INVESTIGATING FLUSH SYSTEM METHOD FOR MINIMUM WATER USAGE OF TOILET SYSTEM

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ABSTRACT

A major concern for most people these days is the use and availability of clean water. With 83 million more people on Earth each year, demands for clean water will keep on rising. Water is everywhere and also important to living things on Earth. But because of the global warming and pollution, water has become deficit in many parts of the world. It can be foreseen that one day water will become a very valuable asset for countries in the future as energy is now. In this study, focus will be given more on the effect of water tank designs in reducing the volume of water usage in toilet system. Testing was divided into two sections that were experimental study and simulation study. First, experimental study conducted to test the performance of four different types of tanks and results are recorded. After that, simulation study conducted and data was recorded. The parameters of the study were the effect of depth of water and design of the water tanks towards pressure and volume flow rate of the water. Based from the test results, comparison was calculated. With percentage error below than 5 percent, it has been determined that simulation study was indeed suitable for this study. To achieve the objectives of this study, the change in design of water tank was proposed to minimize the amount of water used without sacrificing the performance of the toilet. By modifying the water tank designs, the amount of water used inside the tank can be decreased. From simulation study that has been conducted for two design concepts, pressure exerted from the tanks only lost a little amount of energy. As conclusion, by changing the design of water tanks without changing the water level, one could help reduce the amount of water used for flushing his waste. At the same time, it will not affecting the performance of the whole toilet system.

ABSTRAK

Satu kebimbangan utama bagi kebanyakan penduduk dunia pada hari ini ialah penggunaan serta bekalan air bersih. Dengan lebih daripada 83 juta orang di lahirkan setiap tahun, permintaan untuk air bersih akan terus meningkat. Air boleh di dapati di mana-mana jua dan amat penting untuk kehidupan di Bumi. Tetapi disebabkan pemanasan global serta pencemaran, air telah menjadi berkurangan di kebanyakan tempat. Boleh diramalkan bahawa suatu hari nanti air akan menjadi aset yang amat berharga bagi sesebuah negara pada masa akan datang sebagaimana permintaan untuk tenaga pada masa sekarang. Dalam kajian ini, tumpuan akan lebih diberikan kepada kesan reka bentuk tangki air dalam mengurangkan jumlah penggunaan air bagi keseluruhan sistem tandas. Ujian akan dibahagikan kepada dua bahagian iaitu kajian eksperimen dan simulasi. Kajian eksperimen dijalankan untuk menguji prestasi empat jenis tangki dan keputusan direkodkan. Kemudian, kajian simulasi dijalankan dan data direkodkan. Parameter kajian ini ialah kesan kedalaman air serta reka bentuk tangki air terhadap tekanan dan kadar aliran isipadu air. Berdasarkan dari keputusan ujian, perbandingan telah dikira. Dengan ralat peratusan bawah daripada 5 peratus , ia membuktikan bahawa kajian simulasi sememangnya sesuai untuk kajian ini. Bagi mencapai objektif kajian, perubahan dalam reka bentuk tangki air telah dicadangkan untuk mengurangkan jumlah air yang digunakan tanpa mengorbankan prestasi tandas. Dengan mengubah reka bentuk tangki air, jumlah air yang digunakan di dalam tangki dapat dikurangkan. Dari kajian simulasi yang telah dijalankan terhadap dua konsep reka bentuk, didapati hanya sedikit kehilangan tekanan sahaja yang dikesan. Kesimpulannya, dengan menukar reka bentuk tangki air tanpa mengubah paras air, ia dapat membantu mengurangkan jumlah air yang digunakan untuk mengepam keluar bahan buangan. Pada masa yang sama, ia tidak akan memberi kesan kepada prestasi keseluruhan sistem tandas.

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LIST OF SYMBOLS AND ABBREVIATIONS

W.C	Water Closet
HET	High Efficiency Toilet
WSAP	Water Efficient Appliances and Plumbing
MaP	Maximum Performance Test
CAD	Computer Aided Design
CFD	Computer Fluid Dynamics
SI	Standard International Units
SPAN	Suruhanjaya Perkhidmatan Air Negara
WEPLS	Water Efficient Products Labeling Scheme
ΔP	Change of Pressure
P	Pressure
F	Force
A	Area
ρ	Density of Fluid

g	Gravitational Acceleration
h	Elevation/Depth
γ	Specific Weight of the Fluid
Pa	Pascals
Nm^{-2}	Newton per square meter area

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CHAPTER 1

INTRODUCTION

1.1 Water Crisis

A major concern for most people these days is the usage and availability of water. Malaysians spends a large portion of water compared to other consumers in the region. The findings of a study made available to the New Sunday Times (2010), Malaysians wasted the most water that is 226 liters average per day, compared with 155 liters in Singapore and 90 liters in Thailand. And from the same survey, 70 per cent of Malaysians were not likely or not very likely to reduce water usage in their homes in the next three years.

From the other survey, the major water consumption in houses in Australia are water compartment, shower and laundry whereby contributing to 32%, 26% and 21% respectively (Cummings, Wright, & Bonollo, 2001). Thus, the idea of reducing the amount of water used by the water closet (W.C.) seems to offer great potential to reduce overall water usage.

1.2 High Efficiency Toilets

According to National Geographic Magazine (April 2010 issues), with 83 million more people on Earth each year, water demand will keep going up unless we change how we use it. Other facts from this magazine are that in 15 years, 1.8 billion people will live in regions of severe water scarcity.

Water is everywhere and also important to living things on Earth. But because of the global warming and pollution, water has become deficit in many parts of the world. Preserving water nowadays has become an important issue for many countries. According to Cheng, Lee, Liu, & Hsia (2010) it can be foreseen that water will become a very valuable asset for countries and areas in the future as energy is now.

According to McDougall & Wakelin (2007), the increasing importance of water conservation has led to renewed interest in the possibilities for reductions in overall building use through reduced W.C. flush volume operation. Thus, improving water efficiency in home can decrease the water usage and at the same time can save a lot of money. In Australia, they have realize that the most water consume for in-house usage is from the water closet (Figure 1.1). Hence, Australia has established the Water Efficient Appliances and Plumbing group (WEAP) which is responsible to encourage reduction in the volumes of water used by bathroom application (Cummings, Wright, & Bonollo, 2001).

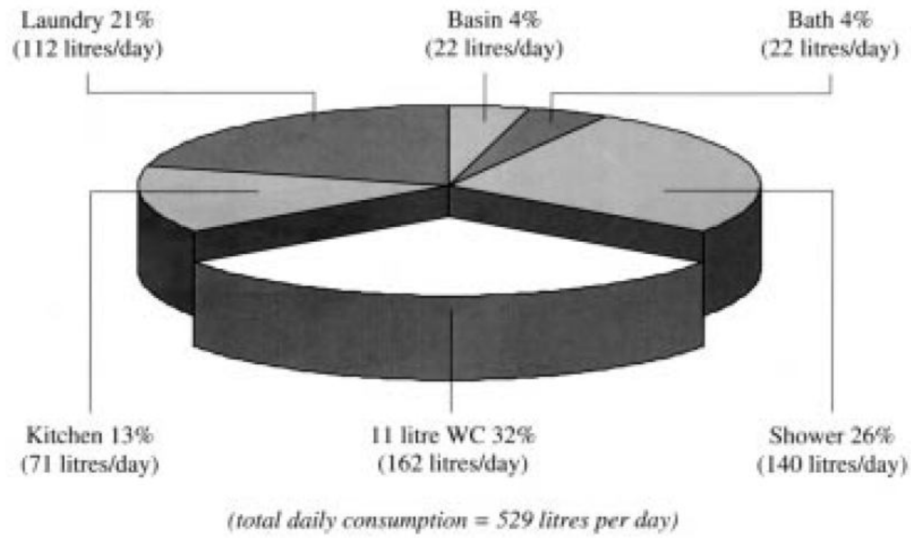

Figure 1. 1: In-house water consumption in a typical Australia (Cummings, Wright, & Bonollo, 2001)

Today, toilet research and development has brought us High-Efficiency Toilets (HET). From continuous usage of this device we can save a lot of water while still maintaining the ability to get the job done. According to director of product for American Standard Brands and Globe Union Group, both of them agree that HET are toilets that use at least 20 percent less water than a standard 1.6 gallons per flush toilet (The Reeves Journal Staff, 2012). From the calculation (shown below) we can conclude that the maximum water usage for HET is only 1.28 gallons which is equivalent to 5.82 liters of water.

$$\frac{20}{100} \times 1.6 \text{ gallons} = 0.32 \text{ gallons}$$
$$1.6 \text{ gallons} - 0.32 \text{ gallons} = 1.28 \text{ gallons (5.82 liters)}$$

The difference between the HET and standard toilets is that HET use less water per flush. There are a variety of high efficiency toilets available in the market. Among many, the three types that most preferred by consumers are Dual Flush Toilets, Ultra Low Flow (ULF) Toilets, and Waterless Urinals.

1.3 Dual Flush Toilets vs. Ultra-Low Flow Toilets

The dual flush toilet system incorporates two flushes, full flush for solids and a partial flush for liquids. The full flush typically uses full 6 liters (1.6 gallons) of water and the partial flush is between 3 to 3.8 liters (0.8 to 1.0 gallons) of water. There are two types of dual flush system which are gravity assisted and pressurized system. The differences between them is the gravity assisted relies on gravity pulling the water out from the tank and help to get rid of the waste. Meanwhile a pressurized system incorporates a system in pumps inside the tank to force the water into the bowl and eliminate the waste into the drain system.

Meanwhile, the Ultra-Low Flow Toilets are extremely efficient and use only 3 liters (0.8 gallons) of water per flush. The system used a vacuuming effect which is the combination of air and water efficiently to get rid of the waste. When the toilet is flushed, the water from the tank enters the bowl causing pressure to build on the trapway. The trapway allows wastewater to exit and creating the vacuum effect. One of the examples of the ultra-low flow toilets is The Stealth UHET (Ultra High-Efficiency Toilet) which utilizes an air transfer system to achieve better performance.

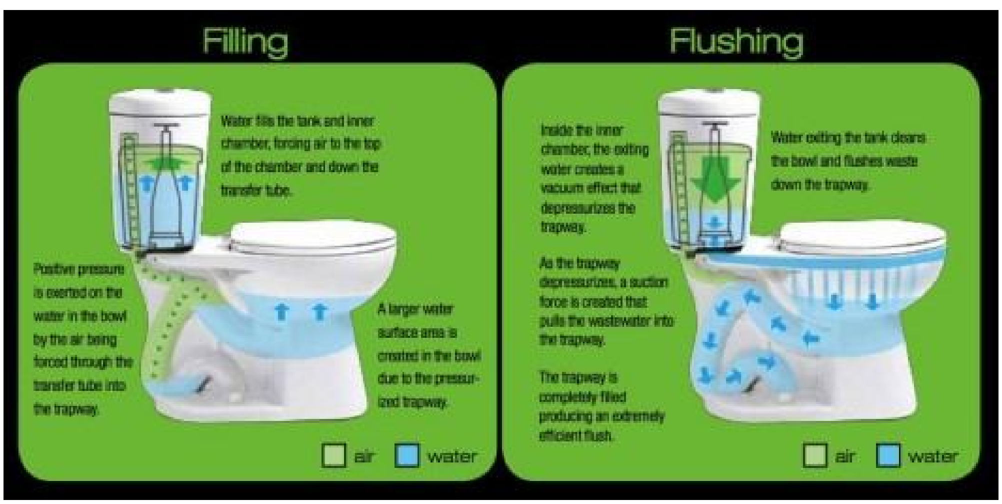

Figure 1. 2: Niagara Stealth Toilet (www.gizmag.com)

Currently, the dual flush toilet system owes its popularity to its water saving properties, reliability, and simplicity resulting in relatively low monthly bill payments. First developed in one of the driest continents that are Australia, today it has been widely used in many countries in Europe and Asia. The principle behind dual flush toilets is that less water is used to flush liquids from the bowl than is used when flushing solids. Liters per flush depend on the model and the manufacturer.

1.4 Research Background

Disposal of human waste has been an issue since humans have inhabited the Earth. In the prehistoric time, men relieved themselves out of the door such as at the rivers, woods and shrubs to answer the nature's call. In 1596, Sir John Harrington of England invented the first flush toilet. Nearly 200 years after that, in 1775 an inventor named Alexander Cummings received the first patent for a water closet (Kravetz, 2009). And since then, the evolutions of flush toilet continued. Nowadays, all toilets manufactured after the year 1995 came in many water-saving options and perform as better as or even better than the older models. Most of them use no more than 7.27 liters per flush while the older ones utilized as much as 22.73 liter per flush!

Assuming that homes built before 1995 and the toilets were those of the old-fashioned ones, the toilet tanks most probably used 16 liters (3.5 gallons) or 23 liters (5 gallons) of water. Though the uses of water by individuals are different, in this case we assume that the user will flush the toilets 3 times a day. By multiplying 3.5 gallons (15.91 liter) of water by the number of times per day we can determine the total volume of water used to flush the toilet each day by a person based on the calculation as follow:

$$3.5\,\text{gallons} \times 4\,\text{flushes} = 14\,\text{gallons}\ (63.65\,\text{liter})$$
$$14.0\,\text{gallons} \times 7\,\text{days} = 98\,\text{gallons}\ (445.52\,\text{liter})$$
$$98\,\text{gallons} \times 4\,\text{weeks} = 392\,\text{gallons}\ (1{,}782.07\,\text{liter})$$
$$392\,\text{gallons} \times 12\,\text{months} = 4{,}704\,\text{gallons per year}\ (21{,}384.82\,\text{liter})$$

The calculation above shows the volume of water flushed by a person in one year. The total volume of clean water used to flush human's solids or liquids by using old flush system in one year takes 4,704 gallons or 21,384.82 liters per year. Just imagine if the number of people who live in a house is more than one. It will not only affecting the owner of the house financially, environment will be affected as well.

Now, if we change the older flush system with the newer ones which have been equipped with toilets that use 1.6 gallons (7.27 liter) of water per flush we can calculate the difference of water consumption from these two systems using the same formula as mention earlier. As we can see from the calculation below, the new toilet flush which has been equipped with 1.6 gallons of water per flush only consumes 2,150.4 gallons of water per year. This new system will not only save a great amount of water but it also save a lot of money, keeping financial problems at bay!

$$1.6\,\text{gallons} \times 4\,\text{flushes} = 6.4\,\text{gallons}\ (29.09\,\text{liter})$$
$$6.4\,\text{gallons} \times 7\,\text{days} = 44.8\,\text{gallons}\ (202.30\,\text{liter})$$
$$44.8\,\text{gallons} \times 4\,\text{weeks} = 179.2\,\text{gallons}\ (814.66\,\text{liter})$$
$$179.2\,\text{gallons} \times 12\,\text{months} = 2{,}150.4\,\text{gallons per year}\ (9{,}775.92\,\text{liter})$$

Obviously we can help our mother nature to conserve clean water by decreasing our water usage. Thus, the use of High Efficiency Toilet (HET) is suitable to help improve water efficiency at home or industries to reduce water usage and indirectly will help to save money.

In this project, the researcher is concern about decreasing the amount of clean water flushed into the toilets. Not only in Australia or United States of America, Malaysian government is also concerned about this issue. In Malaysia, Water Efficient Product Labeling Scheme (WELPS) has been initiated by SPAN (National Water Services Commission) in promoting good practices of water demand management in Malaysia.

WELPS adopts three (3) stars rating labeling systems. The more stars on the label mean that the product is more efficient and consumes lesser water, thus promoting water conservation (SPAN, 2013)

1.5 Theoretical Background

Toilets come in many shapes, size and flush the mechanisms depend on the design and manufacturers. There are also many types of water closets (W.C.) in the market. Each of them has different design with different mechanism to get rid of the waste. One of these many designs utilizes siphon effect to flush and is very widely used at home.

Each day, millions of people living in Malaysia use toilet flush and in the process it consumes millions of liters of water. According to Kennedy (2011), to reduce the amount of water consumption, the new kind of toilets, urinals, faucets and showerheads are available. Thus, the use of HET is suitable to solve problems for those who wants to conserve water.

Apparently, water issues are always the main topics concerning the use of toilets. Since every day people need to go to the toilet, one of the solutions that can help to minimize the volume of water flushed in the toilet bowls is by changing to High Efficient Toilets (HET). High Efficiency Toilets (HET) can help to reduce the water usage by 20 percent. And to be qualified as HET, the toilet must be able to flush 350 grams of solids (Marymor, 2010).

To obtain a better flush effect, a sufficient volume of the water for each flush is crucial. Many countries have set that the volume of the water need to be flushed is no more than 6 liters (Cheng, Lee, Liu, & Hsia, 2010). In Malaysia, under the scope of Malaysian Standards both flush volume and the flow rate is no more than 6 liters of water and 1.8 liters per second. These criteria are essential for the proper functioning of toilets that are manufactured based on the requirements of Malaysians Standards (Huat, 2002).

Besides that, Suruhanjaya Perkhidmatan Air Negara (SPAN) has set the standards for the water efficiency product according to their grade as shown in Table 1.1. The star is given to the products according to their performance in promoting water conservation for water closet. With this labeling system it will facilitate consumers to identify a more efficient product at the point of the purchase. The stars represent efficiency and water consumption of each product. The more stars on the label mean that the product is more efficient and consumes less water (Guidelines for Voluntary Water Efficient Products Labelling Scheme, 2013).

The products which have been approved as Water Efficient Product (WEP) will be labeled with approved water efficiency label. Information on the label consists of the star rating, WELPS Registration number, brands, model and water consumption rate of the product as shown in Figure 1.3.

Figure 1. 3: Water Efficiency Label (Guidelines for Voluntary Water Efficient Products Labelling Scheme, 2013)

Table 1. 1: Conversion of water consumption to water efficiency rating for water closet (Guidelines for Voluntary Water Efficient Products Labelling Scheme, 2013)

Water Consumption **Flush volume per flush** **(fv) (litre/flush)**	**Water Efficiency Grade**	**Rating**	**Symbol on Label**
Full Flush $fv \leq 6.0$ Reduced Flush $fv \leq 3.5$	Efficient	1★	★
Full Flush $fv \leq 5.0$ Reduced Flushed $fv \leq 3.0$	Highly Efficient	2★	★★
Full Flush $fv \leq 4.0$ Reduced Flush $fv \leq 2.5$	Most Efficient	3★	★★★

1.6 Problem Statement

Every typical house will have one or more toilets. Normal human needs to go to the toilet at least once a day. Toilets have become a necessity to human since they have been introduced to men. Can we imagine life without toilets? Can we imagine not having proper place to relieve ourselves? Toilets are prominent to human and even nowadays people celebrate World Toilet Day every 19th of November each year.

With the vast and growing populations today, the amount of water used in the toilet will cause a big issue. Just imagine if the use of conventional or older models of flush toilet can consume 4,704 gallons (21,384.82 liter) of water per year per person. The amount of water consumption will increase a lot more if we are to use these old models in universities, shopping malls, industries, office buildings or hotels. The volumes of water use will absolutely increase with the number of users.

In order to overcome the existing problem, the use of dual flush with gravity fed is logical to achieve optimum reduction of water usage per flush. The new system works by using as little water as possible to flush solid and liquid waste. With a pressure support, it is possible to flush with minimal water usage. In this study, the change in parameter as height of the water will be used to increase the pressure and wash down the waste without having to use a lot of water. In this research, Solidwork software with CFD integrated will be used to get the data and they will be compared with the experimental testing.

1.7 Objectives

The present research has the following objectives:

i. To investigate the best gravity water tanks design for efficiency of flow rates.
ii. To investigate the flow rate from the flush system by using SolidWork Flow Simulation Software.
iii. To analyze the pressure of the flush system by using SolidWork Flow Simulation Software
iv. To propose the suitable design of gravity toilet flush system from findings of this research work.

1.8 Scope of Research Work

This research presents an investigation of the method applied for minimum water usage of water tanks for a toilet system. It is tested by increasing the pressure, mass flow rate or volume flow rate of the water without increasing the amount of water used inside the water tanks. The parameters studied were the effect of height (or depth) of water and the design of the water and the design of the water tanks in the toilet system. The test is done in room temperature conditions and normal water pressure provided for Malaysian buildings and housings.

The type of water tanks used in this research is limited to gravity fed flush system for 4.5L/3L model tanks. However, the flow of the water to the rim, bowl and siphon of the toilet are not included. Testing will be done by using SolidWork Flow Simulation software. Then, the results from the simulation will be compared with experimental study (real-life experiment) to determine the accuracy of the results obtained from the simulation data.

1.9 Hypotheses

Experiments and practical use of manometer while studying fluid mechanics show us that pressure in a fluid increases with depth. This is because more fluid rests on deeper layers and the effect of this "extra weight" on a deeper layer is balanced by an increase in pressure (Cimbala & Cengel, 2008). In other words, pressure in a static fluid increases linearly as the depth does. The main hypothesis for this thesis is the pressure exerted by the tanks can be increased with the depth of water inside the tanks. Testing will be done by experimental study and simulation study. The main characteristic that will be changed in the testing are the outer and inner design of the tanks without increasing amount of water volume use for flush.The amount of water can be hypothesized to produce the same amount of pressure even with small volume of water. The minimum amount of water tested is 4.5L of water to flushed solid waste in the bowl.

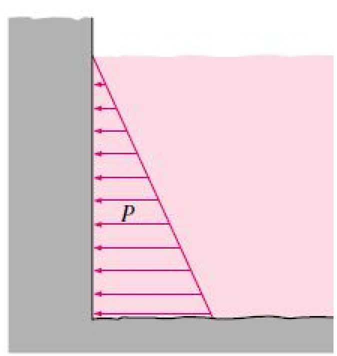

Figure 1. 4: The pressure fluid at rest increases with depth (Cimbala & Cengel, 2008)

1.10 Dissertation Content

There are eight chapters covered in the thesis.

Chapter 1 covers the introduction of water crisis which focuses on the water usage for flushing system. Besides that, this chapter also covers the introduction of types of toilet in the markets, the advantages and disadvantages of each of the toilet types. The focus is on the gravity fed type of toilet. Inside this chapter also presents the problem statement, objectives of the present studies, research scope and finally thesis organization.

Chapter 2 provides literature review that covers the information on water pressure, how its responds towards elevation, volume flow rate of water and hydrostatic paradox. It also reviews on revolution of toilets from the first invention of 12L per flush until current inventions that only use 4.5L per flush. Besides that, this chapter also covers about how the toilets works from the water fills the tanks until the water flushed into the siphon.

Chapter 3 described the methodology used for this study. Inside this chapter also describe briefly the procedures and flow of the process to gathered the data and testing done for the whole study. The method used for this study is more on experimental study and simulation study.

Chapter 4 presents the experimental procedures and analysis required to verify the data simulated by using Solidwork Flow Analysis software. The experiment is divided into two sections that are experiment 1 and experiment 2. In experiment 1, testing for pressure and time taken is done on different design of water tanks. Data taken is for full flush and half flush mode. Meanwhile for experiment 2, testing is done only on two different types of water tanks. This time testing is done to collect the data of effect of volume of water and height of water towards pressure and time taken. Testing for this second experiment is done in full flush mode. All data taken from both experiment is then recorded in Excel spreadsheet.

In Chapter 5, testing of different types of water tanks done in Chapter 4 is done via computer simulation. The software used for simulation testing is Solidwork software. By using its flow simulation software, pressure and volume flow rate produce by the water tanks can be predicted. The results produce by this software is recorded in Excel spreadsheet for comparison process.

Chapter 6 covers the results and discussion of all the obtained testing mention in Chapter 3. The results shows are response to the problems posed in Chapter 1. There are few goals set to drive the collection of the data. Most of them are to achieve the objectives stated for this study. Inside this chapter also provided the results and analysis for design optimization proposed for this study.

Chapter 7 explained about the contribution of these findings in development of toilets design. The findings from this research can prove that with minimum volume of water, the toilets still can perform as good as their ancestor toilets without wasting too much water. Besides that, the clean water that can be saved from flushing the waste can be used as a drinking water and at the same time can avoid unnecessary or overspend bill payments.

Chapter 8 summarizes the conclusions made in the present study and recommendations for future research in this particular area. The conclusions are written based on the findings reported in Chapter 6. Recommendations for future studies are presented due to their significance with the current research.

CHAPTER 2

STATE OF ART

2.1 Introduction

Pressure is the element to reduce the amount of water used to flush the waste from the toilet bowl. The use of technology such as pressure assist flush can help to minimize the amount of water usage per flush. This new system works by using as little water as possible to flush solid and liquid waste. It helps to conserve water and minimize the threat to global warming issues. Nevertheless, the biggest problem with this technology is that they are very noisy, usually making loud explosive sound. Besides, this type of flushing technology is also expensive to repair because of its complexity compared to gravity assist flush method (Marymor, 2010).

The present study is focused on the gravity assist flush method for reduction of water inside the toilet tanks without sacrificing the performance of the toilet itself. These objectives can be achieved by increasing the pressure exerted at the bottom of the water tanks.

2.2 Pressure

Pressure is the name of a force by one body on another by compression. it can be defined as a normal force exerted by a fluid per unit area (Cimbala & Cengel, 2008). Since pressure is defined as force per unit area, the unit for pressure is Newton per square meter (N/m^2) or Pascals (Pa). Pressure has been applied in many ways in our daily life. For example, it can be used in car tire; aircraft fly because of the air pressure exerted on the wings, balloons inflates because of the air pressure inside and a lot more applications of pressure.

Atmospheric pressure is the product exerted by the weight of the atmosphere. At sea level, the atmospheric pressure has an average value of one atmosphere (1 atm) and gradually decreases when the altitude increases. The decline of atmospheric pressure with elevation is given in table below.

Table 2. 1: The effect of elevation on atmospheric pressure (Cimbala & Cengel, 2008)

Elevation (meter, m)	Pressure (kiloPascal, kPa)
0 (sea level)	101.325kPa
1000	89.88kPa
2000	79.50kPa
5000	54.05kPa
10,000	26.50
20,000	5.53

2.3 Relationship between Pressure and Elevation

When diving especially at a deeper level, anyone would notice the pressure on his eardrums. This shows that change in pressure occur when dive in the water. Figure 2.1 shows that the pressure of a liquid is directly proportional to the depth. If the fluid is at rest or at constant velocity, equation for pressure distribution can be as mention below:

$$\Delta P = \rho g h \qquad (2.1)$$

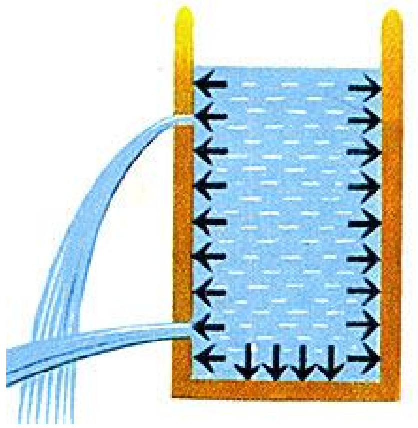

Figure 2. 1: Pressure increase with depth (www.wikipedy.com)

Consider the density (ρ) of the fluid used is constant, we can conclude that the increment in depth will increase the pressure for a given fluid (see Figure 2.1). This is what the diver experiences when diving deeper inside the water. Since the pressure at the free water surface is normally be atmospheric pressure (P_{atm}), thus

$$\Delta P = \rho g h + P_{atm} \qquad (2.2)$$

2.4 The Hydrostatic Paradox

From equation 2.1, the pressure exerted by a fluid is dependent on the specific weight of the fluid γ and its elevation h. The weight of the fluid present will not affect the pressure exerted at the bottom of the container. From Figure 2.2 shown below, although the weight of the fluid is obviously different in the four cases, the pressure and the force on the bases of the vessels are still the same, depending on the depth h and the base area A.

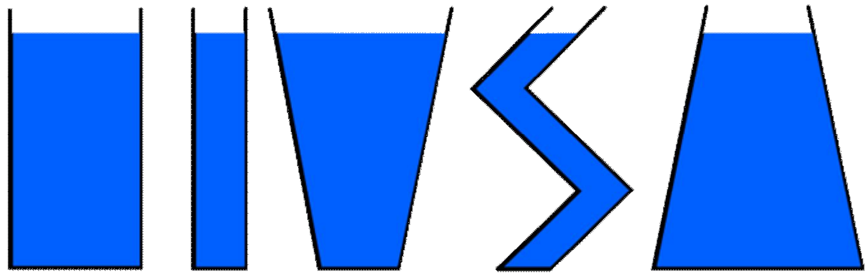

Figure 2. 2: The Hydrostatic Paradox (http://commons.wikimedia.org)

2.5 Rate of Discharge

Besides pressure, rate of discharge produced by the tanks also plays an important parameter in the success of High Efficient Toilets applications. The rate of discharge that will be considered in this research is the Mass Flow Rate and the Volume Flow Rates. Mass Flow Rates are defined as the amount of mass flowing through a cross section per unit time and denoted by M. Meanwhile, a volume flow rate is defined as the volume of the fluid through a cross section area per unit time and denoted by Q. (Cimbala & Cengel, 2008)

$$M = \rho A v \quad (2.3)$$

$$Q = Av = \frac{V}{\Delta t} \quad (2.4)$$

According to the Malaysian Standards (2011), rate of discharge for independent cistern when tested shall discharge minimum 1.8L/s for full flush and minimum 1.4L/s for reduced flush. Usually the manufacturer of WC product will do the testing by recording the time for each flush. The formula for the testing is shown in equation 2.4. For instant, the time taken for dual flush type 6/3L is about 5 to 3 seconds respectively as the mass flow rate and volume flow rate is shown in Table 2.2.

Table 2. 2: Calculation for Mass and Volume Flow Rate

Volume Flow Rate	**Mass Flow Rate**
$Q = Av = \frac{V}{\Delta t}$ $= \frac{6L}{5s} = 1.2L/s$ $Q = Av = \frac{V}{\Delta t}$ $= \frac{3L}{3s} = 1L/s$	$M = \rho Q = \left[\frac{1000kg}{1m^3}\right]\left[\frac{1m^3}{1000L}\right]\left[\frac{1.2L}{s}\right]$ $= 1.2kg/s$ $M = \rho Q = \left[\frac{1000kg}{1m^3}\right]\left[\frac{1m^3}{1000L}\right]\left[\frac{1L}{s}\right]$ $= 1kg/s$

Results from the calculation shown above (Table 2.2) shows that the mass and volume flow rates produce by this dual flush system is not yet up to the Malaysian Standards requirements. Thus, to increase the amount of water discharged, time taken per flush have to be reduced. To achieve this criteria the design of the toilets itself have to be adjusted to reduce the time taken per flush.

2.6 Toilet Design

Reducing water consumption is a requirement in many countries nowadays. Domestic water usage in toilets can be a significant contributor to overall consumption. Studies indicate that the minimization of WC flush volume has been shown to be the most effective method currently available to reduce toilet water use. According to Cummings, Wright, & Bonollo (2001), WC flush volume reduction was identified as the best method to minimizing potable water usage without affecting our comfort. As shown in Figure 2.3, this approach has led to relatively rapid decrease in WC flush volumes, and a corresponding reduction in average dailyper capita WC water usage. Furthermore, efficient use of water can avoid the consumers from having to pay too much water bills. There are three main systems that work together to make the system successful and efficiently work. According to Marymor (2010), for a toilet to flush effectively, the size and shape of the bowl of the trap must be matched to the size of the flush valve, timing, location and volume of the water. Adjust any of these parameter can cause poor performance of the toilet system.

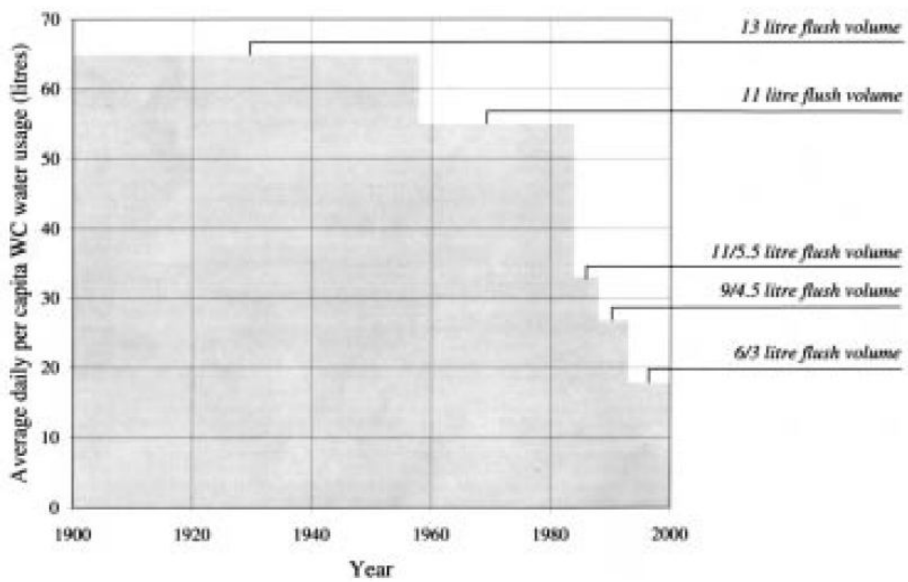

Figure 2. 3: Reduction in maximum WC flush volume since 1900 in Australia (Cummings, Wright, & Bonollo, 2001)

2.7 Mechanism of Toilet Flush

If we take off the tank cover and take a look inside the water tank in our toilets, there are three main elements that works together to make the system successfully run. These three main elements in the toilet are bowl siphon, flush mechanism and refill mechanism. They might look difference according to brands and patent, but they are actually the same in terms of their functions.

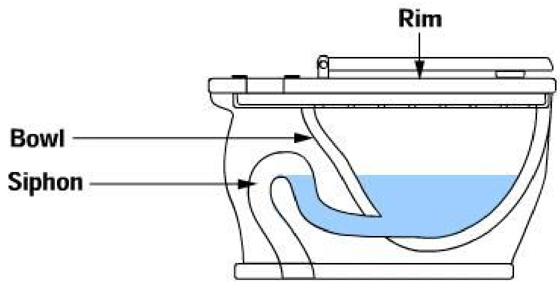

Figure 2. 4: The Bowl Siphon (Howstuffworks.com)

2.7.1. Flush Mechanism

Most of people will notice the water tank attached inside the toilets. The purpose of the tank is to act like a bucket of water. The theory is simple; when we pour the water from the bucket inside the bowl, the water level in the bowl will not rise. This is because the extra water will immediately spills over the edge of siphon tube and drains away (refer to Figure 2.4). When we have enough water to go into the bowl, and fast enough with certain amount of pressure it will activate the siphon. Thus, cleans the bowl from the liquid or solid waste. The same technique is used when we attach the water tank with the toilet bowls. The tank holds several liters of water and when we flush, all the water inside the tank is dumped into the bowl in about few seconds (Braiin, 2008). This is equivalents to pouring a bucket of water in the bowl. The system used to flush the water is called Flush Mechanism.

The Flush Mechanism consist of overflow tube, flush valve, handle and the most important part is its tank. From Figure 2.5, there is a chain attached to the handle on the side of the tank. When the handle is pulled, it will pulls together the flush valve. The flush valve will lift up and reveal a 5.08cm to 7.62cm diameter drain hole (Braiin, 2008). This drain hole allows water to enter the bowl in few seconds and push the waste inside the bowl to the siphon.

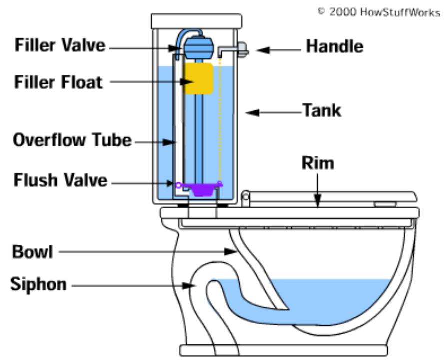

Figure 2. 5: The Flush Mechanism (Howstuffworks.com)

2.7.2. Refill Mechanism

All the water inside the tanks will dump into the bowl to activate the siphon. Once the tank is emptied, the flush valve will close by itself and covers the drain hole to allow the water to refill the tanks again. From here, the refill mechanism is used to fill up tanks with enough water to start the whole process all over again. The refill mechanism is consists of filler valve and filler float. Filler valve can turns the water on and off. The valve turns the water on when the filler float (or ball floats) falls. As the water level rises, the float will also rises and turns off the filler valve (Braiin, 2008).

2.8 Flush Tank Design

The principle and operation of High-Efficiency Toilets are depending on their designs. From removing waste by using flush water volume to increasing pressure and velocity of the water, the design of HET is the main catalyst. Nowadays, toilet bowls are specially design so that the water will tend to swirl less than traditional toilets. Reducing the swirl will result in reducing the loss of energy in the water because of the friction, drag or turbulence which will affect the performance of HET.

The design of the water tanks also plays the same important role as well as the toilet bowl. The designs of the tanks will determine the velocity and pressure of the water that will activate the siphon and at the same time cleaning the bowl. Besides, the material selection is also vital. Most people know that the toilet is made of vitreous china. It is simply because of its strong material. Its smooth surface will help to reduce friction when the water is flushed into the toilet bowl. With extra benefits like easy-to-handle maintenance and cleaning characteristics, vitreous china is a suitable material for making toilet bowl and tanks.

To engineers a complete new flushing tank can take a long time to develop. Traditionally, the development process of the high performance toilet is done manually by the master craftsman and it involves many trials before we can get the suitable design for the toilet. This method needs long development period, high expenses and more difficulties for developing new water saving products (Wang, Xiu, & Tan, 2011). Nowadays, computer has taken much of what used to be done by hands. Start with basic drawings by using pencil and paper, designers today use software called Computer Aided Design (CAD) to virtually generate their idea. Unlike traditional method, CAD model that has been generated has the entire geometry of the toilet in a virtual 3D format. In addition, the models then can undergo simulation testing which examines the physics of the water flows through the toilet system. The time taken to develop the new water saving design by using this CAD software can be reduced and the design is not necessarily done by the master craftsman. For this study, SolidWork software will be used to generate the 3D drawings and simulation will be done via SolidWork Flow Simulation software.

2.9 Conclusion

In conclusion, water is essential in our daily lives. With the rise of global warming and pollution issues rises nowadays water becomes even more important in many parts of the world. Preserving water resources has become an important issue for many countries. Statistics data from many researchers suggest that more than 50 percent of a family water usage is spent on sanitary (Cheng, Lee, Liu, & Hsia, 2010).

Thus, the use of low-flow water and High Efficiency Toilet is suitable and need to be implemented to reduce the amount of water flushed into the bowl for using less water to flush liquid or solid waste is really makes sense. If we manage to reduce the amount of fresh-water used to flush in the bowl, the remaining fresh-water can be used for other activities such as bathing, cleaning, drinking and etc.As conclusion, today's high efficiency toilets (HETs) are helping the consumer to conserve water. In United States, it requires that toilets sold use no more than 1.6 gallons (6 liters) per flush (Elliot, 2008). According to Huat (2002), Malaysian Standards for both the flush volume and flow rate are 6 liters (1.32 gallons) and 1.8 liters per second. From the criteria of WaterSense label from U.S. Environmental Protection Agency (EPA), our toilets are considered to be efficient.

With a combination of suitable design and technology, the new types of flushing method is possible. Unlike the first generation of toilets, new advanced technology toilets are able to save water with no trade-off in flushing power. The introduction of WEPLS Program in Malaysia, makes it easier for consumers to identify HET in the marketplace. Toilets with WEPLS approved label have been through testing set by SPAN to test both criteria and performance. This proves the products that have been labeled with such labels are reliable and marketable.

In this study, the researcher will simulate the design of flush tank system by using SolidWork Flow Simulation software to check whether the performance is same with the data collected from the experimental study. The next chapter will explain about the method that use to gathered the data for this study.

CHAPTER 3

METHODOLOGY

3.1 Overview

The purpose of this chapter are to describe the methodology used for this study. Besides that, this chapter also dedicated to describe briefly the procedures used in collecting the data from experimental study and simulation study. As shown in Figure 3.1 is Flow Chart of the Methodology.

3.2 Objectives and Variables

Usually before starting scientific experiment or investigation, researcher needs to identify the problems in the first place. In this study, the problems that needs to be investigate is the pressure and volume flow rate exerted from different design of water tanks. There are three variables sets for this study that is constant variables, manipulated variables and responding variables. Since the experiment is done in standard room temperature and pressure, fixed variables sets for this study are temperature and atmospheric pressure. Besides that, the source of water is come from standard industry piping. Thus, the type of water used (pipe water) is considered as constant variables too.

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