP ratings has led some manufacturers to boost flushing power at the expense of other significant factors. In addition to clearing solids, an effective flush should scour the porcelain and leave perfectly clear water in the bottom of the bowl — and do so without making a lot of noise.

Flushing Technology

There are a variety of methods for achieving an effective flush and exchange of water, including siphoning, wash-down, and power flushing (**Figure 2**).

Siphoning. The toilets in most U.S. residences are siphoning models. When the toilet is flushed, water flows to the rim and to a jet near the bottom of the bowl. The jet, which is aimed toward the back of the toilet, pushes water up and over the high point of the trap, creating a powerful siphon that pulls water and solids into the drain. Water from the rim scours the porcelain and refills the bowl. You can identify a siphoning toilet by the sound it makes when it sucks the bowl empty.

The siphoning method allows for a large "water spot" — the area of the water in the bowl (**Figure 3, page 3**). A large water spot reduces the incidence of staining and "skid marks" by preventing solids from hitting the porcelain. Some manufacturers use other bowl-cleaning strategies as well, such as putting an ultra-smooth finish on the porcelain or incorporating rim jets designed to scour the bowl as it refills (**Figure 4, page 3**).

Wash-down. Although toilets based on the wash-down principle are the norm in Europe, they're less common here. When the flush valve is opened, water floods the bowl from under the rim and pushes waste out through the trap. It has been my experience that backwash can occur when the wall of water hits the back of the trap, leaving discolored water in the bowl. To leave clear water in the bowl, the user may have to flush a second time.

Another shortcoming of the wash-

Figure 1. The WaterSense label was created to make it easier to find and choose water-efficient plumbing products. Labelled toilets have undergone third-party testing showing that they can clear at least 350 grams of solids from the bowl while using no more than 1.28 gallons per flush.

Figure 2. Most of the toilets sold in this country rely on siphoning action to pull waste into the drain (far left). The siphon is initiated by a jet in the bottom of the bowl, which uses a portion of the flush water to push waste over the high point of the trap. The remaining water comes out from the rim and refills the bowl. Wash-down toilets (center left) send the entire flush to the rim, flooding the bowl from above and pushing waste out through the trap. A power-flush model (near left) is equipped with a vessel that contains water and compressed air. The air propels the water into the bowl at high velocity, producing a flush that is both powerful and loud.

American Standard (left), Kohler (center and right)

Toto (both photos)

Figure 3. Siphoning toilets tend to stay clean because the water spot — the area of the water inside the bowl — is large enough to keep solids away from the porcelain (left). A wash-down model typically requires frequent brushing because its water spot is too small (right) to keep solids off the bowl.

Figure 4. Toto's double cyclone models contain a pair of jets under the rim that the maker says are particularly effective at scouring the bowl.

down design is that it requires a bowl with steeply sloped sides so that the water falls with enough force to clear solids. This shape results in a small water spot, which greatly increases the incidence of staining. That's why a cleaning brush stands next to most toilets in Europe.

The size of the water spot — which can usually be found in the manufacturer's specifications — varies greatly among types of toilets. As an example, consider two HETs from Toto: The Eco Drake (siphoning) and Aquia II (dual-flush wash-down). At $10\frac{1}{4}$ inches by $8\frac{1}{2}$ inches, the Eco Drake's water spot is more than three times the size of the Aquia II's, which is $4\frac{1}{2}$ inches by 6 inches. This is typical of the difference between siphoning and wash-down fixtures.

Power-assisted flush. Inside the tank of a power-flush toilet is a vessel containing flush water and air compressed by incoming water. When the flush valve is opened, water is propelled into the bowl at high velocity. This type of toilet has a large water spot and may consume as little as 1.0 gpf in a single-flush model.

The biggest problem with power-flush toilets is that they're noisy — anywhere from loud to explosively loud. As a result, we rarely recommend them to homeowners, although they typically do an effective job of clearing the bowl. Power-flush models are also more complicated than gravity models, making them more expensive to repair.

Caroma

Figure 5. Dual-flush toilets like this Caroma use a full flush for solids and a half flush for liquid. Instead of a standard lever, the fixture has a dual-flush button on top of the tank (above).

Dual-Flush Doubts

A dual-flush toilet has a full flush for solids and a partial flush for liquids (**Figure 5**). The full flush typically contains 1.6 gallons of water and the partial flush between 0.8 and 1.0 gallons. The performance goal for this design is to average less than 1.28 gpf over time, which qualifies the product as an HET.

Dual-flush models have been getting a lot of great press, but I'm not convinced they live up to the hype. Choosing between different flushes is confusing to people unaccustomed to this kind of toilet, so they may hit the wrong button. Also, the amount of water in the light flush may be insufficient to leave perfectly clear water in the bowl, leading users to double-flush or use the heavy flush for everything. When that happens, the toilet loses its water-saving advantage.

The most serious problem has to do with the nature of the flush. Most dual-flush models are wash-downs, because a partial flush is typically too small to create strong siphoning action. We have

installed dual-flush wash-down toilets from Caroma and Toto and found they required regular brushing. Power-assisted dual-flush models are available, but they tend to be loud. American Standard recently introduced the H2Option, a dual-flush toilet that has a large water spot and is said by its maker to create strong siphonic action. We have yet to install one of these toilets, so we don't know how well they actually work.

Conversion kits. The current emphasis on "green" has led to the introduction of products for converting single-flush toilets into dual-flush models. It's a good idea on paper, but so far there's been no independent testing to show that they actually work.

In any event, designing a truly effective conversion kit is a tall order. For a toilet to flush effectively, the size and shape of the bowl and trap must be matched to the size of the flush valve, and timing, location, and volume of the water flows all must be adjusted accordingly. Change any one aspect without accounting for the others, and performance is likely to suffer. The early 1.6-gpf models are a good example: Many performed badly because they were not designed from the ground up to work with that amount of water; in effect they were 3.5-gpf toilets with less water in the tank. Fixtures designed to work with a particular amount of water need that amount to flush properly.

Field-Tested Favorites

We try to steer clients toward toilets we know they'll be satisfied with. To find out which models work best, we field-tested a series of toilets by installing them in our office bathroom. After a couple of months of use, we compared notes on the performance of each model before replacing it with another.

We've tested six different toilets in the past year, all but one of which were early-release HETs from manufacturers with wide distribution in our area. All had MaP scores between 550 and 1,000 grams (**Figure 6**). Despite the range in scores, we were unable to discern any difference in their ability to clear solids — they all did a consistently great job.

However, we found notable differences in backwash, cleanliness, and noise. Our staff gave a thumbs-down to the Kohler, American Standard, and Caroma models for various combinations of these attributes. The Kohler Wellworth Pressure Lite toilet, for instance, was explosively loud and had frequent occurrences of dirty water remaining in the bowl. The American Standard FloWise fixture suffered from backwash and required constant porcelain brushing. And the Caroma, with its dual-flush action, was confusing for some to use and had pronounced problems with backwash and soiled porcelain.

After a year of testing, we decided we liked Toto's Eco (E-Max) series best. It's quiet, clears the bowl of solids, leaves clear water after the flush, and rarely requires brushing. We generally recommend it to our clients, and — because there are several models in the Eco E-Max series to choose from — they can usually find a style they like.

Drain Transport

When 1.6-gpf toilets first came out, there was some concern that they would not provide enough water to deliver waste to

Toilet Specs

Manufacturer	Model	Type	Gallons per flush	WaterSense	MaP score	Lunt Marymor assessment of additional factors			
						Ability to clear the bowl	Backwash	Porcelain staining	Noise
American Standard	FloWise 2073.014 — elongated bowl	siphon	1.28	yes	750	excellent	yes	yes	quiet
Caroma	Sydney Smart270 — easy height, elongated bowl	dual-flush wash-down	0.8 or 1.28	yes	600	excellent	yes	yes	quiet
Kohler	Cimmaron, K-3489	siphon	1.28	yes	1,000	excellent	yes	yes	quiet
Kohler	Wellworth Pressure Lite K-3505T — elongated bowl	pressure assist	*1.4	no	1,000	excellent	yes	no	loud
Toto	Eco Drake CST744E — round bowl	siphon	1.28	yes	600	excellent	no	no	quiet
Toto	Eco Guinevere MS974224CEFG	siphon	1.28	yes	550	excellent	no	no	quiet

*now available in a 1.0-gpf WaterSense model

Figure 6. The author evaluated several toilets sold in his area by installing them in the bathroom of his shop and then comparing notes with the other people who used them. The fixtures were judged on the basis of flushing power, noise, and the cleanliness of the water and bowl after the flush.

How Toilets Are Tested

In preparation for a MaP test, soybean paste is extruded into 3/4-inch-diameter cylinders (above). Testing is performed by dropping a predetermined mass of cylinders into the toilet (left), adding tissue, and then flushing. The process is repeated with successively larger amounts of soybean paste until flushing no longer clears the bowl.

Photos: Veritec Consulting and Koeller and Co.

Toilets sold in the U.S. must comply with performance standards developed by the American Society of Mechanical Engineers in conjunction with manufacturers. The ASME standards, however, have barely been heard of outside of the plumbing industry. Far better known is a voluntary performance standard based on MaP (Maximum Performance) testing, which was developed at the behest of the Canadian Water and Wastewater Association (CWWA) and a consortium of U.S. and Canadian utilities.

The beauty of the MaP test is that it provides a realistic measurement of the single most important aspect of performance: the ability to completely remove solids in a single flush. Under the ASME standard, toilets are tested by flushing sponges, paper, nylon granules, and nylon balls. In the MaP test they flush toilet paper and tubular pieces of soybean paste (miso), which — to put it delicately — look and behave like the real thing.

The MaP test is performed by dropping miso and a specified number of sheets of toilet paper into the bowl and then flushing. Miso is added in increments of 50 or 100 grams with testing performed until either the bowl won't clear or 1,000 grams (2.2 pounds) is reached. Each toilet model is rated on its ability to clear the bowl of solids with a single flush. Units that fail to meet the minimum 350-gram criteria do not receive a rating.

When testing began in 2003, the threshold requirement was 250 grams, which according to a British medical study is the "maximum average fecal size" of the males in that study. For the sake of consistency, the MaP standard was revised upward when the EPA adopted a 350-gram standard for the WaterSense program.

MaP testing is performed on an ongoing basis, and the results are reported every four to six months. The latest edition of the report came out in October 2009 and contains MaP scores for more than 2,000 different toilet models. It can be accessed from a variety of Web sites, including that of the testing company — Veritec Consulting (veritec.ca) — and the California Urban Water Conservation Council (cuwcc.org). — *David Frane*

the sewer. But experience has shown that this is rarely a problem in residential construction, where horizontal drain runs are short. If the initial flush doesn't push the waste all the way to its destination, water from the tub, shower, and washing machine will soon purge the line.

But problems can develop when the toilet is connected to a long horizontal waste run and there are no high-volume fixtures nearby. An example would be a commercial half-bath on a concrete slab in a warehouse. We once did service work for a client who had a 1.6-gpf toilet in a half-bath with an 80-foot horizontal drain line that likely didn't slope enough. The only way to keep it from clogging was to purge it occasionally by pouring buckets of water down the toilet — hardly an ideal solution.

In new installations, I encourage the architect to locate bathrooms as near to a sewer outfall as possible, or on a lateral that contains other fixtures that will purge the line. As long as there is 1/4 inch per foot of slope, the line will usually clear satisfactorily. Because the initial wave of flush water carries farther in a smaller pipe, we like to use 3-inch (rather than 4-inch) drainpipe when we're concerned about the length of the horizontal run — but only after making sure that the option is permitted by the local code.

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