AUTOMATIC FLUSH VALVE PERFORMANCE (GALLONS PER FLUSH) MEASURED FROM FIXTURES IN A MIXED-USE CLASSROOM/OFFICE BUILDING AT TEXAS A&M UNIVERSITY

A Thesis

by

SALILLA LERTBANNAPHONG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2005

Major Subject: Construction Management

AUTOMATIC FLUSH VALVE PERFORMANCE (GALLONS PER FLUSH) MEASURED FROM FIXTURES IN A MIXED-USE CLASSROOM/OFFICE BUILDING AT TEXAS A&M UNIVERSITY

A Thesis

by

SALILLA LERTBANNAPHONG

Submitted to Texas A&M University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Approval as to style and content by:

Paul K.Woods (Chair of Committee)	James W. Craig (Member)
F. Michael Speed (Member)	James W. Craig (Head of Department)

May 2005

Major Subject: Construction Management

ABSTRACT

Automatic Flush Valve Performance (Gallons per Flush) Measured from Fixtures in a Mixed-Use Classroom/Office Building at Texas A&M University.

(May 2005)

Salilla Lertbannaphong, B.A., King Mongkut's University of Technology (Thonburi), Bangkok, Thailand

Chair of Advisory Committee: Dr. Paul K. Woods

Since water-use characteristics and the new technology of plumbing fixtures have changed, it is significant to educate a facility manager in the characteristics of these systems. Also, it is necessary to provide a better understanding of parameters that may determine the suitability of retrofitting plumbing fixtures.

The 1992 Energy Policy Acts enforces 1.6-gallon per flush (gpf) for a toilet and 1.0 gpf for a urinal. In response to the regulation, the purpose of this research is to measure automatic flush valve performance (gpf) of fixtures in a mixed use classroom building at Texas A&M University. Water consumption (gpf) among three types of fixtures; low-consumption manual, old optic automatic and improved optic automatic systems are measured by using a magnetic water flow meter.

The data in the study were analyzed to determine compliance with plumbing standards and to compare the average water volume per flush cycle of toilets in the men's and women's restrooms. Finally, the results of the data show that retrofitting the old optic automatic with the improved optic automatic system resulted in water savings of about 15.80% in toilets, and urinals.

To My Family

ACKNOWLEDGEMENTS

I would like to express my gratitude to Dr. Paul Woods. His professionalism in academic and research activities has broadened my knowledge in the field of construction and facility management. I am so thankful for his support, encouragement throughout my study, and providing me a research fund. Many thanks also go to the other committee members, Dr. James Craig and Dr. Michael Speed, for their valuable comments and time. I express my sincere thanks to Dr. Graham for giving me the chance to study at Texas A&M University. My future would be in doubt if I did not get the opportunity from him. Thanks to graduate student officers, Ms. Raupe, Ms. Stephanie, and Ms. Nichols for providing and facilitating documents for my studies.

To Panida, Siritip, and Kampanart, Krisanee, I thank you for supporting, assisting and encouraging me through the difficult time. Many thanks to Hoonsik, Ute Duvenhage, and Min Chen for assistance and advice in research. Thanks to Jan Gerston for the nice editorial guidance.

Special thanks to my wonderful parents and family for their love, support and encouragement. I also thank Chuttchaval who is always by my side through ups and downs and makes me feel so special. To all of my friends, Thai student association, Deixing, Chaohong, and Kwanchai, I thank you all for being great companions and thank you for encouraging me.

TABLE OF CONTENTS

Page

Page

LIST OF FIGURES

FIGURE Page

FIGURE Page

LIST OF TABLES

TABLE Page

INTRODUCTION

General Facts

Americans consume almost 4.8 billion gallons of water daily for flushing toilets and urinals. In a public building such as a school, an office building and so on, toilet water usage alone can account for approximately one-third of all water used. Replacing high-consumption fixtures with low-consumption fixtures will provide water and cost saving, and offer a short payback period of potentially less than four years (Sloan Valve Company, 2004).

The 1992 Energy Policy Acts established the water consumption standards for four types of plumbing fixtures manufactured after January 1, 1994: toilets, kitchen and lavatory faucets, showerheads, and urinals. Under the regulations, plumbing fixtures must meet the standards for maximum water consumption (United States General Accounting Office, 2000). See table 1.

Table 1.

The 1992 Energy Policy Act, water consumption standards.

Fixture type	Maximum allowable water use
Toilets, including gravity tank-type toilets, flushometer tank toilets, and electromechanical hydraulic toilets	1.6 gallons per flush
Kitchen and lavatory faucets	2.5 gallons per minute, when measured at a flowing water pressure of 80 pounds per square inch
Showerheads	2.5 gallons per minute, when measured at a flowing water pressure of 80 pounds per square inch
Urinals	1.0 gallons per flush

This thesis follows the style of the *Journal of Construction Education.*

Although the 1992 Plumbing Standards require 1.6-gallon (6 liter)-per-flush toilets and 1.0-gallon-per-flush urinals, the volume of water used by toilets and urinals vary from the manufacturer's reported flow rate (Vickers, 2001). Hence, this study will assess the plumbing fixtures of the Langford Architecture building to identify if those low flow toilets and urinals comply with the Energy Policy Act 1992.

Importance

Efficient water use has environmental, public health and economic benefits in maintaining aquatic ecosystems and protecting water resources. It also saves homeowners money on their water bills.

Facility Management

There are three types of toilet fixtures in this study: low-consumption manual, old optic automatic and improved optic automatic systems that are popular in the market and used in the most buildings. Therefore, it is significant to educate a facility manager in the characteristics of these three types of fixtures. Also, it is necessary to provide a better understanding of parameters that may determine the suitability of retrofitting plumbing fixtures.

Facility Water Management

Based on the previous study, it has been shown that toilets account for over a third of the water used in most buildings (North Carolina Department of Environmental and Natural Resources, 2003); hence the 1992 Energy Policy Act enforces 1.6-gallon (6 liter) per flush of a toilet and 1.0 gallon per flush of a urinal.

In respond to the regulation, water facility management is one of the most crucial aspects of facility management. It is integrating people with effective low-consumption plumbing systems. Since water-use characteristics and the new technology of plumbing fixtures have changed, the facility manager's job is more challenging.

Facility Manager Role

The facility managers are the people who are responsible for operation of the water system. Furthermore, they also have the responsibility to provide water to occupants in a safe cost-effective manner as well as comply with the 1992 Plumbing Standard.

Major Problems and Potential Advantages of Retrofitting Low-consumption Fixtures

The major problems that facility managers have encountered are raising cost of water supply and return on investment. With the low-consumption plumbing technology, a facility manager is capable of operating water system more efficiently, thus enabling cost reduction that better fits the budget. Furthermore, it yields short a payback period of less than four years.

Finally, the result of this study presents a facility manger with the practical standard for low-consumption plumbing fixtures. Facility managers are therefore better able to anticipate the capital cost of plumbing fixtures and predict the monetary saving by retrofitting sanitary fixtures.

Statement of Problem

Problem

The purpose of this research is to determine water consumption in gallons per flush by comparing three types of fixtures: (1) low-consumption manual, (2) old optic automatic and (3) improved optic automatic system. This will be done for toilets and urinals in restrooms of the Langford Architecture Building A at Texas A&M University whether they comply with the 1992 Energy Policy Act standard or not.

Subproblems

This study will determine the actual water consumption in gallons per flush of (1) low-consumption manual, (2) old optic automatic system, and (3) improved optic automatic of toilets and urinals.

Definitions

Flushometer Valve Toilet

A tankless toilet with the flush valve attached to a pressurized water supply pipe. When activated, the connecting pipe supplies water to the toilet at a flow rate necessary to flush waste into the sewer.

GPCD – Gallon per capita per day

GPD –Gallons per day

GPF – Gallon per flush

MGD – Millions of gallons per day

Gravity-flush Toilet

A toilet with a rubber stopper (flapper valve) that releases water from the toilet tank, after which gravity forces the contents of the toilet bowl through a trap way for discharge into the wastewater system.

Low-consumption Toilet

A toilet that consumes no more water than 1.6 gallons per flush is also referred to as a low-flow toilet.

Low-consumption Urinal

A urinal consumes no more water than 1.0 gallons per flush is also referred to as a low-flow urinal.

Old Optic Automatic Flushometer

This system is a low-consumption flushvalve used in 1.6 gpf in toilets and 1.0 gpf in urinals. This system is isolated from the operator by means of a battery powered infrared sensor. Once the user enters the sensors effective range and then steps away, the Flushometer Solenoid initiates the flushing cycle to flush the fixture.

Improved Optic Automatic Flushometer

This system is a low-consumption flushvalve used in 1.6 gpf in toilets and 1.0 gpf in urinals. This system is an isolated from operator by means of advanced batter-operated flushometer. It protects the solenoid from water, and a new sensor that is NEMA 6 compliant against moisture to eliminate most detection errors and field adjustments.

Water Meter

A water meter is an instrument that measures water consumption; often installed by a water utility to measure end use consumption such as uses by a household, a building facility, or an irrigation system.

Retrofit

Retrofit means to provide, install, change, or adjust plumbing fixtures or other parts, devices, or equipment to save water and make operation more efficient.

Assumptions

1. Frequency of use among fixtures is equal.
2. The magnetic water flow meter installed in the basement of the Langford Architecture building operates properly.
3. Valve gpf remains constant over study
4. Gallons per flush are the only determining factor affecting water consumption of toilets and urinals; other conditions are equivalent.
5. Gallon per flush is dependent on the types of valves of toilets and urinals.

Importance of the Study

The importance of this study is that it will help a facility manager better understand whether or not retrofitting the improved optic automatic valves helps reduce water consumption and save money for their operation.

LITERATURE REVIEW

Study 1—The Cost-Effectiveness of Retrofitting Sanitary Fixtures in Restrooms of a University Building

Basic Information

Author

Byounghoon Hwang

Source

Thesis, MS Construction Management, Department of Construction Science, College of Architecture, Texas A&M University, College Station, Texas

Study Date

August 2003

Location

Building A. Ernest Langford Architecture Center at Texas A&M University

Study Objectives

The purpose of the study is to compare measured gallons per flush (gpf) in water use by retrofitting existing toilets and urinals in a classroom office building with low-consumption valves and fixtures.

Data

Data Collection Period

August 2002 to November 2002

Observational Unit

The flush of a toilet or urinal

Variables

The dependent variable of this research was water volume in gallons per flush. The independent variables were valve style (manual low-consumption, old automatic and new automatic), fixture type (toilets or urinals) floor (1, 2, 3, 4) sex (men, women).

Population of Interest

Flush valve toilets and urinals in combined-use classroom/office buildings.

Sample

Water volume per flush cycle in gallons per flush was measured at least 10 times for each of the 24 toilets and 12 urinals over each phase of the study.

Methods

The water volume per flush of conventional toilets and urinals was measured using the plug method. Each test was repeated ten times per fixture. Since, the plug measurement method proved ineffective, the balloon measurement method was devised. Additionally, an electronic water meter was installed to easily obtain backup data.

All water volumes per flush measurements were repeated ten times per fixture while keeping the other fixtures turned off. The researcher then used statistical analysis to find which method was the most reliable and to compare the water volume per flush of all phases in toilets and urinals.

Findings

Comparisons among the three phases in toilets and urinals showed that the water volume per flush of toilets, from highest to lowest, was tune-up, low-consumption automatic and low-consumption manual, respectively. In urinals, the water volume per flush of urinals, from highest to lowest, was tune-up, low-consumption automatic and low-consumption manual, respectively.

Conclusions

The retrofitting of high-consumption fixtures with low-consumption fixtures provides cost and water saving. Low-consumption manual valves proved to use the least amount of water per flush.

Relevance to Current Study

This research compared the water volume per flush of three systems in toilets and urinals. This study will also measure gpf of fixtures in the same building. The only change will be that new optic automatic valves will be installed to replace the low-consumption manual valves. Data collection techniques are also similar. Therefore, based on this study, we expect the low-consumption manual valve to have lower gallons per flush than the improved optic automatic valve.

Study 2—The Water Economy of a Low Flush Toilet in a Water-Deficient Region

Basic Information

Source

Water Resource Research Center, Caribbean Research Institute

Author

Albert E. Pratt

Publication Date

July 1979

Location

Virgin Islands, St. Thomas

Study Objectives

The purpose of this project was to measure water usage at a public restroom facility for a period before and after upgrading with low-flush toilets. The study also monitored maintenance and operational problems and projected the net effects that wide-scale use of low-flush equipment could have on the present level of demand for government water production and distribution.

Data

Data Collection Period

January 1976 to June 1979

Observational Unit

Daily water meter reading

Variables

The dependent variable in this study was the gallons of water used.

Population of Interest

Public restroom facility at Red Hook Ferry Dock, St. Thomas, Virgin Islands

Sample

The total gallons of water used in all five toilets were read daily for 16 months by means of a meter.

Method

Five low-flush toilets replaced the conventional toilets in a public restroom facility at Red Hook Ferry Dock, St. Thomas. Microphor LF-310 stainless steel toilets were used. These low-flush toilets are designed to operate on 2 quarts of water per flush. A water meter was installed in the feed line between the storage tank and the restroom to measure the amount of water used. The operation of the facility was monitored for 17 months, from February 24, 1977 to June 22, 1978. Water delivery was recorded and analyzed for each day from January 1, 1976 to June 30, 1979.

Findings

The water reduction ratio of 3.6:1 accounted for 36,500 gallons of water reduction and an estimated saving of $156 in one year.

Conclusions

Replacing these conventional toilets with low-flush toilets generated a savings in the cost of and amount of water used.

Relevance to Current Study

This study analyzes the cost saving and water use reduction due to replacing conventional toilets with low-flush toilets. Therefore, we expect the low-consumption fixtures in the current study to use less water than the conventional fixtures.

Study 3—Water Infrastructure, Water Efficient Plumbing Fixtures Reduce Water Consumption and Wastewater Flows

Basic Information

Source

United States General Accounting Office, Washington D.C.

Author

Not stated

Publication Date

August 2000

Location

This study was conducted on 12 sites in Boulder, Colorado; Cambridge and Waterloo, Ontario, Canada; Denver, Colorado; Eugene, Oregon; Las Virgenes, California;

Lompoc, California; Phoenix, Arizona; San Diego, California; Scottsdale and Tempe, Arizona; Seattle, Washington; Tampa, Florida; and Walnut Valley, California.

Study Objectives

The purpose of the study was to provide new empirical evidence on variations in water use of plumbing fixtures and other water-using appliances within single-family home.

Data

Data Collection Period

Unknown

Observational Unit

Daily water meter reading for each household.

Variables

The dependent variable is gallons per capita per day, assuming the average number of flushes per day in households with low-flow toilets was 5.04. The independent variable is the installed fixture mix.

Population of Interest

Single family homes in the United States

Sample

A total of 1,200 homes at 12 study sites

Method

A total of 1,200 homes were randomly selected from 12 study sites to measure the impact of using water-efficient plumbing fixtures. The study households include those with low-flow fixtures only, a mixture of low-flow fixtures and higher-volume fixtures, and those with higher-volume fixtures. Sophisticated sensors were placed on each residential water meter. Water use data were recorded daily.

Findings

The average gallons per capita per day (gpcd) show that the households with low-flow fixtures used only 9.5 gpcd. Households with a mixture of low-flow and higher-volume fixtures consumed 17.6 gpcd. High-volume fixture households used 20.1 gpcd.

Conclusions

When comparing the households that used low flow toilet only to higher volume toilet only, it concluded that the low-flow fixtures consume 40 percent less water for flushing than high-volume fixtures.

Relevance to Current Study

This study found that low-consumption fixtures caused less water to be used per capita than either a mix of fixtures or high-volume fixtures alone. Therefore, we expect the low-consumption fixtures in the current study to use less water than the original fixtures.

Analysis of the Literature

The first two studies attempted to determine if the low-flush or low-consumption fixtures were effective in cost and water savings. The result of the studies confirmed that low-consumption fixtures are able to save water and cost.

In all three studies, water meters were the effective equipment used to measure the water consumption. In the first study, the researcher attempted to determine whether the magnetic water flow meter was reliable as compared to the other methods, plug and balloon. From the result, it concluded that the magnetic water flow meter provided more reliable though possibly less accurate data than the other measurement methods.

The conclusion of all three studies indicated that the reduction of water consumption can be achieved by using low-flow toilets. Therefore, it is expected that this research study will show that low-consumption toilets will use less water than the original toilet.

RESEARCH HYPOTHESES, LIMITATIONS, AND DELIMITATIONS

μ_{WCL} = Population mean of low-consumption manual toilets.

μ_{WCO} = Population mean of old optic automatic toilets.

μ_{WCN} = Population mean of improved optic automatic toilets.

μ_{UL} = Population mean of low-consumption manual urinals.

μ_{UO} = Population mean of old optic automatic urinals.

μ_{UN} = Population mean of improved optic automatic urinals

Toilet Hypotheses

Hypothesis One

The US Energy Policy Act of 1992 requires that all toilets sold in the United States use 1.6 gallons per flush (gpf) or less. Three types of toilets will be compared in this study to compare water volume per flush and to ensure all three comply with the requirement of 1.6 gallons per flush or less. The study will test the following null and research hypothesis.

The Null Hypothesis

The water volume per flush in toilets of improved optic automatic system, old optic automatic system, and low-consumption manual are equal to 1.6 gpf.

Ho: $\mu WCN = 1.6$ gpf

Ho: $\mu WCO = 1.6$ gpf

Ho: $\mu WCL = 1.6$ gpf

The Research Hypothesis

The water volume per flush in toilets of improved optic automatic system, old optic automatic system, and low-consumption manual all differ from1.6 gpf.

(Ha: μWCN # μWCO # μWCL # 1.6 gpf)

Research Objective

Determine the water volume per flush of toilets and whether they comply with the 1992 US Energy Policy Act requirement of 1.6 gpf.

Hypothesis Two

To determine whether the average water volume per flush of all three types of toilets is equal, the study will be test the following null and research hypothesis.

The toilet dataset effect model is as follows:

$$Y_{ijklm} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + e_{ijkl} + d_{ijklm}$$

Where Y_{ijklm} is the response variable water consumption, μ is the mean of the response variable; τ_i is the fixed effect due to method (i = 1,2,3); β_j is the fixed effect due to floor; (j = 1,2,3,4); γ_k is the fixed effect due to type of rest room (k = 1,2); $(\tau\beta)_{ij}$ is the interaction between methods and floor; $(\tau\gamma)_{ik}$ is the interaction between methods and type of rest room; $(\beta\gamma)_{jk}$ is the interaction between floor and type of rest room; $(\tau\beta\gamma)_{ijk}$ is the interaction among all three factors; e_{ijkl} is the random effect due to difference in experimental units; d_{ijklm} is the random effect due to difference in sub-sampling (m=1,..,10).

The Null Hypothesis

The average water volume per flush, measured in gallons per flush, in toilets of three systems—improved optic automatic system, old optic automatic system and low-consumption manual—is equal.

Ho: $\mu WCN = \mu WCO$

Ho: $\mu WCN = \mu WCL$

Ho: $\mu WCO = \mu WCL$

The Research Hypothesis

At least one of the average water volume per flush of toilets in women's and men's restrooms differs from the rest.

Objectives

1. Determine which factors affect average water volume per flush (gpf).
2. Identify if the means differ among three flushometer systems.

Urinal Hypotheses

Hypothesis Three

The 1992 US Energy Policy Acts requires that the water of urinals must not exceed 1.0 gallon per flush. Three types of urinals will be examined in this study to determine if the water volume per flush for all three types complies with the requirement of 1.0 gallons per flush. The study will be tested by the following null and research hypothesis.

The Null Hypothesis

The water volume per flush in urinals of improved optic automatic system, old optic automatic system, and low-consumption manual are equal to 1.0 gpf.

Ho: μUL = 1.0 gpf

Ho: μUO = 1.0 gpf

Ho: μUN = 1.0 gpf

The Research Hypothesis

The water volume per flush in urinals of improved optic automatic system, old optic automatic system, and low-consumption manual differs from 1.0 gpf.

(Ha: μ_{UN} # μ_{UO} # μ_{UL} # 1.0 gpf)

Objective

Determine the water volume per flush of urinals to determine whether they meet the 1992 Energy Policy Act requirements.

Hypothesis Four

To determine whether the average water volume per flush of all three types of urinals is equal; the study will be tested by the following null and research hypothesis.

The urinal dataset effect model is as follows:

$Y_{ijklm} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + + e_{ijl} + d_{ijlm}$

Where Y_{ijlm} is the response variable water consumption, μ is the mean of the response variable, τ_i is the fixed effect due to methods (i = 1,2); β_j is the fixed effect due to floor (j = 1,2,3,4); $(\tau\beta)_{ij}$ is the interaction between methods and floor; e_{ijl} is the random effect due to difference in experimental units; d_{ijlm} is the random effect due to difference in sub-sampling (m=1,..,10).

The Null Hypothesis

The average water volume per flush in urinals of three systems, improved optic automatic system, old optic automatic system and low-consumption manual are equal.

Ho: $\mu N = \mu O$

Ho: $\mu N = \mu L$

Ho: $\mu O = \mu L$

The Research Hypothesis

At least one of the average water volume per flush of urinals in men's restrooms differs from the rest.

Objective

Determine the average water volume per flush of urinals. Compare to find how the means differ between urinals.

Limitation of the Study

This research is limited to toilets and urinals in both men and women's restrooms on all four floors in the Langford Architecture Building A at Texas A&M University.

Delimitation of the Study

1. This research is limited to study only three versions of two types of fixtures: low-consumption manual, old optic automatic and improved optic automatic toilets and urinals.
2. The data of the study are concerned only with the water volume per flush corresponding to the each type of sanitary fixture.
3. Water volume measured in gallons per flush will be measured using an electronic meter in the building.

RESEARCH METHODOLOGY

Research Data General Information

Analysis Period

The building was successfully monitored. The data of three toilet systems on both toilets and urinals was collected: low-consumption manual during October 2002, old optic automatic system during November 2002, and improved optic automatic system during November 2003 in both men's and women's restrooms. The two objectives of the data collection efforts were to determine whether water consumption of all three systems—low-consumption manual, old optic automatic, and improved optic automatic system—comply with the 1992 Energy Policy Act Standard and to determine whether the improved optic automatic system is the most effective system.

Location

The study was conducted in Building A, Ernest Langford Architecture Center at Texas A&M University, College Station, Texas.

Research Data

Observational Unit

The observational unit in this research is flush of a toilet or urinal.

The Dependent Variable

The dependent variable is the volume of water used per flush by the toilet or urinal.

The Independent Variables

Fixture Types

Three flushometer systems were monitored in this research: (1) low-consumption manual, (2) old optic automatic system, and (3) improved optic automatic system. These three systems are different in operation and specification.

Gender

Both men's and women's restrooms were studied in this research.

Floor

The Langford Architecture Building A, Texas A&M University has four floors with rooftop and basement. Men's and women's restroom are located on all four floors. No restrooms are located on rooftop and basement.

Population of Interest

The populations of interest are toilets and urinals in combined-use classroom/office buildings.

Sample

Water volume in gallons per flush was measured at least 10 times for each of the 12 urinals and 24 toilets over each phase of the study.

Experimental Setup

Fixtures

There are two toilets and three urinals in each men's restroom, and four toilets in each women's restroom for a total of 24 toilets and 12 urinals in the building. The women's restroom layout is shown in figure 1. The layout of the first floor men's restroom (figure 2) differed from restrooms on other floors (figure 3).

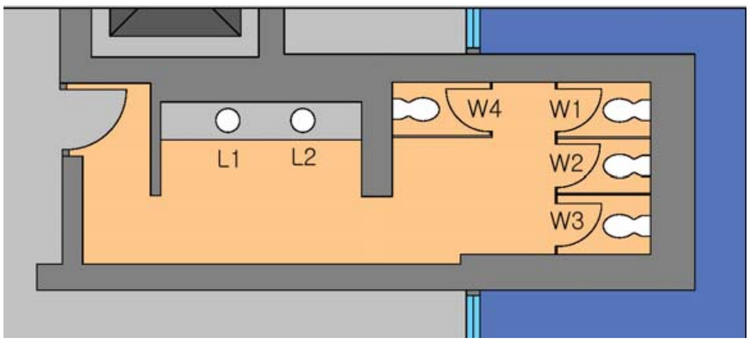


Figure 1: Women's Restroom Layout (Four toilets)

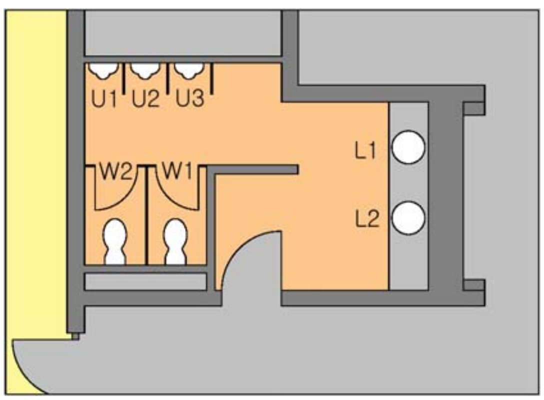


Figure 2: First Floor Men's Restroom Layout (Two Toilets and Three Urinals)

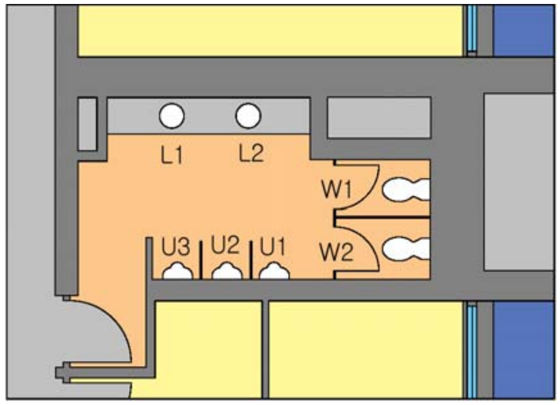


Figure 3: Second, Third, and Fourth Floor Men's Restroom Layout

Fixture Types in the Study

Toilets and Urinal Flushometer Systems

Low-consumption manual (Royal Model, Model 111 low-consumption)

Data for the low-consumption manual were collected from the exposed toilet flushometer Royal 111, Sloan Valve Company (figures 4 and 5). It is operated by manual control. The flush cycle uses 1.6 gpf. The essential specifications of Royal 111 are non-hold-open handle, fixed-metering bypass, no external volume adjustment to ensure water conservation, and flush accuracy controlled (Sloan Valve Company, 2004). The specifications and operation detail are included in Appendix B.

Figure 4: Low-Consumption Manual Flushometer (Sloan Valve Company, 2004)

Figure 5: Low-Consumption Manual Toilet and Urinal (Hwan, 2003)

Old optic automatic (Royal Model, Optima Plus, RESS-C-1.6 low-consumption)

Flush volume of the old optic automatic system for both toilets and urinals was collected from the sensor-operated closet flushometer, Royal Optima Plus model, Sloan Valve Company (figures 6 and 7). The flush cycle uses 1.6 gpf. The flushometer operates by battery-powered infrared sensor. Once the user enters the sensor's effective range and then steps away, the flushometer solenoid initiates the flushing cycle. The manufacturer claims that automatic operation provides water usage savings over other flushing devices and reduces maintenance and operation cost (Sloan Valve Company, 2004). The specifications and operation detail are included in Appendix B.

Figure 6: Old Optic Automatic Flushometer (Sloan Valve Company, 2004)

Figure 7: Old Optic Automatic Toilet and Urinal (Hwan, 2003)

Improved optic automatic (G2 Optima Plus, 8111 low-consumption model)

Gallons per flush for the improved optic automatic system for both toilets and urinals were collected from the sensor-operated closet flushometer, G2 Optima Plus model, Sloan Valve Company (figure 8). The flush cycle uses 1.6 gpf. The flushometer activates via multilobular sensor detection to provide the ultimate in sanitary protection and automatic operation. A battery-powered infrared sensor detects the occupant and completes the flush when the user steps away. Batteries can be changed without turning off the water. The patented isolated operator ensures reliability by isolating the solenoid components from the water (Sloan Valve Company, 2004). The specification and operation detail are included in Appendix B.

Figure 8: Improved Optic Automatic Flushometer (Sloan Valve Company, 2004)

Fixture Identification in the Study

Numerals and letters identify the location of each fixture. The fixtures are numbered clockwise in each restroom. For example 4ww3 identifies fourth floor of the building, women's restroom, and toilet number 3 (figure 9), or 4mu1 identifies fourth floor of the building, men's restroom, and urinal number1 (figure 10).

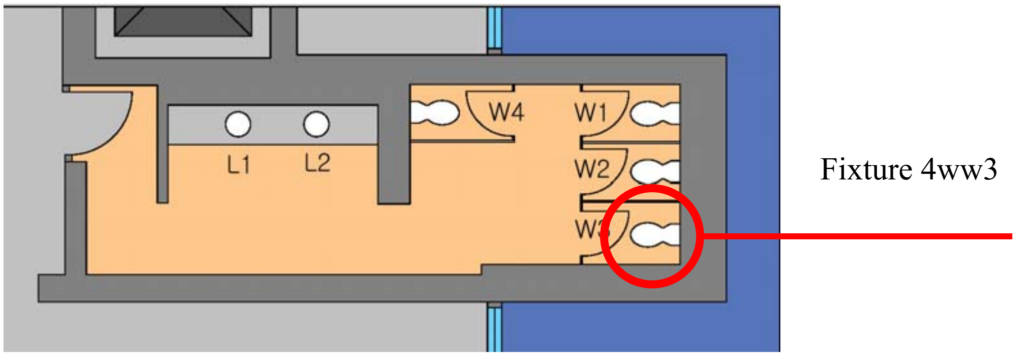


Figure 9: Fourth Floor Women's Restroom Layout (Hwan, 2003)

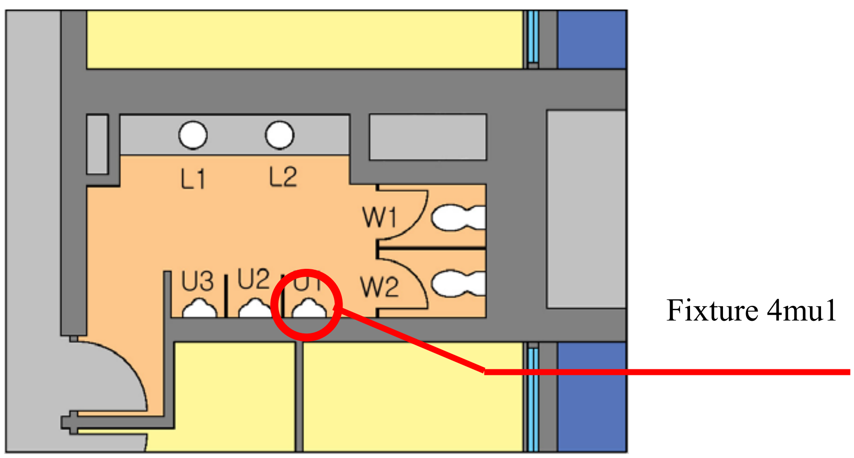


Figure 10: Fourth Floor Men's Restroom Layout (Hwan, 2003)

Experimental Apparatus (Magnetic Water Flow Meter)

Rosemount 8712C magnetic water flow meter (figure 11) was installed in the basement of the Langford Architecture Building A. The water meter measures the amount of water used by the flush cycle of a toilet or a urinal. This measurement is taken while keeping all other fixtures and water appliances turned off. The specifications of the Rosemount 8712C are included in Appendix A.

Figure 11: Magnetic Water Flow Meter in Basement of Architecture Building A

Measurement Method

The data of each phase was collected over one weekend day between 7:00 p.m. and 12:00 a.m. when few people were in the building. Preventive measures were undertaken to ensure that while a water measurement was being taken, no other fixture was being flushed. Gallons per flush of toilets and urinals were measured by flushing each fixture 10 times.

Data Analysis

Statistical Analysis

One Sample t Test

The one-sample t Test is the method used to compare the mean of a sample to a population mean. According to the 1992 Energy Policy Acts Standard, the population mean of toilets is 1.6 gpf. The population mean of urinals is 1.0 gpf.

Analysis of Variance

Design Procedure

A fixed effect model design with sub-sampling in ANOVA was used in the experimental study. No method of randomization was applied in the study. There are 10 sub-samples per experimental unit in the study.

Factors in the Experiment

Four factors were applied in the treatment structure: flushometer type, fixture type, floor level in the building and restroom gender.

Toilet and Urinal Dataset Effect Model

The Toilet Dataset Effect Model

A three-way ANOVA with sub-sampling is used to analyze the data. Then, Tukey, Scheffe, LSD, Bonferroni, and Dunnett's procedure were used to compare the improved optic automatic system with the low-consumption manual and old optic automatic system.

The model is as follows:

$Y_{ijklm} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + e_{ijkl} + d_{ijklm}$

Where Y_{ijklm} is the response variable water consumption; μ is the mean of the response variable; τ_i is the fixed effect due to methods (i = 1,2,3); β_j is the fixed effect due to floor (j = 1,2,3,4); γ_k is the fixed effect due to type of rest room (k = 1,2); $(\tau\beta)_{ij}$ is the interaction between methods and floor; $(\tau\gamma)_{ik}$ is the interaction between methods and type of rest room; $(\beta\gamma)_{jk}$ is the interaction between floor and type of rest room, $(\tau\beta\gamma)_{ijk}$ is the interaction among all three factors; e_{ijkl} is the random effect due to difference in experimental units; d_{ijklm} is the random effect due to difference in sub-sampling (m=1,..,10).

The Urinal Dataset Effect Model

A two-way ANOVA with sub-sampling was used to analyze the urinal data set. The Dunnett's procedure was used to compare the improved optic automatic system with low-consumption manual and old optic automatic system.

The model is as follows:

$Y_{ijklm} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + + e_{ijl} + d_{ijlm}$

Where Y_{ijlm} is the response variable water consumption; μ is the mean of the response variable; τ_i is the fixed effect due to methods (i = 1,2); β_j is the fixed effect due to floor (j = 1,2,3,4); $(\tau\beta)_{ij}$ is the interaction between methods and floor; e_{ijl} is the random effect due to difference in experimental units; d_{ijlm} is the random effect due to difference in sub-sampling (m=1,..,10).

RESULTS, TOILET STUDY

The results of the data obtained were analyzed to answer the research objective and to test hypotheses one and two. Interpretations of the findings are shown in the figures and tables in this section.

Comparison to the Standard

The results of the data were analyzed to determine compliance with plumbing standards and to compare the average water volume per flush cycle of toilets in the men's and women's restrooms on each floor. Three toilet types—flushometer, low-consumption manual, old optic automatic and improved optic automatic system—at the Langford Architecture Building, Texas A&M University were tested as detailed in the tables and figures in this section.

Low-consumption Manual

Graphs (univariate)

Table 2 and Figure 12 show the low-consumption manual average water volume per flush in gallons per flush of toilets in men's and women's restrooms on each floor. There are two toilets in each men's restroom and four toilets in each women's restroom. Comparison of average water volume per flush cycle in men and women's restrooms on each floor is shown in figure 12. Water volumes per flush cycle are greater in men's restrooms than women's restrooms on each floor except on the fourth floor.

Table 2.

Gallons per flush of toilets, low-consumption manual.

	Floor	Men/Women	Fixture type	fixture no.	gpf	Avg_Men	Avg_Women
1mw1	1	m	w	1	1.522		
1mw2	1	m	w	2	1.854		
1ww1	1	w	w	1	1.774		
1ww2	1	w	w	2	1.417		
1ww3	1	w	w	3	1.563		
1ww4	1	w	w	4	1.575	1.69	1.58
2mw1	2	m	w	1	1.506		
2mw2	2	m	w	2	1.508		
2ww1	2	w	w	1	0.953		
2ww2	2	w	w	2	1.512		
2ww3	2	w	w	3	1.802		
2ww4	2	w	w	4	1.325	1.51	1.40
3mw1	3	m	w	1	1.811		
3mw2	3	m	w	2	1.706		
3ww1	3	w	w	1	1.469		
3ww2	3	w	w	2	1.683		
3ww3	3	w	w	3	1.454		
3ww4	3	w	w	4	1.420	1.76	1.51
4mw1	4	m	w	1	1.669		
4mw2	4	m	w	2	1.753		
4ww1	4	w	w	1	1.958		
4ww2	4	w	w	2	1.594		
4ww3	4	w	w	3	1.849		
4ww4	4	w	w	4	1.920	1.71	1.83

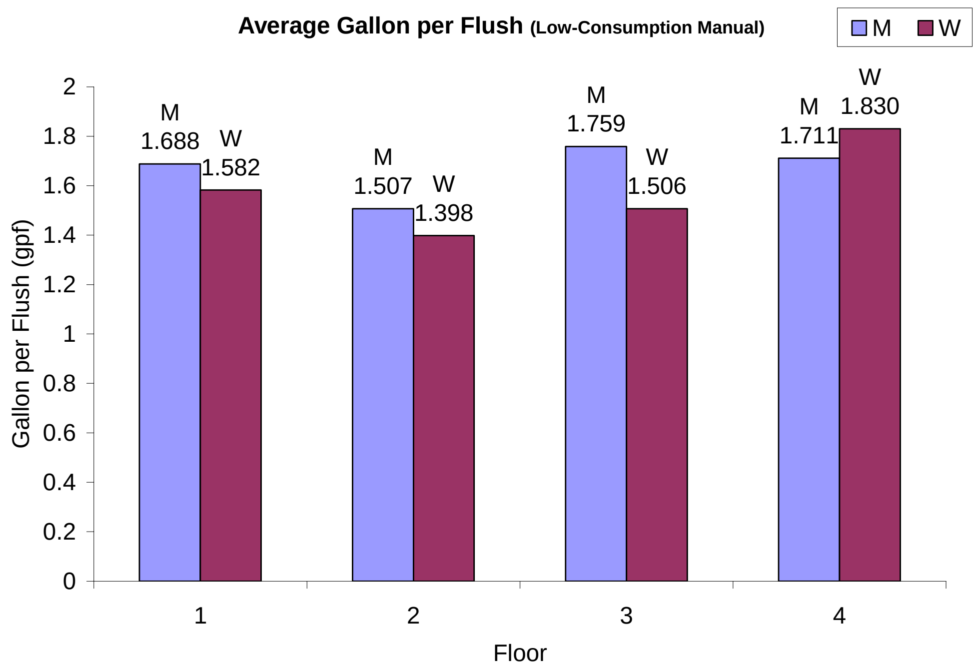


Figure 12: Average Gallon per Flush of Toilets, Low-Consumption Manual

T Test

To answer hypothesis one, a one sample t test was conducted to analyze whether the water volume of low-consumption manual is 1.6 gpf.

Table 3 shows the one-sample statistics in gallons per flush of low-consumption manual toilets. There were 240 observations in the population with a mean 1.6083 gpf.

Table 4 shows the result of the one-sample t test. The difference is at 0.05 level, α =0.05. The significant value from the t test is 0.569. The null hypothesis in this case is that the water consumption in gpf of all phases equals 1.6 gpf. As the significant value 0.569 is higher than 0.05, there is no significant difference between the mean and the standard. Thus, we cannot reject the null hypothesis.

Table 3.

One-sample statistics, gpf of toilets, low-consumption manual.

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
gpf	240	1.6083	.22553	.01456

Table 4.

One-sample t test, gpf of toilets, low-consumption manual.

	One-Sample Test					
	Test Value = 1.6					
	t	df	Sig. (2-tailed)	Mean difference	95% Confidence Interval of the Difference	
					Lower	Upper
Gpf	.570	239	.569	.0083	-.0204	.0370

Old Optic Automatic System

Graphs (univariate)

Table 5 and Figure 13 show the average water volume per flush of old optic of toilets in men and women's restrooms on each floor. There are two toilets in each men's restroom and four toilets in each women's restroom. Comparing average gallons per flush by men's and women's restrooms on each floor is shown in figure 13. Water volume appears higher in men's restrooms than women's restrooms on each floor except on the second floor.

Table 5.

Gallons per flush of toilets, old optic automatic system.

	Floor	Men/Women	Fixture type	fixture no.	gpf	Avg_Men	Avg_Women
1mw1	1	m	w	1	2.192		
1mw2	1	m	w	2	2.018		
1ww1	1	w	w	1	1.934		
1ww2	1	w	w	2	1.543		
1ww3	1	w	w	3	2.206		
1ww4	1	w	w	4	1.461	2.105	1.786
2mw1	2	m	w	1	1.4		
2mw2	2	m	w	2	2.436		
2ww1	2	w	w	1	2.084		
2ww2	2	w	w	2	2.101		
2ww3	2	w	w	3	1.597		
2ww4	2	w	w	4	2.198	1.918	1.995
3mw1	3	m	w	1	2.045		
3mw2	3	m	w	2	2.483		
3ww1	3	w	w	1	2.156		
3ww2	3	w	w	2	1.778		
3ww3	3	w	w	3	2.42		
3ww4	3	w	w	4	2.136	2.264	2.1225
4mw1	4	m	w	1	2.003		
4mw2	4	m	w	2	2.08		
4ww1	4	w	w	1	1.458		
4ww2	4	w	w	2	1.947		
4ww3	4	w	w	3	1.877		
4ww4	4	w	w	4	2.122	2.0415	1.851

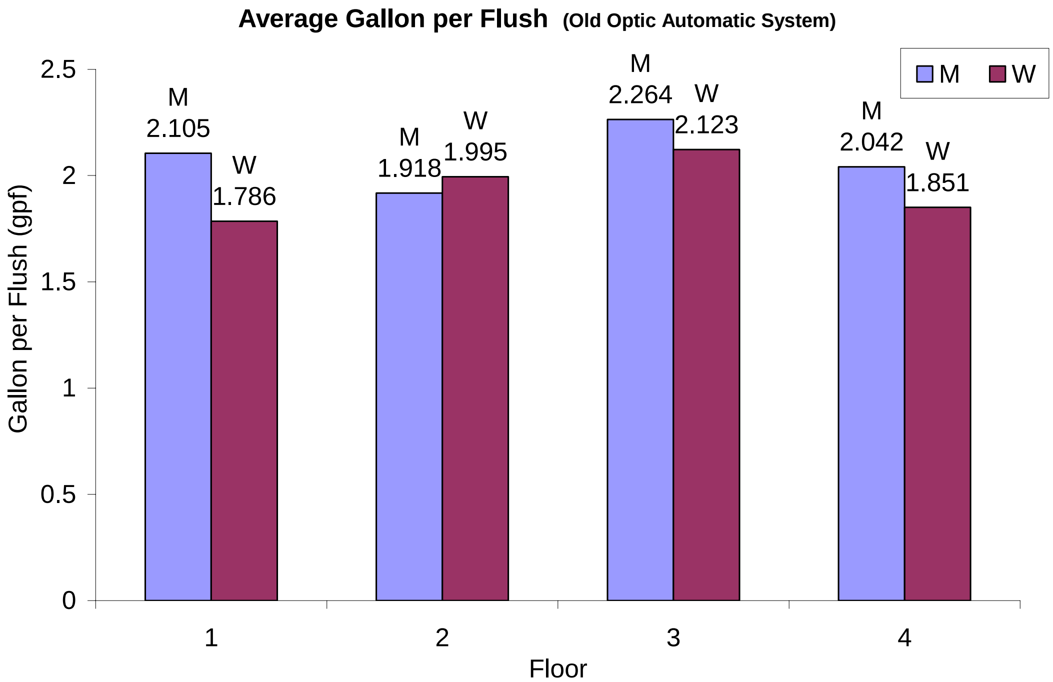


Figure 13: Average Gallons per Flush of Toilets, Old Optic Automatic System

T Test

To answer hypothesis one, one sample t test was conducted to analyze whether the water volume of old optic automatic system equals 1.6 gpf.

Table 6 shows the one-sample statistics in gallons per flush of the old optic automatic system of toilets. There were 240 observations in the population with a mean 1.9866 gpf.

Table 7 shows the result of the one-sample t test. The difference is significant at 0.05 level, α =0.05. The significant value from t-test is 0.000. The null hypothesis in this case is that the water consumption in gpf of all phases equals to 1.6 gpf. As the significant value 0.000 is lower than 0.05, there is no significant difference between mean and the standard. Thus, we cannot reject the null hypothesis.

Table 6.

One-sample statistics, gpf of toilets, old optic automatic system.

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
gpf	240	1.9877	.30670	.01980

Table 7.

One-sample t test, gpf of toilets, old optic automatic system.

	One-Sample Test					
	Test Value = 1.6					
	t	df	Sig. (2-tailed)	Mean difference	95% Confidence Interval of the Difference	
					Lower	Upper
gpf	19.527	239	.000	.3866	.3476	.4256

Improved Optic Automatic System

Graphs (univariate)

Table 8 and Figure 14 show the improved optic automatic average water volume per flush cycle of toilets in men and women’s restrooms on each floor. There are two toilets in each men’s restroom and four toilets in each women’s restroom. Comparing average gallons per flush by men’s and women’s restrooms on each floor is shown in figure 14.

It indicates that water volume per flush appears higher in men's restrooms than women's restroom on each floor except on the second floor.

Table 8.

Gallons per flush of toilets, improved optic automatic system.

	Floor	Men/Women	Fixture type	fixture no.	gpf	Avg_Men	Avg_Women
1mw1	1	m	w	1	1.65		
1mw2	1	m	w	1	1.68		
1ww1	1	w	w	1	1.07		
1ww2	1	w	w	1	1.6		
1ww3	1	w	w	1	1.63		
1ww4	1	w	w	1	2.07	1.67	1.59
2mw1	2	m	w	1	1.68		
2mw2	2	m	w	1	1.55		
2ww1	2	w	w	1	1.64		
2ww2	2	w	w	1	1.86		
2ww3	2	w	w	1	1.69		
2ww4	2	w	w	1	1.78	1.62	1.74
3mw1	3	m	w	1	1.59		
3mw2	3	m	w	1	1.86		
3ww1	3	w	w	1	1.48		
3ww2	3	w	w	1	1.71		
3ww3	3	w	w	1	1.89		
3ww4	3	w	w	1	1.7	1.73	1.70
4mw1	4	m	w	1	1.78		
4mw2	4	m	w	1	1.54		
4ww1	4	w	w	1	1.51		
4ww2	4	w	w	1	1.82		
4ww3	4	w	w	1	1.76		
4ww4	4	w	w	1	1.5	1.66	1.65

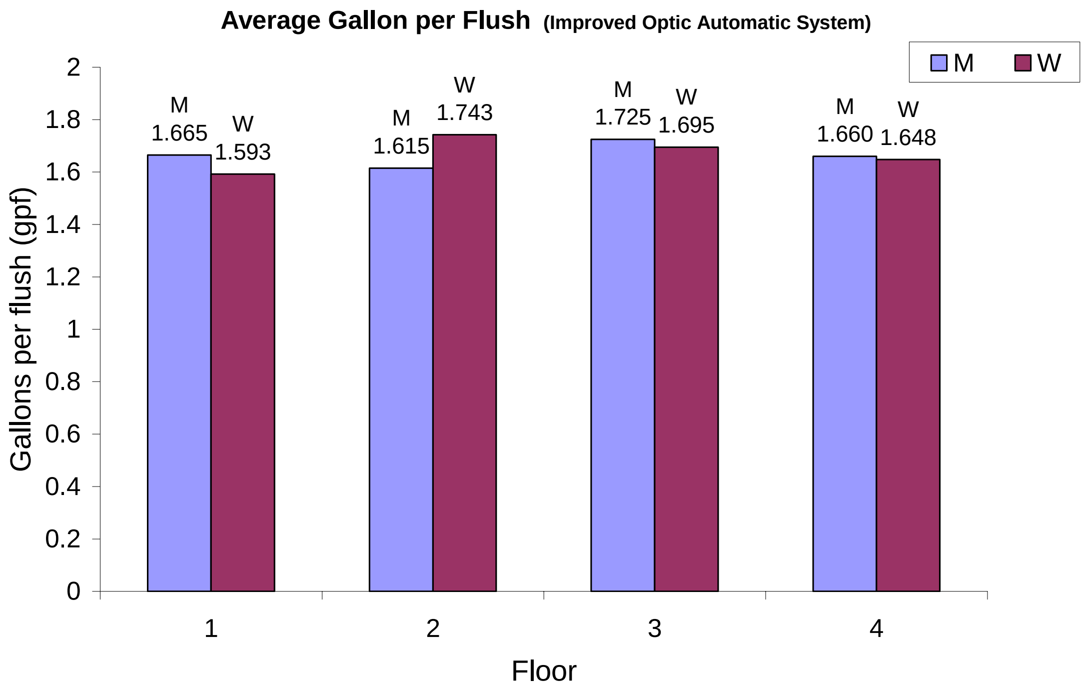


Figure 14: Average Gallons per Flush of Toilets, Improved Optic Automatic System

T Test

To answer hypothesis one, one sample t test was conducted to analyze whether the water volume in gpf of improved optic automatic system equals 1.6 gpf.

Table 9 shows the one-sample statistics in gallons per flush of improved optic automatic system of toilets. There were 240 observations in the population with a mean 1.6695 gpf.

Table 10 shows the result of the one-sample t test. The difference is significant at 0.05 level, α =0.05. The significant value from the t test is 0.000. The null hypothesis in this case is that the water consumption in gpf of all phases equals to 1.6 gpf. As the significant value 0000 lower than 0.05, there is a significant difference between mean and the standard. Thus, we reject the null hypothesis.

Table 9.

One-sample statistics, gpf of toilets, improved optic automatic system.

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
gpf	240	1.6695	.1995	.01288

Table 10.

One-sample t test, gpf of toilets, improved optic automatic system.

	One-Sample Test					
	Test Value = 1.6					
	t	df	Sig. (2-tailed)	Mean difference	95% Confidence Interval of the Difference	
					Lower	Upper
gpf	5.392	239	.000	.0695	.0441	.0948

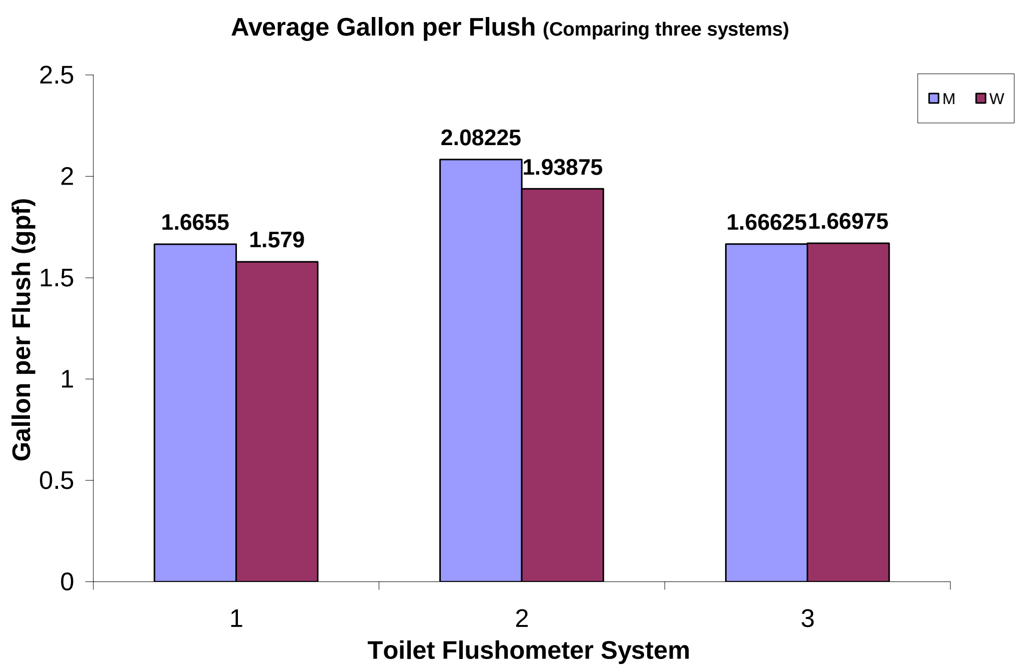
Graphs (univariates) Comparing Three Phases in the Study

From table 11 and figure 15, water consumption of low-consumption manual and improved optic automatic systems in the graph appear the same level; however, a slightly lower value occurred with the old optic automatic system.

Table 11.

Average gallons per flush of toilets, comparing three systems.

	Low-Consumption		Old Optic Automatic		Improved Optic Automatic	
Floor	Men	Women	Men	Women	Men	Women
1	1.69	1.58	2.11	1.79	1.67	1.59
2	1.51	1.40	1.92	2.00	1.62	1.74
3	1.76	1.51	2.26	2.12	1.73	1.70
4	1.71	1.83	2.04	1.85	1.66	1.65



1.Low-consumption Manual 2. Old Optic Automatic System 3. Improved Optic Automatic System

Figure 15: Average Gallons per Flush, Comparing Three Systems

Analysis of Variance (ANOVA) by Phase

To answer hypothesis two, the analysis of variance was conducted to determine which factors affect water volume per flush in toilets. Then the multiple-comparison Dunnett's procedure was conducted. Dunnett's procedure treats one group as a control and compares all other groups against it. In this study, it was used to compare the improved optic automatic versus old optic automatic system and low-consumption manual toilets.

Objective One

The objective one is to determine which factors affect average water volume per flush.

ANOVA Table

Types of flushometer, gender, and floors are the factors used to examine in the study. Table 12, the analysis of variance (ANOVA) table, identifies which factors affect gpf. The test is significant at 0.05 level, α =0.05. Table 12 shows that the significant value of type, gender, and floor are 0.000, 0.23, and 0.379, respectively. Therefore, statistically it is demonstrated that only the type of flushometer affects the difference in gpf, as the significant value is 0.000, lower than 0.05.

Table 12.

The Analysis of Variance (ANOVA) table, toilets.

Dependent variable: gpf					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	3.069	23	.133	2.077	.016
Intercept	199.817	1	199.817	3111.077	.000
Type	1.918	2	.959	14.930	.000
Gender	.092	1	.092	1.429	.238
Floor	.202	3	.067	1.050	.379
Type*Gender	.058	2	.029	.454	.638
Type*Floor	.328	6	.055	.850	.538
Gender*Floor	.105	3	.035	.545	.654
Type*Gender*Floor	.128	6	.021	.332	.917
Error	3.083	48	.064		
Total	227.745	72			
Corrected Total	6.152	71			

a. R squared = .499 (Adjusted R squared = .259)

Objective Two

Objective two is to identify which means differ among three flushometer systems

Multiple Comparison Table

From ANOVA table 12, we have a statistical reason to confirm that only the type of flushometer affects water volume per flush. A multiple comparison was conducted to explore the difference between the three types of fixtures.

Table 13, multiple comparison table, showed the mean difference between types of all phases.

Improved Optic Automatic System Versus Low-Consumption Manual

The mean difference is significant at 0.05 level, α =0.05. Table 12 is the multiple comparison, Dunnett's procedure results. The significant value of improved optic automatic system versus low-consumption manual is 0.908. The null hypothesis in this case is no water volume difference between the improved optic automatic and low-consumption manual phases. As the significant value is higher than 0.05, there is no significant difference between improved optic automatic system and low-consumption manual. Thus, we cannot reject the null hypothesis.

Improved Optic Automatic System and Old Optic Automatic System

The mean difference is significant at 0.05 level, α =0.05. Table 12 shows the multiple comparison Dunnett's procedure. The significant value of the improved optic automatic system versus the old optic automatic system is 0.000. The null hypothesis in this case is water volume per flush difference between the improved optic automatic and the low-consumption manual phases. As the significant value is lower than 0.05, there is a significant difference between the improved optic automatic system and old optic automatic system. Thus, we reject the null hypothesis.

Table 13.

The Analysis of Variance (ANOVA), multiple-comparison, Dunnett's procedures, higher than controls, toilets.

Multiple Comparisons

Dependent Variable: gpf

Dunnett (>control)[a]

(I) TYPE	(J) TYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval
					Lower Bound
low	improved	-.0601	.07316	.908	-.2036
old	improved	.3181*	.07316	.000	.1746

Based on observed means.

* The mean difference is significant at the 0.5 level.

a. Dunnett t tests treat one group as a control and compare all other groups against it.

Low-consumption Manual and Old Optic Automatic System

The mean difference is significant at 0.05 level, α =0.05. Table 14 is the multiple comparison, Dunnett's procedure, without floor and gender controls. The significant value of low-consumption manual versus old optic automatic system is 0.000. The null hypothesis in this case is no water volume difference between the low-consumption manual and the old optic automatic phases. As the significant value lower than 0.05, there is significant difference between the low-consumption manual and the old optic automatic system. Thus, we reject the null hypothesis.

Table 14.

The Analysis of Variance (ANOVA), multiple comparison, Dunnett's procedure, less than controls, toilets.

Multiple Comparisons					
Dependent Variable: gpf					
Dunnett (<control)[a]					
(I) TYPE	**(J) TYPE**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**
					Upper Bound
improved	old	-.3181*	.07316	.000	-.1746
low	old	-.3782*	.07316	.000	-.2348

Based on observed means.

* The mean difference is significant at the 0.5 level.

a. Dunnett t tests treat one group as a control and compare all other groups against it.

Scatter Plot Analysis

Water volume data from 10 flushes on 24 toilets of each of three types of toilet—low-consumption manual, old optic automatic, and improved optic automatic—were averaged to obtain average water volume for flush for each type of fixture. Average flush volumes from a total of 24 toilets of each type were randomly collected. The scatter plot data is shown in figures 16 through 18.

Figure 16 shows the scatter plot of average gallon per flush of low-consumption manual phase. The mean of the average gpf is 1.61.

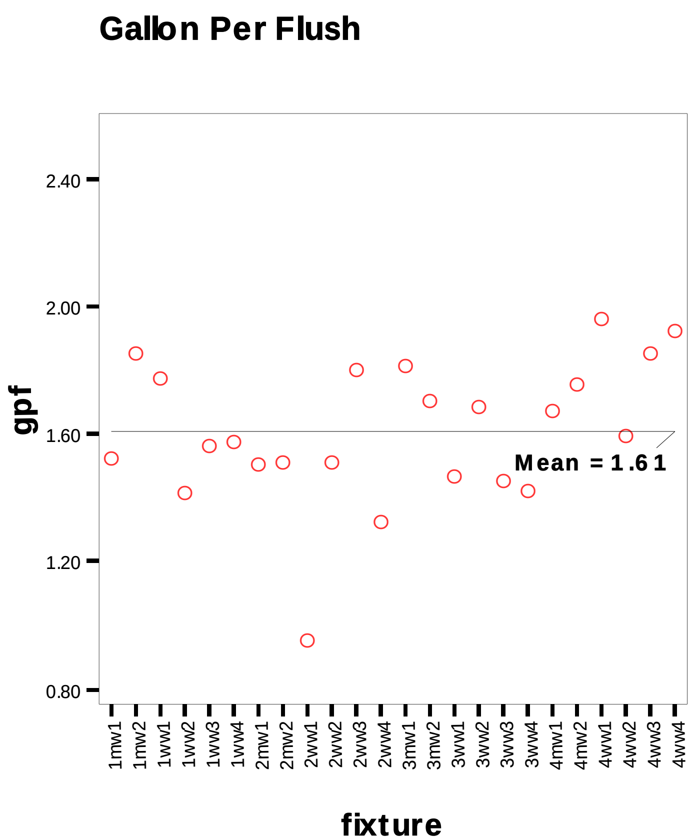


Figure 16: Scatter Plot of Toilet, Low-Consumption Manual Phase Data

Figure 17 shows the scatter plot of average gallon per flush of old optic automatic phase. The mean of the average gpf is 1.99.

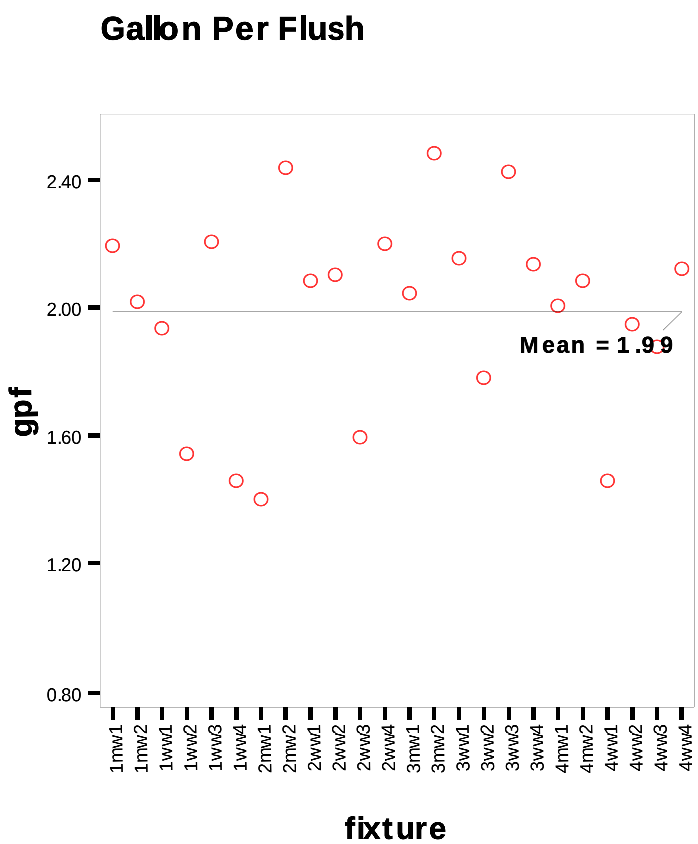


Figure 17: Scatter Plot of Toilet, Old Optic Automatic Phase Data

Figure 18 shows the scatter plot of the average water volume per flush of improved optic automatic system. The mean of the average gpf is 1.67.

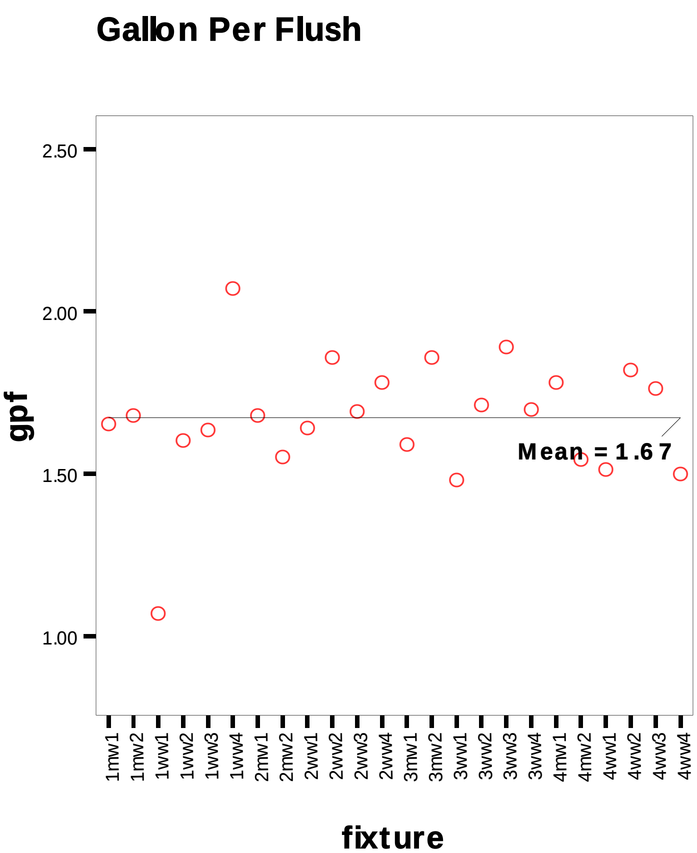


Figure 18: Scatter Plot of Toilet, Improved Optic Automatic Phase Data

RESULTS, URINAL STUDY

The results of the data obtained were analyzed to answer the research objective and to test the hypotheses three and four. Interpretations of the findings are shown in the figures and tables in this section.

Comparison to the Standard

The results of the study were analyzed to determine compliance with plumbing standards and compare the average water volume per flush of urinals in the men's restroom on each floor. Three types of flushometers—low-consumption manual, old optic automatic system, and improved optic automatic system—at the Langford Architecture Building, Texas A&M University were tested as detailed in the tables and figures in this section.

Low-Consumption Manual

Graphs (univariate)

Table 15 and Figure 19 show the average water volume per flush of the low-consumption manual urinal in the men's restroom on each floor. The water consumption of low-consumption urinals on floors 1 through 4 is 0.68 gpf, 0.74 gpf, 0.65 gpf, and 0.61 gpf, respectively. All fixtures consume less 1.0 gpf. Figure 19 shows the highest water volume per flush by urinals on the second floor; the lowest gpf on the fourth floor.

Table 15.

Gallons per flush of urinal, low-consumption manual.

	Floor	Men/Women	Fixture type	fixture no.	gpf	Average
1mu1	1	m	u	1	0.62	
1mu2	1	m	u	2	0.73	
1mu3	1	m	u	3	0.67	0.68
2mu1	2	m	u	1	0.64	
2mu2	2	m	u	2	0.77	
2mu3	2	m	u	3	0.82	0.74
3mu1	3	m	u	1	0.64	
3mu2	3	m	u	2	0.65	
3mu3	3	m	u	3	0.66	0.65
4mu1	4	m	u	1	0.62	
4mu2	4	m	u	2	0.60	
4mu3	4	m	u	3	0.62	0.61

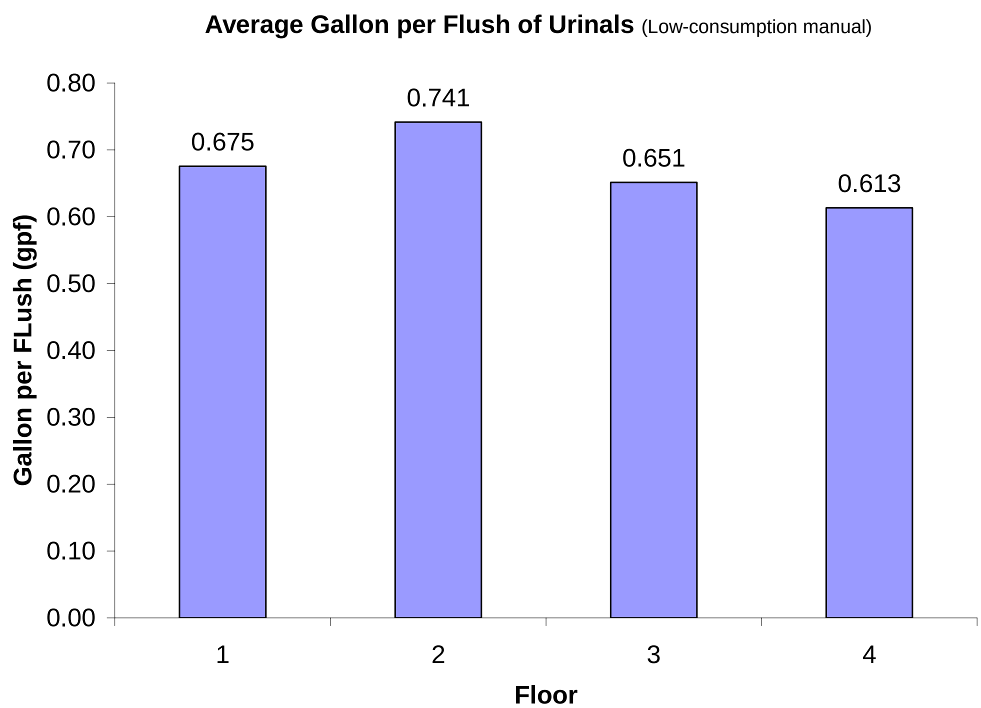


Figure 19: Average Gallons per Flush of Urinal, Low-Consumption Manual

T Test

To answer hypothesis three, a one sample t test was conducted to analyze whether the water volume of low-consumption manual systems is 1.0 gpf.

Table 16 shows the result of the one-sample t test. The mean difference is significant at 0.05 level, α =0.05. The significant value from t test is 0.000. The null hypothesis in this case is that the water consumption of all phases equals 1.0 gpf. As the significant value 0.000 is lower than 0.05, there is significant difference between mean and the standard. Thus, we reject the null hypothesis

Table 17 shows the one-sample statistics in gallons per flush of low-consumption manual urinals. There were 120 observations in the population with a mean 0.6674 gpf.

Table 16.

One-sample statistics, gpf of urinals, low-consumption manual.

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
gpf	120	.6674	.07815	.00713

Table 17.

One-sample t test, gpf of urinals, low-consumption manual.

	One-Sample Test					
	Test Value = 1.0					
	t	df	Sig. (2-tailed)	Mean difference	95% Confidence Interval of the Difference	
					Lower	Upper
gpf	-46.615	119	.000	-.3326	-.3467	-.3184

Old Optic Automatic System

Graphs (univariate)

Table 18 and Figure 20 show the average water volume per flush of old optic automatic system urinals in men's restroom on each floor. The water consumption of fixtures on floors 1 through 4 is 0.73 gpf, 0.81 gpf, 0.81 gpf, and 0.57 gpf, respectively. All fixtures show water consumption lower than 1.0 gpf. Figure 20 shows the highest water volume per flush in urinals on the second floor; the lowest gpf on the fourth floor.

Table 18.

Gallons per flush of urinal, old optic automatic system.

	Floor	Men/Women	Fixture type	fixture no.	gpf	Average
1mu1	1	m	u	1	0.438	
1mu2	1	m	u	2	0.929	
1mu3	1	m	u	3	0.836	0.73
2mu1	2	m	u	1	0.959	
2mu2	2	m	u	2	0.67	
2mu3	2	m	u	3	0.794	0.81
3mu1	3	m	u	1	0.949	
3mu2	3	m	u	2	1.017	
3mu3	3	m	u	3	0.449	0.81
4mu1	4	m	u	1	0.424	
4mu2	4	m	u	2	0.318	
4mu3	4	m	u	3	0.971	0.57

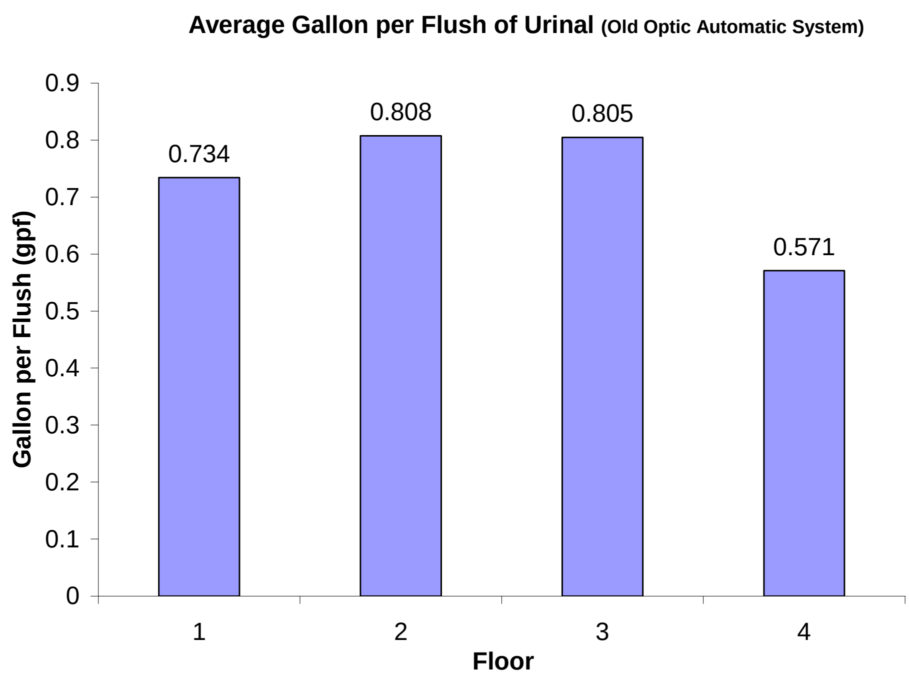


Figure 20: Average Gallons per Flush of Urinal, Old Optic Automatic System

T Test

To answer hypothesis three, one sample t test was conducted to analyze whether the water volume of old optic automatic system equals 1.0 gpf.

Table 19 shows the one-sample statistics in gallons per flush of old optic automatic system of urinal. There were 120 observations in the population with a mean 0.7296 gpf.

Table 20 shows the result of the one-sample t test. The mean difference is significant at 0.05 level, $\alpha = 0.05$. The significant value from t-test is 0.000. The null hypothesis in this case is that the water consumption in gpf of all phases equals to 1.0 gpf. As the significant value 0.000 is lower than 0.05, there is significant difference between mean and the standard. Thus, we reject the null hypothesis.

Table 19.

One-sample statistics, gpf of toilets, old optic automatic system.

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
gpf	120	.7296	.25041	.02286

Table 20.

One-sample t test, gpf of toilets, old optic automatic system.

	One-Sample Test					
	Test Value = 1.6					
	t	df	Sig. (2-tailed)	Mean difference	95% Confidence Interval of the Difference	
					Lower	Upper
gpf	-11.829	119	.000	-.2704	-.3157	-.2251

Improved Optic Automatic System

Graphs (univariate)

Table 21 and Figure 21 show the average water volume per flush of the improved optic automatic system urinal in the men's restroom on each floor. The water consumption in fixtures on floors 1 through 4 is 1.07 gpf, 0.92 gpf, 0.92 gpf, and 0.98 gpf, respectively. The water volume per flush of the first floor alone is a slightly higher than 1.0 gpf. The others are lower than 1.0gpf. Figure 22 shows the highest flush volume of urinals on the first floor; the lowest gpf on the second and third floor.

Table 21.

Gallons per flush of urinal, improved optic automatic system.

	Floor	Men/Women	Fixture type	fixture no.	gpf	Average
1mu1	1	m	u	1	1.08	
1mu2	1	m	u	2	1.09	
1mu3	1	m	u	3	1.03	1.07
2mu1	2	m	u	1	0.93	
2mu2	2	m	u	2	0.83	
2mu3	2	m	u	3	0.99	0.92
3mu1	3	m	u	1	1.11	
3mu2	3	m	u	2	1.00	
3mu3	3	m	u	3	0.65	0.92
4mu1	4	m	u	1	0.77	
4mu2	4	m	u	2	1.11	
4mu3	4	m	u	3	1.06	0.98

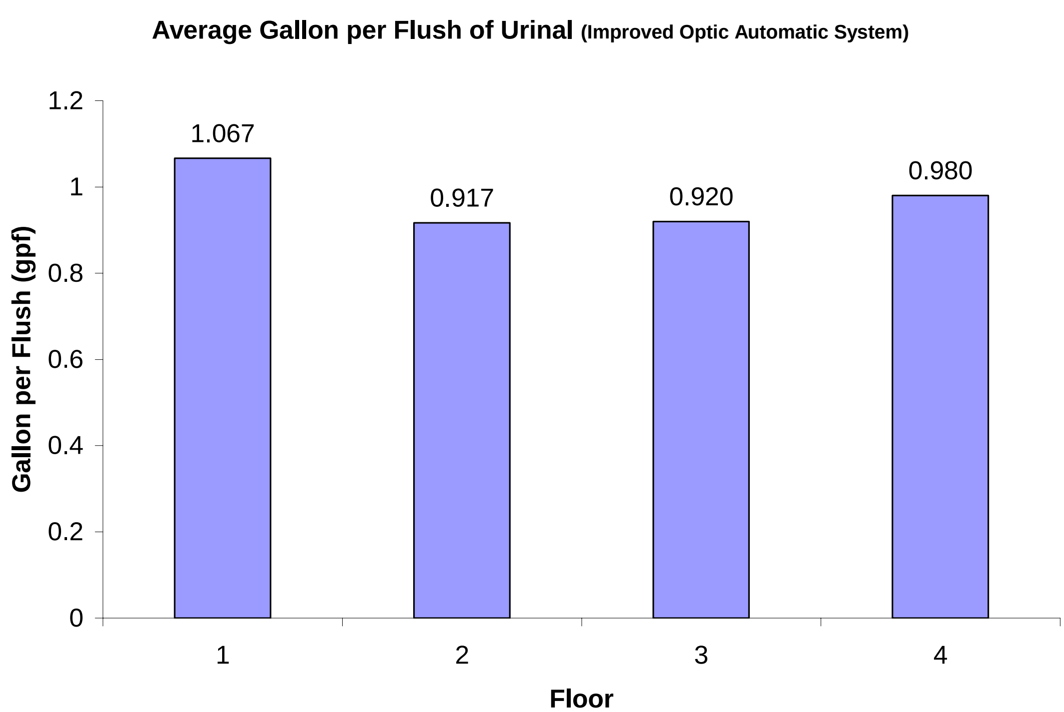


Figure 21: Average Gallons per Flush of Urinal, Improved Optic Automatic System

T Test

To answer hypothesis three, a one sample t test was conducted to analyze whether the water volume of the improved optic automatic system equals 1.0 gpf.

Table 22 shows the one-sample statistics in gallons per flush of the improved optic automatic system of urinal. There were 120 observations in the population with a mean 0.9712 gpf.

Table 23 shows the result of the one-sample t test. The mean difference is significant at 0.05 level, $\alpha = 0.05$. The significant value from t-test is 0.049. The null hypothesis in this case is that the water consumption in gpf of all phases equals to 1.0 gpf. As the significant value 0.049 is lower than 0.05, there is significant difference between mean and the standard. Thus, we reject the null hypothesis.

Table 22.

One-sample statistics, gpf of urinals, improved optic automatic system.

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
gpf	120	.9712	.15903	.01452

Table 23.

One-sample t test, gpf of urinals, improved optic automatic system.

	One-Sample Test					
	Test Value = 1.6					
	t	df	Sig. (2-tailed)	Mean difference	95% Confidence Interval of the Difference	
					Lower	Upper
gpf	-1.986	119	.049	-.0288	-.0576	-.0001

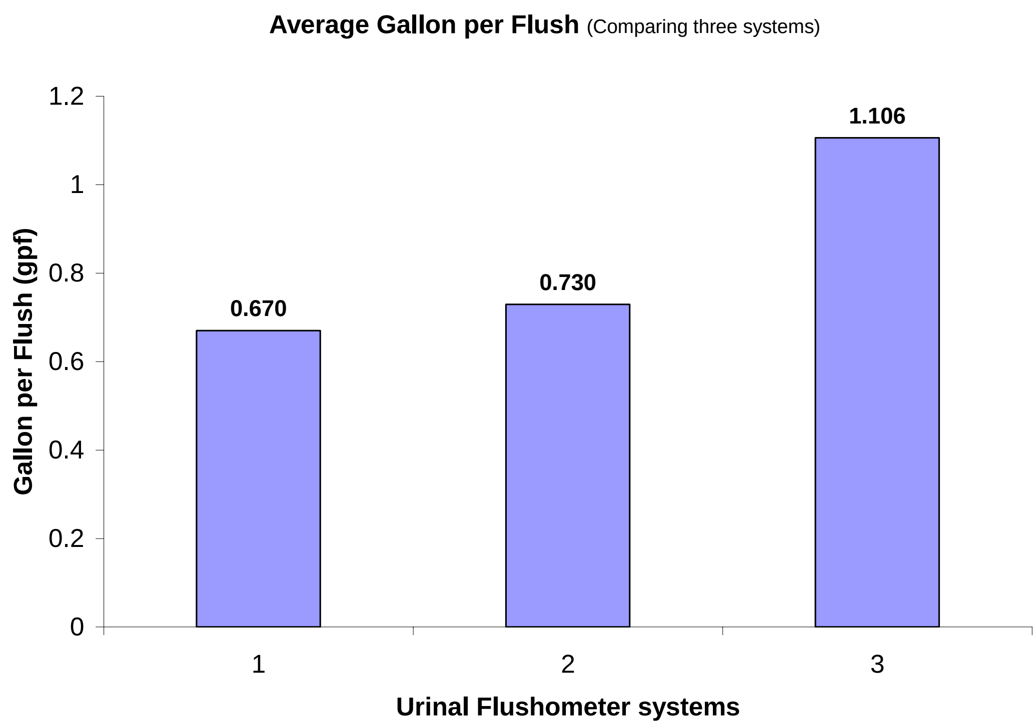
Graphs (univariates) Comparing Three Phases in the Study

Table 24 and figure 21 show that the improved optic automatic system has the highest water consumption among the three urinal types. The lowest water volume per flush was exhibited by the low-consumption manual consumed, which used an average of 0.67 gpf.

Table 24**.**

Average gallons per flush of urinal, comparing three systems.

Floor	Low-Consumption	Old Optic Auto	Improved Optic Auto
1	0.68	0.734	1.607
2	0.74	0.808	0.917
3	0.65	0.805	0.92
4	0.61	0.571	0.98
average	0.67	0.7295	1.106



1. Low-consumption Manual 2. Old Optic Automatic System 3. Improved Optic Automatic System

Figure 22: Average Gallons per Flush of Urinal, Comparing Three Systems

Analysis of Variance (ANOVA) by Phase

To answer hypothesis four, an analysis of variance was conducted to determine which factors affect water volume per flush in urinals. Then the multiple-comparison Dunnett's procedure was conducted. Dunnett's procedure treats one group as a control and compares all other groups against it. In this study, it was used to compare the improved optic automatic versus old optic automatic system and low-consumption manual urinals.

Objective One

The objective one of this research is to determine which factors affect average water volume per flush.

ANOVA Table

In this study, the researcher assumed that there are two factors—type of flushometer and floor—affected the mean difference of water consumption. The analysis of variance (ANOV) table identified which factors affect gpf. The test is significant at 0.05 level, α =0.05. Table 25 shows that the significant value of floors and types are 0.662 and 0.001, respectively. Therefore, statistically it is demonstrated that only the type of flushometer affects water volume per flush, as the significant value is 0.001, lower than 0.05.

Table 25.

The Analysis of Variance (ANOVA) table, urinals.

Dependent variable: gpf					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	.791	11	.072	2.061	.067
Intercept	22.474	1	22.474	643.758	.000
Floor	.063	3	.021	.599	.622
Type	.609	2	.305	8.724	.001
Floor*Type	.119	6	.020	.570	.750
Error	838	24	.035		
Total	24.103	36			
Corrected Total	1.629	35			

a. R squared = .498 (Adjusted R squared = .250)

Objective Two

The objective two is to identify which means differ among three flushometer systems

Multiple Comparison Table

From ANOVA table 25, we have a statistical reason to confirm that only the type of flushometer affects flush water volume. A multiple comparison was conducted to explore the difference between the three types of fixtures.

Table 26, multiple comparisons table, showed the mean difference between types of all phases.

Improved Optic Automatic System Versus Low-Consumption Manual

The mean difference is significant at 0.05 level, $\alpha = 0.05$. Table 26 is the multiple comparison, Dunnett's procedure. The significant value of improved optic automatic system versus low-consumption manual is 1.000. The null hypothesis in this case is no gpf difference between improved optic automatic and low-consumption manual phases. As the significant value 1.000 is higher than 0.05, there is no significant difference between improved optic automatic system and low-consumption manual. Therefore, we cannot reject the null hypothesis.

Improved Optic Automatic System and Old Optic Automatic System

The mean difference is significant at 0.05 level, $\alpha = 0.05$. Table 26 shows the multiple comparison, Dunnett's procedure. The significant value of the improved optic automatic system versus the old optic automatic system is 1.000. The null hypothesis in this case is no water volume per flush difference between the improved optic automatic and the old optic automatic phases. As the significant value 1.000 is higher than 0.05, there is no significant difference between improved optic automatic system and low-consumption manual. Thus, we cannot reject the null hypothesis.

Table 26.

The Analysis of Variance (ANOVA), multiple-comparison, Dunnett's procedures, higher than controls, urinals.

Multiple Comparisons

Dependent Variable: gpf

Dunnett (>control)[a]

(I) TYPE	(J) TYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval
					Lower Bound
low	improved	-.3008	.07628	1.000	-.4540
old	improved	-.2413	.07628	1.000	-.3945

Based on observed means.

a. Dunnett t tests treat one group as a control and compare all other groups against it.

Low-consumption Manual and Old Optic Automatic System

The mean difference is significant at 0.05 level, α =0.05. Table 27 is the multiple comparison, Dunnett's procedure, without the insignificant variable *floor*. The significant value of low-consumption manual versus old optic automatic system is 0.341. The null hypothesis in this case is no water volume per flush difference between the low-consumption manual and the old optic automatic phases. As the significant value is higher than 0.05, there is no significant difference between low-consumption manual and old optic automatic system. Thus, we cannot reject the null hypothesis.

Table 27.

The Analysis of Variance (ANOVA), multiple-comparison, Dunnett's procedure, less than controls, urinals.

Multiple Comparisons

Dependent Variable: gpf

Dunnett (<control)[a]

(I) TYPE	(J) TYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval
					Upper Bound
low	improved	.2413	.07628	1.000	.3945
old	improved	-.0595	.07628	.341	.0937

Based on observed means.

a. Dunnett t tests treat one group as a control and compare all other groups against it.

Scatter Plot Analysis

Water volume data from 10 flushes for 12 urinals of each of three types of urinals — low-consumption manual, old optic automatic and improved optic automatic—were averaged to obtain average water volume for each type of fixture. Average flush volumes from a total of 12 fixtures of each type were randomly collected. The scatter plot data is shown in figures 22 through 24.

Figure 23 shows the scatter plot of average gallon per flush of the low-consumption manual phase fixture. The mean of the average gpf is 0.67.

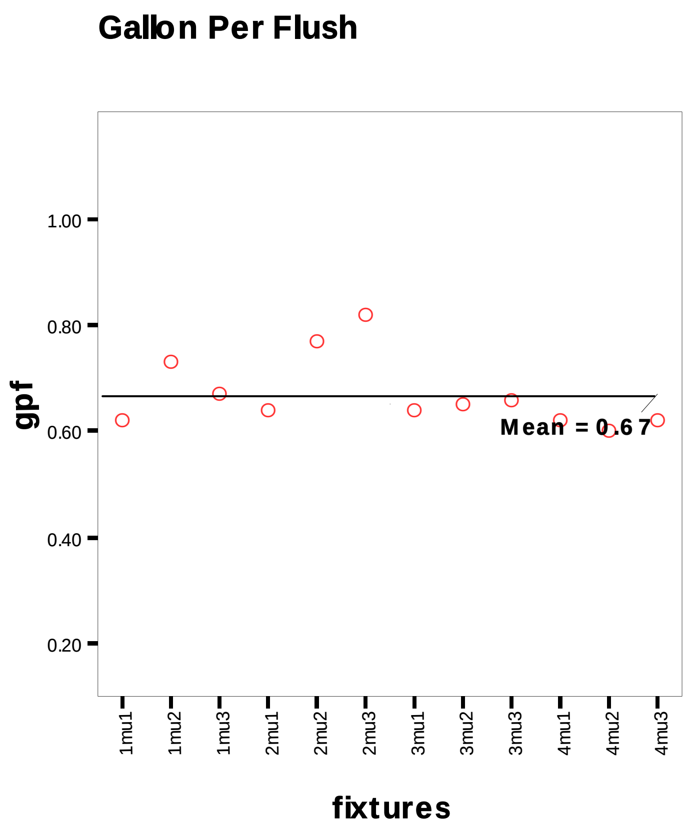


Figure 23: Scatter Plot of Urinal, Low-Consumption Manual Phase Data

Figure 24 shows the scatter plot of average gallon per flush of old optic automatic phase. The mean of the average gpf is 0.73.

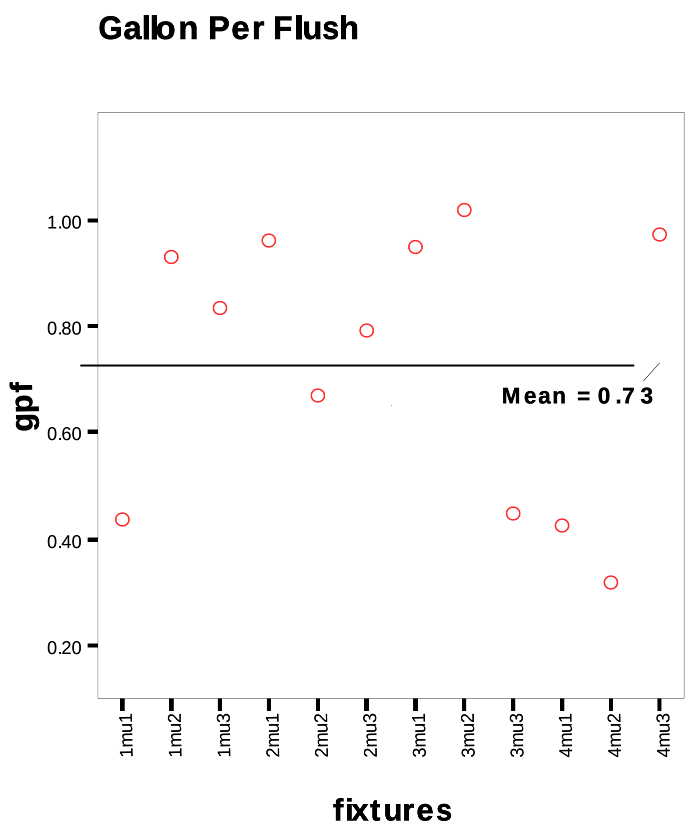


Figure 24: Scatter Plot of Urinal, Old Optic Automatic Phase Data

Figure 25 shows the scatter plot of average gallon per flush of improved optic automatic system. The mean of the average gpf is 0.97.

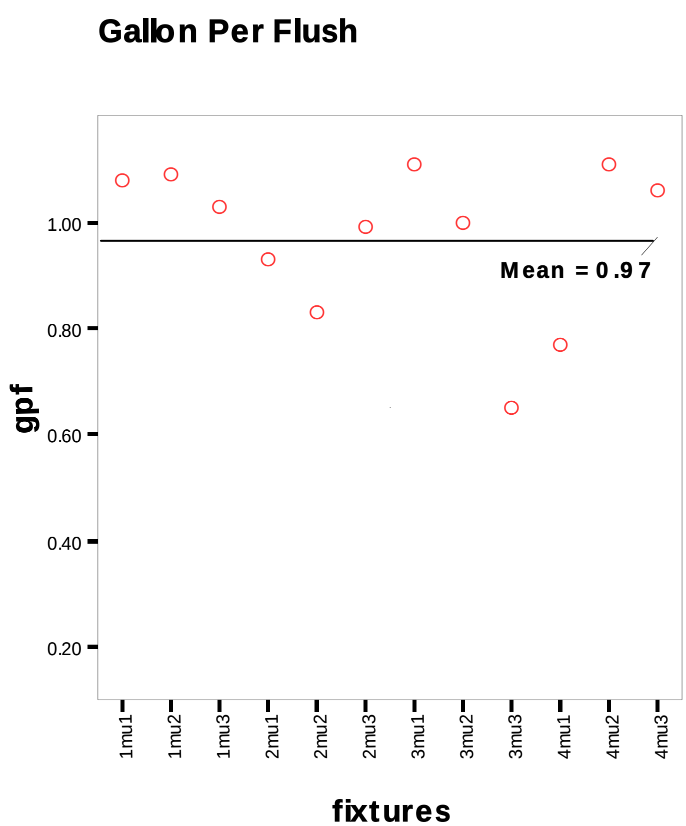


Figure 25: Scatter Plot of Urinal, Improved Optic Automatic Phase Data

CONCLUSION

Toilets

Hypothesis One

The data were examined to evaluate the following null and research hypotheses.

The Null Hypothesis

Ho: The water volume per flush measured in gallons per flush in the three types of toilets—improved optic automatic system, old optic automatic system, and low-consumption manual—is 1.6 gpf or less. (Ho: $\mu_{WCN} = \mu_{WCO} = \mu_{WCL} = 1.6$ gpf)

The Research Hypothesis

Ha: The water volume per flush measured in gallons per flush in three types of toilets—improved optic automatic system, old optic automatic system, and low-consumption manual—is not equal to 1.6 gpf.(Ha: μWCN # μWCO # μWCL # 1.6 gpf)

Observations in the Population

A total of 240 observations were conducted in this study.

Objective

To measure the water volume per flush of the improved optic automatic system, old optic automatic system and low-consumption manual toilets in both men's and women's restrooms and determine whether they conform to the 1992 Plumbing Efficiency Act standard. The standard requires 1.6 gpf in toilets.

Table and Figure Analysis

Low-Consumption Manual

From table 28, the mean of low-consumption manual is 1.6083 gpf, and, table 29; it is not significantly different than the standard of 1.6 gpf. Therefore, the water consumption of low-consumption manual is equal to 1.6 gpf and does comply with the 1992 Energy Policy Act standard.

Old Optic Automatic System

From table 28, the mean of old optic automatic system is 1.9866 gpf and, table 29; it is significantly greater than the standard of 1.6 gpf. Therefore, the water consumption of old optic automatic exceeds 1.6 gpf and does not comply with the 1992 Energy Policy Act standard.

Improved Optic Automatic System

From table 28, the mean of improved optic automatic system is 1.6695 gpf and, table 29; it is significantly greater than the standard of 1.6 gpf. Therefore, the water consumption of improved optic automatic exceeds 1.6 gpf and does not comply with the 1992 Energy Policy Act standard.

Table 28.

Univariate statistics conclusion (toilet).

gpf	N	Mean	Std. Deviation	Std. Error Mean
Low-consumption manual	240	1.6083	0.22553	0.01456
Old optic automatic	240	1.9866	0.30670	0.01980
Improved optic automatic	240	1.6695	0.19955	0.01288

Table 29.

One-sample t test conclusion (toilet).

gpf	Test value = 1.6					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Low-consumption manual	.570	239	.569	0.0083	-0.0204	0.0370
Old optic automatic system	19.527	239	0.000	0.3866	0.3476	0.4256
Improved optic automatic system	0.5392	239	0.000	0.0695	0.0441	0.0948

Hypothesis Two

The data are examined by the following the null and research hypothesis.

The Null Hypothesis

Ho: The average water volume per flush measured in gallons per flush in toilets of three systems, improved optic automatic system, old optic automatic system and low-consumption manual, are equal. (Ho: $\mu_N = \mu_O = \mu_L$)

The Research Hypothesis

Ha: At least one average water volume per flush measured in gallons per flush of toilets in women's and men's restrooms differs from the rest.

Observations in the Population

A total of 72 observations were conducted in this study.

Objective One

Objective one is to determine which factors affect average water volume per flush.

Analysis of Variance Table Analysis

The result as shown in the analysis of variance (ANOV) table indicates that only the types of flushometer in toilets are significant, while the other variables, such as genders and floors, are not significant. Therefore, the type of flushometer is the only factor influencing in difference of water consumption.

Objective Two

Objective two is to identify which means differ among three flushometer systems.

Multiple Comparisons Table Analysis

Improved Optic Automatic System and Low-Consumption Manual

As shown in table 30, there is no significant difference at $p < .05$ between low-consumption manual and improved optic automatic systems. Therefore it can be concluded that the gallons per flush that these two systems use is statistically equal.

Improved Optic Automatic System and Old Optic Automatic System

As shown in table 30, there is a significant difference at $p < .05$ between old optic automatic and improved optic automatic systems. Therefore it can be concluded that the gallons per flush of old optic automatic is greater than that of the improved optic automatic system.

Low-Consumption Manual and Old Optic Automatic System

As shown in table 30, there is a significant difference at $p < .05$ between old optic automatic and low-consumption manual. Therefore it can be concluded that the gallons per flush of old optic automatic is greater than that of the low-consumption manual.

Table 30.

The Analysis of Variance (ANOVA), multiple-comparison, Dunnett's Procedure (toilets).

Multiple Comparisons						
Dependent Variable: gpf						
a) Dunnett (>control) b) Dunnett (<control)[a]						
(I) TYPE	**(J) TYPE**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95%Confidence Interval**	
					Lower Bound	**Upper Bound**
a) low	improved	-.0601	.07316	.908	-.2036	
a) old	improved	.3181*	.07316	.000	.1746	
b) low	old	-.3782*	.07316	.000		-.2348

Based on observed means.

* The mean difference is significant at the 0.5 level.

a. Dunnett t tests treat one group as a control and compare all other groups against it.

Conclusion

The water volumes per flush of low-consumption manual and improved optic automatic are not significantly different. However, there are significant differences between old optic automatic and improved optic automatic systems, and also low-consumption manual and old optic automatic systems. The water volume per flush of old optic automatic is higher than low-consumption manual and improved optic automatic systems. Finally, it can be concluded that the gallon per flush that these three systems use exceeds 1.6 gpf, and do not comply with the standard.

Urinals

Hypothesis Three

The data are tested by the following null and research hypothesis.

The Null Hypothesis

Ho: The water volume per flush (gpf) of improved optic automatic system, old optic automatic system and low-consumption manual are equal to 1.0 gpf.

(Ho: $\mu_{UL} = \mu_{UO} = \mu_{UN} = 1.0$ gpf)

Research Hypothesis

Ha: The water volume per flush of the improved optic automatic system, old optic automatic system and low-consumption manual differs from 1.0 gpf.

(Ho: μ_N # μ_O # μ_L # 1.0 gpf)

Observations in the Population

A total of 120 observations were conducted in this study.

Objective

To determine the water volume per flush measured for the improved optic automatic system, old optic automatic system and low-consumption manual in all urinals in men's restrooms meet the standards of the 1992 Plumbing Standards called for 1.0 gpf.

Table and Figure Analysis

Low-consumption manual

From table 31, the mean of low-consumption manual is 0.6674 gpf and, table 32; it is significantly lower than the standard of 1.0 gpf. Therefore, the water consumption of low-consumption manual less than 1.0 gpf and does comply with the 1992 Energy Policy Act standard.

Old optic automatic system

From table 31, the mean of old optic automatic system is 0.7296 gpf and, table 32; it is significantly lower than the standard of 1.0 gpf. Therefore, the water consumption of old optic automatic less than 1.0 gpf and does comply with the 1992 Energy Policy Act standard.

Improved optic automatic system

From table 31, the mean of old optic automatic system is 0.9712 gpf and, table 32; it is significantly lower than the standard of 1.0 gpf. Therefore, the water consumption of improved optic automatic less than 1.0 gpf and does comply with the 1992 Energy Policy Act standard.

Table 31.

Univariate statistics conclusion (urinal).

gpf	N	Mean	Std. Deviation	Std. Error Mean
Low-consumption manual	120	0.6674	0.7815	0.00713
Old optic automatic	120	0.7296	0.25041	0.02286
Improved optic automatic	120	0.9712	0.15903	0.01452

Table 32.

One-sample t test conclusion (urinal).

gpf	Test value = 1.0					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Low-consumption manual	-46.615	119	0.000	0.3326	-0.346	0.3184
Old optic automatic system	-11.829	119	0.000	0.2704	0.3157	0.2251
Improved optic automatic system	-1.986	119	0.049	0.0288	0.0576	0.0001

Hypothesis Two

The null hypothesis and research hypothesis are in the following:

The Null Hypothesis

Ho: The average water volume per flush (gpf) in urinals of three systems, improved optic automatic system, old optic automatic system and low-consumption manual are equal. (Ho: $\mu_N = \mu_O = \mu_L$)

The Research Hypothesis

Ha: At lease one of the average water volumes per flush (gpf) of urinals in women's and men's restrooms differs from the rest.

Observations in the Population

A total of 35 observations were conducted in this study.

Objective One

The objective one of this research is to determine which factors affect average water volume per flush.

Analysis of Variance Table Analysis

From the result, it indicates that only types of flushometer in urinal are significant, while the floors are not significant. Likewise, type of flushometer is the only factor influencing the difference of water consumption in gpf.

Objective Two

Objective two is to identify which means differ among three flushometer systems

Multiple Comparisons Table Analysis

Improved optic automatic system and low-consumption manual

As shown in table 33, there is no significant difference at $p < .05$ between low-consumption manual and improved optic automatic systems. Therefore it can be concluded that the gallons per flush that these two systems use is statistically equal.

Improved optic automatic system and old optic automatic system

As shown in table 33, there is no significant difference at $p < .05$ between old optic automatic and improved optic automatic systems. Therefore it can be concluded that the gallons per flush that these two systems use is statistically equal.

Low-consumption manual and old optic automatic system

As shown in table 33, there is no significant difference at $p < .05$ between low-consumption manual and improved optic automatic systems. Therefore it can be concluded that the gallons per flush that these two systems use is statistically equal.

Table 33.

The Analysis of Variance (ANOVA), multiple-comparison, Dunnett's procedure (urinals).

Multiple Comparisons

Dependent Variable: gpf

a) Dunnett (>control)[a] b) Dunnett (<control)[a]

(I) TYPE	(J) TYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
a) low	improved	-.3008	.07628	1.000	-.4540	
a) old	improved	-.2413	.07628	1.000	-.3945	
b) low	old	-.0595	.07628	0.341		-.0937

Based on observed means.

a. Dunnett t tests treat one group as a control and compare all other groups against it.

Conclusion

From the result above, the water volumes per flush are not significantly different in low-consumption manual and improved optic automatic systems, and also old optic automatic and improved optic automatic systems. However, the water volume per flush of low-consumption manual and old optic automatic systems appear significantly different. Water volume per flush of low-consumption manual is higher than old optic automatic system. Finally, it can be concluded that the gallons per flush that these three systems use are statistically equal and less than 1.0 gpf. They do comply with the standard.

Discussion

1. Low-consumption manual toilets exhibit the lowest water consumption as measured in gallons per flush.
2. The operation of improved optic automatic flushometer in toilets consumed less water, on average, than the old optic automatic flushometer.
3. The water per flush of all three systems, low-consumption manual, old optic automatic and improved optic automatic, in toilet exceed the standard of 1.6 gpf. On the other hand, they comply with the standard of 1.0 gpf in urinal.
4. When the fixtures are installed, they need to be calibrated to achieve flush water volume as listed in the specification. Additionally, fixtures must operate properly to achieve water savings.

Recommendation for Further Study

Accordingly the fixtures need to be calibrated after installation for proper operation. Thus, the further study of results after calibrating should be conducted to ensure that the actual field-measured gpf is as nears the specification as possible.

We suspect that the stop valve position may be the major factor affecting water volume in gpf for these low-consumption fixtures although the manufacturer claimed that the stop valve position does not affect water volume per flush. Hence, further study in this effect should be considered.

Based on the result above, although the means of all three systems in urinals are not significantly different in this study, a further study with a larger number of observations might find there are significant differences in water volume per flush.

REFERENCES

Hwan, B. (2003). “The Cost-Effectiveness of Retrofitting Sanitary Fixtures in Restrooms of a University Building”. Masters thesis, Department of Construction Science, Texas A&M University, College Station.

North Carolina Department of Environmental and Natural Resources Division of Pollution Prevention and Environmental Assistance. Water efficiency: Water management options. [WWW document] URL http://www.sustainablenc.org/thewaytogo/water/chap_4.htm (retrieved December 19, 2003).

Pratt, A. (1979). *The Water Economy of a Low-Flush Toilet in a Water Deficient Region.* Virgin Islands. Caribbean Research Institute, College of the Virgin Islands.

Sloan Valve Company (2004). “Sloan Valve Company Product Groups”. Retrieved May 9, 2004, [WWW document] URL: http://www.sloanvalve.com/products.asp.

United States General Accounting Office. (2000). *Water Infrastructure: Water-Efficient Plumbing Fixtures Reduce Water Consumption and Wastewater Flows.* Washington, DC.

Vickers, A. (2001). *Handbook of Water Use and Conservation*, Waterplow Press, Amherst, MA.

Supplemental Sources

A Massachusetts Water Resources Authority Publication (AMWRAP). “Facts about Ultra Low Flush Toilets”. [WWW document] URL http://www.mwra.state.ma.us/publications/ulftoilets.pdf, (retrieved December 19, 2003).

Arizona Municipal Water Users Association, Regional Water Conservation Committee (AMWUA, RWCC). (2003). Facility Manager’s Guide to Water Management. [WWW document] URL http://www.amwua.org/fmgtwm.pdf, (retrieved December 19, 2003).

Archambault, S. (2000). “One-Sample T Test;” Psychology Department, Wellesley College. [WWW document] URL http://www.wellesley.edu/Psychology/Psych205/onettest.html,(retrieved June 20, 2004).

Association of Manitoba Municipalities. “Water Efficiency School.” [WWW document] URL http://www.amm.mb.ca/, (retrieved December 19, 2003).

Chaplin, S. (1998). *Water Efficiency: The Next Generation*. Rocky Mountain Institute, Snowmass, CO.

Dickinson, A.M., Maddaus, L.A.and Maddaus, W.O. (2001). "Benefits of the United States Nationwide Plumbing Efficiency Standards". [WWW document] URL http://www.isf.uts.edu.au/whatsnew/PlumbingStandardsPaper.pdf, (retrieved December 19, 2004).

Howell, D. C. (1998). *Glossary of Fundamental Statistics for the Behavioral Sciences*; Fourth Edition. [WWW document]URL http://www.uvm.edu/~dhowell/StatPages/Fundamentals/Glossary.html, (retrieved June 13, 2004).

Lewis, B. (2000). *Facility Manager's Portable Handbook*. New York: McGraw-Hill.

Longnecker, M.and Ott, R.L. (2001).*An Introduction to Statistical Methods and Data Analysis, Fifth Edition*. Pacific Grove, CA, Duxbury Thomson Learning, Inc.

Parker, K. (2002). "Determination of Maximum Flow Rate in a Building Water Supply System by Means of Acoustic Observation". Doctoral dissertation, Texas A&M University, College Station.

Reid, R. (1996). *Water Quality and Systems: A Guide for Facility Managers*. Up Word Publishing. Inc., New York.

Rocky Mountain Institute. (1991). *Water Efficiency: A Resource for Utility Managers, Community Planners, and Other Decision Makers*. Snowmass, CO.

Rosemount Inc. (2000). "Model 8712 C/U/H Magnetic Flowmeter Transmitters." [WWW document]URL http://www.rosemount.com/ document/man/4729man.pdf, (retrieved Aug 29, 2004).

Shea, K. (2000). "Frequency of Plumbing Fixture Use Through Audio Sampling." Doctoral dissertation, Texas A&M University, College Station.

Swaffield, J.A.and Wise A.F.E. (2002). *Water, Sanitary and Waste Services for Building*. Woburn: MA, Butterworth-Heinemann.

"Water Audit Procedure for Large Water Consumers." [WWW document] URL http://www.dep.state.pa.us/dep/subject/hotopics/ drought/facts/audit.pdf, (retrieved December 19, 2003).

APPENDIX A

Magnetic Water Flow Meter Specification

00809-0100-4729
English
Rev. CA

Model 8712C/U/H Magnetic Flowmeter Transmitters

ROSEMOUNT®
FISHER-ROSEMOUNT™

Section 6

Specifications

SPECIFICATIONS

Functional Specifications

Flowtube Compatibility

Model 8712C is compatible with all Rosemount flowtubes – Model 8705, Model 8707, and Model 8711. The Model 8712U is also compatible with AC and DC powered flowtubes of other manufacturers. The Model 8712H is only compatible with Model 8707 high-signal flowtube.

Flowtube Coil Resistance

Model 8712C: 25 Ω maximum

Model 8712U: 350 Ω maximum

Model 8712H: 10 Ω maximum

Flow Rate Range

Capable of processing signals from fluids that are traveling between 0.04 and 30 ft/s (0.01 to 10 m/s) for both forward and reverse flow in all flowtube sizes; full scale continuously adjustable between –30 and 30 ft/s (–10 to 10 m/s)

Conductivity Limits

Process liquid must have a conductivity of 5 microsiemens/cm (5 micromhos/cm) or greater for Model 8712C/U; process liquid must have a conductivity of 50 microsiemens/cm (50 micromhos/cm) for the Model 8712H (excludes the effect of interconnecting cable length in remote mount transmitter installations)

Power Supply

Model 8712C/U:	115 or 230 V ac ±10%, 50–60 Hz or 10–30 V dc
Model 8712H:	115 V ac ±10%, 50–60 Hz

Installation Coordination

Installation (overvoltage) Category II

Power Consumption

Model 8712C/U: 20 watts maximum

Model 8712H: 300 watts maximum

Ambient Temperature Limits

Operating

Model 8712C/U:	–20 to 140 °F (–29 to 60 °C) with local operator interface
	–30 to 150 °F (–34 to 66 °C) without local operator interface
Model 8712H:	–20 to 130 °F (–29 to 54 °C) with or without local operator interface

Storage

–22 to 176 °F (–30 to 80 °C)

Humidity Limits

0–100% RH at 120 °F (49 °C), decreases linearly to 10% RH at 130 °F (54 °C)

Enclosure Ratings

NEMA 4X, CSA Enclosure Type 4X

Output Signals

Analog Output Adjustment

4–20 mA, jumper-selectable as internally or externally powered 5 to 24 V dc; 0 to 1000 Ω load

Engineering units – lower and upper range values are user-selectable

Output automatically scaled to provide 4 mA at lower range value and 20 mA at upper range value; full scale continuously adjustable between -30 and 30 ft/s (-10 to 10 m/sec), 1 ft/s (0.3 m/s) minimum span

HART communications, digital flow signal, superimposed on 4–20 mA signal, available for control system interface; 250 Ω required for HART communications

Scalable Frequency Adjustment

0-1000 Hz, externally powered at 5 to 24 V dc, translator switch closure up to 5.75 w; pulse value can be set to equal desired volume in selected engineering units; pulse width adjustable from 0.5 to 100 m/s.

Local operator interface automatically calculates and displays maximum allowable output frequency.

Auxiliary Output Function

Externally powered at 5 to 24 V dc, transistor switch closure up to 3 W to indicate either:

Reverse Flow: Activates switch closure output when reverse flow is detected; reverse flow rate is displayed

Zero Flow: Activates switch closure output when flow goes to 0 ft/s

Positive Zero Return

Forces outputs of the transmitter to the zero flow rate signal level; activated by applying a contact closure

Software Lockout

Security lockout jumper on the electronics board can be set to deactivate all LOI and HART-based communicator functions to protect configuration variables from unwanted or accidental change

Output Testing

Analog Output Test

Transmitter may be commanded to supply a specified current between 3.75 and 23.25 mA

Pulse Output Test

Transmitter may be commanded to supply a specified frequency between 1 and 1000 Hz

Turn-on Time

30 minutes to rated accuracy from power up,
5 seconds from power interruption

Start-up Time

0.2 seconds from zero flow

Low Flow Cutoff

Adjustable between 0.04 and 1 ft/s (0.01 and 0.3 m/s); below selected value, output is driven to the zero flow rate signal level

Overrange Capability

Signal output will remain linear until 110% of upper range value or 33 ft/s; signal output will remain constant above these values; out of range message displayed on LOI and the HART Communicator

Damping

Adjustable between 0.2 and 256 seconds

Flowtube Compensation

Rosemount flowtubes are flow-calibrated and assigned a calibration factor at the factory. The calibration factor is entered into the transmitter, enabling interchangeability of flowtubes without calculations or a compromise in accuracy.

Model 8712U transmitters and other manufacturer's flowtubes can be calibrated at known process conditions or at the Rosemount NIST-Traceable Flow Facility. Transmitters calibrated on site require a two-step procedure to match the known flow rate.

Hazardous Locations Certifications

N0 Factory Mutual (FM) Approval Non-incendive, non-flammable fluid service for Class I, Division 2 Groups A, B, C, and D; Dust-ignition proof for Class II/III, Division 1 Groups E, F, and G hazardous locations. T5 temperature level
AND
Canadian Standards Association (CSA) Approval Suitable for use in Class I, Division 2 Groups A, B, C, and D; Dust-ignition proof for Class II/III, Division 1, Groups E, F, and G hazardous locations

N5 Factory Mutual (FM) Approval Non-incendive, flammable fluid service for Class I, Division 2 Groups A, B, C, and D; Dust-ignition proof for Class II/III, Division 1 Groups E, F, and G hazardous locations. T5 temperature level

CE CE Marking

Performance Specifications

(System specifications are given using the frequency output and with the unit at referenced conditions.)

Accuracy

Model 8712C/U with Model 8705 Flowtube

System accuracy is ±0.5% of rate from 1 to 30 ft/s (0.3 to 10 m/s); between 0.04 and 1.0 ft/s (0.01 and 0.3 m/s), the system has an accuracy of ±0.005 ft/s; analog output has the same accuracy as frequency output plus an additional 0.01% of span

Model 8712H with Model 8707 Flowtube

System accuracy is ±0.5% of rate from 3 to 30 ft/s (1 to 10 m/s); between 0.04 and 3.0 ft/s (0.01 and 0.3 m/s), the system has an accuracy of ±0.005 ft/s; analog output has the same accuracy as frequency output plus an additional 0.1% of span

Model 8712C/U with Model 8711 Flowtube

System accuracy is ±0.5% of rate from 3 to 30 ft/s (1 to 10 m/s); below 3 ft/s (1 m/s), the system has an accuracy of ±0.015 ft/s (0.005 m/s); analog output has the same accuracy as frequency output plus an additional 0.1% of span

Model 8712U with Other Manufacturers' Flowtubes

When calibrated in the Rosemount Flow Facility, system accuracies as good as 0.5% of rate can be attained. Analog output has the same accuracy as frequency output, plus an additional 0.05% of span.

There is no accuracy specification for other manufacturers' flowtubes calibrated in the process line.

Vibration Effect
±0.1% of span per SAMA PMC 31.1, Level 2

Repeatability
±0.1% of reading

Response Time
0.2 seconds maximum response to step change in input

Stability
±0.1% of rate over six months

Ambient Temperature Effect
±1% per 100 °F (37.8 °C)

RFI Effect
Class 1, A, B, C: ±0.5% of span at 3 V/m per SAMA PMC 33.1, wires and conduit

Supply Voltage Effect
Transmitter meets supply voltage effect requirements of SAMA PMC 31.1, Section 5.10.1 through 5.10.5; transmitter withstands surges in supply voltage as specified in IEEE 472, 1974

Physical Specifications

Materials of Construction

Housing

Low-copper aluminum, NEMA 4X and IEC 529 IP65

Pollution Degree 2

Paint

Polyurethane

Cover Gasket-

Rubber

Electrical Connections

Three ¾–14 NPT connections provided on the base of the transmitter; screw terminals provided for all of the connections; power wiring connected to the transmitter only; remote mounted transmitters require only a single conduit connection to the flowtube; integrally mounted transmitters are factory-wired to the flowtube

Cable Requirements for Remote-Mount Transmitters

Description	P/N
Signal Cable (20 AWG) Belden 8762, Alpha 2411 equivalent	08712-0061-0001
Coil Drive Cable (14 AWG) Belden 8720, Alpha 2442 equivalent	08712-0060-0001
Combination Signal and Coil Drive Cable (18 AWG)(1) Belden 9368 equivalent	08712-0750-0001

(1) Combination signal and coil drive cable is not recommended for high-signal magmeter system. For remote-mount installations, combination signal and coil drive cable should be limited to less than 100 ft (30 m).

Remote transmitter installations require equal lengths of signal and coil drive cables. Integrally mounted transmitters are factory-wired and do not require interconnecting cables.

Lengths from 5 to 1,000 feet (1.5 to 300 meters) may be specified and will be shipped with the flowtube. When ordering the combination cable, the lengths specified must be from 5 to 500 feet (1.5 to 150 meters).

Cable longer than 100 feet (30 meters) is not recommended for high-signal systems.

Line Power Fuses

115 V ac systems

1 amp, Quick-acting Bussman AGCI or equivalent

5 amp, Quick-acting Bussman AGCI or equivalent (Model 8712H only)

230 V ac systems

0.5 amp, Quick-acting Bussman AGCI or equivalent

10–30 V dc systems

3 amp, Quick-acting Bussman AGCI or equivalent

Transmitter Dimensions and Weight

Transmitter: approximately 9 lb (4 kg);

Add 1 lb (0.5 kg) for local operator interface – see Figure 15.

ORDERING INFORMATION

NC = No Charge
NA = Not Applicable

		Availability		
Model	**Product Description**	**C**	**U**	**H**
8712C	Magnetic Flowmeter Transmitter	•	NA	NA
8712U	Universal Magnetic Flowmeter Transmitter	NA	•	NA
8712H	High-Signal Magnetic Flowmeter Transmitter (For use with Model 8707 High-Signal Flowtube only.)	NA	NA	•
Code	**Transmitter Style**	**C**	**U**	**H**
R	Remote (2-inch pipe or surface mounting)	•	•	•
T	Integral (mounted to flowtube)	•	•	•
Code	**Power Supply Voltage**	**C**	**U**	**H**
03	10–30 V dc	•	•	NA
12	115 V ac, 50–60 Hz	•	•	•
24	230 V ac, 50–60 Hz	•	•	NA
Code	**Hazardous Location Certifications**	**C**	**U**	**H**
N0	Factory Mutual (FM) Class I, Division 2 Approval for nonflammable fluids; Canadian Standards Association (CSA) Class I, Division 2 Approval	•	•	•
N5	Factory Mutual (FM) Class I, Division 2 Approval for flammable fluids	•	•	•
CE	CE Marking	•	•	NA
Code	**Options**	**C**	**U**	**H**
B6	Stainless Steel 4-bolt Kit for 2-inch Pipe Mount	•	•	•
C1	Custom Configuration (Completed CDS 00806-0100-4668 required with order)	•	•	•
C4	Analog output levels compliant with NAMUR recommendations NE43, 18-January-1994(1) and high alarm level	•	•	•
CN	Analog output levels compliant with NAMUR recommendations NE43, 18-January-1994(1) and low alarm level	•	•	•
D1	High Accuracy Calibration [0.25% of rate from 3 to 30 ft/s (0.9 to 10 m/s)] matched flowtube and transmitter system(2)	•	NA	NA
M4	Local Operator Interface (LOI)	•	•	•
T1	Battery-backed Totalizer	•	•	NA
Typical Model Number: 8712C R 12 N0 M4				

(1) NAUMUR-compliant operation; alarm latch operations are pre-set at the factory and can not be changed to standard operation in the field.
(2) Option Code must be ordered for both flowtube and transmitter.

APPENDIX B

Low-Consumption Manual Specification

Royal II® Model Flushometer 110/111

Description
Exposed Water Closet Flushometer for floor mounted or wall hung top spud bowls.

Flush Cycle
☐ Model 110 Water Saver (3.5 gpf/13.2 Lpf)
☐ Model 111 Low Consumption (1.6 gpf/6.0 Lpf)

Specifications
Quiet, Exposed, Diaphragm Type, Chrome Plated Closet Flushometer with the following features:

- PERMEX™ Synthetic Rubber Diaphragm with Dual Filtered Fixed Bypass
- ADA Compliant Metal Oscillating Non-Hold-Open Handle with Triple Seal Handle Packing
- Aesthetically contoured Cover, Handle Socket and Flanges
- 1" I.P.S. Screwdriver Bak-Chek™ Angle Stop
- Free Spinning Vandal Resistant Stop Cap
- Adjustable Tailpiece
- High Back Pressure Vacuum Breaker Flush Connection with One-piece Bottom Hex Coupling Nut
- Spud Coupling and Flange for 1½" Top Spud
- Sweat Solder Adapter with Cover Tube and Cast Set Screw Wall Flange
- High Copper, Low Zinc Brass Castings for Dezincification Resistance
- Non-Hold-Open Handle, Fixed Metering Bypass and No External Volume Adjustment to Ensure Water Conservation
- Flush Accuracy Controlled by CID™ Technology
- Diaphragm, Handle Packing, Stop Seat and Vacuum Breaker to be molded from PERMEX™ Rubber Compound for Chloramine Resistance

Valve Body, Cover, Tailpiece and Control Stop shall be in conformance with ASTM Alloy Classification for Semi-Red Brass. Valve shall be in compliance to the applicable sections of ASSE 1037, ANSI/ASME 112.19.6, and Military Specification V-29193.

Special Finishes
☐ PB Polished Brass (PVD Finish)
☐ GP Gold Plate (PVD Finish)
☐ BN Brushed Nickel (PVD Finish)
☐ SF Satin Chrome

See Accessories Section of the Sloan catalog for details on these and other Flushometer variations.

® Certified ® Listed by I.A.P.M.O.

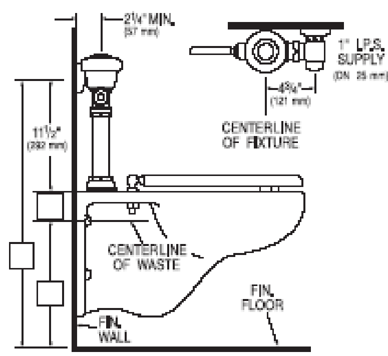
This space for Architect/Engineer approval

Job Name ____________ Date ____________
Model Specified ____________ Quantity ____________
Variations Specified ____________
Customer/Wholesaler ____________
Contractor ____________
Architect ____________

The information contained in this document is subject to change without notice.

SLOAN

SLOAN VALVE COMPANY • 10500 SEYMOUR AVE. • FRANKLIN PARK, IL. 60131
Ph: 1-800-9-VALVE-9 or 1-847-671-4300 • Fax: 1-800-447-8329 or 1-847-671-4380
Made in the U.S.A. www.sloanvalve.com



Royal II 110 S.S. — Rev. 0 (02/03)

Old Optic Automatic System Specification

SLOAN®
OPTIMA SYSTEMS

Royal® Model

OPTIMA® *plus*

Battery Powered Closet Retrofit

RESS-C-4.5
RESS-C-3.5
RESS-C-1.6

Description
Battery Powered, Sensor Operated Royal® Model Retrofit Conversion Kit for Exposed Closet Flushometers.

Flush Cycle
☐ Model RESS-C-4.5 (4.5 gpf/17 Lpf)
☐ Model RESS-C-3.5 Water Saver (3.5 gpf/13.2 Lpf)
☐ Model RESS-C-1.6 Low Consumption (1.6 gpf/6.0 Lpf)

Specifications
Quiet, Exposed, OPTIMA *Plus*®, Battery Powered, Sensor Operated Closet Flushometer Retrofit Conversion Kit for Sloan **Royal**® and **Regal**® Flushometers with the following features:

- PERMEX™ Synthetic Rubber Diaphragm with Dual Filtered Fixed Bypass
- ADA Compliant OPTIMA *Plus*® Battery Powered Infrared Sensor for automatic "No Hands" operation
- Engineered Plastic Cover Assembly with Integral Window
- User friendly three (3) second Flush Delay
- Courtesy Flush™ Override Button
- Four (4) Size AA Batteries included
- "Low Battery" Flashing LED
- Infrared Sensor Range Adjustment Screw
- Initial Set-up Range Indicator Light (first 10 minutes)
- Chrome Plated Metal Handle Cap
- Free Spinning, Vandal Resistant Stop Cap for Sloan H-600 Series Control Stop
- Installation Tools provided
- Diaphragm to be molded from PERMEX™ Rubber Compound for Chloramine resistance

Variations
☐ BD Beam Deflector (for high rough-in valves)
☐ MC Metal Cover
☐ Z Locking Ring for Zurn® Flush Valve Bodies

See Accessories Section and OPTIMA Accessories Section of the Sloan catalog for details on these and other OPTIMA *Plus*® Flushometer variations.

RESS-C shown installed on an existing Sloan Flushometer.

RESS-C units do *NOT* include a Valve Body, Supply Stop or Vacuum Breaker.

ADA Compliant

Automatic
Sloan OPTIMA *Plus*® equipped Flushometers provide the ultimate in sanitary protection and automatic operation. There is no need for AC hookups or wall alterations. The Flushometer operates by means of a battery powered infrared sensor. Once the user enters the sensor's effective range and then steps away, the Flushometer Solenoid initiates the flushing cycle to flush the fixture.

Hygienic
User makes no physical contact with the Flushometer surface except to initiate the Override Button when required. Helps control the spread of infectious diseases.

Economical
Automatic operation provides water usage savings over other flushing devices. Reduces maintenance and operation costs.

Warranty
3 year (limited)

UL® Listed CSA® Certified

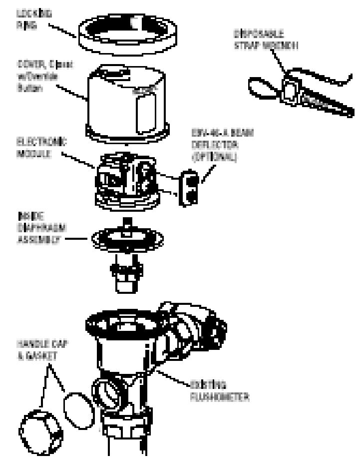
This space for Architect/Engineer approval

Job Name ______________ Date ______
Model Specified ______________ Quantity ______
Variations Specified ______________
Customer/Wholesaler ______________
Contractor ______________
Architect ______________

RESS-C-4.5
RESS-C-3.5
RESS-C-1.6

▶ **Description**
Battery Powered, Sensor Operated Royal® Model Retrofit Conversion Kit for Exposed Closet Flushometers.

▶ **Flush Cycle**
☐ Model RESS-C-4.5 (4.5 gpf/17 Lpf)
☐ Model RESS-C-3.5 Water Saver (3.5 gpf/13.2 Lpf)
☐ Model RESS-C-1.6 Low Consumption (1.6 gpf/6.0 Lpf)



ELECTRICAL SPECIFICATIONS

▶ **Control Circuit**
Solid State
6 VDC Input
8 Second Arming Delay
3 Second Flush Delay

▶ **OPTIMA Sensor Type**
Active Infrared

▶ **OPTIMA Sensor Range**
Nominal 22" - 42" (559 mm - 1067 mm), Adjustable ± 8" (203 mm)

▶ **Battery Type**
(4) AA Alkaline

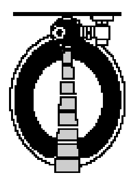
▶ **Battery Life**
3 Years @ 4,000 Flushes/Month

▶ **Indicator Lights**
Range Adjustment/Low Battery

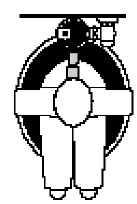
▶ **Operating Pressure**
15-100 psi (104 - 689 kPa)

OPERATION

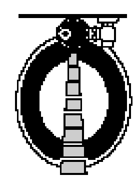
1. A continuous, invisible light beam is emitted from the OPTIMA Plus Sensor.



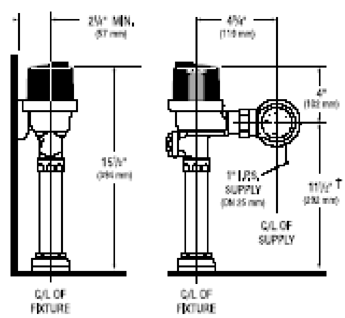
2. As the user enters the beam's effective range (22" to 42") the beam is reflected into the OPTIMA Plus Scanner Window and transformed into a low voltage electrical circuit. Once activated, the Output Circuit continues in a "hold" mode for as long as the user remains within the effective range of the Sensor.



3. When the user steps away from the OPTIMA Plus Sensor, the circuit waits 3 seconds (to prevent false flushing) then initiates an electrical signal that operates the Solenoid. This initiates the flushing cycle to flush the fixture. The Circuit then automatically resets and is ready for the next user.



ROUGH-IN
(on existing Sloan Model 110/111Flushometers)



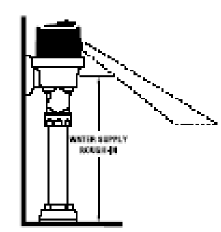
† Typical Water Supply Rough-in dimensions of existing Sloan Model 110/111 Flushometer.

VARIATIONS

☐ **MC** METAL COVER

RESS-C-4.5-MC
RESS-C-3.5-MC
RESS-C-1.6-MC

☐ **BD** BEAM DEFLECTOR



Specify when water supply rough-in is greater than 16" (406 mm) above the top of the bowl.
Failure to use the Beam Deflector in these installations will result in user complaints.

SLOAN VALVE COMPANY • 10500 SEYMOUR AVENUE • FRANKLIN PARK, IL 60131
Phone: 1-800-9-VALVE-9 or 1-847-671-4300 • Fax: 1-800-447-8329 or 1-847-671-4380 • http://www.sloanvalve.com

 Printed in the U.S.A. Made in the U.S.A. Royal Optima Plus RESS-C S.S. — Rev. 1 (01/02)

Improved Optic Automatic System Specification

SLOAN®
OPTIMA SYSTEMS
Battery Powered Flushometers

G2 OPTIMA *plus*®

Model
8110/8111

Description
Exposed, Battery Powered, Sensor Operated G2® Model Water Closet Flushometer for floor mounted or wall hung top spud bowls.

Flush Cycle
☐ Model 8111 Low Consumption (1.6 gpf/6.0 Lpf)
☐ Model 8110 Water Saver (3.5 gpf/13.2 Lpf)

Specifications
Quiet, Exposed, Diaphragm Type, Chrome Plated Closet Flushometer for either left or right hand supply with the following features:

- PERMEX™ Synthetic Rubber Diaphragm with Dual Filtered Fixed Bypass
- Flex Tube Diaphragm designed for improved life and reduced maintenance
- ADA Compliant OPTIMA *Plus*® Battery Powered Infrared Sensor for automatic "No Hands" operation
- Infrared Sensor with Multiple-focused, Lobular Sensing Fields for high and low target detection
- Isolated Latching Solenoid Operator, isolates magnetic components from water contact
- Engineered Metal Cover with replaceable Lens Window
- User friendly three (3) second Flush Delay
- Courtesy Flush™ Override Button
- Four (4) Size AA Batteries factory installed
- "Low Battery" Flashing LED
- Infrared Sensor Range Adjustment Screw
- Initial Set-up Range Indicator Light (first 10 minutes)
- 1" I.P.S. Screwdriver Bak-Chek™ Angle Stop
- Free Spinning, Vandal Resistant Stop Cap
- Adjustable Tailpiece
- High Back Pressure Vacuum Breaker Flush Connection with One-piece Bottom Hex Coupling Nut
- Spud Coupling and Flange for 1½" Top Spud
- Sweat Solder Adapter with Cover Tube and Cast Set Screw Wall Flange
- High Copper, Low Zinc Brass Castings for Dezincification Resistance
- Fixed Metering Bypass and No External Volume Adjustment to Ensure Water Conservation
- Flush Accuracy Controlled by CID™ Technology
- Diaphragm, Stop Seat and Vacuum Breaker to be molded from PERMEX™ Rubber Compound for Chloramine resistance

Valve Body, Tailpiece and Control Stop shall be in conformance with ASTM Alloy Classification for Semi-Red Brass. Valve shall be in compliance with the applicable sections of ASSE 1037, ANSI/ASME A112.19.6 and Military Specification V-29193. Installation conforms to ADA requirements.

Special Finishes

☐	PB	Polished Brass (PVD Finish)
☐	GP	Gold Plate (PVD Finish)
☐	BN	Brushed Nickel (PVD Finish)
☐	SF	Satin Chrome

See Accessories Section and OPTIMA Accessories Section of the Sloan catalog for details on these and other OPTIMA *Plus*® Flushometer variations.

ADA Compliant

Automatic
Sloan G2 Optima *Plus*® Flushometers activate via multi-lobular sensor detection to provide the ultimate in sanitary protection and automatic operation. A battery powered infrared sensor sets the flushing mechanism after the user is detected and completes the flush when the user steps away.

Functional & Hygienic
Touchless, sensor operation eliminates the need for user contact to help control the spread of infectious diseases. The G2 Optima *Plus* Flushometer is provided with an Override Button to allow a "courtesy flush" for individual user comfort.

Economical
Sloan installed batteries speed installation and provide years of metered flushing to control the use of water and energy. Batteries can be changed without turning off the water. The patented Isolated Operator ensures reliability by isolating the solenoid components from the water.

Warranty
5 year (limited)

UL® Listed   CSA® Certified

This space for Architect/Engineer approval

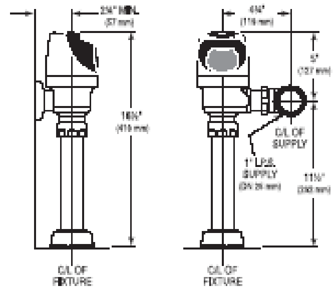
Job Name ____________ Date ______
Model Specified ____________ Quantity ______
Variations Specified ____________
Customer/Wholesaler ____________
Contractor ____________
Architect ____________

Model

8110/8111

Description
Exposed, Battery Powered, Sensor Operated G2® Model Water Closet Flushometer for floor mounted or wall hung top spud bowls.

Flush Cycle
☐ Model 8111 Low Consumption (1.6 gpf/6.0 Lpf)
☐ Model 8110 Water Saver (3.5 gpf/13.2 Lpf)

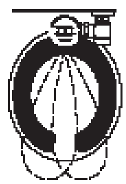


ELECTRICAL SPECIFICATIONS

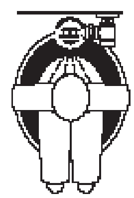
- **Control Circuit**
  Solid State
  6 VDC Input
  8 Second Arming Delay
  3 Second Flush Delay
- **OPTIMA Sensor Type**
  Active Infrared
- **OPTIMA Sensor Range**
  Nominal 22" - 42" (559 mm -1067 mm), Adjustable ± 8" (203 mm)
- **Battery Type**
  (4) AA Alkaline
- **Battery Life**
  3 Years @ 4,000 Flushes/Month
- **Indicator Lights**
  Range Adjustment/Low Battery
- **Operating Pressure**
  15 - 100 psi (104 - 689 kPa)
- **Sentinel Flush**
  Once Every 24 Hours After the Last Flush

OPERATION

1. A continuous, invisible light beam is emitted from the OPTIMA *Plus* Sensor.



2. As the user enters the beam's effective range (22" to 42") the beam is reflected into the OPTIMA *Plus* Scanner Window and transformed into a low voltage electrical circuit. Once activated, the Output Circuit continues in a "hold" mode for as long as the user remains within the effective range of the Sensor.

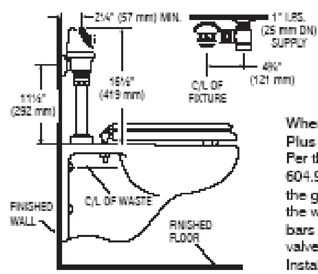


3. When the user steps away from the OPTIMA *Plus* Sensor, the circuit waits 3 seconds (to prevent false flushing) then initiates an electrical signal that operates the Solenoid. This initiates the flushing cycle to flush the fixture. The Circuit then automatically resets and is ready for the next user.

VALVE ROUGH-IN

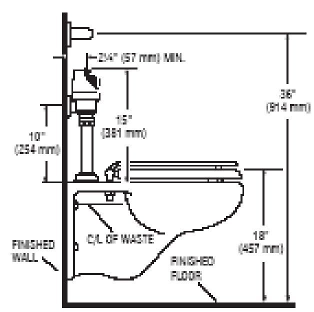
Typical Water Closet Installation

Model 8110/8111



When installing the G2 Optima Plus in a handicap stall:
Per the ADA Guidelines (section 604.9.4) it is recommended that the grab bars be split or shifted to the wide side of the stall. If grab bars must be present over the valve, use the Alternate ADA Installation as shown to the right.

Alternate ADA Installation
Lower water supply rough-in to 10" (254 mm) and mount grab bar at the 36" (914 mm) maximum allowed height.



SLOAN VALVE COMPANY • 10500 SEYMOUR AVENUE • FRANKLIN PARK, IL 60131
Phone: 1-800-9-VALVE-9 or 1-847-671-4300 • Fax: 1-800-447-8329 or 1-847-671-4380 • www.sloanvalve.com

 Printed in the U.S.A. Made in the U.S.A. G2 Optima Plus 8110 S.S. — Rev. 0a (05/08)

VITA

Salilla Lertbannaphong

44 Soi Somdejprapinklao 1 Somdejprapinklao rd.
Bangyeekhan Bangplat, Bangkok 10700 Thailand
662-4335541, salillale@hotmail.com

Education

Master of Science in Construction Management

Texas A&M University, May 2004

Bachelor of Architecture

King Mongkut's University of Technology (Thonburi)

Thailand, March 1999

Professional Experience

Arch Design and Construction Co., Ltd

Site Architect, 2000-2002

Architect

Architect, 1999-2000

Qualification

Facility Management Certificate, Texas A&M University, 2005

Honor and Award

Sloan Design Engineering Research Scholarship,

Texas A&M University, 2004-2005

Others

Member: International Facility Management Association

Facility Management Chapter

Treasurer and Secretary, KMUTT Architecture School, 1996-1998

Treasurer, Thai Student Association, 2003-2004