LABORATORY EVALUATION

OF

SELECTED 1.6-gpf TOILET FIXTURES

USING

CURRENT AND PROPOSED INDUSTRY STANDARDS

March 2001

Lead Agency:
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Study Sponsors:

American Water Works Association, Texas Chapter
Austin, TX, City of
Best Management Partners, El Cerrito, CA
East Bay Municipal Utility District, Oakland, CA
City of Los Angeles Department of Water and Power
Marin Municipal Water District
Metropolitan Water District of Southern California
Phoenix, AZ, City of
San Diego County Water Authority
San Francisco, CA, Water Department, City of
San Jose, CA, City of
Santa Clara Valley Water District
Seattle, WA, City of
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CAUTION TO THE READER

When viewing, interpreting, and applying the results of the performance tests described in this document, the reader must take into account the following:

1. The selection and testing of only one of each toilet fixture model does not provide a statistically valid representation of all toilet fixtures of a given model. Therefore, the results shown in this report should be viewed only as a possible indication of the "real world" performance of toilets. To obtain statistically reliable results, a larger sample of each of these products would be required for the tests conducted.

2. Many of the toilet fixtures included in this study were of pre-1999 manufacture and were never expected to perform as well as those of current vintage. Therefore, the test results are NOT an indication of the performance capabilities of the entire body of 1.6-gpf fixtures available today in the marketplace.

3. A number of the fixture models tested in this study have been replaced by the manufacturers with newer, better-performing fixtures. This includes enlarged trapways, improved bowl hydraulics, and more reliable and improved tank trim (flush valves, flappers, fill valves, etc.). Although these types of changes are regularly incorporated into their toilet fixtures, manufacturers generally do not change the model names. Therefore, toilet fixtures with the same model names as those appearing in this study may be found in manufacturers' current catalogs and at retail outlets, but these new units may be substantially different in performance than those tested by Stevens.

In view of the above, the reader is cautioned NOT to make purchase decisions in today's marketplace based upon the information contained within this report.

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BACKGROUND

For several years, proposals for changes to the ASME A112.19.2 and 19.6 national standards for water closets have been considered by the ASME project team designated for this purpose[1]. The primary focus of the changes has been on the bulk media test that is intended to replicate and measure solid waste removal. A number of different test media have been considered by the project team, each of which has been independently tested by manufacturers and others in their own laboratory facilities. To date, consensus has not been reached on the media that best simulates real world conditions.

In early 2000, some water utilities indicated a need to determine if the various changes then being considered for adoption by the ASME project team would, in fact, discriminate among water closets. That is, would the proposed test media yield a more rigorous test protocol which, in turn, would adequately discriminate between "good" and "bad" toilets. In brief, water utilities wanted to be assured that the proposed standard would do what they believe the existing standard does not do, i.e., apply a minimum requirement that does not permit poor performing toilets to be certified for sale in the U.S.

Original Scope of Study

Therefore, 14 water utilities and one consulting firm determined to jointly sponsor an independent test program. The stated objective of the test program was to:

> "identify, purchase and laboratory test a series of water closets for which field experience is available. A second objective is to analyze the gathered data as supporting documentation for the recommended tests proposed for the (ASME) Standard." (Stevens proposal, February 3, 2000)

Generally, the goal of the program was to determine if and how the proposed standards and test protocols would represent an improvement over the current requirements as specified in ASME A112.19.2 and 19.6 national standards.

Among the toilet fixtures to be included in the study were those that had been surveyed as a part of the 1999 Customer Satisfaction Survey completed for the Metropolitan Water District of Southern California (MWD) as well as other fixtures with available field experience. In addition to measuring the flush performance of these fixtures against the existing and proposed national standards, it was also intended to attempt to correlate those test results to customer satisfaction as disclosed within the MWD survey.

The Sponsors retained the services of the Stevens Institute of Hoboken, NJ, to conduct a series of performance tests on a minimum of 13 toilet fixtures. A summary of these tests as originally proposed by Stevens in February 2000 is shown in Table 1. More detail on the testing protocol may be found in Appendix B.

[1] Membership of the project team is shown in Appendix A.

Table 1. Summary of Proposed Functional Performance Tests for Toilets - Initial Version

Attribute/Classification → Test Regime ↓	Class C - Residential: Total media (min. requirement)	Class B - Commercial: Total media (min. requirement)	Class A - Heavy Use/Assembly: Total media (min. requirement)
1. Waste Removal - Mixed media with Neutrally buoyant wastes	10 sponges + 6 papers (14 media removed)	12 sponges + 10 papers (18 media removed)	12 sponges + 15 papers (23 media removed)
2. Waste Removal - Mixed media with Specific Gravity >1	75 cotton rolls + 6 paper (73 media removed)	85 cotton rolls + 10 paper (85 media removed)	85 cotton rolls + 15 paper (90 media removed)
3. Waste Removal-Single media with Specific Gravity < 1	100 polypropylene balls (75 removed)	100 polypropylene balls (75 removed)	100 polypropylene balls (75 removed)
4. Waste Removal - Mixed media with Specific Gravity < 1	100cm^3 granules = approx. 2,500 granules (<125 remaining)	100 cm^3 granules = approx. 2,500 granules (<125 remaining)	100 cm^3 granules = approx. 2,500 granules (<125 remaining)
5. Surface Wash (ink line test)	(maximum 2 inches AND no segment > 0.5 inches)	(maximum 2 inches AND no segment > 0.5 inches)	(maximum 2 inches AND no segment > 0.5 inches)
6. Water Consumption	1.6 gallons max.	1.6 gallons max.	1.6 gallons max.

Note: Media with Specific Gravity <1 floats on the surface of the water, while media with Specific Gravity >1 sinks to the bottom of the well of the bowl.

The waste removal media included above and being considered by the ASME project team at that time (February 2000) for inclusion into the national standard were as follows:

- Synthetic open-cell polyurethane sponges, white, 20 X 20 (±1) X 57 (±3) mm having a density of 17 (±1.7) kg/m^3 when new.
- Kraft anti-tarnish paper, 7.5 X 6 inches 15 pound, 486 sheets to the ream.
- Cotton wrapped (dental) rolls with a soft non-woven fabric, 3/8" in diameter and approximately 1.5" long.
- Disc-shaped high density polyurethane (HDPE) granules of 0.170 ±0.010 in. (4.32 ±0.25 mm) diameter thickness and an average bulk density of 0.940-0.950 kg/m^3 (specific gravity < 1.0).
- Polypropylene balls having a diameter of 0.75 ±.015 in. (19mm) and the density per ball between 850-900 kg/m^3 (specific gravity > 1.0). NOTE: These polypropylene balls are part of the existing standard.

Modified Scope of Study

Later in 2000 and following authorization of this study, the ASME project team separately made modifications to its proposed national standard and the test media to be employed. As a result, similar modifications were made to the scope of this study by eliminating the cotton (dental) rolls, while adding balls measuring approximately 1/4-inch in diameter. These balls (quantity of 100) were added as sinking media to the test shown as number 4 in Table 1.

In addition, the three-level classification of toilets as shown in Table 1 was eliminated and all toilets were measured against the "Class B - Commercial" minimum requirements. Therefore the final version of the Stevens study requirements are shown in Table 2.

Table 2. Summary of Proposed Functional Performance Tests for Toilets - Final Version

Test Regime	All Toilet Fixtures Total media (minimum requirement)
1. Waste Removal -Mixed media with Neutrally buoyant wastes	12 sponges + 10 papers (18 media removed)
2. Waste Removal - Single media with Specific Gravity < 1	100 polypropylene balls (0.75" diameter) (75 removed)
3. Waste Removal--Mixed media with Specific Gravity < 1 AND Specific Gravity > 1	100 cm^3 granules = approx. 2,500 granules (<125 remaining) PLUS 100 nylon balls (0.25" diameter) (100 removed)
4. Surface Wash (ink line test)	(maximum 2 inches AND no segment > 0.5 inches)
5. Water Consumption	1.6 gallons max.

Note: Media with Specific Gravity <1 floats on the surface of the water, while media with Specific Gravity >1 sinks to the bottom of the well of the bowl.

Finally, the scope of the study was expanded to encompass additional toilet fixtures, increasing the original number of 13 fixtures as proposed by Stevens to 18 fixtures.

Study Sponsors

Sponsors of the Stevens study were as follows (shown in alphabetical order):

American Water Works Association, Texas Chapter
Austin, TX, City of
Best Management Partners, El Cerrito, CA
East Bay Municipal Utility District, Oakland, CA
Los Angeles Department of Water and Power
Marin Municipal Water District
Metropolitan Water District of Southern California
Phoenix, AZ, City of
San Diego County Water Authority
San Francisco, CA, Water Department, City of
San Jose, CA, City of
Santa Clara Valley Water District
Seattle, WA, City of
Southern California Water Company
Upper San Gabriel Valley Municipal Water District

The Lead Agency for the work was the California Urban Water Conservation Council, Sacramento, CA.

KEY STUDY ELEMENTS

ASME Standards and Related Test Protocols

The existing ASME/ANSI A112.19.6 national standard calls for a series of performance tests on toilet fixtures, only two of which deal with the removal of solids:

- Ball test: consists of test no. 2 in Figure 2
- Granule test: consists of the granule portion of test no. 3 in Figure 2

In both cases, the media have a Specific Gravity of less than 1.0 and float on the water surface in the bowl.

It is widely accepted by those in the plumbing industry and in water conservation that these two tests do not adequately reflect real world performance demands upon a toilet fixture. As a result, some contend that a few fixtures are reaching the U.S. marketplace that barely meet the requirements of the national standards but do not function effectively in the field. Therefore, the move toward a more rigorous performance standard is supported by the plumbing industry, water utilities, and the water conservation community.

In considering modifications to the performance requirements for toilet fixtures (in particular the removal of solids), the ASME project team has been considering a variety of media, including sponges, balls, granules, paper, and cotton dental rolls. During the course of the Stevens study, the ASME project team altered its proposed standard for fixture performance to eliminate the cotton dental rolls and, later, to modify the size and number of sponges. The scope of the Stevens study was therefore also modified to reflect the latest proposals from the team.

Selected Toilet Fixtures

In 1999, the Metropolitan Water District of Southern California (MWD) sponsored a survey of 1,300 residential customers who had received or purchased a new toilet fixture through one of its agency programs in 1998 or 1999[2]. The 13 most frequently installed toilet fixture models were selected as representative of those programs; 100 customers installing each model were surveyed by telephone and mail. For a complete discussion of the study's methodology and findings, please review the final report (available upon request).

Of the 13 models covered in the 1999 MWD satisfaction survey, 10 were included in this study by the Stevens Institute. In addition, another eight toilets were selected and included, bringing the total fixtures in the Stevens study to 18 (refer to Table 3). Of the total of 18, two 3.5-gallon toilets (nos. 6 and 9) and two pressure-assisted models (nos. 4 and 8) were included as a basis for comparison.

[2] Metropolitan Water District of Southern California: *Ultra-Low-Flush Toilets, Customer Satisfaction Survey,* December 1999.

Because it was intended to test toilet fixtures with known field experience, some of the older models were taken from the Stevens inventory of toilets purchased for previous test work. Others were obtained directly from the manufacturers. Only one fixture of each model was included in the test program. The age of the fixtures and their source is shown in Table 3 below:

Table 3. Toilet Fixtures Tested

Toilet Fixture Brand/Model and Flush Volume	Date of Manufacture		Source of Fixture	Included in MWD Satisfaction Survey
	Tank	Bowl		
1. American Standard Cadet 2164.1 (1.6-gpf)	Mar'00	04-03-00	Purchased	X
2. American Standard Hydra (1.6-gpf)	Aug '00	08/04/00	Purchased	
3. Briggs Abingdon 4965/4875-5 (1.6-gpf)	9-11-97	10-8-97	Purchased	X
4. Eljer Quiet Flush 150-403 (pressure-assist; 1.6-gpf)	6-25-99	10-27-99	Manufacturer	
5. Eljer Patriot 131-2120-82 (1.6-gpf)	1-21-00	10-22-99	Purchased	X
6. Gerber 28-290/30W (3.5-gpf)	5-7-96	05-20-96	Manufacturer	
7. Industria Ceramica del Centro - Quasar (1.6-gpf)	Sep '00	Sep '00	Purchased	
8. Kohler K3458 (pressure-assist; 1.6-gpf)	12-20-96	9-11-96	Purchased	
9. Kohler (3.5-gpf)	11-6-97	11-12-97	Purchased	
10. Kohler Wellworth Lite (1.6-gpf)	12/21/00	12/08/00	Purchased	X
11. Kohler Rialto K-3386 (one-piece-1.6-gpf)	12-8-99		Purchased	X
12. Mansfield Alto 130-160 (1.6-gpf)	2-21-00	02-10-00	Purchased	X
13. Niagara N2202TP (1.6-gpf)	11/25/96	08/16/95	Manufacturer	X
14. Niagara Constant N2210B (1.6-gpf)	4-9-99	Jul'99	Manufacturer	
15. Niagara Flapperless N2216 (1.6-gpf)	3-9-99	02-24-00	Manufacturer	
16. St. Thomas Marathon 4301-943 (1.6-gpf)	6-25-96	11/14/96	Manufacturer	X
17. Toto CST703 (1.6-gpf)	2-17-97	1997	Purchased	X
18. Western Pottery Aris (1.6-gpf)	Sep '00	06/23/00	Manufacturer	X

Notes
(1) Purchased: Fixture purchased by Stevens Institute from retail sources for previous laboratory tests.
(2) Manufacturer: Fixture provided to Stevens Institute by the manufacturer.

Prior to commencing the test process, each of the 18 fixtures was physically inspected and critical features identified. Those features are displayed in Figure 4.

Table 4. Physical Characteristics of Tested Toilet Fixtures

	Gal/ flush	Flush Mech	Bowl Contour	Water Surface in Bowl			Trapway Dia. (in)	Trap Seal Depth (in)
				Width	Length	Area (sq in)		
1- American Standard Cadet 2164.1	1.6	Grav	Round	7.75"	10.0"	77.5	1.875"	2.375"
2- American Standard Hydra	1.6	Grav	Round	7.50"	8.0"	60.0	1.625"	2.375"
3- Briggs Abingdon 4965/4875-5	1.6	Grav	Round	6.50"	8.50"	55.3	1.750"	1.500"
4- Eljer Quiet Flush 150-403 (press-assist)	1.6	PA	Elong	12.0"	15.5"	186.0	2.000"	2.375"
5- Eljer Patriot 131-2120-82	1.6	Grav	Round	7.75"	8.0"	62.0	1.875"	2.000"
6- Gerber 28-290/30W	3.5	Grav	Round	7.25"	8.5"	61.6	1.875"	2.125"
7- Industria Ceramica del Centro - Quasar	1.6	Grav	Round	7.12"	7.0"	49.7	1.500"	1.375"
8- Kohler K3458 (pressure-assist)	1.6	PA	Elong	10.5"	12.5"	131.2	2.000"	3.125"
9- Kohler (3.5-gpf)	3.5	Grav	Elong	8.0"	8.0"	64.0	2.125"	2.125"
10- Kohler Wellworth Lite	1.6	Grav	Round	10.38"	8.9"	92.6	1.875"	2.125"
11- Kohler Rialto K-3386 (one-piece)	1.6	Grav	Round	8.25"	8.75"	72.2	1.875"	2.125"
12- Mansfield Alto 130-160	1.6	Grav	Round	7.0"	7.75"	54.3	1.625"	2.875"
13- Niagara N2202TP	1.6	Grav	Round	7.5"	9.0"	67.5	2.000"	2.500"
14- Niagara Constant N2210B	1.6	Grav	Round	7.5"	9.0"	67.5	1.875"	2.250"
15- Niagara Flapperless N2216	1.6	Grav	Round	6.5"	8.25"	53.6	1.875	2.125"
16- St. Thomas Marathon 4301-943	1.6	Grav	Round	6.5"	8.0"	52.0	1.875"	2.125"
17- Toto CST703	1.6	Grav	Round	7.0"	8.0"	56.0	1.750"	2.500"
18- Western Pottery Aris	1.6	Grav	Round	6.75"	8.25"	55.1	1.750"	2.500"

Notes

(1) Flush mechanism: Grav = Gravity fed; PA = Pressure-assisted

(2) Bowl contour: Round = Round front bowl; Elong = Elongated bowl

(3) Water surface (water spot) in bowl: Area shown is not a true measure of the water surface, since the water spot is elliptical in shape.

(4) Trapway diameter: Measured using a series of balls of varying diameters traveling through the entire trapway; this measurement may differ from that listed by the manufacturer on its specification sheets or sales literature.

(5) Trap seal depth: Determined using a tape measure.

FINDINGS AND CONCLUSIONS

Stevens conducted functional performance tests in accordance with the test regime shown in Table 2, which represents the waste removal requirements of both the existing and proposed ASME national standards for toilet fixtures. Test results are shown in the Stevens Final Report, Appendix C[3] and summarized in Table 5 on the following page.

Important findings are:

Existing ASME Standard

- Water Consumption Test: After adjusting the water level in accordance with manufacturers' instructions, all of the 18 toilet fixtures were tested for water consumption at 20, 50, and 80 psi in accordance with the existing standard[4]. Five of the 16 1.6-gpf toilet fixtures exceeded the maximum; four of the five, however, were 1.67-gpf or less. One fixture tested at 1.79-gpf. Both of the 3.5-gpf rated fixtures flushed at substantially less than 3.5 gallons.

  Three of the 1.6-gpf fixtures, when adjusted to the manufacturers' recommended water line, flushed at 1.20, 1.28, and 1.30 gallons.

- Ball - Granule - Ink Line Tests: Three of the 18 fixtures each failed to meet one of the other performance requirements under the existing ASME standards. Two of these three fixtures were manufactured in 1999 and 2000, while the remaining fixture (a 3.5-gpf toilet) was manufactured in 1996.

- Dye Test: All of the 18 fixtures met the requirements of the dye test.

Proposed ASME Standard (additional tests)

- Mixed Media Sponge/Paper Test: Four of the 16 - 1.6-gpf toilet fixtures failed to meet the requirements of the Sponge/Paper test. One 3.5-gpf fixture also failed to meet those requirements.

- Mixed Media Granule/Ball Test: All fixtures removed the 100 nylon balls from the well of bowl. With the granules, one 1.6-gpf fixture failed to meet the requirements of this test. That fixture was the same fixture that failed the granule test under the existing standard. All 17 of remaining toilet fixtures passed the proposed granule/ball test.

Correlation with Customer Satisfaction

The 10 toilets that were also included in the MWD customer satisfaction survey performed as shown in Table 6.

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[3] Note that the toilet fixture listings and data presented in the Stevens Final Report are in a different order that that shown in Tables 1 through 6 in this report. This change was necessitated by the need to list fixtures in alphabetical order.

[4] The existing standard specifies that water consumption shall be measured at three static test pressures (20, 50, and 80 pounds per square inch - psi) and the results averaged. The average consumption shall not exceed 1.6 gallons averaged over the three pressures and shall not exceed 2.0 gallons at any one pressure.

Table 5. Test Results

	ASME A112.19.2 and 19.6 - PERFORMANCE TESTS (Existing and Proposed)						
	Existing Performance Tests					Proposed (new) Mixed Media Tests	
	BALL	*GRANULE*	*INK LINE*	*DYE*	*WATER CONSUMPTION*	*SPONGE/PAPER*	*GRANULE/BALL*
						New test	*100 - 1/4" balls added to existing granules*
Test Description >>>>>>>>>	*100 floating 3/4" polypropylene balls in the bowl*	*2500 floating granules in the bowl*	*Water soluble ink line marked 1" below rim of bowl around entire bowl circumf.*	*30 ml of dye solution added to bowl water*	*Water consumption (flush volume) determined over range of static water pressures (20, 50, and 80 psi)*	*Sponges (12) and paper balls (10) in the bowl*	*2500 floating granules in the bowl plus 100 nylon 1/4" diameter balls sinking in the bowl*
Performance Requirement >>>	*Flush minimum of 75 balls*	*No more than 125 granules visible in bowl after flush*	*No more than total of 2" of ink line remaining; no remaining segment longer than 1/2"*	*Dilution ratio of at least 100:1 shall be achieved after flushing once*	*Average water consumption (over all 3 pressures) shall not exceed 1.6 gal for "low consumption" units; average may not be more than 2.0 gal at any one pressure. Figures below are average for the 3 pressure levels. NOTE: Fixture nos. 6 and 9 are 3.5-gpf units*	*A minimum of 18 of the mixed media must be flushed out of the fixture on the first flush*	*No more than 125 granules visible in bowl after flush; no balls visible after flush*
1- American Standard Cadet 2164.1	93 balls flushed	**42 visible granules**	0	>100	**1.67 gallons**	22 total media removed	15 granules remained
2- American Standard Hydra	99	14	0	>100	1.57	**8**	19
3- Briggs Abingdon 4965/4875-5	83	64	0	~100	1.30	**17**	77
4- Eljer Quiet Flush 150-403 (pressure-assist)	100	7	0	>100	**1.65**	22	6
5- Eljer Patriot 131-2120-82	83	**172**	0	>100	1.55	21	**210**
6- Gerber 28-290/30W (3.5-gpf)	95	77	**2.5"**	~100	3.20	**16**	81
7- Industria Ceramica del Centro - Quasar	99	13	0	>100	1.57	21	19
8- Kohler K3458 (pressure-assist)	100	7	0	>100	1.57	22	13
9- Kohler (3.5-gpf)	86	9	0	>100	3.02	21	14
10- Kohler Wellworth Lite	**73**	91	0	>100	1.58	20	96
11- Kohler Rialto K-3386 (one-piece)	92	64	0	>100	1.28	21	11
12- Mansfield Alto 130-160	98	14	0	>100	1.20	22	15
13- Niagara N2202TP	97	25	0	>100	**1.66**	**13**	37
14- Niagara Constant N2210B	98	46	1.16"	~100	**1.79**	22	43
15- Niagara Flapperless N2216	95	17	0	>100	1.49	22	24
16- St. Thomas Marathon 4301-943	93	42	0	>100	1.60	**15**	46
17- Toto CST703	93	23	0	>100	1.53	18	11
18- Western Pottery Aris	88	83	0	>100	**1.62**	22	43

NOTES: ***This table is the compilation of 3 runs of every test and it is explained as follows:***
The Ball test results represent the number of balls flushed out of the fixture.
The Granule test results represent the number of granules remaining visible in the bowl.
The Ink test results represents the length of the mark left behind.
The Dye test results represent the dilution ratio.
The Mixed Media test results represents the number of media removed.
The combined Granule/Ball test results represent granules remaining visible in the bowl. All balls were removed by every fixture.
Shaded cells indicate a "failure" in that test category.

Table 6. Toilet Fixture Rankings - Performance Test and MWD Customer Survey

	Toilet Fixture Brand/Model	Mixed Media Performance Tests (Ranking)		MWD Customer Satisfaction Survey		
		Sponge/ Paper	Granule/ Ball	Overall Rating	High Rating	Recommend Toilet
1	American Standard Cadet 2164.1	1	3	1	2	1
3	Briggs Abingdon 4965/4875-5	8 (failed)	8	8	8	8
5	Eljer Patriot 131-2120-82	4	10 (failed)	10	10	10
10	Kohler Wellworth Lite	6	9	6	7	5
11	Kohler Rialto K-3386 (one-piece)	4	1	7	6	6
12	Mansfield Alto 130-160	1	3	3	4	7
13	Niagara N2202TP	10 (failed)	5	9	9	9
16	St. Thomas Marathon 4301-943	9 (failed)	7	5	5	4
17	Toto CST703	7	1	2	1	2
18	Western Pottery Aris	1	6	4	3	3

Notes
(1) Rankings are based upon "1" being top ranked.
(2) Fixtures with identical performance in the Stevens test are given equal ranking.
(3) Rankings for MWD customer satisfaction survey are taken from Tables 1, 2, and 10 within that study

Conclusions

The study results showed that:

1. Five of the 16 - 1.6-gpf fixtures failed the water consumption test, although their actual flush volume was not significantly higher than the ASME standard. Three of the 16 fixtures (fixture nos. 3, 11, and 12), however, flushed at substantially *less* than 1.6 gallons when the manufacturers' specified water level was set. This could have affected the flush performance in the subsequent tests of these units.

2. In addition to water consumption, three of the 18 fixtures did not meet one other component of the existing ASME standards. The remaining 15 fixtures met the requirements of the standards in the areas tested. Except for fixture no. 6, which experienced difficulty meeting the proposed sponge/paper mixed media test as well, there was no indication that the failure of the remaining two fixtures shows any widespread non-compliance with the existing standard. Additional testing of multiple units of the same models would be required to determine if such a non-compliance trend might exist.

3. Five of the 18 fixtures did not meet the sponge/paper mixed media component of the proposed ASME standard, one of which was a 3.5-gpf fixture. Of the five fixtures, four were manufactured in 1997 and earlier. This seems to confirm that the proposed sponge/paper component may be able to discriminate between the older, less-effective toilet fixtures and the newer, second generation models of 1.6-gpf fixtures. Therefore, the sponge/paper test appears to provide additional performance challenges to toilet fixtures beyond those contained within the existing ASME standards. If these tests were incorporated into the ASME national standards, they would represent a more stringent set of certification requirements for toilet fixtures.

4. Only one fixture of the 18 did not meet the granule/ball mixed media component of the proposed ASME standard. It was the same fixture (no. 6) that did not meet the granule test under the existing standard; it was manufactured in 1999 and 2000. This indicates that the granule/ball mixed media test does not add a significant performance demand to the existing standard.

5. There appears to be little universal correlation between these laboratory performance test results and customer satisfaction with toilets (refer to Table 6), although the toilet fixtures on the extreme ends of the ranking, i.e., fixture nos. 1 (best) and 10 (worst), seem to correlate fairly well.

Caveats and Cautions

When viewing, interpreting, and applying the results of the performance tests described in this document, the reader should be aware of and take into account the following:

1. The selection and testing of only one of each toilet fixture model does not provide a statistically valid representation of all toilet fixtures of a given model. Therefore, the results shown in this report should be viewed only as a possible indication of the "real world" performance of toilets. To obtain statistically reliable results, a larger sample of each of these products would be required for the tests conducted.

2. Many of the toilet fixtures included in this study were of pre-1999 manufacture and were never expected to perform as well as those of current vintage. Therefore, the test results are not an indication of the performance capabilities of the entire body of 1.6-gpf fixtures available today in the marketplace.

3. A number of the fixture models tested in this study have been replaced by the manufacturers with newer, better-performing fixtures. This includes enlarged trapways, improved bowl hydraulics, and more reliable and improved tank trim (flush valves, flappers, fill valves, etc.). Although these types of changes are regularly incorporated into their toilet fixtures, manufacturers generally do not change the model names. Therefore, toilet fixtures with the same model names as those appearing in this study may be found in manufacturers' current catalogs and at retail outlets, but these new units may be substantially different in performance than those tested by Stevens.

In view of the above, the reader is cautioned not to make purchase decisions in today's marketplace based solely upon the information contained within this report.

APPENDIX A

Membership of the ASME/ANSI A112.19.2 and 19.6 project teams:

Name	Organization Represented	19.2 Member	19.6 Member
Tom Konen, Chair	Stevens Institute of Technology	X	X
Myron Ament	Consultant	X	X
Bruce Antunez	Coast Foundry & Manufacturing	X	X
Julius Ballanco	Consultant	X	X
Dave Berge	5D Infusion Canada		X
Johan Bouwer	Sanitary for All Ltd.	X	
Thomas Broyles	Peerless Pottery	X	X
Sidney Cavanaugh	Delta Faucet Company	X	X
Peter DeMarco	American Standard	X	X
Oscar Dufau	Fluidmaster	X	X
Fernando Fernandez	Toto U.S.A.	X	X
Lawrence Galowin	Nat'l Institute of Stds & Technology	X	X
Charles Graham	Martech Enterprises	X	X
Patrick Higgins	P. J. Higgins & Associates	X	X
Edwin Ho		X	X
Dale Holloway	SGS U.S. Testing	X	X
Marina Ilha		X	X
Martin Joedicke	Friedrich Grohe	X	
Tom Kenney	Natl. Assoc. of Home Builders Research Foundation	X	X
Morrie Klimboff	Consultant	X	X
Mike Kobel	International Assoc. of Plumbing & Mechanical Officials (IAPMO)	X	X
John Koeller	AWWA	X	X
Norman Kummerlen	Moen Incorporated	X	X
John Lauer	Sloan Valve	X	X
Donato Lozano	Lamosa	X	X
R. Bruce Martin	W/C Technology Corporation	X	X
William McDonnell	Metropolitan Water District	X	X
Perry Meikle	Underwriters Laboratories	X	X
Lee Mercer	Moen Incorporated	X	X
Jerry Murray	Crane/Universal Rundle	X	X
Jim Neumann	Eljer Plumbingware	X	X
Barry Pines		X	
Burt Preston	Mansfield Plumbing	X	X
Lori Radavich	Lavelle Industries	X	X
Darrell Rasell	Caroma U.S.A.	X	X
Shabbir Rawalpindiwala	Kohler Company	X	X
Robert Sallick		X	
James Sargent	Consultant	X	X
Richard Schnakenberg	Frugal Tech	X	X
George Shillington	Consultant	X	X
Paul Sullivan	Lavelle Industries	X	X
David Viola	Plumbing Manufacturers Institute	X	X

APPENDIX B

Stevens Test Protocol [5] (Excerpts)

7 Methods of Tests for Water Closets

7.1.2.3 Unit Adjustment. Test pressure for the individual laboratory tests for all water closets shall be set at 35 psig.

(a) *Gravity-Type Flush Tank Water Closets.* The water level in the tank and the fill time shall be adjusted according to the manufacturer's instructions and specifications for the tank. In the absence of such instructions and specifications, the tank shall be filled to the water line where marked or, in the absence of a mark, to a point 1 in. (25mm) below top of highest point of the overflow, and the supply fill valve (ballcock) shall be set in the full flow position. Water closets which require special supply pressures shall be adjusted in accordance with manufacturer's instructions. This requirement shall apply for all tests.

7.1.2.4 If the particular test calls for a test load, the test load shall be placed in the water closet bowl.

7.1.2.5 The flush device shall be tripped, held for one second and released in a normal manner.

7.1.2.6 The water closet shall be allowed to discharge into a receiving vessel. Test materials remaining in the bowl, if any, and those discharged through the closet outlet shall be observed. Then, if required for removal of all test material, the water closet shall be flushed again one or more times without additional test media to remove all material from the bowl or trapway before each replicate test run. One or more runs shall be made for each test condition, as stated in the detailed procedures for the individual test.

7.1.2.7 The results shall be evaluated and the data shall be reported in accordance with the detailed procedures specified for each test. 7.1.3 through 7.1.6.

7.1.3 Removal of Solids

7.1.3.1 Mixed Media with Neutrally Buoyant Wastes

(a) Test Method

(1) Test Media. Synthetic open cell polyurethane sponges, white, 20 X 20 (+/- 1) X 57 (+/- 3) mm having a density of 17 (+/- 1.7) kg/m^3 when new. Sponges are to be conditioned (soaked) in water 24 hours before use. New sponges are to be used for each test set (4 replicates).

---

[5] This protocol includes only the procedures for test nos. 1, 2, 4, and 5 as shown in Table 2 and only the granule portion of test no. 3 in that same table.

Kraft anti-tarnish paper, 7.5 X 6 inches 15 pound, 486 sheets to the ream. Paper may be purchased from McIntyre Paper Co. Crinkle each of the required number of sheets in your hand to form the required number of loose balls approximately two (2) inches in diameter. Hold the paper balls under the water for three (3) to five (5) seconds to saturate the medium before each test run.

(2) Procedure. Place the required number of new conditioned sponges in the test bowl and squeeze them under water to remove air saturating the media. The sponges should be floating with the top of each sponge even with the water surface. If the sponges are floating higher, they may have air trapped inside and it will be necessary to re-squeeze them to remove the air. Slowly refill the well with water to ensure a full depth of seal. Drop the required number of saturated paper balls (see procedure under Test Media above), into the well, and flush the unit. The actuator shall be depressed and held for one (1) second. After the flush cycle is completed, count and record the number of sponges and paper balls discharged through the fixture. Flush the fixture a second time to remove any remaining media, record the results. Note any clogs on the data sheet. A clog is defined as media trapped within the fixture, which causes a backup of water in the bowl on subsequent flushes. A clog requires multiple flushes or mechanical action to clear the fixture. Repeat the procedure three times.

(3) Report. The number of sponges and paper balls remaining visible in the bowl after the initial flush, the number flushed out, and the number remaining in the trapway shall be reported.

(a) Performance Requirement. For acceptance, in three of the four replicates, (one result is discarded) the indicated number of sponges and paper balls shall be flushed out of the fixture on the initial flush. The remaining, if any shall be flushed out on the second flush. A clog shall constitute failure. The fixture shall discharge 18* media on the first flush.

* *Media indicates sponges and/or paper balls*

7.1.3.3 Ball Test

(a) Test Method

(1) Test Media. The test media shall be 100 polypropylene balls having a diameter of 0.75 +/- .015 in. (19mm) and the density per ball between 850-900 kg/m^3.

(2) Procedure. The 100 balls shall be dropped in the bowl and the flush release device shall be tripped. After completion of this initial flush, balls remaining visible in the bowl and those passing completely out of the trapway (out of the fixture) shall be counted. Trap seal restoration (see para. 7.1.6.3 for procedure) shall be observed. This shall complete one test run. The procedure shall be repeated until three set of data are obtained.

(3) Report. The number of balls remaining visible in the bowl after initial flush, the number flushed out, and the number remaining in the trapway shall be reported.

(b) Performance Requirement. For acceptance, 75 balls per initial flush shall be flushed out of the bowl, based on the average of three initial flushes.

7.1.4 Water Change (Granule Test Method)

(a) Test Method

(1) Test Media. The test media shall be 6 cu. in. (100,000 mm^3) (approximately 2500 count) disc-shaped high density polyurethane (HDPE) granules of 0.170+/- 0.010 in. (4.32 +/- 0.25 mm) diameter thickness and an average bulk density of 0.940-0.950 kg/m^3.

(2) Procedure. The 6 cu. in. (100,000 mm^3) of PE granules shall be added to the water in the bowl. The flush device shall be tripped and released. After completion of this initial flush, the granules remaining visible in bowl shall be counted. The trap seal restoration (see para. 7.1.6.3 for procedure) shall be observed. Three sets of data shall be obtained.

(3) Report. The number of granules remaining visible in the bowl after flushing shall be reported.

(b) Performance Requirement. Not more than 125 granules (5%) shall be visible in the bowl after each initial flush for all classes of fixtures on two of the three replicate flushes.

7.1.5 Washing of Flushing Surface (Rim Wash)

(a) Test Method

(1) Test Media. The test media shall be applied by an artist's felt-tipped pen containing a contrasting colored, water-soluble ink.

(2) Procedures. The flushing surface shall be scrubbed clean with commercial scouring powder to remove any build-up or deposits on the walls. The surface shall be rinsed and dried with oil free air. A line shall be inked around the circumference of the flushing surface at a level one (1) inch below the rim jets of the bowl, limiting the line to a maximum distance of 3.75 in. below the highest point to the rim at that location. This line shall be permitted to be less than one (1) inch below the jets in order to achieve the 3.75 in. maximum dimension. The flush device shall be tripped and released and the line shall be observed during and after the flush. When the flushing cycle is completed (tank completely refilled or flushometer (pfd) cycle completed and trap refill water delivery completed), the lengths of the unwashed line segments where the ink has remained on the flushing surface shall be measured, and their approximate position in the bowl noted. This shall complete one test. The procedure shall be repeated until three sets of data are obtained. If any portion of the ink line is removed by splashing water, the test run shall be disregarded and the unit shall be retested.

(3) Report. The number and lengths of the ink line segments remaining and their positions in the bowl shall be reported.

(b) Performance Requirements. The total length of ink line segments remaining on the flushing surface after each flush shall not exceed 2 in. (50mm) as averaged over three test runs. No individual segments shall be longer than _ in. (13mm).

7.1.6 Water Consumption and Hydraulic Characteristics

7.1.6.1 Water Consumption Test

(a) Test Method

(1) Apparatus. A test apparatus shall be assembled. The receiving vessel shall be permitted to be tested with either a vessel, which is calibrated in volume increments not exceeding 0.1 gal. (0.4 L) or with the use of an electronics scale with readout in increments not exceeding 0.1 gal. (0.4L)

(2) Procedure. The static pressure shall be observed, and then the flush release device shall be tripped. When the main flush is completed, as indicated by cessation of the trailing flow, which occurs at the end of the principle discharge, the volume received in the vessel (main flush volume) shall be observed. Again the volume (total flush volume) shall be observed after cessation of flow of the excess trap refill water (after flow) occurs, subsequent to the first observation. Trap seal restoration shall be measured (see para. 7.1.6.3 for procedure). This shall complete one test run. The procedure shall be repeated until four sets of data are obtained at 20 psi, 50 psi, and 80 psi static pressure.

(3) Report. Static pressure and total flush volume.

(b) Performance Requirements.

(1) The average water consumption (total flush volume) shall not exceed 1.6 gal. (6.0 L) based upon average values from three of the four replicates.

(2) Cycle time shall not exceed seconds for residential fixtures, 60 seconds for commercial fixtures and 20 seconds for heavy use/assembly fixtures.

APPENDIX C

LABORATORY EVALUATION OF SELECTED 1.6 GPF TOILETS USING CURRENT AND PROPOSED INDUSTRY STANDARDS

By

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Nikhil Kumar and Priya Aggarwal

Report No. 649

March 28, 2001

Prepared by

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LABORATORY EVALUATION OF SELECTED 1.6 GPF TOILETS USING CURRENT AND PROPOSED INDUSTRY STANDARDS

By

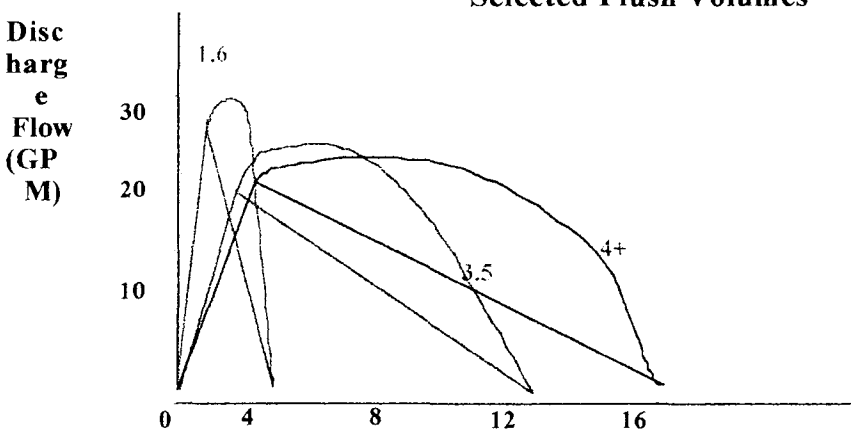
Demetrio Arosemena,
Nikhil Kumar and Priya Aggarwal

INTRODUCTION

The Energy Policy Act of 1992 established a maximum flush volume for toilets at 1.6 gallons per flush. The Department of Energy's implementing regulations[1] require all toilets sold in the United States meet the prescribed limit on water conservation and a series of functional performance tests defined in the industry standard ASME A112.19.6, Hydraulic Performance Requirements for Water Closets and Urinals[2]. This legislation challenged the manufacturers of plumbing fixtures and resulted in the evolution of toilets with very different hydraulic characteristics. These changes are illustrated in Figure 1, where the hydraulic characteristics may be seen as discharge flow versus time. Traditionally, toilets flushed on 3.5 and 4 gallons with cycle times ranging from 12 to 16 seconds. The new toilets flush on 1.6 gallons maximum and have cycle times ranging from 4 to 5 seconds.

[1] Energy Policy Act, 42 U.S.C. 6295
[2] American Society of Mechanical Engineers, New York, N.Y.

Figure 1. Flow Rate vs. Time
Selected Flush Volumes



These substantially different discharge curves have had a great influence on functional performance. Traditional toilets provide ample time for body waste, paper and non-woven fabric consumer products to mix with bowl water and transfer the material to the drainage system where they are transported to an acceptable point of disposal.

The new fixtures, discharging within 4 to 5 seconds exhibit rapid transfers of wastes and other materials to the drainage system and require alternate techniques to evaluate their functional performance. At present, Stevens Institute of Technology is leading the effort to introduce bulk media tests into the governing product standards, ASME A112.19.2, Vitreous China Plumbing Fixtures, and ASME A112.19.6, Hydraulic Characteristics of Water Closets and Urinals.

In 1999, the Metropolitan Water District of Southern California (MWD) completed a customer satisfaction survey[3] gathering feedback from customers who received and installed one or more 1.6 gallons per flush toilets through either a rebate or distribution program. Thirteen toilet models, installed in 1998 and 1999, were included within the survey. The toilets were rated on a scale of 1 to 10 and were based on 100 customers per toilet model. The survey considered among other items the following: waste removal, surface cleaning, blocking and clogging, and double flushing.

In this current study, ten toilets, with model numbers the same as those surveyed in 1999 by MWD, were laboratory tested, along with eight other models. The ten fixtures in the MWD survey were ranked one to ten based on how well the customer believed the toilet removed solid waste from the bowl. The ten toilets from the customer satisfaction survey were then compared with the results of this study as a means to explore relationships between laboratory tests and field performance.

OBJECTIVE

The primary objective of this work was to compare selected toilets using the present and proposed ASME testing procedures. Secondary objectives include correlation of the laboratory data with field experience and the assessment of the ability of the proposed ASME mixed media test to identify fixtures with marginal performance.

[3] Ultra-Low-Flush Toilets, Customer Satisfaction Survey, Metropolitan Water District of Southern California, December 1999.

PRODUCTS TESTED

The product identification shown in Table 1 has been used throughout the report. A key relating this number with the manufacturer's name and model designation is given in Table 5.

Table 1. Products Tested

Product Identification	Date of Manufacture		Source
	Tank	Bowl	
1	2-17-97	1997	Purchased
2	Mar'00	04-03-00	Purchased
3	Sep '00	06/23/00	Manufacturer
4	2-21-00	02-10-00	Purchased
5	12/21/00	12/08/00	Purchased
6	11/25/96	08/16/95	Manufacturer
7	N/A	12-8-99	Purchased
8	6-25-96	11/14/96	Manufacturer
9	9-11-97	10-8-97	Purchased
10	1-21-00	10-22-99	Purchased
11	Sep '00	Sep '00	Purchased
12	Aug '00	08/04/00	Purchased
13	4-9-99	Jul'99	Manufacturer
14	3-9-99	02-24-00	Manufacturer
15	6-25-99	10-27-99	Manufacturer
16	12-20-96	9-11-96	Purchased
17	11-6-97	11-12-97	Purchased
18	5-7-96	05-20-96	Manufacturer

METHODOLOGY

1. Physical Characteristics. Prior to testing, each fixture was physically inspected to determine the following: flushing mechanism, bowl contour, water surface, trapway size and trap seal depth.

2. Functional Performance.

Current Requirements: Each fixture was tested in accordance with the procedures defined in the ASME Standard A112.19.6-1995. Data was gathered for the following: flush volume, waste removal using polypropylene balls and polyethylene granules, surface wash using water-soluble markers and water change by measuring the dilution of the bowl water using dye. See Table 2.

Proposed Requirements: Each fixture was tested to two proposed requirements. The first addresses waste removal wherein polyurethane sponges and Kraft paper are used to simulate neutrally buoyant body wastes. The second is a modified granule test wherein 1/4-inch diameter balls are added to the polyethylene granules. These 100 nylon balls have a specific gravity greater than one. See Table 2.

Table 2. Sanitary Performance Test Media and Requirements

Test Media	Performance Requirements	Status
Current Requirements		
1. Ball Test: 100 polypropylene balls having a diameter of _-inch and an average bulk density of 0.85-0.90 grams/cm^3	An average of 75 balls shall be flushed out of the bowl on each initial flush based on three initial flushes.	Industry Standard
2. Granule Test: 100 ml of disc-shaped polyethylene granules 2-3 mm diameter, and an average bulk density of 0.94-0.95 grams/cm^3 (SG < 1)	Not more than 125 granules (5 percent) shall be visible in the bowl after each initial flush.	Industry Standard
3. Surface Washing Test: felt tip pen with dark color water-soluble ink; ink line marked 1-inch below the rim of the bowl around the entire interior circumference	The total length of line segments remaining on the flushing surface after each flush shall not exceed two inches as averaged over three test runs. No individual segment shall be longer than one-half inch.	Industry Standard
4. Water Change Test: water-soluble dye-methylene blue.	A dilution ratio of at least 100 shall be obtained in each initial flush.	Industry Standard
Proposed Requirements		
5. Mixed Media Test: 12 sponges with 10 Kraft papers, specific gravity < 1.	Eighteen of the 22 media shall be removed on the first flush.	Proposed
6. Mixed Granules/Balls Test: 100ml of disc shaped polyethylene granules (same granules as described in No. 2 above) and 100 nylon balls with specific gravity >1.	Not more than 125 granules nor any nylon balls shall be visible in the well after each initial flush.	Proposed

RESULTS

1. Physical Characteristics. The results of the physical inspection identifying the flushing mechanism, bowl contour, water surface, trapway size, and trap seal depth are given in Table 3. Sixteen gravity operated and two pressure assist toilets were evaluated. Three elongated fixtures were part of the products tested. The water surface expressed as the product of the width times the length ranged from a low of 49.7 to a high of 186 square inches. The average water surface calculated by this method, excluding the pressure assist units, is 62.6 square inches.

The minimum trapway size as measured by a ball pass technique was 1-1/2 inches. The maximum was 2-1/8 inches.

Trap seal depths ranged from a minimum of 1-3/8 inches, which is less than the 2-inch minimum required, to a maximum of 3-1/8 inches.

2. Functional Performance.

Current Requirements. The results of the functional performance tests based on the current ASME requirements are shown in Table 4. Five of 16 1.6-gpf fixtures exceeded the maximum allowable flush volume. Flush volumes ranged from a low of 1.20 gallons to a high of 1.79 gallons.

One fixture, number 5, failed the current polypropylene ball test discharging 73 balls, two less than the required 75. Fixture number 10 failed the current granule test leaving behind 172 granules, an amount in excess of the maximum 125. Fixture number 18 failed the surface wash test. All fixtures passed the water change tests.

Proposed Requirements. Five fixtures failed to discharge the required number of mixed media as defined in the proposed revision to the Standard. All fixtures discharged the 100 nylon balls with specific gravity greater than one. One fixture, again number 10, failed the granule test by leaving behind 210 granules.

3. Comparison with MWD Customer Satisfaction Survey. Graphic presentations of these results are given in Figures 2 to 5. Figure 6 illustrates the results of the waste removal properties of the MWD Customer Satisfaction survey fixtures based on the existing polypropylene ball test. No clear relationship between the laboratory test and the field survey results was observed.

Figure 7 illustrates the results of the waste removal properties of the MWD survey-ranked fixtures based on the proposed mixed media test. Again, no clear relationship between the laboratory test and the field survey results was observed.

Table 3. Physical Characteristics of Fixtures

Fixture	Flushing Mechanism	Bowl Contour	Water Surface			Trapway Size (in.)	Trap Seal Depth (in.)
			Width (in.)	Length (in.)	Area (sq.in.)		
1	Gravity	Round	7	8	56.0	1-3/4	2-1/2
2	Gravity	Round	7.75	10	77.5	1-7/8	2-3/8
3	Gravity	Round	6.75	8.25	55.1	1-3/4	2-1/2
4	Gravity	Round	7	7.75	54.3	1-5/8	2-7/8
5	Gravity	Round	10.38	8.90	92.6	1-7/8	2-1/8
6	Gravity	Round	7.50	9	67.5	2	2-1/2
7	Gravity	Round	8.25	8.75	72.2	1-7/8	2-1/8
8	Gravity	Round	6.50	8	52.0	1-7/8	2-1/8
9	Gravity	Round	6.50	8.50	55.3	1-3/4	1-1/2
10	Gravity	Round	7.75	8	62.0	1-7/8	2
11	Gravity	Round	7.12	7.0	49.7	1-1/2	1-3/8
12	Gravity	Round	7.5	8	60.0	1-5/8	2-3/8
13	Gravity	Round	7.50	9	67.5	1-7/8	2-1/4
14	Gravity	Round	6.5	8.25	53.6	1-7/8	2-1/8
15	Pressure assist	Elongated	12	15.5	186.0	2	2-3/8
16	Pressure assist	Elongated	10.50	12.5	131.2	2	3-1/8
17	Gravity	Elongated	8	8	64.0	2-1/8	2-1/8
18	Gravity	Round	7.25	8.5	61.6	1-7/8	2-1/8

Note: Fixtures 17 & 18 are 3.5-gpf units

Table 4. Functional Performance of Fixtures

Fixture	Current Requirements					Proposed Requirements		
		Waste Removal					Mixed Granules/Balls	
	Average Flush Volume (gallons)	Poly Balls (100 balls in)	Granules SG <1 (2500 granules)	Surface Wash Length (inches)	Water Change (dilution)	Mixed Media Quantity Removed (22 media in)	SG > 1	SG < 1
ASME Requirement	1.60 maximum	75 balls out of bowl	< 125 remaining	2" max. remaining	>100 required	Minimum of 18 removed	Zero remaining	<125 remaining
1	1.53	93	23	0	>100	18	0	11
2	1.67	93	42	0	>100	22	0	15
3	1.62	88	83	0	>100	22	0	43
4	1.20	98	14	0	>100	22	0	15
5	1.58	73	91	0	>100	20	0	96
6	1.66	97	25	0	>100	13	0	37
7	1.28	92	64	0	>100	21	0	11
8	1.60	93	42	0	>100	15	0	46
9	1.30	83	64	0	~100	17	0	77
10	1.55	83	172	0	>100	21	0	210
11	1.57	99	13	0	>100	21	0	19
12	1.57	99	14	0	>100	8	0	19
13	1.79	98	46	1.16	~100	22	0	43
14	1.49	95	17	0	>100	22	0	24
15	1.65	100	7	0	>100	22	0	6
16	1.57	100	7	0	>100	22	0	13
17	3.02	86	9	0	>100	21	0	14
18	3.20	95	77	2.5	~100	16	0	81

DISCUSSION

Body wastes range widely in form, texture and mass. As such, this laboratory has encouraged the use of a wide range of media in evaluating the functional performance of fixtures[4]. Many manufacturers take this into consideration in designing products and it is evident that compromises are required. Designers must balance the efficient removal of wastes with specific gravity greater than one with the removal of buoyant materials.

In this test work, the emphasis focused on neutrally buoyant simulated wastes and, therefore, may give an incomplete picture with respect to overall performance and consumer acceptance.

CONCLUSIONS

The results of this investigation and study enable us to conclude:

1. Thirty-one percent of the 1.6-gpf toilets evaluated in this study exceeded the maximum flush volume permitted under the federal regulations.

2. Most fixtures complied with the functional performance established by present industry standards.

3. Four of sixteen 1.6-gpf fixtures failed to comply with the proposed mixed media test.

4. No clear relationship was observed between the laboratory-measured functional performance and the results of a recent customer satisfaction survey.

Approved:

(s)

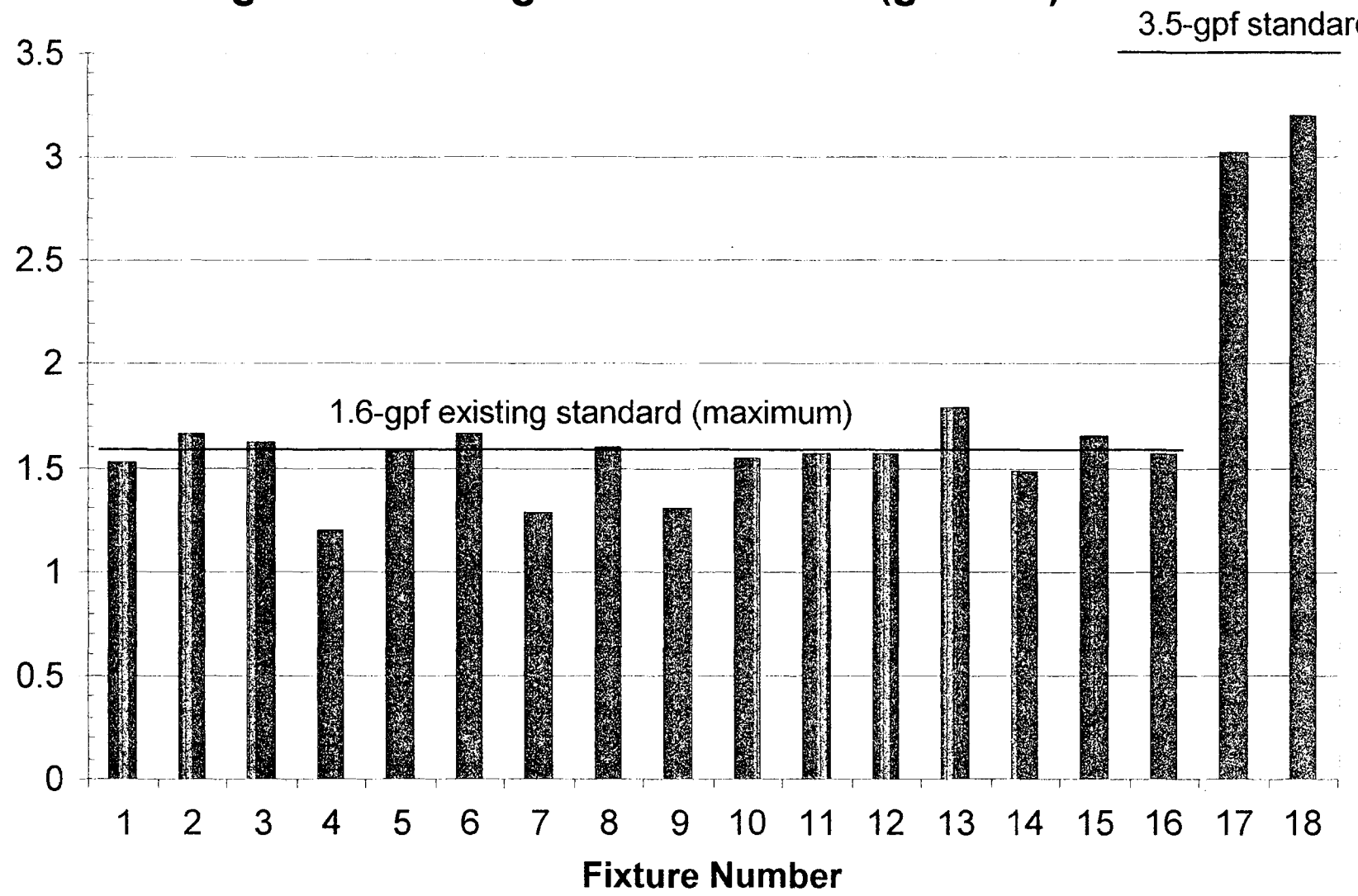
Thomas P. Konen

[4] Defining the Functional Performance of Toilets, PLUMBING ENGINEER, Volume 28, Number 4, Northbrook, IL, April 2000.

Table 5. Key to Tables 1, 3 and 4

Fixture Number	Manufacturer and Model
1	Toto CST703
2	American Std. Cadet
3	Western Pottery Aris
4	Mansfield –Alto
5	Kohler Wellworth
6	Niagara N2202TP
7	Kohler Rialto
8	St. Thomas-Marathon
9	Briggs Abingdon
10	Eljer Patriot
11	Industria Ceramica del Centro-Quasar
12	American Std. Hydra
13	Niagara Constant TM
14	Niagara Flapperless
15	Eljer P.A.
16	Kohler P.A.
17	Kohler 3.5
18	Gerber 3.5

Figure 2. Average Flush Volume (gallons)



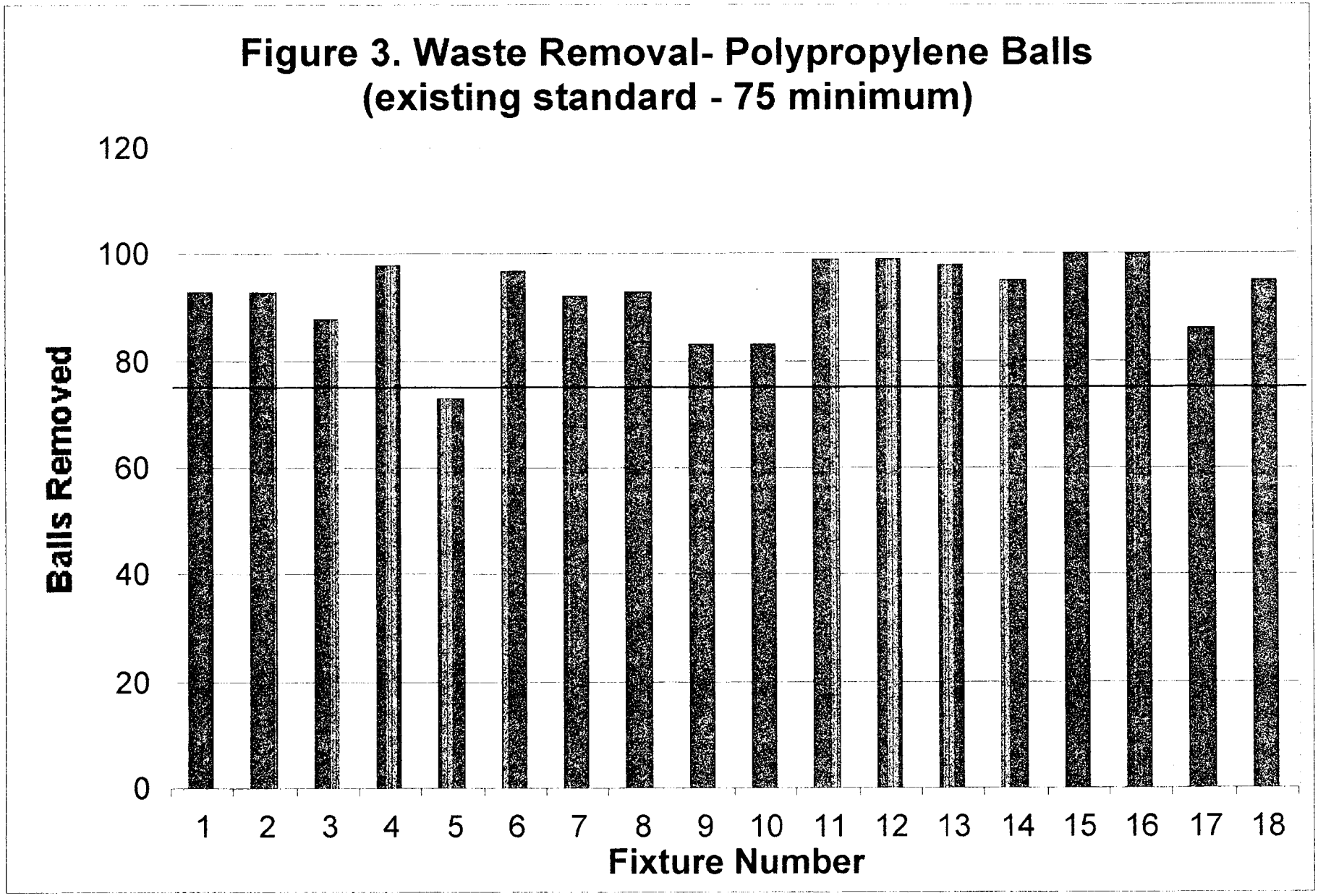


Figure 3. Waste Removal- Polypropylene Balls
(existing standard - 75 minimum)
Balls Removed
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Fixture Number

Figure 4. Waste Removal-Granules (existing standard - 125 maximum)

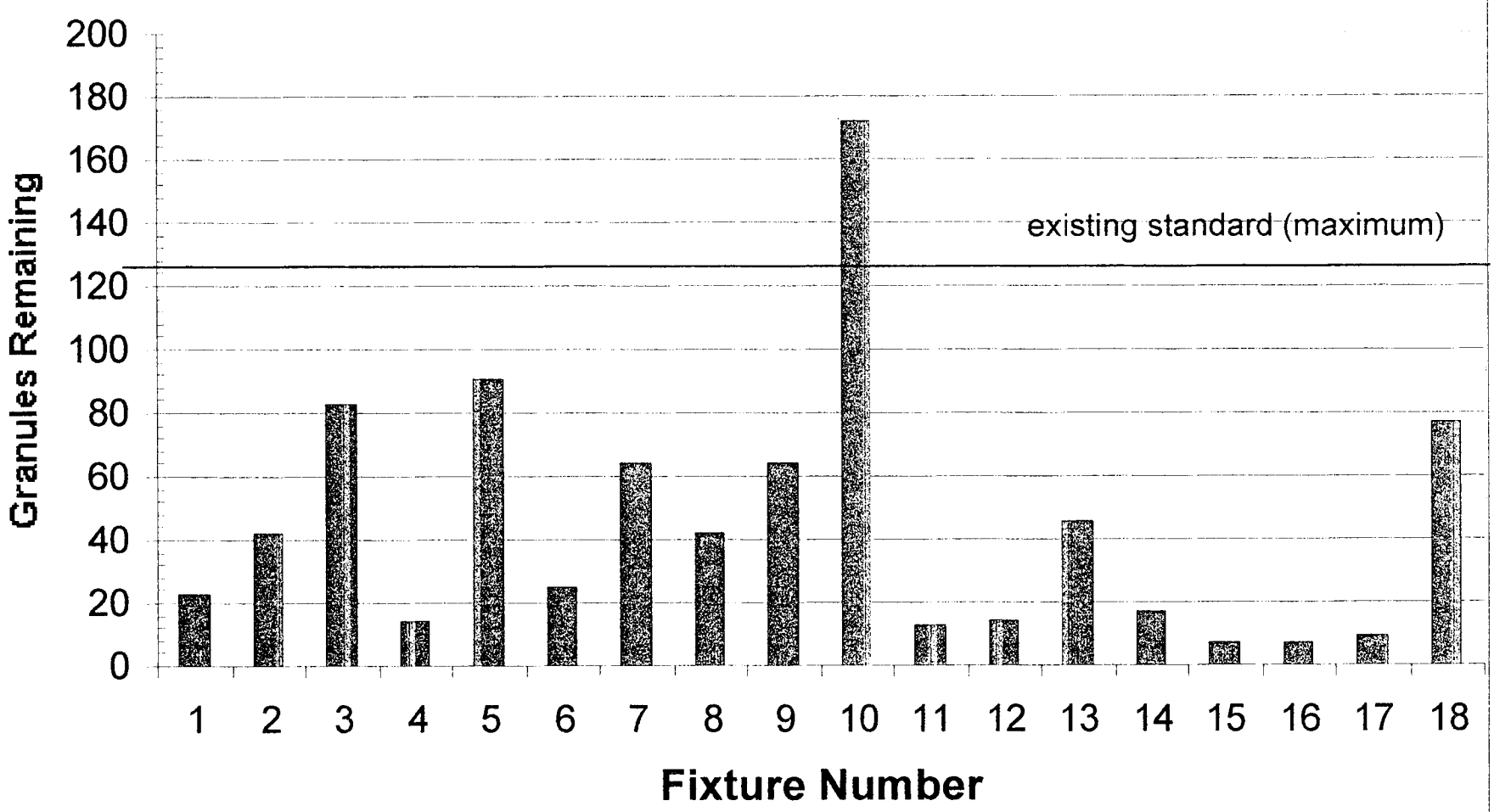


Figure 5. Waste Removal-Mixed Media (proposed standard - minimum 18 removed)

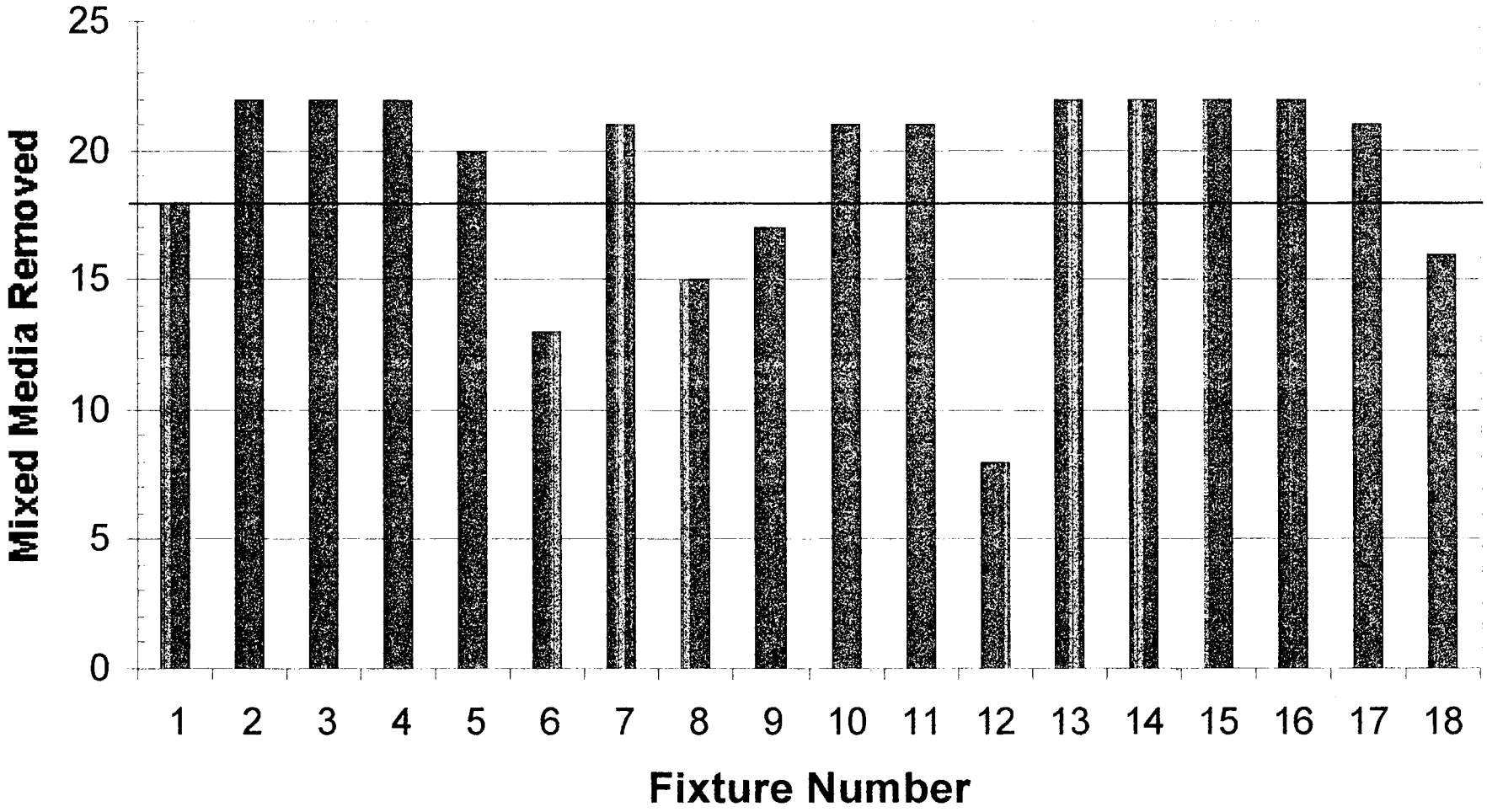


Figure 6. Waste Removal (current requirements - minimum 75) vs. Fixtures Ranked According to MWD Customer Satisfaction Survey

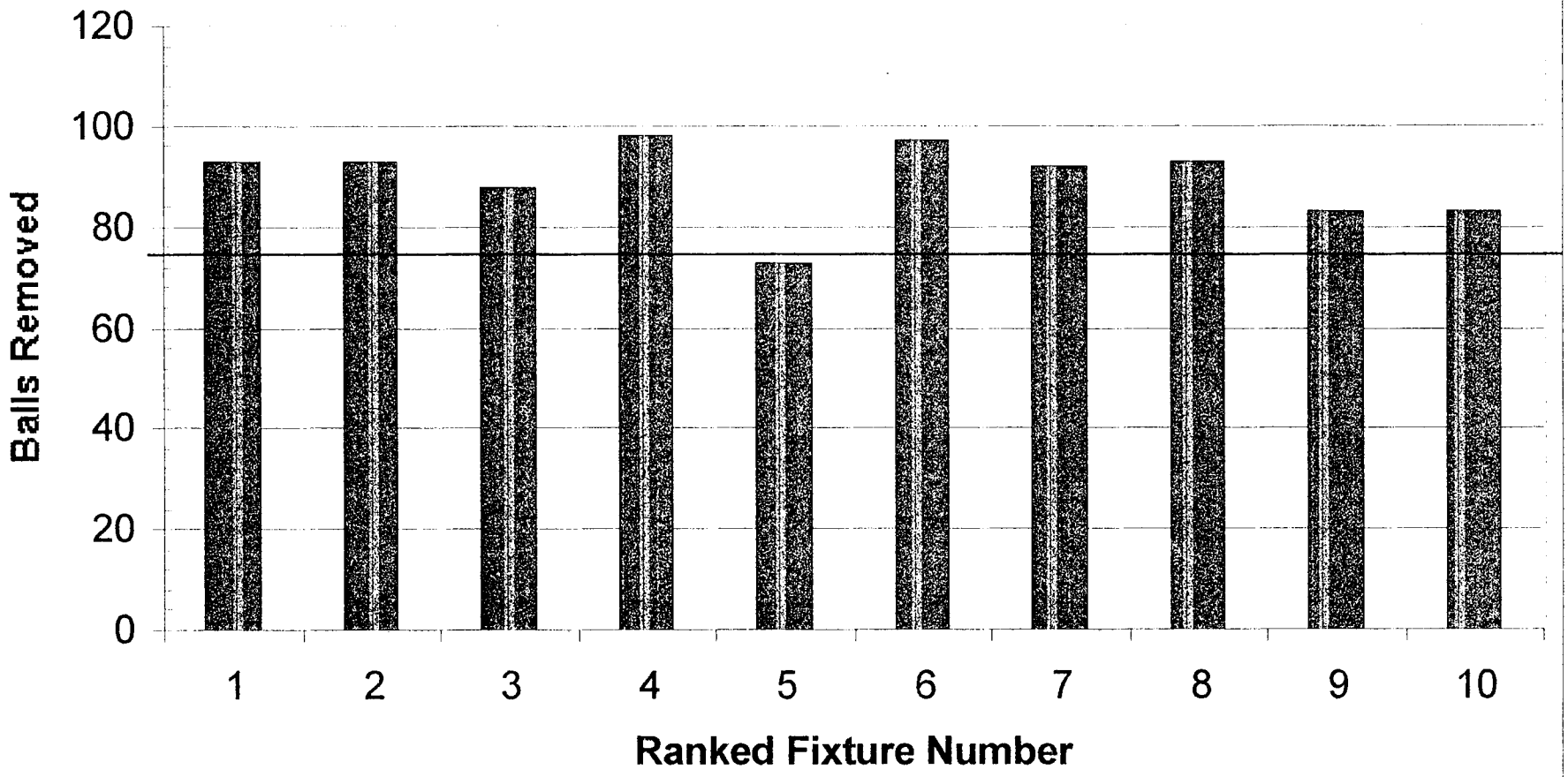


Figure 7. Waste Removal (current requirements - 125 maximum) vs. Fixtures Ranked According to MWD Customer Satisfaction Survey