RESEARCH REPORT

MAXIMUM PERFORMANCE TESTING OF POPULAR WATER-EFFICIENT TOILET MODELS

HOUSING TECHNOLOGY SERIES

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Maximum Performance Testing of Popular Water-Efficient Toilet Models

Final Report

December 2003

by

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Initiated in 2003 by CMHC and other interested organizations in Canada, the Maximum Performance (MaP) Testing program was a cooperative effort between Canadian and American municipalities and water agencies. Supporting partners include:

Canada

- Canadian Water and Wastewater Association (CWWA) – LEAD AGENCY
- B.C. Capital Regional District, Victoria, British Columbia
- B.C. Buildings Corporation, Victoria, British Columbia
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- Calgary, Alberta
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- Halifax, Nova Scotia
- Hamilton, Ontario
- Montreal, Quebec
- Ottawa, Ontario
- Region of Durham, Ontario
- Region of Halton, Ontario
- Region of Peel, Ontario
- Region of Waterloo, Ontario
- Toronto, Ontario
- Winnipeg, Manitoba

U.S.A.

- California Urban Water Conservation Council, Sacramento, California
- East Bay Municipal Utility District, Oakland, California
- Los Angeles Department of Water and Power, Los Angeles, California
- Seattle Public Utilities, Seattle, Washington
- Tampa Bay Water, Clearwater, Florida

We gratefully acknowledge the contributions from these participating agencies and municipalities.

Disclaimers

The information in this report is believed to be an accurate description of the units tested and the results obtained. Every effort was made to ensure the accuracy of the findings including, but not limited to, preparation of a detailed test protocol, careful selection and procurement of the products to be tested, and third-party oversight of testing protocol implementation. However, because only one or two units of each model were tested, these results should not be considered as fully representative of the typical or average production of the models tested. The results shown in this report should be viewed only as an indication of expected "field" results.

Although the test protocol utilized a media whose physical properties closely resembles typical human waste, the reader is reminded that there is an enormous variation in human waste from person to person, and from one day to another.

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Readers are invited to distribute this report in whole or in part but any changes made to the document must be approved by the CWWA.

Readers are reminded that this report represents a "snap shot" of the performance levels achieved by certain toilets at a particular time and with particular trim. Manufacturers sometimes make permanent or temporary changes to trim components or to model designs without changing the model names. As such, changes to the models tested in this report may have occurred since the testing was completed.

Manufacturers tend to make periodic changes and improvements to their various models. As such, it is expected that several models tested as part of this study may be improved over time (in fact several models were improved and re-tested even during the course of this project). Performance results, therefore, may need to be periodically updated.

The selection of toilets tested as part of this program is in no way intended to represent all of the various makes and models available, nor is it intended to provide a comprehensive list of all toilets that might be expected to perform either well or marginally in the field.

The results obtained during this testing program are not guarantees of performance.

Acknowledgements

Some of the toilet fixtures, adjustable flappers, and some other elements used in this test program, were not readily available at retail outlets and were thus contributed by the manufacturers.

Certain individuals also contributed to the development of the test methods and to the general base of knowledge resulting from this study. Their contributions are also much appreciated:

- Peter DeMarco, American Standard
- Fernando Fernandez, Toto U.S.A.
- Al Dietemann and David Broustis, Seattle Public Utilities
- Michael Hazinski, East Bay Municipal Utility District

Executive Summary

Although virtually all toilet models sold in Canada and the U.S. meet both the flush volume and performance requirements of the Canadian Standards Association (CSA) and the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME), there remains some question as to whether models that meet the minimum certification requirements meet the expectations of the consumer. What's more, since certification testing offers only a pass/fail grading, there is currently no easy way to distinguish between superior and marginal toilet models available in the market.

Although other toilet performance studies have been completed, none of these have been performed using test media as realistic as that used in this test, nor has a quantifiable performance benchmark—based on the results of relevant medical data—been established.

The Maximum Performance (MaP) testing project was developed to identify how well popular toilets models perform using a realistic test media, and to grade each toilet model based on this performance. A soybean paste having similar physical properties (density, moisture content) to human waste was used in combination with toilet paper as the test media. In addition to using a realistic test media, all toilet samples rated at 6 litres (1.6 gallons) were adjusted to flush at that volume prior to testing to ensure a level playing field.

The developed testing protocol required the soybean paste to be extruded through a 7/8-inch (22 mm) die and cut into 50-gram specimens (each specimen approximately 100 mm or 4-inches in length). Toilet models were subjected to progressively larger loadings (in 50-gram increments) until the unit failed to completely clear the bowl in at least two of three attempts.

Two groups of toilet models were tested as part of this program—the first group was comprised of production models (two samples of each) purchased "off the shelf", while the second group included single samples, samples provided by the manufacturer, or prototype models. **All** toilet samples, however, were subjected to the same test protocol.

As stated earlier, it was important to identify a performance benchmark level for acceptable solids flushing performance. The results of a British medical study (*Variability of Colonic Function in Healthy Subjects*) were used to establish this benchmark level at 250 grams—the average maximum fecal size of the male participants in the study. The results of the MaP testing were quite remarkable in their variance. Approximately 45% of the group of models purchased "off the shelf" failed to meet the 250-gram performance criteria. What's more, while some popular models struggled to clear 100 g, others removed more than 900 g.

The results of the adjustable flapper replacement testing illustrated that common 2-inch (50 mm) replacement flappers cannot be installed on all toilet models (e.g., models that utilize non standard-sized flappers, pressure-assist models, and models where existing trim components interfere with replacement flapper operation). What's more, the results also show that it is not always possible to adjust these flappers to obtain the rated flush volume (generally 6 litres / 1.6 gallons).

A potentially significant problem concerning water savings erosion has been confirmed as part of the "standard flapper" replacement testing. Results show that a large percentage of toilet models flush with considerably higher volumes if the original flapper is replaced with a standard flapper. This is especially important as the life of a typical flapper is projected to be approximately five years (vs. about 25 years for the toilet itself). As a result, toilet flappers may be replaced three or four times during the life of the toilet and, if it is replaced with a standard flapper, 50 % or more of the expected water savings could be lost. Based on the likelihood of lost savings, it raises the question as to whether municipalities and water agencies should even be offering subsidies for toilets where a flapper replacement could result in significantly increased flush volumes.

The water change-out rate for all toilets was measured under liquid-only conditions by adding a brine mixture to the water in the bowl and measuring the conductivity of the water, then flushing and re-measuring the conductivity. The difference in conductivity was used to calculate the percentage of water changed-out during the flush. The results showed that all toilet models performed well in this test—even models that struggled to meet the 250-gram performance benchmark—and, therefore, it appears that a high water change-out rating may not be a good predictor of toilet performance.

Overall, the MaP testing protocol appears to be well-received by both water providers and manufacturers alike. It is expected that many agencies and municipalities will consider the results of MaP testing when evaluating which toilet models to subsidize or rebate and, as such, it is also expected that many more toilet models (models not previously tested and models that have been improved) will undergo MaP testing. It is important, therefore, that the performance charts included in this report are regularly updated to reflect the latest product offerings from the plumbing industry.

1.0 Background

Most residential toilet models exceed customer performance expectations while flushing with no more than 6 litres (1.6 gallons). However, recent research in Canada and the U.S. conclude that there are also certified and commercially available models that do not meet customer expectations.

There are two key concerns:

1) Fixtures that fail to meet the maximum 6-litre flush requirements of the Canadian Standards Association (CSA)[1] or the 1.6-gallon requirements of the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME)[2] result in toilets that flush with either too much or too little water;
2) Fixtures that do not flush effectively result in customer complaints and the need for double flushing.

Currently, however, there is no convenient way for the customer to distinguish between good and marginal performers. In addition, this lack of information on toilet performance levels has served to create a negative perception regarding 6-litre (1.6-gallon) technology in general, as opposed to identifying only those "bad apples."

1.1 Performance Studies

In absence of specific scoring information from certifying agencies, a number of studies have been undertaken in Canada and the U.S. to assess performance characteristics of individual toilet makes and models. These studies have not retested toilets to CSA or ASME protocols but rather endeavored to measure flush performance and water consumption—two key issues for homeowners and water conservation specialists. Three examples of recent studies include:

CMHC Independent Toilet Testing Study

This 2001 study was undertaken by CMHC to evaluate flushing performance using blue food dye to test liquid carry out, Kool-Aid™ powder to test bowl wash down, and toasted oat O's breakfast cereal to test each model's ability to remove floating media (vs. the sponges, kraft paper, plastic balls, plastic discs, etc., used by CSA). An important element of this study was the recognition that the test media used by certification agencies and the Independent Toilet Testing Study do *not accurately simulate human waste*.

Consumer Reports®

A Consumer Reports® article (*Successful water-savers*, October 2002) gave six of 19 gravity-flushing toilets tested the lowest grade possible for flushing solid waste: 32 % were classified as Poor, 26 % as Fair, 21 % as Good, 21 % as Very Good, and zero as Excellent. All of these toilet fixtures are certified for sale in the United States and Canada.

[1] 6-litre toilets are only mandated for new construction in Ontario and Vancouver; 13-lpf (3.5-gpf) fixtures are readily available to the retail consumer

[2] Certification testing is intended to ensure that each model meets a specific set of minimum requirements for health and safety, product integrity, and performance. There is no differentiation in certification between a toilet model that just meets the minimum requirements and one that surpasses those requirements.

NAHBRC Study

The September 2002 study conducted by the National Association of Home Builders Research Center (NAHBRC) and sponsored by Seattle Public Utilities and the East Bay Municipal Utility District (EBMUD) was an important step in providing consumers with performance information. The report, *Water Closet Performance Testing*, ranked the performance level of 49 popular toilet models based on each fixture's ability to flush both floating and sinking sponges. These models were then ranked against each other as opposed to being presented in a pass/fail manner. The NAHBRC study identified a significant range in toilet performance with scores ranging from 0 to 82, with lower numbers indicating better performance, but no minimum level of performance was identified. To obtain the final report, visit:

http://www.cuwcc.org/Uploads/product/NAHB_ToiletReport.pdf

2.0 Maximum Performance (MaP) Test

2.1 Critical Aspects of Test

The Maximum Performance (MaP) project was developed as a natural follow-up to the NAHBRC study, however, it differed in four significant areas:

- NAHBRC test media (floating and sinking sponges) were replaced with a combination of extruded soybean paste and wads of toilet paper. Most would agree that this media more accurately replicates "real-world" demands upon a toilet fixture.
- All models were adjusted to flush at rated volume, generally 6 litres (1.6 gallons), prior to testing.[3]
- A minimum level of acceptable performance was identified.[4]
- Results were presented by flush type to help assess whether differing flush technologies impact toilet performance.

2.2 Minimum Level of Acceptable Performance - Medical Data

A British medical report[5] outlines the results of fecal tests completed on 10 male and 10 female subjects eating normal diets. The study identified the *average maximum*[6] fecal size of the male participants to be approximately 250 grams and the 95th percentile size to be 305 grams[7]. The

[3] The NAHBRC testing attempted to closely mimic a consumer self-installed toilet fixture. As such, toilets were adjusted according to manufacturer's instructions supplied with the packaging—generally to the water line—regardless of the resulting flush volume. Therefore, some toilets flushed at greater than 1.6 gallons (6.0-litres).
[4] Although the NAHBRC report scored performance levels from 0 to 82, there was no indication of what score would constitute an acceptable level of performance.
[5] J.B. Wyman, K.W. Heaton, A.P. Manning, and A.C.B. Wicks of the University Department of Medicine, Bristol Royal Infirmary, *Variability of colonic function in healthy subjects*, 1978.
[6] The average of the largest sample collected from each participant during the program.
[7] It would be expected that only 5% of male samples would be larger than 305 g.

average maximum for women was slightly less at 237 grams, with the 95th percentile at 275 grams. The *average* fecal size of all participants was 130 grams[8].

Based on this study, it appears that for sanitary reasons as well as for customer satisfaction, toilets should flush a *minimum* of approximately 250 grams of solids. Therefore, for the purposes of this study, 250 grams (250 g) was set as a performance benchmark. As noted later in this report, approximately half of the toilet models tested failed to achieve this benchmark level.

Test rig (top left), bulk and extruded media (top right), media (bottom left), and adding media to bowl (bottom right).

2.3 Soybean Paste Test Media

Soybean paste was selected as a test media because its physical characteristics (density, moisture content) resemble those of human waste. The paste used for the solids testing possessed the following specifications: moisture content 51.5 %, pH 4.78, and density 1.16 grams/mL. The paste was extruded through a 7/8-inch (22 mm) diameter die, each specimen being approximately 100 mm (four inches) long and weighing 50 grams (±5 grams). The photos above illustrate the media used in MaP testing.

[8] A toilet only capable of flushing the *average* loading (130 g) would be expected to plug/clog or fail about 50% of the time, therefore, the benchmark of 250 g (average male maximum) was selected for this project.

2.4 Media Source

Although several soybean pastes with varying physical characteristics were evaluated during initial project development, the specific paste used in the MaP testing was obtained from a single Canadian importer. The paste was purchased by Veritec Consulting Inc. in 20-kg (44-lb) containers. Readers wishing further information regarding the paste should contact Veritec directly.

2.5 Summary of Test Protocol

The protocol used in the MaP testing has been well received and is perceived as useful in assessing toilet performance. This is evidenced by the manufacturers' response to initial results. For example, a number of manufacturers have contacted the consultants to have modified toilets or new prototypes tested to the MaP protocol.

The complete MaP test protocol is included in the **Appendix**. The flush performance and water change-out tests predominantly address the issue of customer satisfaction, while flush volume measurements and the flapper replacement data is more of a concern to individuals/water agencies attempting to promote water conservation.

2.6 Selection of Toilet Models

The identification of toilet models to include in the testing was carried out by the participating water agencies and the consultants. Each participant identified fixtures that were popular sellers in their regions based upon: (a) their knowledge of and relationship to the local marketplace, and (b) where applicable, the history of toilet rebate applications received by their agency or municipality. The selection of toilets tested is in no way intended to represent all of the various makes and models available, nor is it intended to provide a comprehensive list of all toilets that might be expected to perform either well or marginally in the field.

Where possible, toilet models were purchased "off-the-shelf" at retail outlets to replicate, as much as possible, purchase by a typical consumer. Because only one or two units of each model were tested, these results should not be considered as fully representative of the typical or average production of the models tested. The results shown in this report should be viewed only as an indication of expected "field" results.

In addition, approximately 30 of the fixtures previously tested at the NAHBRC in 2002 were packaged and shipped from the Maryland laboratory to the consultant's laboratory. As a result, these fixtures were of 2001-2002 vintage and are not necessarily the most current version available in the marketplace[9].

In many cases, both "round front" and "elongated" bowl models were tested and, in one case, an ADA[10] model was tested. Round front toilets are generally found in residential applications (the smaller bowl being more suitable in small bathrooms), whereas elongated toilets are typically found in commercial or institutional settings and some newer homes.

Readers are reminded that this report represents a "snap shot" of the performance levels achieved by certain toilets at a particular time and with particular trim. Manufacturers sometimes make

[9] For instance, the Sanitarios Azteca (Vortens) Sahara tested has not been produced for more than a year.
[10] *Americans with Disabilities Act*, i.e., a handicap model

permanent or temporary changes to trim components or to model designs. As such, changes to the models tested in this report may have been made since the testing was done.

Overall, 80 different toilet fixture models were tested as part of this project. Of these 80 fixtures, 44 were purchased "off-the-shelf" (two samples of each), 37 of which are gravity-fed fixtures (including vacuum-assist) and 7 of which are of pressure-assist technology. These 44 models are listed in **Table 1** with associated test results presented in **Section 3**. For the most part, the 37 gravity-fed models represent the most popular fixtures found in residential applications. The pressure-assisted (PA) fixtures, however, would normally be used in commercial applications.

The remaining 36 models tested were either prototypes (not currently available in the marketplace); samples provided by the manufacturer (MaP required retail product); or single samples (MaP required two samples of each model). The test results for these 36 models have been presented in separate charts and tables to help distinguish between the "off-the-shelf" toilet models tested and all others. These 36 models are listed in **Table 6** with associated test results presented in **Section 4.**

All toilet fixtures were assembled, placed on the test stand, and connected to a water supply. Tank water levels were set to the water line and flush volumes recorded. Adjustments were made, if necessary, to ensure all samples flushed with the rated volume, generally 6 litres (1.6 gallons).

3.0 MaP Test – Models Purchased "Off-the-Shelf"

Table 1 – Models Purchased "Off-the-Shelf" (44 models)

Make	Model	Flush Type	Bowl and Tank Model Nos.
American Standard	Plebe EL	Gravity	4392.312 tank & 3344.312 bowl
American Standard	Cadet	Gravity	2898.012, with 4112.016 tank & 3459.016 bowl
American Standard	Cadet RF	Gravity	2798.012, with 4112.016 tank & 3454.016 bowl
American Standard	Hamilton EL	Gravity	2092-0170-20
American Standard	Cadet (PA) EL	Pressure	4098.100.020 tank & 3099.016.020 bowl
American Standard	Colony Afton RF	Gravity	4392.500.020 tank & 3038.016.020 bowl
American Standard	Ravenna RF	Gravity	4096.516.020 tank & 3454.016 bowl
American Standard	Sonoma RF	Gravity	4392.562.020 tank & 3338.012.020 bowl
Briggs (Proflo)	Abingdon III RF	Gravity	4229 = 4440t/4875b
Briggs (Proflo)	Altima III RF	Gravity	4232 = 4430t/4320b
Briggs (Proflo)	Vacuity EL	Vacuum	4200
Caroma	Tasman RF	Gravity	270 Suite - DUAL FLUSH
Crane	Economiser RF	Pressure	3612 tank & 3824 bowl
Crane	VIP Flush RF	Vacuum	3995
Crane	Cranada RF	Gravity	3503 tank & 3415 bowl
Crane	Cranada II RF	Gravity	3742/3743 tank & 3503 bowl
Eljer	Aquasaver EL	Pressure	1417-00000/137-7025-00
Eljer	Patriot RF	Gravity	091-2120, with 141-2120 tank/131-2120 bowl
Foremost	Premier RF	Gravity	T-8207-W tank & LL-8207-W bowl
Foremost	Regent RF	Gravity	T-5207-W tank & LL-5207-W bowl
Gerber	Aquasaver EL	Gravity	21-712, with 28-790 tank
Gerber	Ultra Flush EL	Pressure	21-302
Glacier Bay	Westminster RF	Gravity	455-685 tank (lined) and 445-684 bowl
Glacier Bay	Aragon IV RF	Gravity	164963
Kohler	Santa Rosa RF	Gravity	3323-0
Kohler	Wellworth RF	Gravity	K3423 toilet, with 4620 tank/4277 bowl
Kohler	Wellworth EL	Gravity	K3422 toilet, with 4620 tank/4276 bowl
Komet	Deco RF	Gravity	DE 611 tank and DE 627 bowl
Mansfield	Alto RF	Gravity	130-160
Mansfield	Quantum EL	Pressure	150 tank & 100 bowl
Niagara	Flapperless RF	Gravity	N2216
Niagara	Turbo RF	Gravity	N2220
Orion	Iris RF	Gravity	51073 tank & 50073 bowl
Sanitarios Azteca (Lamosa)	Sahara RF	Gravity	411
St. Thomas	Marathon RF	Gravity	6201.010
St. Thomas	Mariner II EL	Pressure	6207.020
St. Thomas	Mariner II RF	Pressure	6207.020
Toto	Drake EL	Gravity	CST744S
Toto	CST703 RF	Gravity	CST703
Toto	Ultramax EL	Gravity	MS854114S
Toto	Ultimate EL	Gravity	MS854114
Toto	Ultimate RF	Gravity	MS853113
Vortens	GTA RF	Gravity	3412 tank, 3200 bowl
Western Pottery	Aris RF	Gravity	822

3.1 Flush Performance

The ability of a toilet to completely remove waste in a single flush without plugging or clogging is considered by many to be one of the most important test criteria. The flush performance test was conducted by loading the fixture in 50-gram increments of soybean paste until the toilet model failed to pass 100 % of the media in two of three attempts. Four loosely crumpled balls of toilet paper (six sheets each) were included in each test. The toilet paper used in testing had the following specifications: single ply toilet paper conforming to ASME A112.19.14–2001, section 3.2.5.1.2. All tests were completed at 50 psi static supply pressure. The minimum level of acceptable performance in terms of loading for this project was set at 250 grams (as identified in Section 2.2).

Figures 1, 2, and 3 illustrate the maximum solids loading that each model was able to successfully clear from the bowl in a single flush in at least two of three attempts. **Figure 1** illustrates toilet models that failed to clear the benchmark of 250 grams, while **Figure 2** shows models that cleared between 250 and 500 grams (up to twice the minimum benchmark). Finally, **Figure 3** illustrates models that cleared greater than 500 grams (i.e., more than twice the benchmark of 250 grams). Results for the 44 toilet models were as follows:

- Flushed less than 250 grams: 20 models
- Flushed 250 to 500 grams: 13 models
- Flushed in excess of 500 grams: 11 models

Figure 1 – Models Clearing Less than 250 g

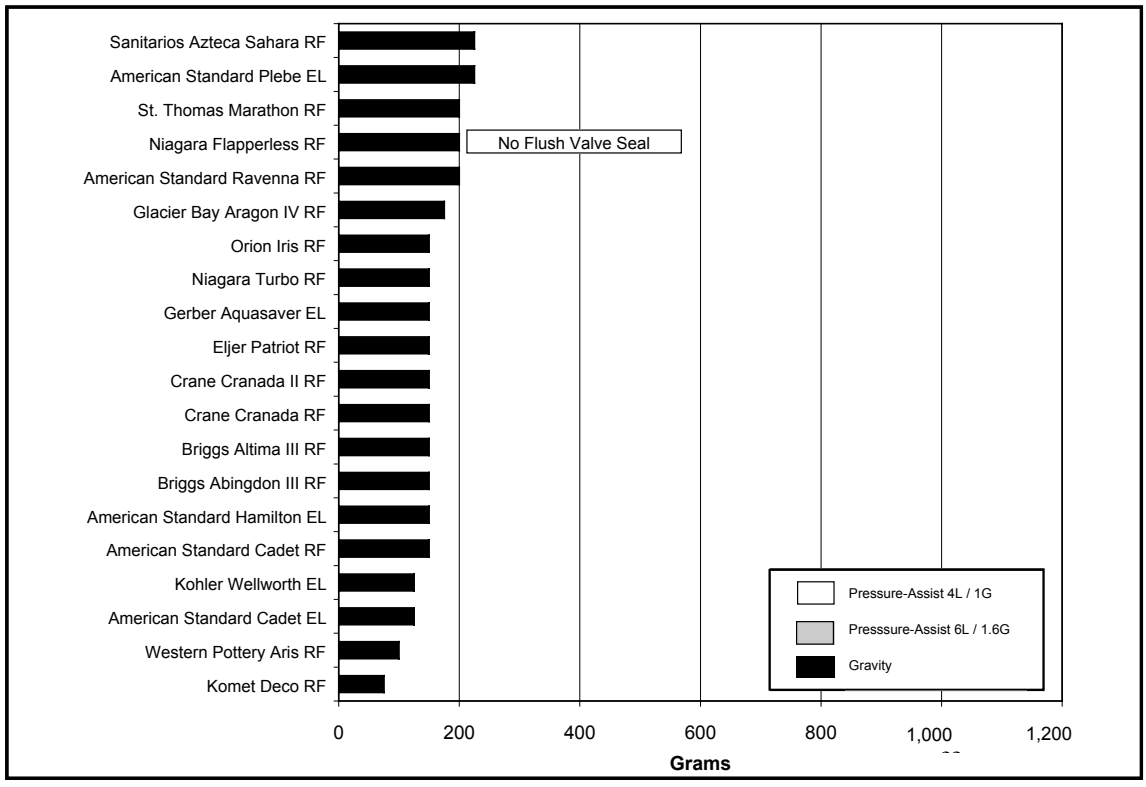


Figure 2 – Models Clearing Between 250 g – 500 g

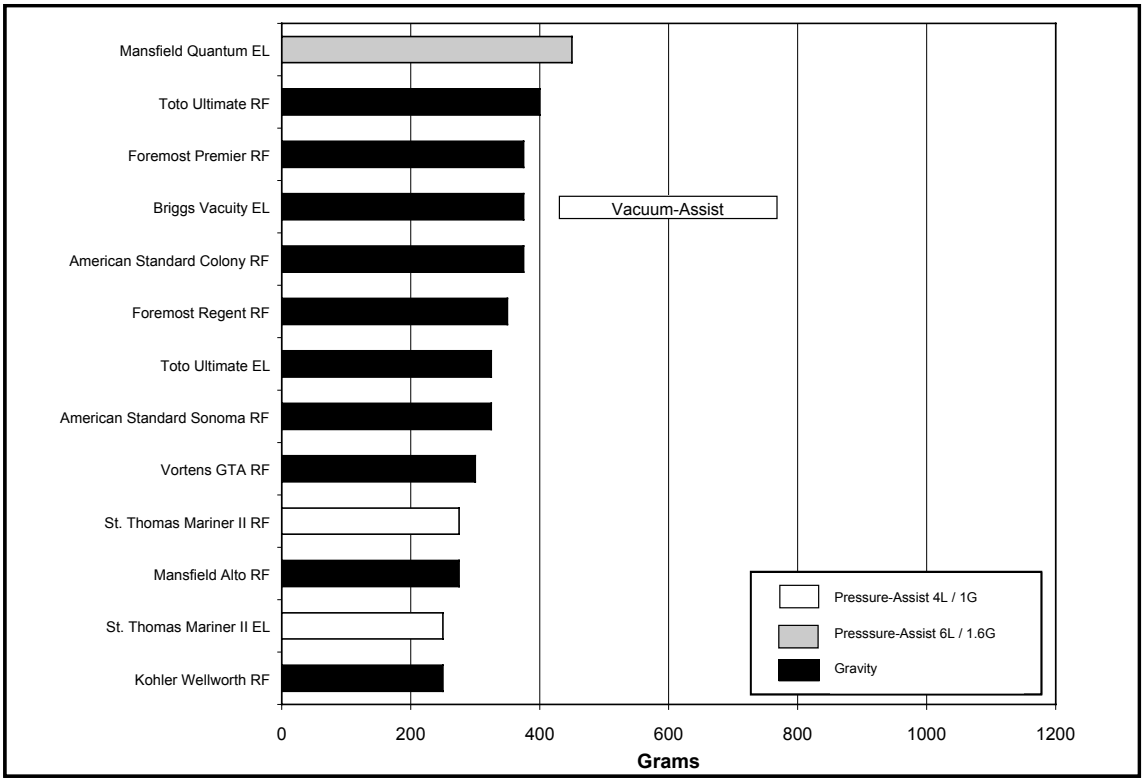
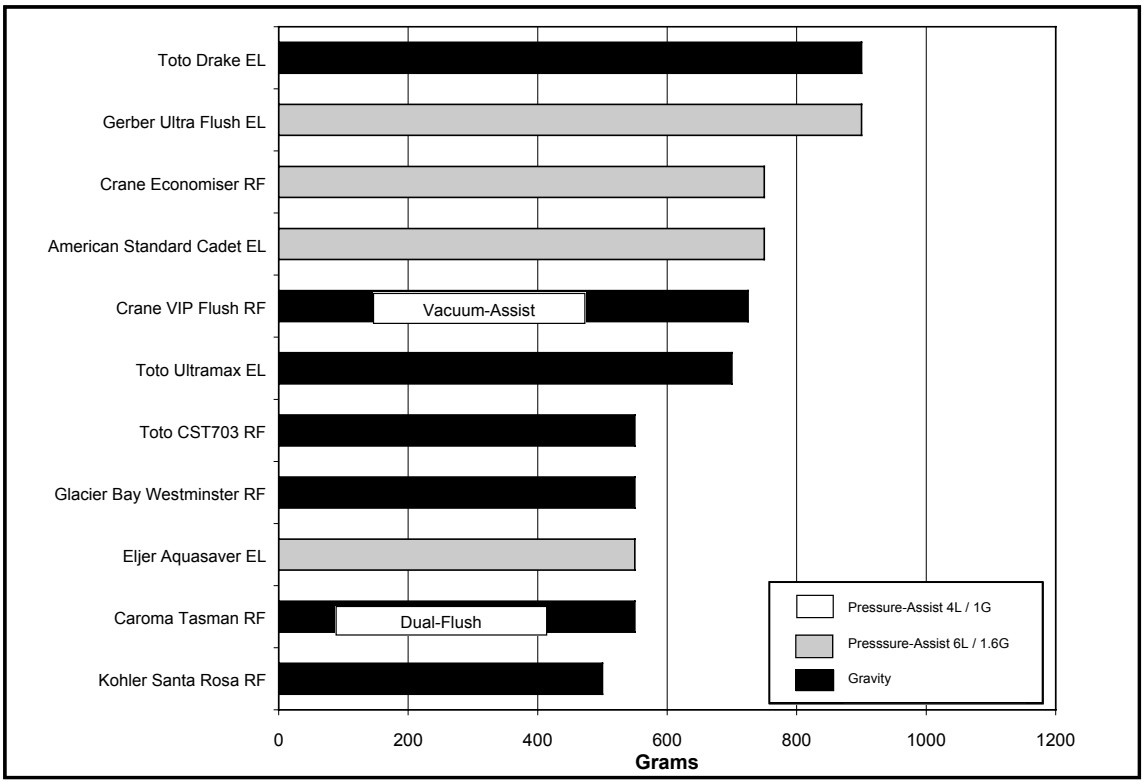


Figure 3 – Models Clearing Greater than 500 g



3.2 Water Exchange Test

The water exchange (or change-out) is an important performance factor to most consumers, since any liquids or solids remaining in the bowl after a single flush usually lead to a second or third flush. The second component of the testing program involved testing the water exchange capability of each model, i.e., percentage of water exchanged during a liquid-only flush.

The water exchange capability was measured using a brine mixture and conductivity meter. Approximately 20 mL of an 18 g/L salt solution were added to the test bowl and stirred gently to ensure uniform mixing; the conductivity of the water was then measured and recorded. Next, the toilet was flushed and allowed to refill. Following refill, the conductivity of the bowl water was again measured and recorded, and the percentage of water change-out calculated.

All models tested achieved a minimum water change-out rate of at least 98 % (i.e., a ratio of 1:50)—even toilets that cleared only 100g of solids. As such, using water change-out ratings under a "liquid only" flush to identify superior performing toilets may be misleading. Problems such as failing to remove all of the color or leaving some materials in the bowl may be more likely when both solids and liquids are being flushed. Because all models scored high change-out rates, no tables have been included for the results of this test.

3.3 After-Market Flapper Compatibility

The third test covered after-market flappers. Although toilets can last for more than 20 years, flappers or flush valves may need replacing after five years. Many flappers sold for after-market replacement have adjustable closure times and, consequently, offer adjustable flush volumes. This can be a concern for water agencies promoting 6-litre (1.6-gallon) toilets. Some flappers use an adjustable dial while others use various inserts to adjust the closure time to suit a particular toilet. Although this may make the after-market flapper somewhat "universal" in its application, it relies upon the consumer to make the correct dial setting or apply the correct insert. As a result, it is likely that many toilets with after-market adjustable flappers are not flushing at 6 litres (1.6 gallons).

This project included testing three different types of adjustable flappers[11] in each toilet model[12] to determine the appropriate setting (dial or insert) to maintain the design flush volume. Approximately 25 of each flapper type were used in the test program (each flapper sample was only used for a small number of tests). Fluidmaster and Niagara Conservation provided samples of their adjustable flappers, while the Frugal Flush adjustable flapper was available in the Veritec inventory. These represent some of the more popular adjustable flappers in the marketplace. The photos on the following page illustrate the flappers used in this testing project.

Test results can help consumers to properly adjust replacement flappers when replacing old or worn flappers, and water agencies performing in-residence customer service audits involving flapper replacements.

[11] Niagara Model No. N3145 (inserts), Fluidmaster Bull's Eye® Adjust-A-Flush® Flapper Model No. 502 (dial), Frugal Flush® Universal Replacement Flapper Model No. 109982 (dial)

[12] Only models using 2-inch diameter flappers were subjected to this portion of the test protocol.

Frugal Flush (insert removed)

Niagara (several inserts shown)

Fluidmaster Adjust-A-Flush

For various reasons, replacement flappers could not be installed in every toilet model. For example, some toilets use proprietary flappers, such as the 3-inch (75 mm) flappers used in the Toto Drake, Ultramax, and Ultimate, the 2-inch (50 mm) disks used in the Mansfield Alto, and the proprietary flush valve seal in the American Standard Champion. Other models excluded from the test were pressure-assisted toilets and toilets where the proper operation of the replacement flapper was prevented by interference from existing trim components. **Table 2** identifies the "off-the-shelf" models where it was not possible to install the replacement flappers.

Table 3 identifies the adjustment setting and the resulting flush volume range for those "off-the-shelf" models that could accept the replacement flappers. To enable the table to be easily read when photocopied or faxed a "star" rating system was used (more stars equals better performance) rather than shading.

Table 2 – "Off-the-Shelf" Models in Which Replacement Flappers Could Not Be Installed

Manufacturer	Model	Reason
American Standard	Cadet EL	Pressure-Assist
American Standard	Colony Afton RF	Interference with other trim
Caroma	Tasman RF	Dual-Flush
Crane	Economiser RF	Pressure-Assist
Eljer	Aquasaver RF	Pressure-Assist
Gerber	Ultra Flush RF	Pressure-Assist
Glacier Bay	Aragon IV RF	Interference
Kohler	Santa Rosa RF	Interference
Komet	Deco RF	No Water line
Mansfield	Alto RF	No Flapper
Mansfield	Quantum EL	Pressure-Assist
Niagara	Flapperless RF	No Flapper
St. Thomas	Mariner II EL	Pressure-Assist
St. Thomas	Mariner II RF	Pressure-Assist
Toto	Drake EL	3" Flapper
Toto	Ultimate EL	3" Flapper
Toto	Ultimate RF	3" Flapper
Toto	Ultramax EL	3" Flapper

Table 3 – "Off-the-Shelf" Models: Settings Required on Adjustable After-Market Flappers

Make	Model	Flapper Data		
		Fluidmaster	Niagara	Frugal Flush
American Standard	Cadet EL	N/A	#2 / *	#5 / *
American Standard	Cadet RF	N/A	#2 / **	#5 / *
American Standard	Hamilton EL	#9 / *	#1 / *	#1 / *
American Standard	Plebe EL	N/A	#2 / ***	#3 / *
American Standard	Ravena RF	N/A	N/A	#5 / *
American Standard	Sonoma RF	N/A	#4 / ***	#5 / **
Briggs (Proflo)	Abingdon III RF	#7 / ***	#2 / ***	#4 / ***
Briggs (Proflo)	Altima III RF	#8 / ***	#2 / ***	#3 / ***
Briggs (Proflo)	Vacuity EL	#9 / *	#1 / *	#1 / *
Crane	Cranada RF	#1 / ***	#5 / ***	#5 / *
Crane	Cranada II RF	#9 / **	#1 / ***	#1 / **
Crane	VIP Flush RF	#9 / **	#1 / ***	#1 / *
Eljer	Patriot RF	#1 / *	#6 / ***	#5 / *
Foremost	Premier RF	#8 / ***	#4 / ***	#5 / **
Foremost	Regent RF	#7 / **	#4 / ***	#5 / **
Gerber	Aquasaver EL	#1 / ***	#4 / ***	#5 / *
Glacier Bay	Westminster RF	#1 / ***	#5 / **	#5 / *
Kohler	Wellworth EL	#1 / ***	#5 / ***	#5 / *
Kohler	Wellworth RF	#1 / **	#6 / ***	#5 / **
Niagara	Turbo RF	#9 / *	#1 / **	#5 / *
Orion	Iris RF	#1 / *	#5 / ***	#1 / ***
Sanitarios Azteca (Lamosa)	Sahara RF	#1 / *	#5 / ***	#5 / *
St. Thomas	Marathon RF	#1 / *	#6 / **	#5 / *
Toto	CST703 RF	#5 / ***	#3 / ***	#5 / ***
Vortens	GTA RF	#2 / ***	#4 / ***	#5 / *
Western Pottery	Aris RF	#1 / *	#5 / ***	#5 / **

Flapper Settings
Fluidmaster: #1 provides minimum volume, #9 provides maximum volume
Niagara: #1 provides maximum volume, #6 provides minimum volume
Frugal Flush: #1 provides maximum volume, #5 provides minimum volume

Adjustment Range of Flappers
*** indicates flapper could be adjusted to within ±0.2 litres (0.05 gallons)
** indicates flapper could be adjusted to within ±0.5 litres (0.13 gallons)
* indicates flapper could NOT be adjusted to within ±0.5 litres (0.13 gallons)
N/A indicates that the flapper could not be properly installed.

3.3.1 "Standard" Flapper Compatibility

In many cases it may not be easy for homeowners to purchase the correct replacement flapper for their toilet fixture. This is particularly true if they are purchasing the flapper at a "big box" retail outlet or hardware store, or if they have forgotten the specific model of their toilet. Installing an incorrect flapper can change the toilet's flush volume and, therefore, affect the flush performance. For example, if the toilet flushes with less water after the flapper is replaced, its ability to clear waste may be compromised; on the other hand, if it flushes with more water, the water-efficiency savings may be partly or totally erased.

Three Models of 'Standard' Flappers

To simulate the effects of replacing the original equipment manufacturer (OEM) flapper (often an early-closing flapper) with the commonly available standard or "universal" flapper[13], all toilets were fitted, where possible, with a standard after-market replacement flapper. The results are presented in **Table 4.** The use of standard flappers, where they could be installed[14], resulted in a range of flush volumes indicating the use of these flappers may lead to significant erosion in water savings or in customer satisfaction.

The test results illustrate that more than 70 % of the models had a significant increase in flush volume when a standard flapper was installed—some flushed with more than 15 litres (4 gallons). The data indicates that a sizable reduction in water savings would occur over time if homeowners replace worn or leaking early-closing flappers with standard flappers. There is currently some discussion among water-efficiency promoters as to whether toilets with early-closing flappers should even be promoted or subsidized by water agencies.

[13] Buoyant flapper of the type typically used prior to the introduction of 6-L / 1.6-G toilets. These flappers remain open until the water level in the tank drops to approximately 25-50 mm (1-2 inches) above the bottom of the tank, resulting in most of the tank water being discharged during the flush cycle. "Early-closing" flappers are so called because they lose their buoyancy and close when there is still a significant portion of water left in the tank.

[14] For reasons discussed in Section 3.2, standard flappers could not be installed on all models tested in the program.

Table 4 – "Off-the-Shelf" Models: Flush Volume with Standard Flapper

Manufacturer	Model	Flush Volume	
		Litres	Gallons
American Standard	Hamilton EL	4.9	1.29
Briggs (Proflo)	Vacuity EL	5.3	1.40
Niagara	Turbo RF	5.7	1.51
Crane	VIP Flush RF	6.0	1.59
Crane	Cranada II RF	6.1	1.61
Foremost	Regent RF	6.4	1.69
Briggs (Proflo)	Abingdon III RF	6.8	1.80
Briggs (Proflo)	Altima III RF	6.9	1.82
Foremost	Premier RF	7.3	1.93
Toto	CST703 RF	7.5	1.98
Mancesa	Charleston RF	8.0	2.11
Mancesa	Ste. Michelle RF	8.6	2.27
Glacier Bay	Westminster RF	9.5	2.51
American Standard	Sonoma RF	9.7	2.56
Eljer	Patriot RF	9.9	2.62
Kohler	Wellworth RF	9.9	2.62
Orion	Iris RF	9.9	2.62
Kohler	Wellworth EL	10.0	2.64
Crane	Cranada RF	11.0	2.91
Vortens	GTA RF	12.0	3.17
St. Thomas	Marathon RF	12.2	3.22
American Standard	Plebe EL	12.4	3.28
Western Pottery	Aris RF	12.7	3.36
Sanitarios Azteca (Lamosa)	Sahara RF	13.8	3.65
Gerber	Aquasaver EL	14.0	3.70
American Standard	Cadet RF	15.2	4.02
American Standard	Cadet EL	15.9	4.20

3.3.2 Flush Volume "Out of the Box"

Approximately one third of the models tested flushed at greater than 6 litres (1.6 gallons) when removed from their factory carton, assembled on the test stand, and adjusted in accordance with manufacturer instructions. Test results are illustrated in **Table 5.**

Prior to MaP testing, all toilets were adjusted to their rated (specified) flush volume.

Table 5 – "Off-the-Shelf" Models: Flush Volume at Waterline

Make	Model	Volume (L)	Volume (G)	Comments
St. Thomas	Mariner II EL	3.6	0.95	4-L / 1-gal PA
St. Thomas	Mariner II RF	3.7	0.98	4-L / 1-gal PA
Eljer	Aquasaver EL	4.5	1.19	6-L / 1.6-gal PA
American Standard	Hamilton EL	5.1	1.35	
American Standard	Ravenna RF	5.2	1.37	
Crane	Cranada RF	5.2	1.37	Rubber Flapper Chain
Glacier Bay	Westminster RF	5.3	1.40	Rubber Flapper Chain
Toto	Ultimate EL	5.5	1.45	3" Flapper
Sanitarios Azteca	Sahara RF	5.5	1.45	Rubber Flapper Chain
Briggs (Proflo)	Vacuity EL	5.6	1.48	Vacuum-Assist
Foremost	Regent RF	5.6	1.48	
Vortens	GTA RF	5.6	1.48	
American Standard	Cadet RF	5.7	1.51	
Foremost	Premier RF	5.7	1.51	
American Standard	Cadet EL	5.8	1.53	
Crane	Economiser RF	5.8	1.53	6-L / 1.6-gal PA
Gerber	Ultra Flush EL	5.8	1.53	6-L / 1.6-gal PA
Mansfield	Alto RF	5.8	1.53	Proprietary Flush Valve Seal
Mansfield	Quantum EL	5.8	1.53	6-L / 1.6-gal PA
Niagara	Turbo RF	5.9	1.56	
Toto	CST 703 RF	5.9	1.56	
American Standard	Colony Afton RF	6.0	1.59	Adjustable Float
American Standard	Sonoma RF	6.0	1.59	
Caroma	Tasman RF	6.0	1.59	Dual-Flush
Crane	VIP Flush RF	6.0	1.59	Vacuum-Assist
Kohler	Wellworth RF	6.0	1.59	Adjustable Float
Kohler	Wellworth EL	6.0	1.59	Adjustable Float
Orion	Iris RF	6.0	1.59	Adjustable Float, Rubber Flapper Chain
American Standard	Cadet (Press.Assist) EL	6.2	1.64	6-L / 1.6-gal PA
Crane	Cranada II RF	6.3	1.66	Rubber Flapper Chain
Toto	Drake EL	6.3	1.66	3" Flapper
Gerber	Aquasaver EL	6.5	1.72	Rubber Flapper Chain
Kohler	Santa Rosa RF	6.5	1.72	
Niagara	Flapperless RF	6.5	1.72	
Toto	Ultramax EL	6.5	1.72	3" Flapper
Eljer	Patriot RF	6.6	1.74	
Toto	Ultimate RF	6.8	1.80	3" Flapper
Briggs (Proflo)	Abingdon III RF	6.9	1.82	Rubber Flapper Chain
American Standard	Plebe EL	7.2	1.90	Adjustable Float
Western Pottery	Aris RF	7.2	1.90	
Briggs (Proflo)	Altima III RF	7.3	1.93	Rubber Flapper Chain
Glacier Bay	Aragon IV RF	7.3	1.93	
St. Thomas	Marathon RF	7.6	2.01	
Komet	Deco RF	9.5	2.50	No Water Line Indicator

4.0 MaP Test – Prototype/Single-Sample/Manufacturer-Supplied Models

Table 6 - Prototype/Single-Sample/Manufacturer-Supplied Models

Make	Model	Flush Type	Bowl and Tank Model Nos. Remarks
American Standard	Champion EL	Gravity	Prototype - 4260.016.020 tank, 3225.016.020 bowl
American Standard	Dual-Flush RF	Gravity	Asian model – not available in North America
Capizzi	Turbo 4.0L (1G) Capizzi	Pressure	Prototype 4L/1-gpf fixture w/ Flushmate IV
Caroma	Caravelle Dual-Flush RF	Gravity	2000 tank & 270 Bowl
Caroma	Caravelle 1.2/0.8-gpf Dual-Flush RF	Gravity	Reduced volume prototype: 4.5/3.0-litres
Corona	Orchid RF	Gravity	8510
Crane	Radcliffe RF	Gravity	3596 tank & 3403 bowl
Eljer	Cypress RF	Gravity	091-0240, with 141-0230 tank/131-2120 bowl
Gerber	Ultra Flush Rear Exit EL	Pressure	28-380 tank & 21-374 bowl
Kohler	Rialto RF	Gravity	3386-0
Komet	Albany EL	Gravity	AL 700
Mancesa	Cyclone 4.0L EL	Pressure	Prototype 1.0-gpf fixture w/ Flushmate IV
Mancesa	Ste. Michelle RF	Gravity	4260 tank, 2360 bowl
Mancesa	Charleston RF	Gravity	4861W tank (lined) and 2856W bowl
Niagara	Flapperless RF	Gravity	Improved bowl hydraulics
Prototype “X”	EL	Pressure	Prototype – new flush technology
Toto	Plymouth EL	Gravity	MS924154F
Toto	Baldwin EL	Gravity	ST7845 tank & C7845F bowl
Toto	Dalton EL	Gravity	ST733 tank & C734F bowl
Toto	Carusoe RF	Gravity	ST706 tank & C715 bowl
Toto	Carlyle EL	Gravity	MS874114SG
Universal Rundle/Crane	Atlas ADA	Gravity	4490 tank, 4278 bowl
Universal Rundle/Crane	Atlas EL	Gravity	4490 tank, 4295 bowl
Universal Rundle/Crane	Atlas RF	Gravity	4490 tank, 4295 bowl
Vitra	Atlantis RF	Gravity	Prototype
Vitra	Atlantis EL	Gravity	Prototype
Vitra	Atlantis EL Unlined	Gravity	6853-003-0122 tank, 5051-003-0075 bowl
Vitra	Atlantis EL Lined	Gravity	6853-003-0273 tank, 5051-003-0075 bowl
Vitra	Atlantis RF Unlined	Gravity	6853-003-0122 tank, 5050-003-0075 bowl
Vitra	Atlantis RF Lined	Gravity	6853-003-0273 tank, 5050-003-0075 bowl
Vortens	Vienna II RF	Gravity	3412 tank, 3207 bowl
Vortens	Genova EL	Gravity	3421-02-V tank & 3121-02-V bowl
Water Management Inc.	RF	Pressure	Private label: WM381 tank & WM342 bowl
Water Management Inc.	EL	Pressure	Private label: WM381 tank & WM372 bowl
Western Pottery	Aris LP RF	Gravity	Prototype
Western Pottery	Aris RF	Gravity	Prototype

As stated earlier, a number of prototype toilet models, single samples of models, or samples provided by the manufacturer were included in the testing[15]. This section describes the test results for these Prototype/Single-sample/Manufacturer-supplied (**PSM)** models, including models that have been modified and improved upon since the start of the MaP testing program. A list of these toilet models is presented in **Table 6**.

In all cases where the manufacturer provided the toilet samples for testing, associated testing costs were paid by the manufacturer. This helped to broaden the scope of the study without adding additional costs to the sponsoring partners.

4.1 Flush Performance

Flush performance testing for the PSM models was completed in accordance with MaP protocol (see Section 3.0). **Table 6** identifies the 36 toilet models tested in this section. Results are presented as follows:

- **Figure 4**: prototype models, i.e., models not available in the market at the time of testing[16] (only production or commercially available models meet MaP criteria).
- **Figure 5**: toilets where only a single sample was tested (MaP criteria requires two samples of each model be tested).
- **Figure 6**: toilet models submitted by the manufacturer (MaP criteria requires models to be purchased "off-the-shelf" for testing).
- **Figure 7**: toilet models that have been modified and improved by the manufacturer since the commencement of the MaP testing (regardless of whether they are prototypes). The following descriptions are provided to help the consumer identify these new fixtures:
  - ✓ New Western Pottery Aris has a siphon jet located at the front of bowl well (sump).
  - ✓ New Niagara Flapperless has a front rim jet vs. a side rim jet.
  - ✓ New Vitra Atlantis does not have a bowl refill line.

[15] Original criteria called for two production toilet models purchased "off-the-shelf" for testing.
[16] One prototype was provided by an inventor and identified in the tables as Prototype X. Unit utilizes a new type of flushing system that operates at slightly less than 4 litres (1 gallon) per flush.

Figure 4 – Prototype Models

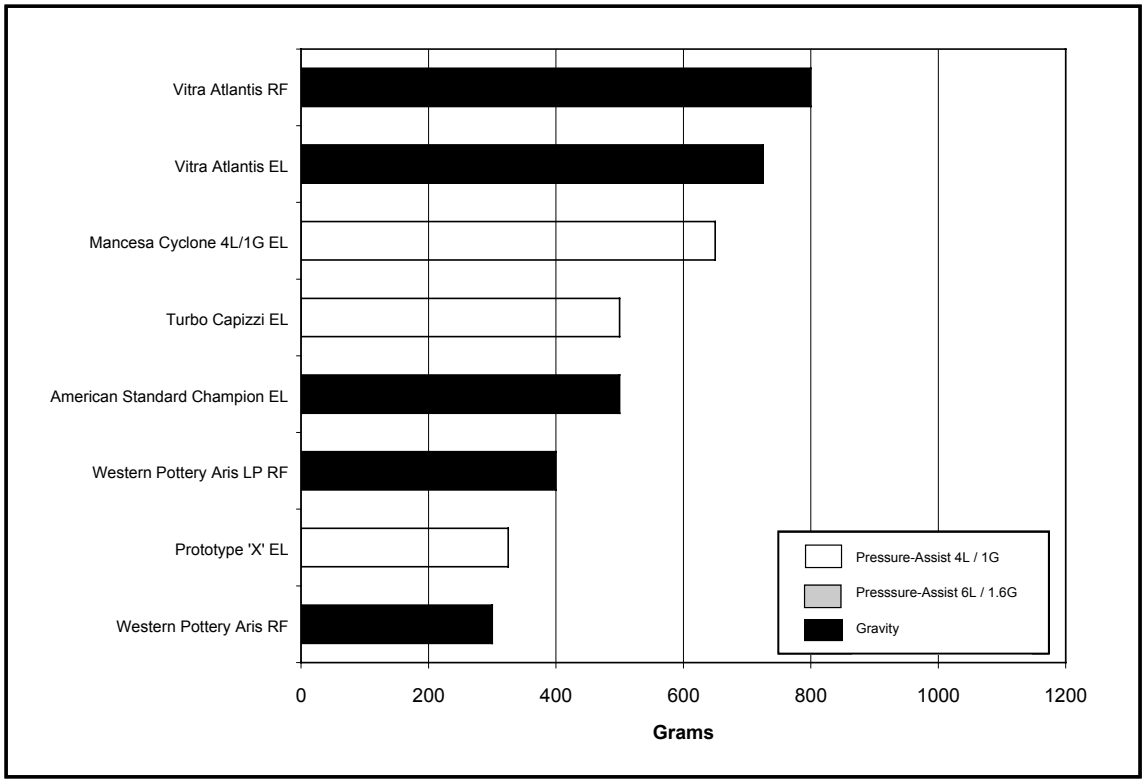


Figure 5 – Single Sample Models

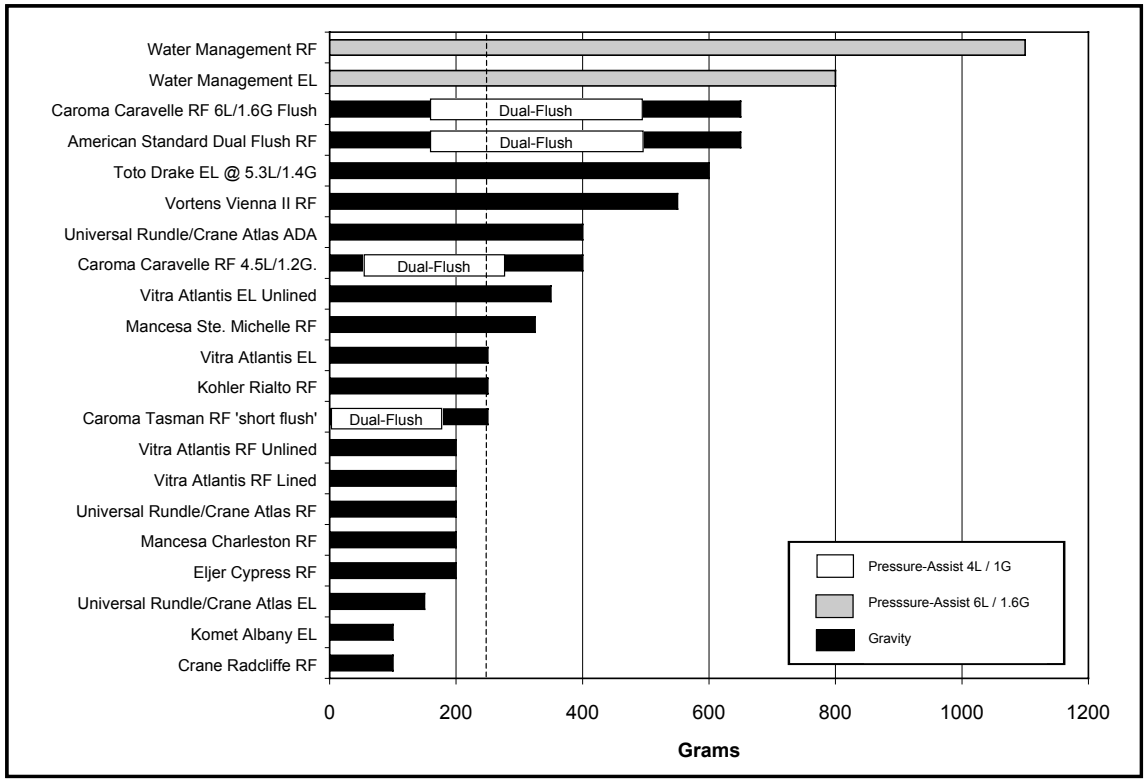


Figure 6 – Models Supplied by Manufacturer

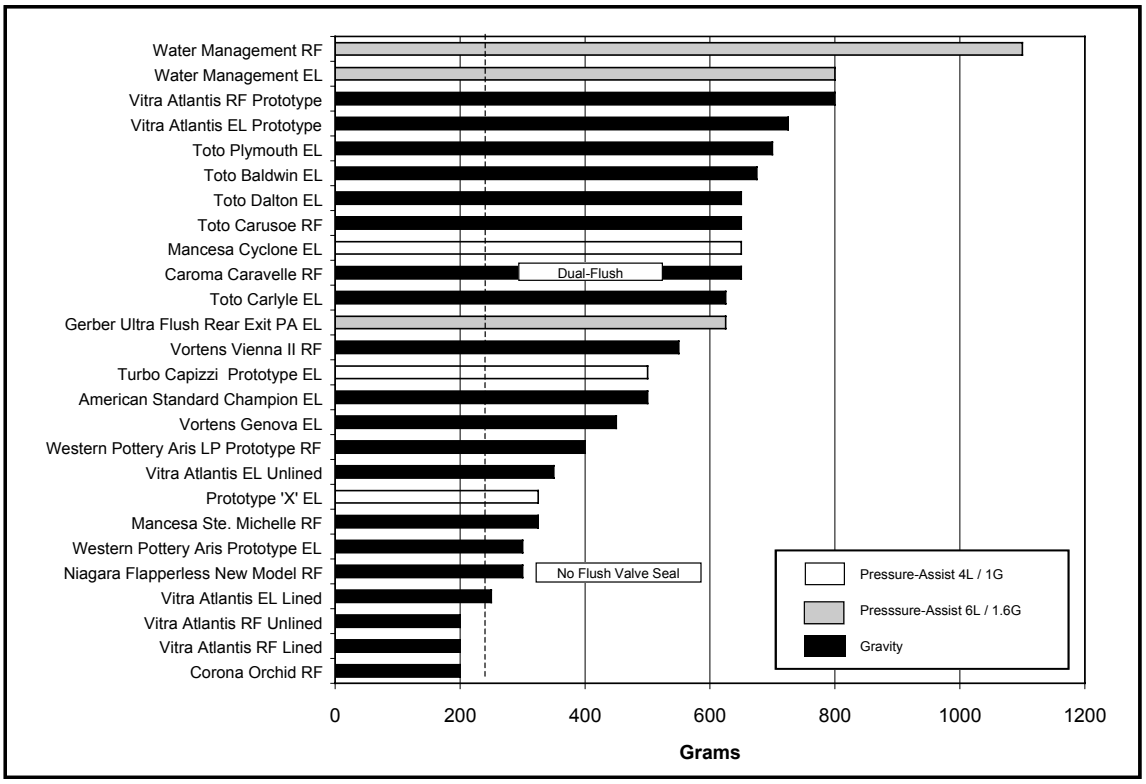
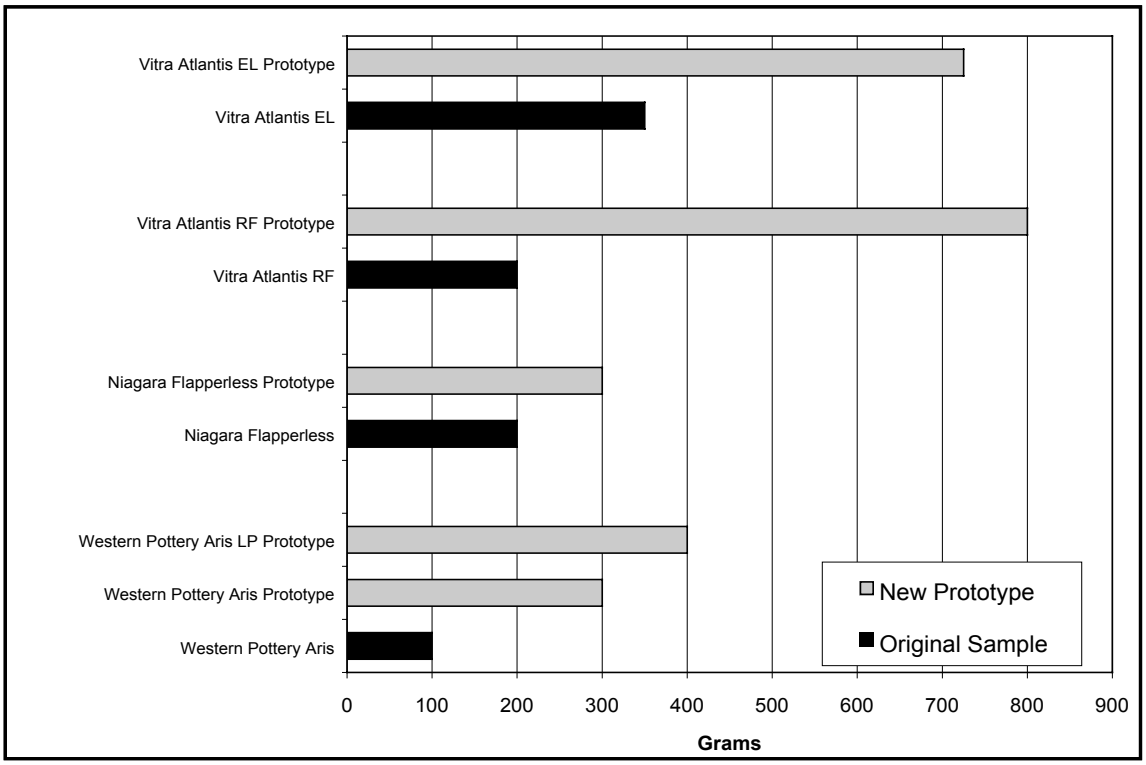


Figure 7 – Models Improved Since Beginning of MaP Testing



4.2 Water Exchange Test

All models tested achieved a minimum change-out rate of at least 98 % (i.e., a ratio of 1:50). See Section 3.1 for complete description.

4.3 After-Market Flapper Compatibility

For a description of the after-market flapper test, see Section 3.2. **Table 7** identifies those models where the installation of after-market flappers was not possible due to flush type or flapper fit. **Table 8** identifies the adjustment setting and the resulting flush volume range for those toilets that could accept the replacement flappers. Like **Table 3, Table 8** uses the "star" system, i.e., more stars equals better performance.

Table 7 – PSM Models: Fixtures in Which Replacement Flappers Could Not Be Installed

Manufacturer	Model	Reason
American Standard	Cadet EL	Pressure-Assist
American Standard	Champion EL	Non-standard 3" Flapper
American Standard	Colony Afton RF	Interference
American Standard	Dual Flush RF	Dual-Flush
Caroma	Tasman RF	Dual-Flush
Caroma	Caravelle RF	Dual-Flush
Crane	Economiser RF	Pressure-Assist
Eljer	Aquasaver RF	Pressure-Assist
Gerber	Ultra Flush RF	Pressure-Assist
Gerber	Ultra Flush Rear Exit EL	Pressure-Assist
Glacier Bay	Aragon IV RF	Interference
Kohler	Rialto RF	Interference
Kohler	Santa Rosa RF	Interference
Komet	Albany RF	Non-standard 3" Flapper
Mancesa	Cyclone EL	Pressure-Assist
Mansfield	Alto RF	No Flapper
Mansfield	Quantum EL	Pressure-Assist
Niagara	Flapperless RF	No Flapper
Niagara	Flapperless Prototype RF	No Flapper
Prototype X	Prototype EL	No Flapper
St. Thomas	Mariner II EL	Pressure-Assist
St. Thomas	Mariner II RF	Pressure-Assist
Toto	Baldwin EL	Non-standard 3" Flapper
Toto	Carusoe RF	Non-standard 3" Flapper
Toto	Dalton EL	Non-standard 3" Flapper
Toto	Plymouth EL	Non-standard 3" Flapper
Water Management Inc.	Private Label EL	Pressure Assist
Water Management Inc.	Private Label RF	Pressure Assist

Table 8 – PSM Models: Settings Required on After-Market Adjustable Flappers

Make	Model	Flapper Data		
		Fluidmaster	Niagara	Frugal Flush
Corona	Orchid RF	N/A	#4 / ***	#5 / *
Crane	Radcliffe RF	#1 / *	#3 / ***	#5 / *
Eljer	Cypress RF	#6 / ***	-	-
Mancesa	Charleston RF	N/A	#3 / ***	#5 / ***
Mancesa	Ste. Michelle RF	N/A	#3 / ***	#5 / ***
Orion	Iris RF	#1 / ***	#5 / **	#5 / *
Sanitarios Azteca (Lamosa)	Sahara RF	#1 / *	#5 / ***	#5 / *
Toto	Carusoe RF	#1 / ***	#4 / ***	#5 / **
Universal Rundle/Crane	Atlas RF	#8 / **	#2 / ***	#3 / ***
Universal Rundle/Crane	Atlas ADA	#8 / ***	#3 / ***	#3 / ***
Universal Rundle/Crane	Atlas EL	#9 / **	#2 / ***	#3 / ***
Vitra	Atlantis EL	#1 / **	#5 / ***	#5 / *
Vitra	Atlantis RF	#1 / ***	#5 / ***	#5 / *
Vitra	Atlantis Prototype EL	#4 / ***	#3 / ***	#5 / **
Vitra	Atlantis Prototype RF	#4 / ***	#3 / ***	#5 / **
Vortens	Genova EL	#1 / *	#5 / ***	#5 / *
Vortens	Vienna II RF	#2 / ***	#5 / ***	#5 / *
Western Pottery	Aris Prototype RF	#9 / ***	#1 / ***	#1 / **
Western Pottery	Aris LoPro Prototype RF	#1 / ***	#5 / ***	#5 / *

Flapper Settings
Fluidmaster: #1 provides minimum volume, #9 provides maximum volume
Niagara: #1 provides maximum volume, #6 provides minimum volume
Frugal Flush: #1 provides maximum volume, #5 provides minimum volume

Adjustment Range of Flappers
*** indicates flapper could be adjusted to within ±0.2 litres (0.05 gallons)
** indicates flapper could be adjusted to within ±0.5 litres (0.13 gallons)
* indicates flapper could NOT be adjusted to within ±0.5 litres (0.13 gallons)
N/A indicates that the flapper could not be properly installed.

4.3.1 "Standard" Flapper Compatibility

For a description of test see Section 3.2.1.

The results of the standard flapper testing, presented in **Table 9**, illustrate that a large percentage of the models tested showed a significant increase in flush volume when a standard flapper was installed—some flushed with more than 12 litres (3 gallons). The data indicate that a sizable reduction in water savings will occur over time if homeowners replace worn or leaking early-closing flappers with standard flappers.

Table 9 – PSM Models: Flush Volume with Standard Flapper

Manufacturer	Model	Flush Volume	
		Litres	Gallons
Western Pottery	Aris Prototype RF	5.8	1.53
Universal Rundle/Crane	Atlas EL	6.3	1.66
Eljer	Cypress RF	6.4	1.69
Universal Rundle/Crane	Atlas RF	6.5	1.72
Universal Rundle/Crane	Atlas ADA	6.6	1.74
Toto	Carusoe RF	7.9	2.09
Vitra	New Atlantis Prototype RF	7.9	2.09
Mancesa	Charleston RF	8.0	2.11
Toto	Dalton EL	8.0	2.11
Vitra	New Atlantis Prototype EL	8.0	2.11
Mancesa	Ste. Michelle RF	8.6	2.27
Western Pottery	Aris LoPro Prototype RF	10.3	2.72
Corona	Orchid RF	10.6	2.80
Vortens	Vienna II RF	12.1	3.20
Vortens	Genova EL	12.3	3.25

4.3.2 Flush Volume "Out-of-the-Box"

Similar to the results in section 3.2.2, approximately one third of these 36 models tested flushed at greater than 6 litres (1.6 gallons) when set at the waterline and adjusted in accordance with manufacturer instructions. The results of this test are illustrated in **Table 10.** Again, prior to performance testing, all toilets were adjusted to their rated (specified) flush volume.

Table 10 – PSM Models: "Out-of-the-Box" Flush Volume at Waterline

Make	Model	Volume, L	Volume, G	Comments
Mancesa	Cyclone EL	3.6	0.95	Rated at 4-L / 1-gal PA
Caroma	Caravelle RF	4.5	1.19	1.2/0.8 gal prototype dual-flush model
Water Management Inc.	Private label EL	5.1	1.35	6-L / 1.6-gal PA
Water Management Inc.	Private label RF	5.5	1.45	6-L / 1.6-gal PA
Gerber	Ultra Flush Rear Exit EL	5.6	1.48	6-L / 1.6-gal PA
Western Pottery	Aris Prototype RF	5.7	1.51	Pedestal Flush Valve
Mancesa	Ste. Michelle RF	5.8	1.53	
Western Pottery	Aris LoPro Prototype RF	5.8	1.53	
Toto	Plymouth EL	5.9	1.56	Non-standard 3" Flapper
Vortens	Vienna II RF	5.9	1.56	
Caroma	Caravelle RF	6.0	1.59	Dual-flush
Eljer	Cypress RF	6.0	1.59	
Kohler	Rialto EL	6.0	1.59	
Mancesa	Charleston RF	6.0	1.59	Rubber Flapper Chain
Vitra	Atlantis RF	6.0	1.59	
Vitra	Atlantis EL	6.0	1.59	
Vitra	Atlantis Prototype RF	6.0	1.59	
Vortens	Genova EL	6.0	1.59	
Toto	Baldwin EL	6.1	1.61	Non-standard 3" Flapper
Toto	Carusoe RF	6.2	1.64	
Toto	Dalton EL	6.2	1.64	
Toto	Carlyle EL	6.3	1.66	3" Non-standard Flapper
Vitra	Atlantis Prototype EL	6.3	1.66	
Corona	Orchid RF	6.3	1.66	Rubber Chain, Variable Volume
Niagara	Flapperless Prototype RF	6.5	1.72	
American Standard	Champion EL	6.8	1.80	Non-standard 3" Flapper
American Standard	Dual Flush RF	6.8	1.80	Prototype Dual-flush
Universal Rundle/Crane	Atlas RF	6.8	1.80	Rubber Flapper Chain
Universal Rundle/Crane	Atlas EL	6.8	1.80	Rubber Flapper Chain
Universal Rundle/Crane	Atlas ADA	7.0	1.85	Rubber Flapper Chain
Crane	Radcliffe RF	7.0	1.85	Rubber Flapper Chain, Variable Volume
Vitra	Atlantis RF	7.0	1.85	
Vitra	Atlantis EL	7.1	1.88	
Komet	Albany RF	11.0	2.90	Non-standard 3" Flapper

5.0 Conclusions

The test program revealed a significant range in the maximum loading levels of the toilet fixtures tested—from less than 100g to more than 1,000g, yet all of these toilets are certified as meeting the minimum standards set forth by CSA and ANSI/ASME.

All of the tested fixtures met the water exchange requirements of the national standards—indicating that this test may not be meaningful in determining overall effectiveness of flush performance.

Of the three after-market adjustable flappers tested, the Niagara N3145 is the most adaptable. Flush volumes could be properly adjusted (i.e., to approximately 6 litres / 1.6 gallons) on approximately 75 % of the models tested with the Niagara, on approximately 50 % with the Fluidmaster, and on only about 20 % with the Frugal Flush.

5.1 Models Purchased "Off-the-Shelf"

Of the 44 fixture models purchased "off the shelf" (for example two production samples tested, not provided by manufacturer) 24 models met or exceeded the minimum 250 g threshold for removal of solid waste (**Figure 2** and **Figure 3**). These 24 fixture models are considered to have excellent flush performance and should all meet or exceed consumer expectations.

Of the 24 fixtures meeting the minimum performance threshold, 11 performed at 500g or greater (**Figure 3**). These fixtures are deemed to be superior products that could be expected to perform under the most difficult demand situations.

5.2 Prototype/Single-Sample/Manufacturer-Supplied (PSM) Models

Some manufacturers made improvements to their models during the course of this project. This not only shows a willingness on the part of those manufacturers to seek better performance, but it also makes it clear that improving the performance of the toilet market is possible.

That manufacturers made improvements based on test results using the MaP protocol signifies an acceptance by the most affected stakeholder (the manufacturers) that the test protocol has merit.

6.0 Recommendations

All toilet fixture models should be required to remove a minimum threshold level of solid waste as represented by the soybean paste used in the maximum performance testing. It is recommended that the threshold be set at 250 g of solids as part of fixture qualification or certification.

The importance of water exchange in certification testing should be reduced or changed in some fashion.

Care should be taken when municipalities, water agencies, or consumers engage in flapper replacement:

- Adjustable flappers cannot be installed in every toilet model.
- Selection of an adjustable flapper for a given toilet fixture model should be based upon the test results shown in **Table 3** and **Table 8,** where possible.
- Priority should be given to subsidizing toilet models that use standard flappers (vs. early-closing flappers, etc.) as these toilets may be more likely to sustain water savings over their physical lifetime. For example, although toilets may last for 20 years or more, flappers may need replacing every five years or so. If early-closing flappers are replaced with standard flappers, a significant portion of the expected water savings may be lost. The use of standard flappers (which are readily available in retail) as original factory OEM trim provides a much greater chance of sustaining savings for the life of the toilet.
- Proprietary flappers (unique to the particular toilet model) are preferred to early-closing models as they are more likely to be replaced with the correct flapper. Proprietary flappers, however, are more difficult than standard flappers for the homeowner to locate and purchase.

It is also recommended that the results of MaP testing be updated on a regular basis to ensure that the performance results are always current, that the latest products in the marketplace are included, and that improvement efforts made by manufacturers are fully recognized.

APPENDIX

Protocol for Maximum Performance (MaP) Toilet Fixture Testing

Scope of Protocol:

- Maximum media loading (in 50 g increments[17]) at which toilet successfully clears all media from bowl without clogging or plugging in two of three tests.
- Percentage of water exchanged when flushing toilet without a media load.
- Range of flush volumes obtained with commercially available adjustable replacement flappers.

A. Solid Media Performance Test

- Media specifications: Fermented bean curd paste having a moisture content of 51.5%, a pH of 4.78, density of 1.16 g/mL[18], extruded through 7/8" diameter die[19], each specimen approximately 100 mm[20] in length and weighing 50 g (±5 g).
- Toilet paper specifications: Each ball of paper comprises six sheets of single ply toilet paper conforming to ASME A112.19.14–2001, section 3.2.5.1.2.
- Drop guide specifications (used to ensure media is dropped into bowl in same manner for all toilets): Plexiglas rectangle large enough to fit across the top of the bowl, 3 mm[21] thick with a 50 mm[22] diameter opening to be placed directly over the sump of the bowl.
- Remove tank and bowl from packaging; assemble on test rig according to manufacturer's instructions. Ensure that tank and bowl are level.
- All tests are completed at 50 PSI[23] static pressure.
- Set tank water level at waterline; flush three times taking note of the flush volume. Adjust volume to 6 litres/1.6 gallons if possible. If unable to set the volume to 6 litres/1.6 gallons, measure and record the actual flush volume.
- Flush the fixture two times to remove all solids, if any, from the fixture.
- Media shall be created in 50 g (±5 g) increments for testing
- Mass of media selected for initial (first round) testing shall be based on the Flush Performance Index (FPI) results from the NAHBRC testing (i.e., toilets that scored well in the FPI are initially tested at a greater mass).
- Place drop guide across the top of the bowl, with the opening aligned directly over the toilet sump (approximately one half inch in front of the trap entrance).
- Drop individual 50 g media specimens through opening until the desired mass of media is in the bowl.
- Drop four balls of toilet paper into the bowl water (where possible) or onto solid media (if required). Wait 10 seconds. Flush the toilet fixture.
- If a successful test (all media removed from the bowl), increase media loading by 50 g and repeat test.

[17] Approximately 0.11 lb.
[18] Approximately 72.4 lb/ft^3
[19] Approximately 22.2 mm
[20] Approximately 4.0 inches
[21] Approximately 1/8 inches
[22] Approximately 2 inches
[23] Approximately 0.34 megapascals

- NOTE: Each toilet is also flushed without media between each test to ensure that all media has been removed from bowl and trap, and that the bowl water is properly recharged.
- If a failed test (waste remains in bowl or trap), decrease media loading by 50 g and repeat test.
- Repeat process until toilet successfully removes the entire media loading from the bowl in two of three attempts.
- Record the weight of the bean curd paste media successfully removed from the bowl.

B. Water Change-Out Capability Test

- Flush the fixture two times to remove all solids, if any, from the fixture.
- Conductivity of the clean bowl water is measured using a conductivity meter (municipal water supply at test facility has conductivity range of approximately 310-330 μS).
- Add approximately 20 mL[24] of an 18 g/L[25] salt solution to the bowl and stir gently to ensure uniform mixing, while assuring that there is no water loss over weir.
- Measure conductivity of diluted salt solution in bowl.
- Flush toilet, wait for flush cycle to complete.
- Measure new conductivity of water in bowl, i.e., volume of residual salt solution present.
- Determine approximate water change-out efficiency as percentage.

C. Replacement Flapper Test

- Adjustable flapper descriptions: Niagara Model No. N3145 (with baffles vs. dial), Fluidmaster Bull's Eye® Adjust-A-Flush® Flapper Model No. 502, Frugal Flush® Universal Replacement Flapper Model No. 109982.
- Replace original equipment flapper with one of the adjustable flappers such as those used in retrofit or repair applications.
- Measure and record the range of volumes obtainable at the highest and lowest settings (dial settings or inserts) when using the replacement flappers.
- Identify and record setting at which flapper flushes with 6 litres/1.6 gallons of water.
- Repeat the test for each of the three adjustable flappers.

[24] Approximately 0.68 oz.
[25] Approximately 2.4 oz/gal

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