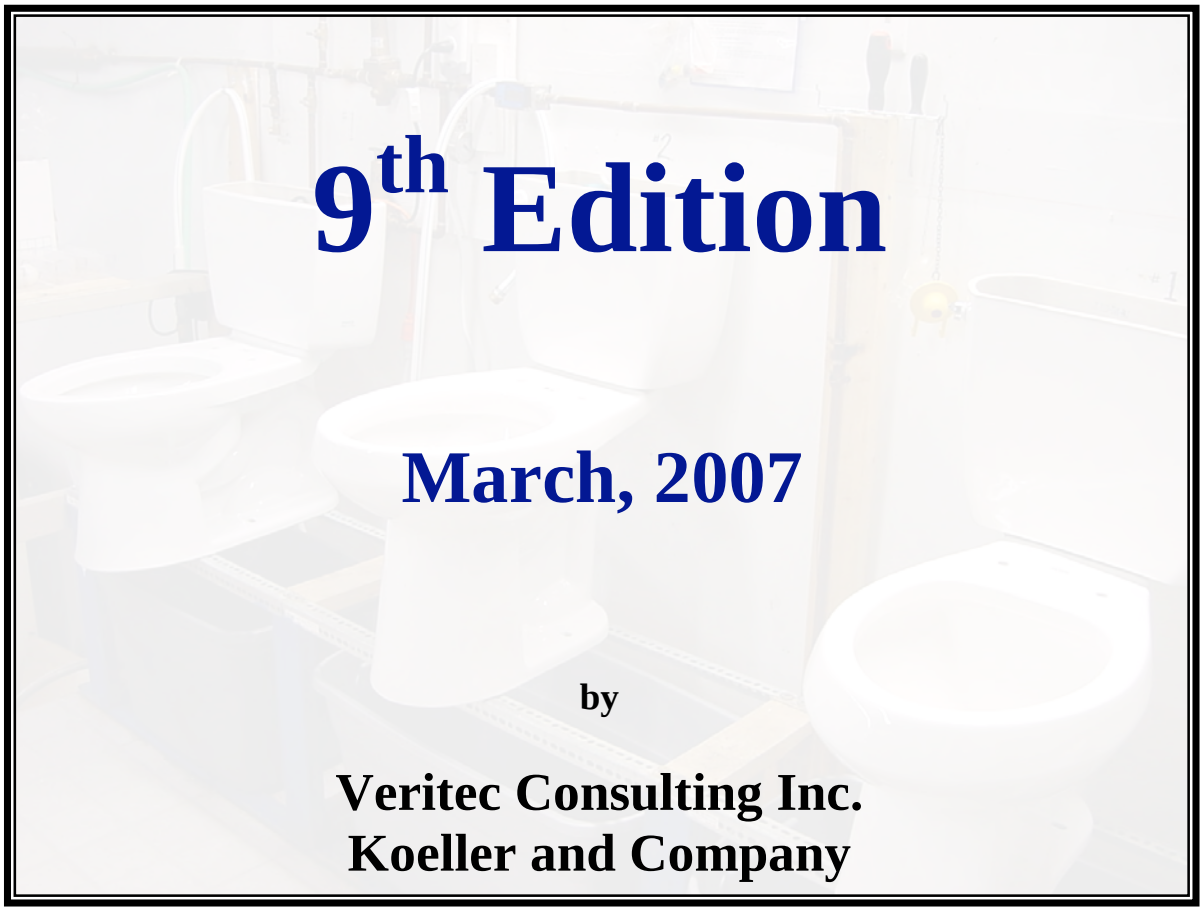
# Maximum Performance (MaP)

## Testing of Popular Toilet Models

**A Cooperative Canadian and American Project**



# 9th Edition

## March, 2007

**by**

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**Important**: This report, originally published in 2003 with the test results for the initial group of toilet fixtures, is periodically updated (approximately every three to six months) and made available free-of-charge on the websites of the Canadian Water and Wastewater Association (CWWA), the California Urban Water Conservation Council (CUWCC), and Veritec Consulting Inc. (see web addresses below). Individual agencies, municipalities, green building organizations, publications, and manufacturers are free to link to these sites provided credit is given.

http://www.cwwa.ca/home_e.asp
(MaP report listed in "What's New" section)

http://www.cuwcc.org/MapTesting.lasso

http://veritec.ca
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# TABLE OF CONTENTS

# Contributors

Initiated in 2003 by municipalities and other interested organizations in Canada, the Maximum Performance (MaP) Testing program was a cooperative effort among Canadian and American partners, including:

Canada

- Canadian Water and Wastewater Association (CWWA) – **LEAD AGENCY**
- B.C. Capital Regional District, Victoria, British Columbia
- B.C. Buildings Corporation, Victoria, British Columbia
- Canada Mortgage and Housing Corporation
- Calgary, Alberta
- Edmonton, Alberta
- Greater Vancouver Regional District, British Columbia
- 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 and third-party oversight of testing protocol implementation. Although the test protocol utilizes a media whose physical properties resemble 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. Because of this variability, and because only a single unit of each model was tested, these results should not necessarily be considered as fully representative of the typical or average performance of the models tested. The results shown in this report should be viewed only as an indication of expected 'field' results for waste removal.

Neither the authors, reviewers, project supporters, sponsoring partners, CWWA, CUWCC, nor their employees make any warranty, guarantee, or representation, expressed or implied, with respect to the accuracy, truth, effectiveness, or usefulness of any information, method, or material in this document, or assume any liability of the use of any information, methods, or material disclosed herein, or for any damages arising from such use. Readers use this report at their own risk.

Neither the authors, reviewers, project supporters, sponsoring partners, CWWA, CUWCC, nor their employees endorse products or manufacturers. Trade or manufacturers' names appear herein not as an endorsement but solely because they are considered important to the object of the project.

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

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

The toilet models tested as part of this program are in no way intended to represent all of the various makes and models available, nor is this report 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.

The reader is reminded that there are criteria *in addition* to solids removal that should be considered when selecting a toilet model, e.g., bowl wash, availability of replacement parts, potential for leakage, noise, physical longevity, etc. MaP testing addresses only a single issue: the ability of a toilet model to completely remove solids in a single flush.

Both consumers and manufacturers are encouraged to provide feedback to the authors of this report, especially regarding issues such as incorrect model numbers, models that are listed but are no longer available, etc.

# Revised MaP Testing Protocol

The 6th Edition of the MaP testing results was the first report on tests that used the new MaP testing protocol. This 9th Edition continues that practice.

Readers are encouraged to read and become familiar with all aspects of the testing protocol, but the primary changes incorporated into the protocol with the 6th Edition were as follows:

- Testing for water change-out was eliminated
- Individual 50g test media specimens (soybean paste) are now encased in a thin latex membrane (similar to a sausage) and can be reused several times. Manufacturers may request that the test be conducted using uncased test media.
- Toilet models must successfully clear all test media in a minimum of four of five attempts (vs. two of three attempts used in earlier test protocol).
- Testing is attempted at following mass loadings: 250g, 300g, 350g, 400g, 500g, 600g, 800g, and 1,000g. No testing is completed with mass loadings exceeding 1,000g.

We believe that the new protocol and test media make it easier and less expensive for manufacturers, laboratories and other organizations to complete MaP testing at their own facilities.

The MaP testing protocol, in its entirety, is provided in **Appendix A**.

## 1.0 BACKGROUND

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 also 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.

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

There are two key concerns:

1) Fixtures that fail to meet the 6-litre maximum flush requirements of the CSA or the 1.6-gallon requirements of the ANSI/ASME[1] result in toilets that flush with either too much;
2) Fixtures that do not flush effectively usually result in customer complaints and the need for double flushing.

Until recently, however, there was no convenient way for the customer to readily distinguish between good and marginal performers. In addition, this lack of information on toilet performance levels has served to create a negative perception regarding *all* 6-litre (1.6-gallon) fixtures in general. Instead, we believe that these negative perceptions should be focused *only* on those toilet fixtures clearly identified (through testing) as the "bad apples".

Although other toilet performance studies have been completed, none of these has 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.

We developed the Maximum Performance (MaP) testing 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 are adjusted, where possible, to their rated flush volume (typically 6 litres / 1.6 gallons) prior to testing to ensure a level playing field.

The original 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 two of three attempts, or to fully restore a minimum 50mm (2-in.) trap seal. Beginning with the 6th Edition of this report, the soybean paste media has been encased as described on the previous page.

[1] 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.

This **9th Edition** of the MaP testing report supersedes all earlier editions. Another 47 toilet fixture models are included in this edition (some of which replaced models in the 8th Edition), bringing the total to approximately 332 different models measured for their flush performance. (Some previously tested models have been re-tested or discontinued by their manufacturer and deleted from the report.) Beginning with the **4th Edition** only a single sample of each toilet model was required to be submitted for testing (previous requirement was two samples). This change was made because of the relative consistency in model performance noted in earlier MaP testing and to better align MaP testing requirements with those of other testing agencies.

The original MaP report (2003) contained information on replacement flapper interchangeability. Information on checking and replacing toilet flappers can now be found on the web at: www.toiletflapper.org.

Whereas MaP testing is strictly performance-related, it is also considered important that those toilet models subsidized by water utilities (e.g., through rebate programs) sustain their water savings over the life of the fixture. The L.A. Supplemental Purchase Specification (SPS) was developed for this purpose and may currently be found at: http://www.cuwcc.org/toilet_fixtures/LADWP_SPS_ULFTReqs_05-11-16.pdf

The original minimum performance benchmark adopted by MaP was 250 grams (250g) of waste. That is, a toilet fixture should completely evacuate at least 250g of waste in a single flush action. This value is based on the results of a British medical study (*Variability of Colonic Function in Healthy Subjects*) that identified 250g as the average maximum fecal size of the male participants in the study. Thus, any toilet that meets or exceeds the 250g performance threshold should meet customer expectations for flushing.

Overall, the MaP testing protocol has been very well-received by consumers, water providers, architects, specifiers, retailers, and manufacturers alike. We expect that many agencies and municipalities will consider the results of MaP testing when evaluating which toilet models to promote, subsidize, or rebate.

It is important to note that the U.S. Environmental Protection Agency (EPA) has adopted 350g as the minimum performance threshold for high-efficiency toilets (HETs) promoted within its new WaterSense program. Furthermore, most water utilities currently adopting toilet replacement rebate and installation programs (with HETs) are also establishing their minimum performance threshold at 350g (some are as high as 500g). Therefore, for the sake of consistency, it is anticipated that the requirements for UNAR (Uniform North American Requirements) for toilet fixtures, which is virtually identical to the EPA's WaterSense program[2] for high-efficiency models, will also adopt 350g as the minimum flushing performance threshold.

Neither the EPA's WaterSense program nor UNAR will post performance scores for included toilet models; models will simply be rated ***Pass*** or ***Fail*** depending upon whether or not they were able to meet the 350g minimum performance threshold and other criteria. Independent of WaterSense and UNAR, however, we will continue to perform and report on MaP testing results via reports such as this.

[2] Except that the WaterSense program confines its labeling to HETs ONLY. WaterSense and its toilet specification may be accessed at: http://www.epa.gov/watersense/

# 2.0 MAXIMUM PERFORMANCE (MAP) TEST

## 2.1 Critical Aspects of Test

MaP testing includes four significant advancements from earlier studies by others and from the national standards promulgated by CSA and ASME:

- Non-realistic test media (sponges, plastic balls and beads, kraft paper, etc.) replaced with combination of encased soybean paste and wads of toilet paper. Most agree this media more accurately replicates "real-world" demands upon a toilet fixture.
- All models are adjusted to rated volume, generally 6 litres (1.6 gallons), prior to testing[3].
- As noted earlier, a minimum level of acceptable performance was identified.

## 2.2 Minimum Level of Acceptable Performance - Medical Data

A British medical report[4] outlines the results of fecal tests completed on 10 male and 10 female subjects eating normal diets. The study identified the *average maximum*[5] fecal size of the male participants to be approximately 250g and the 95th percentile size to be 305g[6]. The *average maximum* for women was slightly less at 237g, with the 95th percentile at 275g. The *average* fecal size of all participants was 130g[7]. (NOTE: The selection of the 350g threshold by the U.S. EPA for its WaterSense Program was based upon achieving a 99.5 percentile threshold.)

Based on this medical study, it appears that for sanitary reasons, as well as for customer satisfaction, toilets should flush a *minimum* of approximately 250g of solids. For the purposes of this study, 250g was set as the initial performance benchmark. Both the MaP threshold of 250g and the U.S. EPA threshold of 350g are shown in **Appendix C**.

## 2.3 Soybean Paste Test Media

Soybean paste was selected as a test media because its physical characteristics (density, moisture content) are reasonably similar to those of human waste. The test media has the following properties: moisture content 51.5 percent, pH 4.78, and density 1.16g/mL. Previously, the media was extruded through a 7/8-inch (22mm) diameter die, each specimen being approximately four inches (100mm) long and weighing 50g (±5g). Beginning with the 6th Edition, the new test protocol encases the specimen in a thin latex membrane, enabling re-use of the specimen for multiple test runs.

The following photos illustrate some of the aspects involved in MaP testing.

[3] High-efficiency toilets (HETs) are adjusted to their rated volume where such adjustments are possible. In most cases, however, adjustability is not available. The flush volume of HETs may be as high as 4.8 litres (1.28 gallons) and even as low as 3.4 litres (0.9 gallons).

[4] 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.

[5] The average of the largest individual "samples" collected from each participant during the program.

[6] It would be expected that only 5% of male samples would be larger than 305g.

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

*Test rig (top left), bulk & extruded media (top right), packaged media (bottom left), dropping media (bottom right).*

## 2.4 Media Source

Although several media with varying physical characteristics were evaluated during initial project development, the specific media used in the MaP testing is obtained in 20-kg (44-lb) containers from a single Canadian importer (the product originates in Japan). Readers wishing further information regarding the paste should contact Veritec directly.

## 2.5 Test Protocol

The MaP test protocol (Version 2.1 - 2005) is included in **Appendix A**. All toilet fixtures are assembled, placed on the test stand, and connected to a municipal water supply (50 psi static pressure). Tank water levels are set to the waterline and flush volumes recorded. Adjustments are made, if necessary and where possible, to ensure all samples flush at their rated volume, generally 6 litres (1.6 gallons) for most fixtures, and less for HETs[8].

The ability of a toilet to completely remove 100 percent of waste in a single flush without plugging or clogging is considered by most consumers and users to be one of the most important test criteria. Testing is conducted by loading the fixture in 50g and 100g increments of test media until it fails to pass 100 percent of the media in four of five attempts. Four loosely crumpled balls of toilet paper (six sheets each) are included in each test run. The toilet paper

[8] High-Efficiency Toilets – HETs flush at 4.8 litres (1.28 gallons) or less per flush.

used in testing has the following specifications: single ply toilet paper conforming to ASME A112.19.14–2006, section 3.2.4.1.

Test results sorted by manufacturer are presented in **Appendix B**. The same results are sorted by performance level and are presented in **Appendix C**.

**Note**: Although individual MaP testing reports identify the maximum flush volume when tested as per the Los Angeles Department of Water and Power (DWP) Supplementary Purchase Specification (LADWP SPS), this should not be confused with Certification to the SPS. Manufacturers are required to submit their product to an IAPMO-recognized laboratory for Certification to the SPS. **Appendix B** and **Appendix C** identify those MaP-tested products that we have tested and/or otherwise determined as meeting the SPS requirements. Not all of the gravity-fed fixtures have actually been Certified by IAPMO to that specification or, in the case of pressure-assist fixtures, been designated by DWP as being in compliance.

## 3.0 CONCLUSIONS

The test program revealed a significant range in the maximum performance levels of the toilet fixtures tested, including some that failed to meet the 250g threshold – yet all of these toilets are certified as meeting the minimum standards set forth by CSA and ANSI/ASME.

**Appendix B** and **Appendix C** separately colour-code (color-code) models clearing less than 250g of media, models clearing from 250g and 500g, and models clearing greater than 500g. Pressure-assisted models, both 6- and 4-L (1.6- and 1.1-G), and HET models are also coded for ease of identification.

## 4.0 RECOMMENDATIONS

Based upon the research conducted and the test results obtained through this 9th Edition, the authors recommend that:

1. All toilet models be required to remove at least 250g of solids as part of qualification or certification for code-compliance.
2. Municipalities and other rebating agencies should consider giving priority to toilet models that meet both the LADWP SPS and the MaP threshold. SPS-qualified toilets are more likely to sustain water savings over their physical lifetime. MaP tested toilets meeting the recommended threshold are more likely to result in a satisfied customer. Together, these requirements comprise the new Uniform North American Requirements (UNAR) for toilet fixtures. We recommend that all water providers consider using the UNAR specification for future toilet replacement programs. (UNAR is already being used extensively in various parts of North America by water providers as the specification-of-choice.) Further information on the UNAR specification may be obtained from the authors.

# Appendix A

# Maximum Performance (MaP) Testing

## Toilet Fixture Performance Testing Protocol

### Version 2.1 - September 2005[9]

## 1.0 Scope of MaP Testing

1.1 Toilet model maximum performance (MaP) level is identified as the maximum media loading (in discreet increments expressed in grams) at which toilet model successfully clears all media from fixture in at least four of five attempts.

1.2 Tests where toilet sample clogs, plugs, or fails to restore a minimum of a 2-in. (50mm) trap seal following each flushing test will be deemed a failed test.

1.3 MaP test media is comprised of the following:

1.3.1 One or more 50 ± 4g test specimen ("test specimen") consisting of soybean paste contained in latex casing, tied at each end forming a 'sausage' approximately 100 ± 13mm in length and 25 ± 6mm in diameter[10], and

1.3.2 Four loosely crumpled balls of toilet paper ("paper").

## 2.0 Testing Protocol

2.1 Fixture Model Selection

2.1.1 A single randomly selected sample of each toilet model ("sample") is required for testing.

2.1.2 Toilet models that are not *certified* as provided shall be identified as a "**Prototype Model**".

2.2 Set-Up

2.2.1 Samples shall be assembled according to manufacturer's written instructions as contained within the product packaging, and placed on test rig, ensuring tank and bowl are level.

2.2.2 Tank water level shall be adjusted to the level specified by manufacturer in the manufacturer's instructions (e.g., set to waterline).

2.2.3 Static water supply pressure shall be set to 50 ±3 PSIG.

2.2.4 Inlet water temperature shall be 65 to 80°F (18 to 27°C).

2.2.5 Flush sample a minimum of three times prior to commencement of testing.

2.2.6 Re-adjust tank water level to proper level if required.

2.3 Flush Volume Measurement

2.3.1 Measure and record flush volume of sample in accordance with ASME A112.19.2-2003, paragraphs 8.4.1 and 8.4.2.

2.3.2 Samples with measured flush volumes in excess of 0.5 litres (0.13 gallons) greater than their rated flush volume shall be deemed to fail MaP testing requirements due to excessive flush volume.

[9] Version 2 updated in November 2006 to reflect change to Section 3.6 and its reference to the latest version ASME A112.19.14

[10] Approximately 4 ± 0.5 inches in length and 1 ± 0.25 inches in diameter

2.3.3 Samples with measured flush volumes less than 0.5 litres (0.13 gallons) greater than their rated flush volume shall be adjusted, if possible, to their rated flush volume prior to performance testing.

2.3.4 Samples with measured flush volumes less than their rated flush volume shall be tested at their measured volume and this volume shall be recorded on test report.

2.4 Waste Extraction Test

2.4.1 Test specimens shall be formed by hand such that they are roughly cylindrical in shape and uniform in diameter

2.4.2 A test specimen drop guide shall be placed across the top of the bowl, with the centerline of a 2 inch (50 mm) diameter opening 6 inches (15 cm) in front of the center of the seat post holes, equidistance from each hole. Drop guide may be made of plastic or other rigid material, to be no more than 0.5 inch (12 mm) thick, and be of sufficient length to span top of toilet bowl.

2.4.3 Test specimens shall be freely dropped in a vertical orientation through opening in drop guide into bowl. Additional test specimens shall be added, as required, to achieve desired mass loading. Record total mass loading.

2.4.4 Remove drop guide and freely and randomly drop four balls of crumpled toilet paper over centre of bowl sump.

2.4.5 Wait 10 ± 1 seconds.

2.4.6 Flush sample. Collect discharged media in strainer or other suitable container positioned below toilet fixture.

2.4.7 Record test as **Pass** or **Fail** (test is a **Fail** if any waste remains in the bowl or trap, or if minimum 50mm (2-in.) trap seal has not been restored).

2.4.8 Remove (rinse) discharged toilet paper from test specimens, and prepare test specimens for further testing.

2.4.9 Flush sample to clean bowl and trapway and fully restore trap seal.

2.4.10 Increase (or decrease) mass loading, as required, based on the following intervals, and repeat waste extraction test until such time as the maximum loading has been reached as described in paragraph 2.4.11:

- 50g
- 100g
- 150g
- 200g
- 250g
- 300g
- 350g
- 400g
- 500g
- 600g
- 800g
- 1,000g

No testing shall be conducted at mass loading greater than 1,000g.

2.4.11 Record highest mass loading at which toilet test sample successfully removed all test media from fixture and restored minimum 2-in. trap seal in

at least four of five attempts. This loading represents the maximum performance level for the test sample (i.e., the MaP score).

## 3.0 Test Media Specifications

3.1 Soybean paste nominal specifications:

- 35.5% water, 33.8% soybean, 18.5% rice, and 12.2% salt, and having a density of 1.15 ± 0.10 g/mL (i.e., density greater than that of water).

3.2 Latex casing specifications:

- Casings made from non-lubricated latex condoms (LifeStyles® brand, purchased from Ansell Healthcare Products LLC, Dothan, AL 36303 USA).

3.3 Cord used to tie casing:

- 1.0mm diameter polymer cord that will not crack or harden with time (Stretch Magic Bead & Jewelry Cord, Pepperell Braiding Company, P.O. Box 1487, Peperell, MA 01463, 800-343-8114)

3.4 Cased test specimens:

- Each test specimen shall have a mass of 50 ± 4g.
- Test specimens must be able to span clear distance of 76mm (3-in.) for minimum of 15 seconds when tested at room temperature (setup illustrated in Figure 1).
- Test specimens with rips, tears, punctures, or other damage, shall not be used.
- Test specimens may contain small volumes of air, however, specimens that float shall not be used.

3.5 Recommendations for storage of cased test specimens:

- Test specimens should be stored in air-tight containers and refrigerated when not in use. A damp sponge should be placed in bottom of container to prevent test specimen drying.

3.6 Toilet paper specifications:

- Each ball of paper is comprised of six sheets of single ply toilet paper conforming to ASME A112.19.14–2006, section 3.2.4.1.

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**NOTE** Cased test specimens (ready-to-use) may be purchased from:

Veritec Consulting Inc.
1495 Bonhill Road, Unit 12
Mississauga, Ontario, Canada L5T 1M2
Phone (905) 696-9391, ext. 105
Fax (905) 696-9395
bill@veritec.ca

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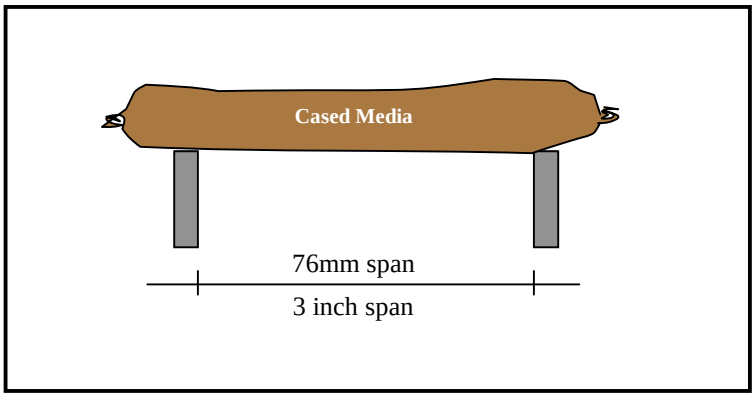


Figure 1

# Glossary of Terms for Appendices B and C

The following terms and acronyms are used in Appendices B and C:

ADA – Americans with Disabilities Act: ADA-qualified toilet fixtures have a minimum bowl height of 16 inches from floor to top of the bowl rim; the toilet seat adds approximately one inch in height, giving the typical ADA fixture an effective bowl height of 17 inches.

EL – Elongated toilet bowl

Gal - Gallons

HET – High-Efficiency Toilet: An HET is defined as a toilet fixture whose average flush volume is equal to or less than 4.8 litres (1.28 gallons) per flush. Dual-flush toilets are classified as HETs because the ratio of reduced flushes (4.1L-1.1G) to full flushes (4.8L-1.6G) results in an average flush volume below the qualifying threshold.

L – Litres (Liters)

MaP – Maximum Performance: In this report, the term applies to toilet fixture flush performance.

RF – Round front toilet bowl

SPS – Supplementary Purchase Specification: The SPS, developed in 2000 by the City of Los Angeles Department of Water and Power and the International Association of Plumbing and Mechanical Officials, is designed to assure the sustainability of the toilet fixture's water savings characteristics; flapper durability and maximum permitted flush volume are the main components of the SPS.