Photo Courtesy Kohler

Low-Flow Update

by Jon Vara

Today's fixtures provide a much better flush than their predecessors, but understanding customer expectations is the key to choosing the right product

When Congress passed the Energy Policy Act of 1992, plumbing-fixture manufacturers were given less than two years to convert from the standard 3.5-gallon flush to 1.6 gallons. With little time available to completely re-engineer their products, most of them approached the problem in the simplest way possible: They rolled out water-saving toilets that were essentially modified versions of existing products, with smaller tanks and narrower trapways meant to give the reduced water volume enough velocity to provide an adequate flush (see Figure 1, next page).

The results left a lot to be desired. The early low-flows quickly earned a reputation for clogging and failing to clear the bowl, often requiring the user to double flush. "It was like Las Vegas," says Virginia plumber Rex Cauldwell. "You'd pull the lever and take bets on whether it was going to go down or not."

That reputation persists because toilets last a long time and many of those early versions are still in service. In reality, though, fixture manufacturers have come a long way in the past decade. Most of the current crop of 1.6-gallon toilets perform as well as or better than the 3.5-gallon models they replaced.

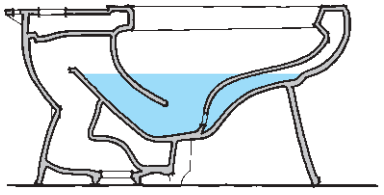
Gravity Toilets

Like their predecessors, most of today's low-flow fixtures are powered purely by gravity. Depressing the flush lever lifts a flapper valve in the base of the tank and allows water to flow

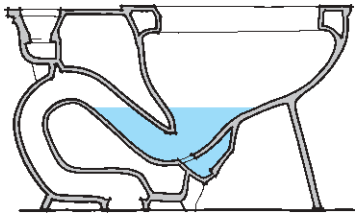
through the hollow interior of the rim and through strategically placed holes in the rim. At the same time, part of the flow — the so-called siphon jet — is directed into the outlet, where it pours up and over the trap to start the siphoning action that drains the bowl of waste.

Traps and tanks. What makes the new toilets perform so much better than the old ones?

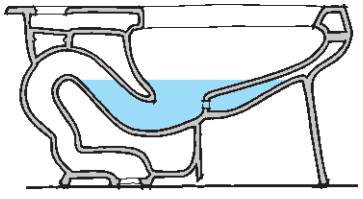
Water-Saving Toilets



3.5-Gallon Fixture



1.6-Gallon Fixture (Early Version)



Modern 1.6-Gallon Fixture

Figure 1. The pre-1992 fixture (top) had an open trapway design that resisted clogging but required 3.5 gallons of water per flush to develop the force needed to move waste through. The early low-flow toilet (center) relied on a much narrower trapway that added velocity to the flow but was far more likely to clog; the limited supply of water also translated into a smaller water spot in the bowl, increasing customer complaints about "skid marks." While the modern fixture, at bottom, also has a narrow trapway, better engineering provides a more efficient flush and a water spot almost as large as that of the old 3.5-gallon model.

For one thing, the science of trapway design has come a long way in the past few years. Toilet manufacturers now use sophisticated computer-modeling techniques to develop traps that provide optimum flow and reduce the frequency of clogs.

Another improvement has been the use of larger tanks to provide increased head. Victorian-era toilet designers accomplished this by mounting the tank on the wall, several feet above the bowl, but modern low-flows use a simpler approach. While the toilets use the required 1.6 gallons per flush, their tanks may contain three gallons or more, which means that the tank never empties completely. As the water flows from the bottom of the tank during the flush cycle, the added weight of the unused water above provides a more forceful flush.

This suggests that, all other things being equal, a one-piece "lowboy" toilet could be expected to deliver a less forceful flush that its two-piece counterpart. American Standard engineer Peter DeMarco confirms that one-piece fixtures do pose some design challenges. "You don't have the gravity head, so it's more difficult to get them to perform," he says. "You have to change the internal configuration in other ways to compensate."

Another advantage of increased-head tanks is reduced sweating in hot, humid weather. Because the tank isn't completely refilled with cold water after each use, the water left in the tank has time to warm up to room temperature. That tempers the incoming water and is often enough to keep the outer surface of the tank above the dew point.

Valve size. Most toilet manufacturers use the 2-inch flush valve that has been the industry standard for about a century. The sole exception is Toto, which introduced a 3-inch valve in 1997 (Figure 2). According to Toto engineer Fernando Fernandez, the resulting high rate of flow from tank to bowl results in an especially rapid, forceful flush. Fernandez claims that other manufacturers haven't adopted the 3-inch valve because Toto holds the patent to the specific trap configuration needed to make its system work.

Pressure- and Vacuum-Assisted Toilets

Consumers who want or need a more powerful flush than gravity alone provides can

choose from a wide range of pressure-assisted models. In place of the unpressurized water tank, flapper, and fill valve found in the back of a standard toilet, pressure-assisted fixtures contain a manufactured energizing unit that works something like the pressure tank in a private well system.

After each flush, household water pressure fills a sealed vessel, creating a cushion of compressed air at the top. When the lever is depressed again, opening the flush valve, the pressurized air rapidly forces the trapped air into the bowl to provide what's best described as a commercial-type flush. In fact, pressure-assisted units were largely confined to commercial applications until a decade or so ago, when the relatively poor performance of the early low-flow fixtures brought them into the residential market. Two Michigan-based companies — Sloan Flushmate and W/C Technology Corp. — manufacture all of the pressure units installed as original equipment by U.S. plumbing-fixture manufacturers (Figure 3). In addition to the standard 1.6-gallon unit, Sloan recently introduced a new model, the Flushmate IV, which uses just 1.1 gallons per flush.

Bang for the buck. Pressure-assisted toilets typically cost about $150 more than comparable gravity fixtures. Some plumbers find that they're a good choice in problem applications, such as in an old drain system with marginal venting.

Aside from the added cost, the biggest drawback to pressure-assisted units is noise. A pressure-assisted flush is both louder and more abrupt than that of a gravity fixture, which gives them a high "startle factor."

"Women hate them," says Bellevue, Wash., plumber Terry Love. "When you're trying to be quiet when you get up in the middle of the night, you're not going to want to flush it at all." Another drawback, Love observes, is that the rapid flow through the trap tends to shred toilet paper, allowing small particles of paper to drift back into the just-emptied bowl.

The "tank-within-a-tank" approach of pressure-assisted toilet units prevents condensation from forming on the external porcelain tank. On the other hand, condensation can form on the surface of the pressure vessel inside the tank, where it may provide a breeding ground for mildew.

Fixtures with pull. A quieter but less aggressive method of adding force to a flush is the vacuum assist incorporated in several models offered by Crane and Briggs. Like pressure-assisted fixtures, vacuum-assisted models contain sealed vessels that refill with each flush. But instead of becoming pressurized during the fill cycle, the vacuum chamber is designed

Toto

Figure 2. The 2-inch flapper valve at right has long been the industry standard. A new 3-inch valve recently introduced by Toto (left) empties the tank faster and provides an aggressive flush with little swirling in the bowl.

Sloan Flushmate

Figure 3. Pressure-assisted toilets use air trapped in a sealed vessel to deliver a forceful — and noisy — flush. Although pressure-assisted fixtures are outwardly similar to conventional gravity toilets, bowl and trapway designs differ. As a result, existing gravity fixtures can't be adapted to work with a pressure-assisted unit.

to create negative pressure as water drains from the tank during the flush. Integral tubing connects the vacuum chamber to the upper bend in the trapway, providing added suction to help clear the bowl (Figure 4).

Pumps and compressed air. Kohler offers another approach to power-assisted flushing with its Power Lite toilets (Figure 5). Instead of relying on vacuum or water pressure, these high-end models contain a small submersible pump that forces water from the tank to the bowl. The manufacturer claims that the resulting flush is comparable to that of a pressure-assisted fixture without the associated noise; the obvious limitation is the need for a GFCI-protected outlet within easy reach of the fixture. The Power Lite models also offer the user a choice of two flush volumes — a standard 1.6- or a water-saving 1.1-gallon flush for liquid waste. A model with an electrically heated seat is also available.

Briggs Plumbing Products

Figure 4. The outwardly conventional-looking Briggs Vacuity (top) develops increased flushing force with an internal tank-mounted vacuum-assist unit (above). As water drains from the closed unit during the flush cycle, an internal connecting tube induces a partial vacuum in the upper portion of the trapway.

Where the ultimate low-flow fixture is required, a California company called Microphor offers several toilets that provide an efficient flush on a mere 2 quarts of water (Figure 6, page 6). There's a significant catch, though: In addition to the usual water-supply-and-drain system, the Microphors need an external supply of compressed air at 60 psi.

In a residential installation, that usually involves installing a hardware-store air compressor in the basement or garage and running a 3/8-inch copper line to the fixture, according to Microphor spokesperson Walt Hess. Hess claims that the air-assisted toilets are being used successfully in the California communities of Carmel and Monterey, where severe water restrictions are in effect, as well as in houses elsewhere that are served by low-yield private wells.

Considering Peak Flow

A key difference between pressure- and vacuum-assisted toilets and most gravity fixtures concerns something called peak flow — the maximum rate at which water passes through the trapway of a given fixture during the flush cycle. Generally speaking, pressure-assisted units have the highest peak flows.

According to Frank Vullo, director of product management for Eljer, the company's pressure-assisted models have peak flows approaching 95 gallons per minute. (Because the entire flush consumes only 1.6 gallons, of course, that high rate of flow is sustained for only a fraction of a second.)

Toto claims that its 3-inch flush valve offers a rate of flow in the area of 50 gallons per minute, which Fernando Fernandez describes as "up there with pressure-assisted toilets." The average gravity fixture, he claims, tops out at about 30 gpm.

The exact figures may be open to question, but it's evident that the Totos and the pressure-assisted units do provide a characteristically rapid flush: Push the handle, and the contents of the bowl are sucked into the drain almost

instantly, with little or no visible swirling action.

That sort of high-speed flush may mean fewer clogs, but manufacturers of gravity toilets based on the traditional 2-inch flush valve tend to downplay its value.

"They're all about forceful, and we're all about a sustained flush," says Kohler engineer Kathryn Streeby. Kohler's gravity fixtures, she contends, are designed to provide a relatively gradual flush that swirls water vigorously around the bowl during the drain cycle. According to Streeby, that still clears bulky waste effectively while also reducing streaking and leaving the bowl cleaner.

Rating Performance

All toilets sold in the U.S. are required to meet ASME standard A112.119.2M, which measures water-exchange and bowl-cleaning performance as well as the ability to flush several types of test media (Figure 7, page 7). But the fact that a given fixture passes the ASME tests doesn't necessarily mean that it will perform satisfactorily in the field.

"ASME is an absolute minimum," says Nick Quattro, director of marketing for Briggs Plumbing Products. "If you don't set the bar higher than that, you'll have a lot of unhappy customers."

Individual manufacturers conduct extensive in-house product testing, but the results are seldom made public in any meaningful way. Performance tests undertaken by consumer groups and public agencies, however, permit some worthwhile (though inconclusive) product-to-product comparisons.

Independent testing. A recent study by the NAHB Research Center is a good case in point. Under contract with two West Coast utilities — Seattle Public Utilities and the Oakland, Calif., East Bay Municipal Utility District — the NAHB researchers subjected 49 current models of popular toilets from 17 different manufacturers to a variety of laboratory tests. Among other things, the researchers evaluated flushing performance, flush volume, trap diameter, and water-spot area.

But the most controversial part of the report was what the researchers termed the "flush performance index" for each toilet, based on the average amount of test media remaining in the bowl after a series of test flushes. The scores for individual toilets ranged from a perfect score of 0 — indicating no material remaining — to a high of 82. (To establish a benchmark for what might be considered unsatisfactory performance in the field, the NAHB researchers also tested three used "problem toilets" that had been the subject of user complaints; these were found to have flush performance numbers ranging from 32 to 44.)

Of the 49 toilets evaluated by the NAHB researchers, 35 were found to have flush performance indexes of ten or under, which the report synopsis describes as a "reasonable criteria for selecting the better performing toilets." Taken at face value, those figures suggest

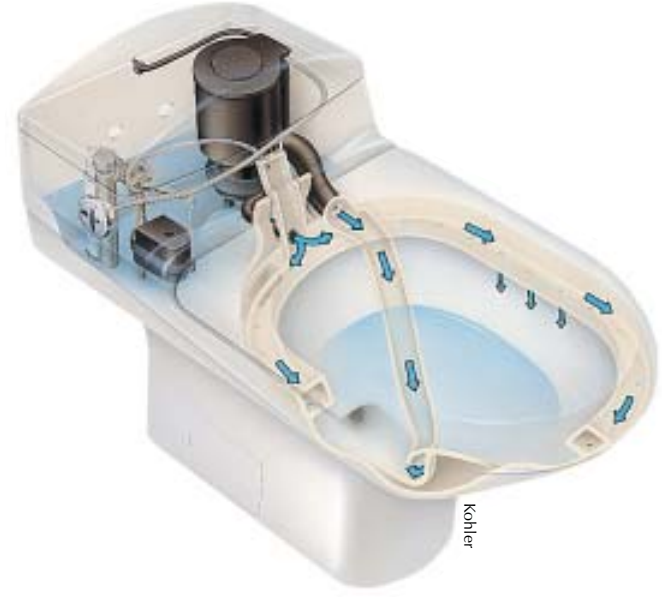


Figure 5. Kohler's Power Lite series of toilets contain compact submersible pumps that are said to produce a flush similar to that of a pressure-assisted fixture. A GFCI-protected outlet is required to supply power to the pump.

that nearly a third of the fixtures on the market don't work very well.

Conflicting studies. The complete report, published on the NAHBRC website in October 2002, caused a furor in the plumbing industry. Manufacturers whose products were found to perform well looked for ways to use that information in their marketing efforts, while others sought to downplay the results.

"I don't want to knock the folks at the NAHB," says Peter DeMarco, "but I have a problem with any test that tries to rate performance using just one type of media. The type of media you choose can determine the results you get." Moreover, DeMarco claims, the NAHBRC test loadings, consisting of various combinations of floating and sinking sponges, were unrealistically heavy. "They were over the top," he says. "They were far above what a toilet would ever encounter in normal use."

Coincidentally, another independent evaluation of low-flow toilets appeared in the October 2002 issue of *Consumer Reports* magazine, about the same time as the NAHBRC report. A side-by-side comparison of the two suggests that critics like DeMarco have a point when they argue that different types of objective tests can yield different results.

Microphor

Figure 6. Microphor makes two residential toilets that use a mere 2 quarts per flush. While the need for a separate source of compressed air makes this impractical for most applications, it's a useful option where local water restrictions or a low-yield well rule out conventional low-flow fixtures.

Of the NAHB's ten best-performing fixtures, for example, the first nine were gravity models. One pressure-assisted toilet, the Gerber Ultra, appeared in tenth place. The *Consumer Reports* researchers, on the other hand, awarded their top eight spots to pressure- or vacuum-assisted fixtures, with two gravity models appearing in the ninth and tenth positions. The Toto Ultramax, which tied for first place with another Toto fixture in the NAHBRC rankings, ranked behind 20 of the 28 toilets evaluated by the *Consumer Reports* staff.

Researcher Bob Hill, who led the NAHBRC team, believes that the differences between the studies stem partly from the different test media and loading rates used, and partly from the fact that the *Consumer Reports* staff considered factors like bowl-washing ability, draining, bowl dilution, and noise in calculating an overall rating for each toilet

"We looked at flushing ability, water-spot area, and flush volume," Hill says, "but didn't try to come up with a weighted average. Our intent was to put the raw data out there and let consumers draw their own conclusions."

Soon after the NAHBRC study appeared, however, the group began to worry that consumers might be drawing conclusions that weren't supported by the data. "When you rank products from top to bottom, the ones in the middle may be performing very well, but they look like they're far down the list," Hill says. "That can be misleading."

The full-length report, *Water Closet Performance Testing,* has been removed from the NAHBRC website (www.nahbrc.org), which now contains only a brief synopsis of the results. The full report, however, can be downloaded in pdf form from a number of other sites on the Internet, such as www.savingwater.org/docs/ToiletReport.pdf.

Cost and Value

Opinions vary on the relationship, if any, between how much a toilet costs and how well it works. After comparing performance data to retail price, for example, the NAHB researchers concluded that "there is no apparent correlation of price with performance." A number of toilets retailing for around $50 were found to perform very well.

Peter DeMarco is adamant that even very

inexpensive toilets can perform well. "If the manufacturer is paying attention to quality control, cost shouldn't be a factor," he says.

Plumbers, on the other hand, tend to take a different view. Rex Cauldwell notes that most of his callbacks and installation problems seem to involve inexpensive builder-grade products. Burlington, Vt., plumber Dennis Deloy agrees. "If you buy a $39 toilet, you're going to get a $39 flush," he says. "I prefer Gerbers. They're about all I use, and I've never had any problems with them."

Terry Love observes that most of the models he's had consistent success with tend to cost $200 or more. "I install lots of different brands, but the new Totos are my favorites," he says. (Love's website, www.terrylove.com, contains his recommendations for specific models from American Standard, Gerber, Kohler, Crane, Universal Rundle, Eljer, Briggs, Mansfield, and other manufacturers, as well as comments from other plumbers.)

Old vs. new. Improved engineering has improved toilet performance overall during the past decade, but it's worth noting that not all of a given manufacturer's products will reflect the current state of the art. New products tend to appear at the high end, while older, less efficient ones are weeded out at the lower end.

"It's a good-better-best–type thing," says Toto's Fernando Fernandez. He notes that his company's Standard Gravity line, which dates from 1994, is still on the market even though two newer product lines — which use the larger 3-inch flush valves and more sophisticated trapway designs — offer superior performance.

"The 'good' product is the builder market," Fernandez says. "I leave it to the sales guys to convince them to upgrade, but I wish builders in general were more responsive to some of the recent advances."

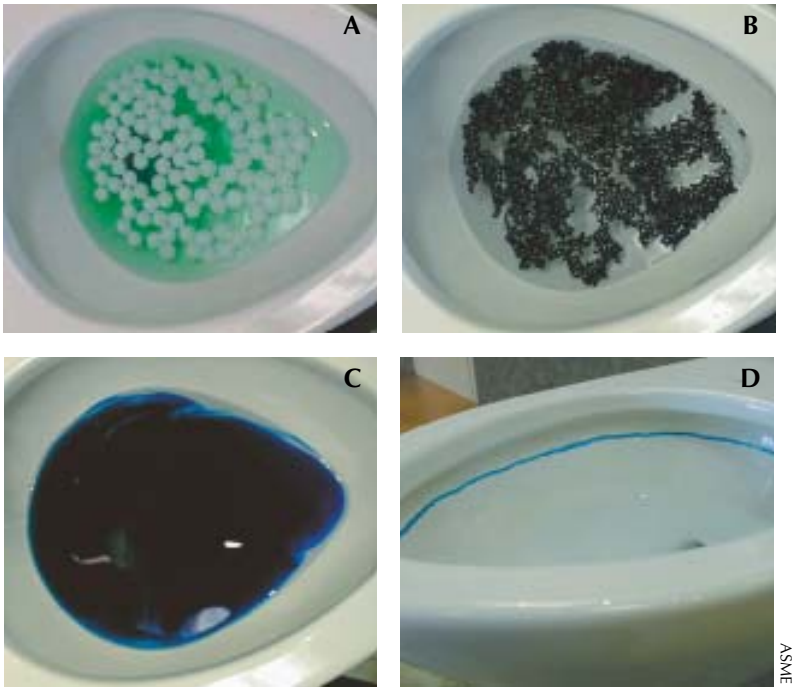
Not surprisingly, most manufacturers show little enthusiasm for telling buyers which of their products use older technology. But knowledgeable suppliers will be able to provide that information, which may be worth knowing in cases where performance is an issue.

Installation and Adjustment

When a low-flow toilet clogs or fails to deliver a complete flush, the user often assumes that an old-style 3.5-gallon fixture would have handled the same situation with ease. This "good old days" mentality is frustrating to manufacturers, who are fond of pointing out that plungers weren't invented in 1992. Peter DeMarco notes that flushing is a chaotic, somewhat unpredictable event. "You can never completely rule out clogging," he says. "Sometimes the waste will just line up in a random way that completely blocks the trapway."

On the other hand, because modern low-flows are more precisely engineered than their predecessors, it's safe to say that they are inherently less tolerant of error. Plumbers and manufacturers alike stress the importance of proper installation, adjustment, and maintenance to trouble-free operation.

Controlling water volume. When the first underperforming low-flows hit the street in the early '90s, many plumbers quickly discovered that providing them with additional water made for a better flush. To avoid complaints and callbacks, enterprising plumbers often modified them to use something closer to the familiar 3.5 gallons per flush. Since



ASME

Figure 7. To meet the minimum ASME performance standard, a toilet must successfully flush 100 3/4-inch polypropylene balls (A) and a quantity of polyethylene granules (B). A dye test (C) and an ink-line test (D) measure the fixture's ability to refill the bowl with clean water and pass enough water through the holes in the rim to minimize "skid marks."

most of those fixtures were 3.5-gallon models that had been adapted by the manufacturer to get by with less, this sort of in-the-field reverse engineering made sense and usually worked fairly well.

That's no longer true. If today's better-engineered toilets are flushed with too much water, their performance will get worse instead of better.

Rex Cauldwell notes that it's important to make sure the tank fills exactly to the manufacturer's fill line, and to adjust the level if necessary. The chain that connects the flapper valve to the flush lever, he finds, is another common source of problems. "If there's too much slack in the chain, it will lie on the flapper and make it close too soon," he says. "I like to have one or two links of slack when the lever is pushed down all the way."

Flapper flap. A typical flapper valve lasts about five years — often less where in-tank bowl cleaners are used. When the original flapper wears out, the homeowner frequently replaces it with a generic flapper from the hardware store. This can mean trouble, because replacement flappers often release much more water than the original manufacturer-supplied valve.

In the NAHB tests, for example, all of the new toilets were found to use close to the mandated 1.6 gallons per flush. In a second round of flush tests, using generic replacement flappers, water consumption shot up to an average of nearly 3 gallons per flush. Other researchers have come up with similar results. To prevent customer dissatisfaction down the road, it's a good idea to stress the need to use the right replacement valve.

Low-Flow Toilet Manufacturers

Afeel Corp. / Huntington Brass
800/888-6604
www.huntingtonbrass.com

American Standard
800/442-1902
www.americanstandard.com

Barclay Products
800/446-9700
www.jhbarclay.com

Briggs Plumbing Products
800/888-4458
www.briggsplumbing.com

Crane Plumbing / Fiat Products
847/864-7600
www.craneplumbing.com

Eljer Plumbingware
800/435-5372
www.eljer.com

Geberit Manufacturing
800/225-7217
www.us.geberit.com

Gerber Plumbing Fixtures
847/675-6570
www.gerberonline.com

Hansgrohe
800/334-0455
www.hansgrohe-usa.com

Jacuzzi Whirlpool Bath
800/288-4002
www.jacuzzi.com

Kallista
888/452-5547
www.kallista.com

Kohler
800/456-4537
www.kohler.com

Kolson
800/783-1335
www.kolson.com

Liette International
252/636-0972
www.lietteinternational.com

Mansfield Plumbing Products
877/850-3060
www.mansfieldplumbing.com

Microphor
800/358-8280
www.microphor.com

Neo-metro Collection
800/591-9050
www.neo-metro.com

Porcher
800/359-3261
www.porcher.com

Renovator's Supply
800/659-0203
www.renovatorssupply.com

Rohl
800/777-9762
www.rohlhome.com

Sloan Flushmate
800/533-3450
www.flushmate.com

St. Thomas Creations
800/538-2284
www.stthomascreations.com

Sterling Plumbing Group
888/783-7546
www.sterlingplumbing.com

Toto USA
800/350-8686
www.totousa.com

Watercolors
845/424-3327
www.watercolorsinc.com

Whitehaus Collection
800/527-6690
www.whitehauscollection.com