DESIGN OF RAINWATER HARVESTING AND FILTRATION SYSTEM FOR DOMESTIC USE

MUHAMMAD FAISAL BIN M.M.AKRAM

A report submitted in fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering (Design & Innovation)

Faculty of Mechanical Engineering.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION.

I declare that this report entitled “Design of Rainwater Harvesting and Filtration System for Domestic Use” is the result of my own work except for quotes as cited in the references.

Signature : ……

Author : ……

Date : ……

APPROVAL.

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Mechanical Engineering with Honors.

Signature : ……

Supervisor Name : PROF. MADYA Ir. Dr. Ts. ABDUL TALIB BIN DIN.

Date : ……

DEDICATION.

I dedicate this thesis to my supervisor, Prof. Madya Ir. Dr. Ts. Abdul Talib bin Din who have guided me throughout this project. This thesis is also dedicated to my parents who have been a great source of support mentally and physically.

ABSTRACT.

This project offers a method of harvesting and filtering rainwater for domestic use. The project purpose is to help meet the increasing demands of water due to the increase of human populations. This can also help household areas or farms that experience high level of rainwater to reduce the run-off that chokes the drain as well as reduce soil erosion. The project also helps reduce the billed water usage for daily use such as by using rainwater to water the plants and to feed the livestock at the farm for farmers. By doing so, the water collected can supplement the domestic water needs and alternatively reduce the water usage. The design is made using CAD software (Fusion 360), and the design is refined based on the previous researchers compiled from the internet and also from the survey handed out to determine the needs of the consumers. The water is collected from the roof, filtered using a specific filtration system and then stored in a tank for later use. The process takes place during raining time and easy to be used or installed.

ABSTRAK.

Projek ini menawarkan kaedah penuaian dan penapisan air hujan untuk kegunaan domestik. Tujuan projek ini adalah untuk membantu memenuhi permintaan air yang semakin meningkat diikuti dengan peningkatan populasi manusia. Ini dapat membantu kawasan ladang atau isi rumah yang mengalami taburan air hujan yang tinggi untuk mengurangkan air hujan berlebihan yang boleh menyebabkan longkang tersumbat dan juga dapat mengurangkan hakisan tanah. Projek itu juga membantu mengurangkan penggunaan air untuk kegunaan harian seperti menggunakan air hujan untuk menyiram tumbuhan dan memberi makan ternakan di ladang untuk penternak haiwan atau petani. Dengan berbuat demikian, air yang dikumpul dapat menambah keperluan air domestik dan secara alternatif mengurangkan penggunaan air. Reka bentuk dibuat menggunakan perisian CAD (Fusion 360), dan reka bentuk dibuat berdasarkan penyelidik terdahulu yang dikumpulkan dari internet dan juga dari tinjauan yang disampaikan untuk menentukan keperluan pengguna. Air dikumpulkan dari bumbung, ditapis menggunakan sistem reka bentuk penapisan tertentu dan kemudian disimpan dalam tangki untuk digunakan kemudian. Proses ini berlaku semasa masa hujan dan mudah digunakan serta dipasang.

ACKNOWLEDGEMENT.

Writing a thesis is hard work and would be impossible without support from other people. First, I want to express my greatest appreciation towards both of my supervisor, Prof. Madya Ir. Dr. Ts. Abdul Talib bin Din who guided me throughout this project. The thesis may not complete without their supervision and guidance. My special appreciation to my friend's spirit and support in providing any assistance and help in order to complete this project. I would also like to express my appreciation towards the PhD and Master's students for sharing their knowledge and helping me to complete the project. A special thanks to my father for his kind gesture in helping me especially in the process of material selection for the product. Last but not least, I would like to express my appreciation to my parents and other members of my family for their emotional, financial support and providing a lovely environment for me to complete the study. I humbly extend my thanks to all concerned persons who co-operated with me in this regard.

TABLE OF CONTENT.

List of Tables.

List of Figures

List of symbols and abbreviations.

DN- Diameter Nominal

PVC- Polyvinyl chloride

HOQ- House of Quality

List of Appendices.

Chapter 1

INTRODUCTION.

This chapter is about the introduction of this thesis project which includes the project overview, problem statement, objectives and scope of work.

1.1 Project Background.

Water is known as one of the most important elements in our daily life. It dominates the surface of Earth and is vital to life on our planet. We all know that as the populations of humans on Earth increases, so does the demands of clean drinkable and useable water.

Studies shown that rainwater can be used as a substitute to be used in helping out on our daily use. Rainwater can be used to help us accomplish various daily task such as washing, cleaning, watering the plants, feeding it to the livestock and many more. Rainwater is said to be useful but not recommended to be drank as drinking water unless it has gone through filtration and treatment process that eliminates the foreign substance or bacteria. By filtering and treating the rainwater, it will be a clean and drinkable water.

Most people are still not convinced that treated rainwater can be used in our daily life. Most people still stick to the water supply that is supplied by the water supply company. By collecting rainwater, it can help reducing the billed water usage in a household, helps from wasting drinkable water to be used on daily things such as washing, cleaning and many more. This can also help reducing the water bills at home and ensure that our homes always have water to spare even when our normal household water supply is having problem.

1.2 Problem Statement.

Water demands rises each day as the populations on Earth increases. The useable and drinkable water availability is going to be a major health issue around the globe, as the world population increases. The need for safe clean water is likely to double in the next decade, where the world population is expected to exceed nine billion. The water supply that is currently in use to supply the Earth's population is decreasing each day. The need of finding a new alternative are researched every day to help fight this current issue. Rainwater is said to be an excellent substitute to replace normal treated water to be used for washing, cleaning, watering the plants, feeding it to the livestock and many other use besides drinking as rainwater are not meant to be drank unless they are filtered and treated properly.

1.3 Objectives.

The objectives of the project are as follows:

i. To design and fabricate a rainwater harvesting and filtration system for domestic use.
ii. To meet the increasing demand of water following the increase of human population on Earth.
iii. To gather the unused water streaming to reduce soil erosion and reduce the run-off which chokes the drains.
iv. Supplement domestic water needs.

1.4 Scope of Project.

The scopes of this project are:

1) Farmers or any other agricultural business owner.
2) Household areas that frequently experience water shortage.
3) Areas that experience a high level of rainfall distribution.

1.5 General Methodology.

The actions that need to be carried out to achieve the objectives in this project are listed below:

1) Literature Review.

   Journals, articles, or any materials regarding the project will be reviewed.

2) Research on Weather Forecast.

   Research on the weather forecast is done by using the data from the internet to identify the type of rain and the total rainfall for each year to determine the total water that can be collected.

3) Report Writing.

   A report on this study will be written at the end of this project.

Chapter 2

LITERATURE REVIEW.

This chapter contains the literature review that based on the objectives and scope of the project. This chapter is conducted in order to complete this research done by reading some journals that have a connection to the project title of "Design of Rainwater Harvesting for Domestic Use". This chapter contains rainwater harvesting collection process, filtration process, water management process, gutter and water catchment design, piping system and design optimization.

2.1 Rainwater Harvesting Process.

Water is an essential element that we used in our daily life. It is one of the most important needs to human being. Rainwater harvesting process is a water collection process mainly used to harvest rainwater by collecting rain water from the roofs or other high surfaces to be stored for later use. It is mainly used to meet the increasing demand of water. The process of rainwater harvesting requires a large area to collect a large amount of rainwater to be filtered and stored for future use especially during rainy seasons to help recover during drought or water shortage [1].

As the population increases, the world will be facing the scarcity of water and will be trying to find other alternatives to help them in recovering for the shortage of water. Factors that contribute to the water scarcity problem are the high population growth, the huge influxes of refugees from neighboring countries, and the impacts of climate change [2].

In conclusion, based from the journal reviewed for the rainwater harvesting process, the main factor that affects the water shortage is the because of the rapid population growth. The matter is currently one of the main factors that contributes to the scarcity of water.

2.2 Filtration Process.

The water filtration process is the single most important aspects in the system. Filtration is important because it holds the key to ensuring the water harvested is safe or unsafe to be used. Filtration are used to remove impurities by lowering contamination level of water. The filtration process for rainwater harvesting system is simple yet important because the water collected needs to go through filtration process before it can be used as water for livestock, plants, cleaning, washing and many more. The most important aspect that needs extra attention to is the filter type [3].

2.2.1 Filter Type.

There are many types of filter that can be used to filter the rainwater collected. The type of filter determines the quality of water on the outcome. The finer the mesh size of the filter, the better the quality of the water will be. There are many types of filter that can be used for rain water harvesting but the most suitable one is the DN 100 filter which is suitable for inline compact filtration system and it is used for a $150m^2$ size roof water collection which is the roof size of a normal-sized house [4].

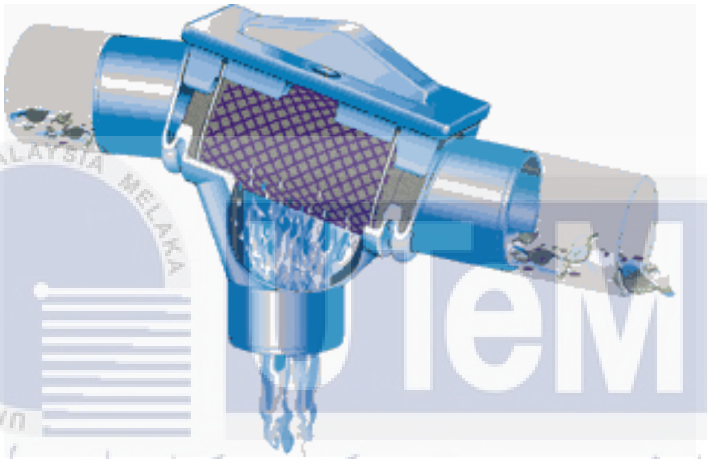


Figure 2.1: Illustration of DN 100 function.

Figure 2.2: DN 100 filter.

Figure 2.3: DN 100 filter measurements.

The example of the filter is as shown in the figure above. The mesh size of the filter cartridge is 0.7mm x 1.7mm which is suitable for filtering rainwater. The

placement of the filter will make it easy for the water to be filtered and to push the excess dirt or unwanted material out of the pipe as shown in Figure 1 above of the illustration on the placement and functions of the filter [5].

In conclusion, on the journal reviewed, it can be confirmed that the use of the DN 100 filter is the most suitable filter that can be used for this system.

2.3 Water Management Process.

Water management process is important in managing the water harvested. The main parameters need to be taken seriously are the water tank and the excess water.

2.3.1 Water Tank.

A water tank is a well-built container with many shapes and sizes for storing water. Water tanks are made to provide storage space for water to be used in many applications such as, drinking, irrigation agriculture, suppressing fire, agricultural farming, for both plants and livestock, chemical manufacturing, preparing foods as well as many other uses. The water tank needed for this rainwater harvesting process is a medium-sized water tank enough to hold a minimum of 200 liter of water that can be used for agriculture, livestock and many other purposes. The most suitable water tank is an opaque tank that blocks sun light from passing through it to prevent algae growth [6].

2.3.2 Excess Water.

Excess water is one of the things that needs extra attention to when harvesting rainwater. The excess water that is collected needs to be dispose of properly to prevent the tank from cracking or damaged by taking in excess water weight. The excess water needs to be measured to be within an optimum level with the capacity of the tank and needs to have an overflow valve that will allow excess water to flow and exit the tank. The excess water flowing out needs to be dispose of into the ground instead of on the ground to prevent stagnant that attract mosquitoes and soil corrosion in the ground near the water tank [7].

2.4 Gutter and Water Catchment Design.

For over two millennia, it was proven that humans have attempted to collect rainwater for domestic and agricultural use with many ways that they can think of. The gutter is one of the devices used to catch and flow the collected rainwater that falls on the roof into a pipe and goes straight to the tank to be stored. The gutter and water catchment is the main body that assists the water collection that is used in the project. The normal domestic roof-based rainwater harvesting systems consists of 4 main components that needs to be considered [8].

Four Main Components.

- A catchment surface (roof)
- A mean of intercepting runoff from the catchment surface (gutters)
- A means to transport water to the reservoir (downspout)
- A reservoir to collect the water

The main components used are to ensure that the water collected from the roof is safely and efficiently gathered. There are many types of gutters used for the process of collecting rainwater, the types vary with shapes and sizes. The gutter efficiency and productivity rely on its ability to capture and transfer runoff from a roof into a storage tank. The most important parameter that needs to be considered when choosing a gutter design is to find the one with the right and suitable cross-section. The focus is the gutter cross-section as the cross section plays the biggest role when catching rainwater because it can help by intercepting the runoff flowing from the roof [9].

There are many different shapes and cross-section of gutter used for buildings and houses these days, the common ones used these days are the V-shaped gutter, Square gutter, Trapezoidal gutter and a Wrap gutter design as shown in Figure 4 below.

Figure 2.4: Cross-section of gutter (from left to right), V-shaped gutter, Square gutter, Trapezoidal gutter and a Wrap gutter design.

The gutter design is unique and have their own benefits and constraints. But the most suitable gutter that were chosen for this project are the Trapezoidal gutter design because it can hold the greatest amount of water flowing due to its big upper cross-section that helps and allows for catchment of both roof runoff and direct rainfall [10].

In conclusion, the gutter and water catchment design need to be chosen properly as it determines the efficiency of the watch that will be collected during rain time.

2.5 Piping System.

The piping system are one of the most important aspects in this rainwater harvesting process. Piping systems are the intermediate between the gutter and the reservoir. It connects the flow of water collected on top of the roof and flow it down into the tank perfectly and efficiently. Piping systems are common these days as they are used widely in almost every place either in houses, buildings, for industrial purposes or many other purposes. The piping system used for this project are a simple piping system used in a normal household as it is a lot cheaper and used widely and easy to be obtained.

The piping system has 2 major parameters that needs to be given proper attention to such as:

- Piping materials
- Piping size

There are many types of piping materials such as cast iron, polyvinyl chloride (PVC), chrome copper, galvanized iron, copper and many more. The one used for this project is the polyvinyl chloride (PVC) piping system as they are light-weight, cheap and easy to be obtained. The PVC are commonly and widely used throughout the world as a means of piping system and implemented in many buildings and also used in many industrial processes. The piping systems illustrations are as shown in Figure 5 [11].

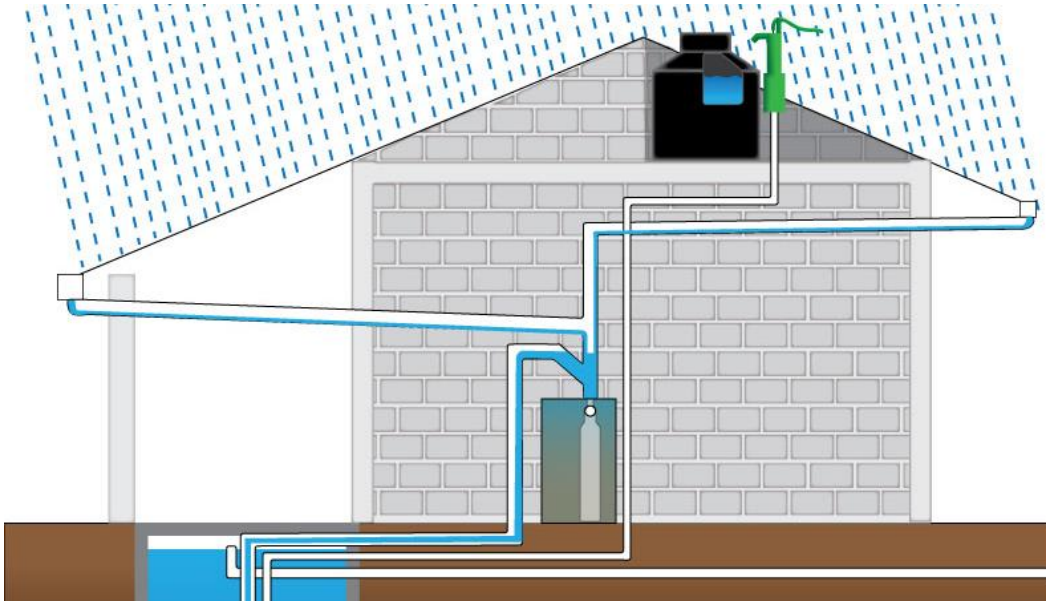


Figure 2.5: Illustration of rainwater gutter and catchment system

In conclusion, the piping system is one of many important aspects needed to be considered in this project in order to help the flow of the rainwater collection going smoothly and efficiently. The types of pipe needed and was chosen for this project is the polyvinyl chloride (PVC) pipe which is the most suitable choice of pipe commonly and widely used by many industries and in many fields because of its light-weight traits, cheap price and easily accessible to be purchased.

2.6 Design Optimization.

Design optimization is known as the process of finding the best design parameters that will help satisfy the project requirements. Design optimization is important to enhance and improve the current design to be much better. The design optimization applied for this project is the first flush diverter.

2.6.1 First Flush Diverter.

The first flush diverter is a device used in most rainwater harvesting system. The first flush diverter is used to divert the first flow of water away from a rainwater catchment system. The first few minutes pass of water in any storm essentially cleans and washes your roof of all the sediments, gravel, leaves, and dirt that have collected since the last rain. The idea is that diverting the first flush can help ensure cleaner water in your rain tanks or barrels.

The first flush diverter is used commonly for rainwater harvesting process and widely used to ensure that the water collected is clean after the first flush. The device comes with many different shapes and sizes, the example of the first flush diverter device and the illustration of the functions are as shown in Figure 6 and Figure 7 below.

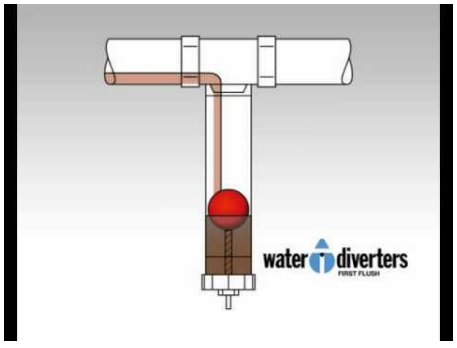


Figure 2.6: First flush diverter device.

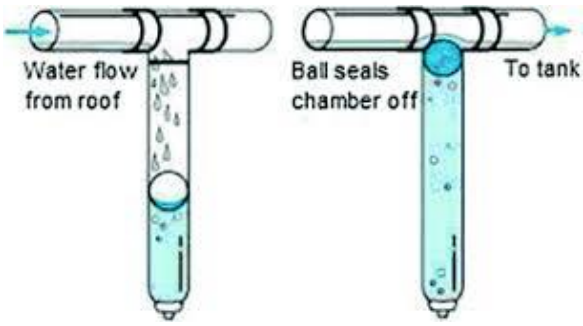


Figure 2.7: Illustration of first flush diverter function.

The first flush is important in collecting a clean rainwater to be used for future use. The effect of using the first flush diverter can give a lot of impact on the clarity of water. The first flush can help increase the clarity of water making the water much clearer, clean and safer to be used. The comparison of the water between using first flush diverter and not using first flush diverter are as shown in Figure 8.

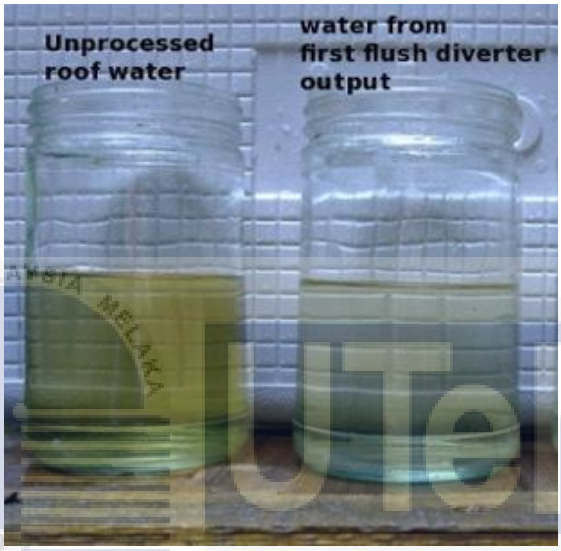


Figure 2.8: Comparison between not using first flush diverter (left) and using first flush diverter (right).

The first flush diverter is an important contraption needed to be used in this project to enhance the clarity and cleanliness of the water collected through this rainwater harvesting process [12].

In conclusion, the first flush diverter is important in the design optimization process as it helps greatly in increasing the clarity of the water collected and can make it a maintenance-free device that can greatly benefits all who uses it in the future.

Chapter 3

METHODOLOGY.

This chapter describes about the investigation method that is used to achieve the objectives. Flow Chart, Gantt Chart, Concept generation, Morphological chart, House of Quality (HOQ), Concept Scoring and Screening and, Final Concept Selection are included in this chapter. The data collection method is the typically determining for the data analysis.

3.1 Flow Chart.

A flowchart refers to as a type of diagram that represents an algorithm, workflow or process. The flowchart will show the steps in a form of boxes with various kinds, and they are connected using an arrow according with their order. This diagrammatic representation will be used to illustrate a solution model for a problem we are trying to solve.

The general flow chart of rainwater harvesting process are shown in Figure 3.2 below. First of all, comparison was made between a few selected models to identify the requirement that needed in the product. From the comparison, the requirement was converted into a House of Quality (HOQ). Next, the idea is brought out by using morphological chart. At morphological chart, a few designs were sketched for their parts. The designs are then combined from morphological chart was and it creates the concept generation. The most suitable concept generation was selected as a final design. After the completion of all the process, cost analysis was determined and calculated to identify the total cost before the start of fabrication process.

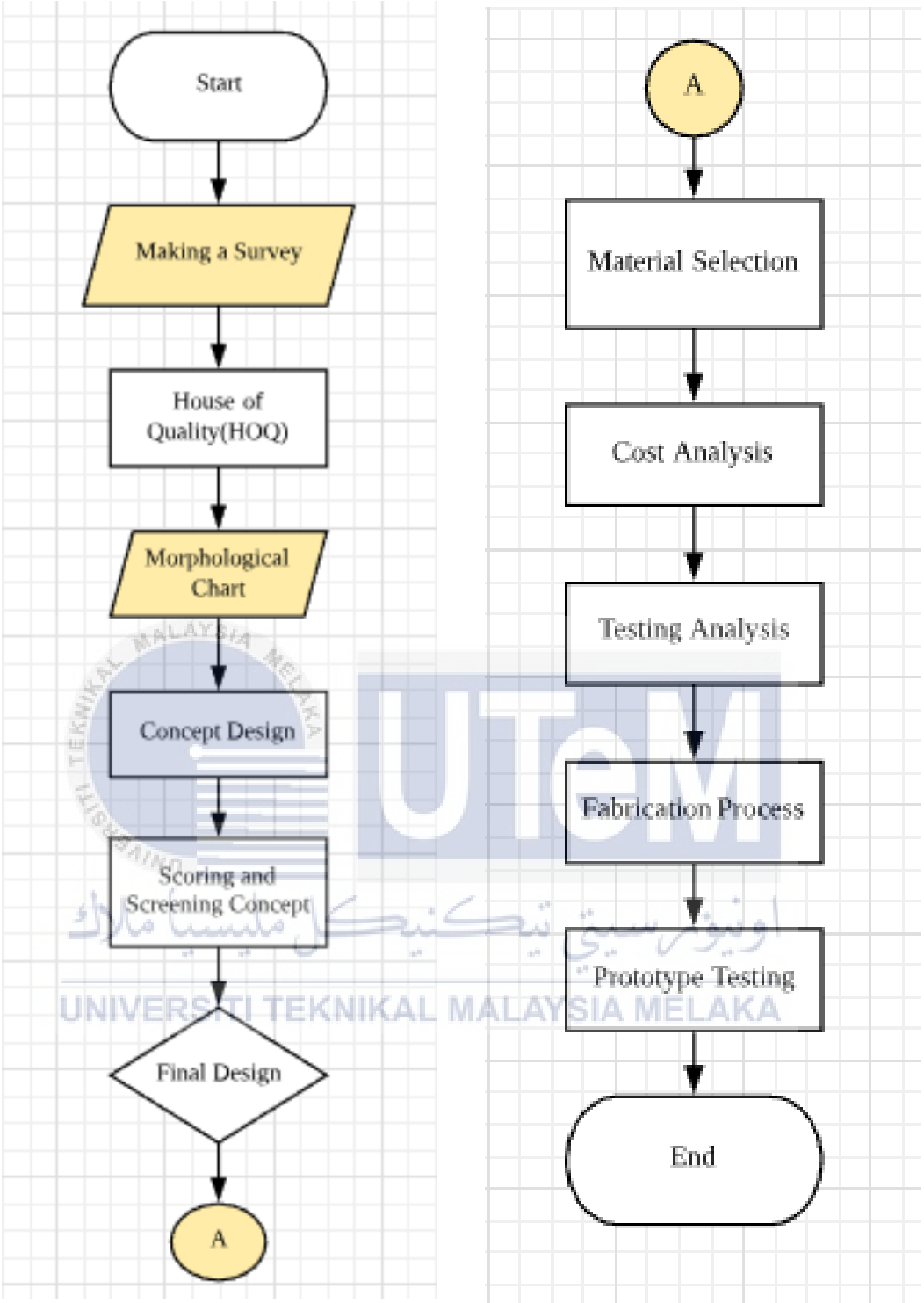


Figure 3.1: Flow Chart of Rainwater Harvesting Process

3.2 Gantt Chart.

Gantt chart is one of the most important things needed before the start of any project. It is a guideline of project progress. It is important as it is used to observe and illustrates the project schedule on the current progress. Table 3.3 below illustrates the schedule aimed for this project. The chart shows task conducted according to week until the completion of this project.

The project started at week 1 semester 1 2018/2019 where the students are required to meet the supervisor and each of their supervisor explains about the project title. At their 3rd week, they will start out their report and it started with chapter 1 where it about identifying the introduction, problem statement, objective and scope. The following two weeks after completed chapter 1, Chapter 2 is then continued. In Chapter 2, it tells about the literature review related with the project that we are assigned to. Most of the literature review came from many other previous journals we came across by searching online, the web, or by article. At week 9, the project moves on with the making of the methodology until week 14. During semester 1, we are obliged to meet up with the supervisor once a week to discuss about the project progress and to get a few comments about the progress to fix or improve according to the supervisor's requirements.

Activities	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Brainstorming and select the title															
Meeting with supervisor															
Chapter 1:Identify introduction, problem statement, objectives and scope															
Chapter 2: Literature review															
Chapter 3: Methodology															
Reference and formatting															
Submission of general conduct form and logbook to supervisor															
Poster presentation															
Submission of PSM 1 reports to supervisor and examiners															

Table 3.1: Gantt Chart Table

3.3 Making a Survey.

A survey is known as a research method used to help in collection of data from a pre-defined group of respondents to gain insights and information on various topics. Surveys carried out have their own purposes and can be carried out in many ways, depends on the method chosen and the objectives that needs to be achieved.

The data is usually obtained by using standard procedures that will ensure each respondent is able to answer the questions easily and avoids using questions that could influence the outcome of the research or study. A survey is done by asking people for information using questionnaires, which can be distributed on paper, or by using technology we possess now we can also distribute those questionnaires using digital media such as social networks, email, QR codes or URLs.

A survey is needed to create a product that fulfil the customer requirement. The survey is very important in order to figure out and understand what the customer really want before the production of the product. Without the survey, it will be difficult to know what their needs and wants are. In some cases, sometimes the product that was made does not satisfy the customers need.

The survey can be done in many ways. The easiest way of doing a survey in this 21st century is by using and online survey form that can be filled up just by using their smartphones. Google form is one the best online survey platform for making a survey. The applications are very easy to be used and can generate the response in a form of pie chart, bar chart and many more. It is easy to use and can help us get more respondent just by a click of a button.

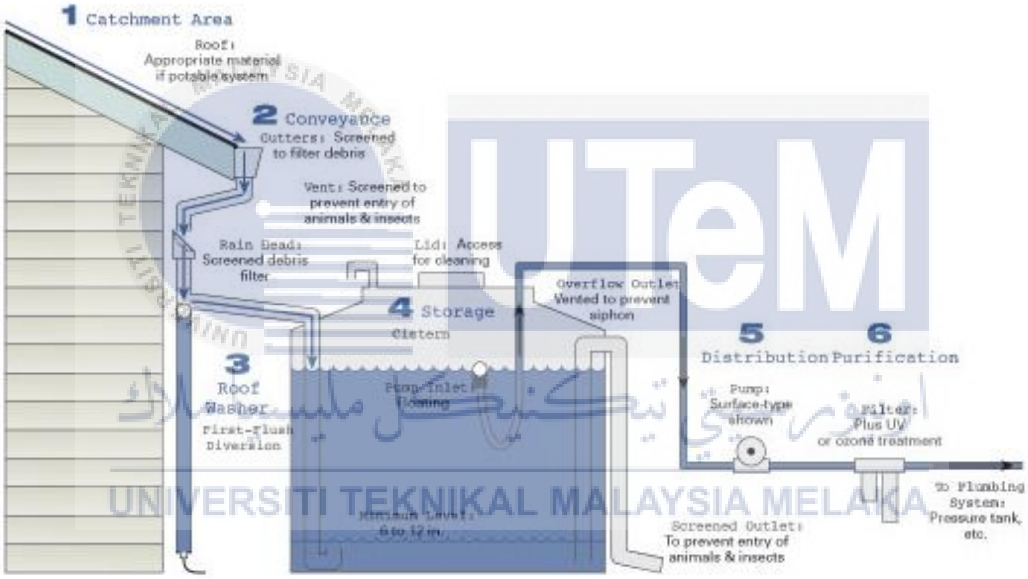
3.3.1 Survey Questions.

Survey on Rainwater Harvesting Machine For Domestic Use.

Rainwater harvesting is a process that harvest the rainwater to be used inn our daily life to replace the normal tap water to be used for activities other than drinking. We are making this survey to determine the requirements that the customers want for the product.

* Required

Rainwater Harvesting Machine



Do you think that the rainwater harvesting process can help solve the water crisis in our daily life? *

	1	2	3	4	5	
Very Disagree	○	○	○	○	○	Very Agree

Do you thin that the product should be compact and light-weight? *

	1	2	3	4	5	
Very Disagree	○	○	○	○	○	Very Agree

Do you think it should be user-friendly and cheap? *

	1	2	3	4	5	
Very Disagree	○	○	○	○	○	Very Agree

How often do you have water shortage problem in your house or district? *

- ◯ Regularly
- ◯ Sometimes
- ◯ Never

How much rain do you experience in your home area? *

- ◯ Everyday
- ◯ Few times a week
- ◯ Once a week
- ◯ Few times a month
- ◯ Once a month
- ◯ Never

Would you buy this product to reduce your water usage? *

- ◯ Yes
- ◯ No
- ◯ Maybe

Do you have any ideas or comments to add to improve this product?

Your answer

3.3.2 Survey Response.

The survey was made, and the data gathered are presented in bar graph. The charts for each question are shown in the figure below. Each of the questions are given to a total of 50 respondents.

Question 1.

Do you think that the rainwater harvesting process can help solve the water crisis in our daily life?

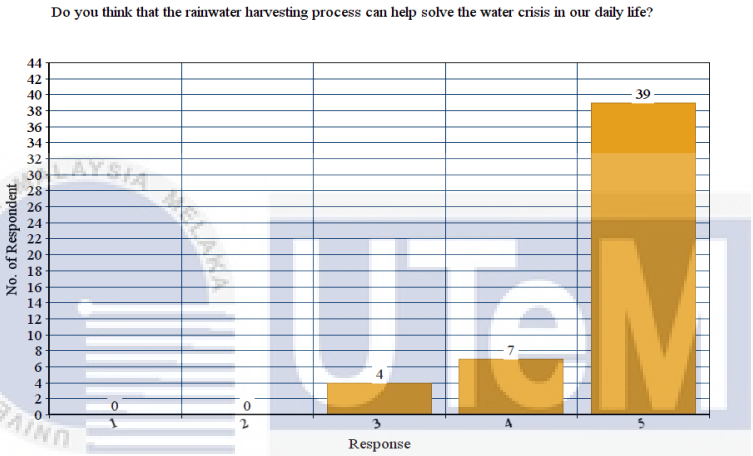


Figure 3.2: Survey Question No. 1

Question 2.

Do you think that the product should be compact and lightweight?

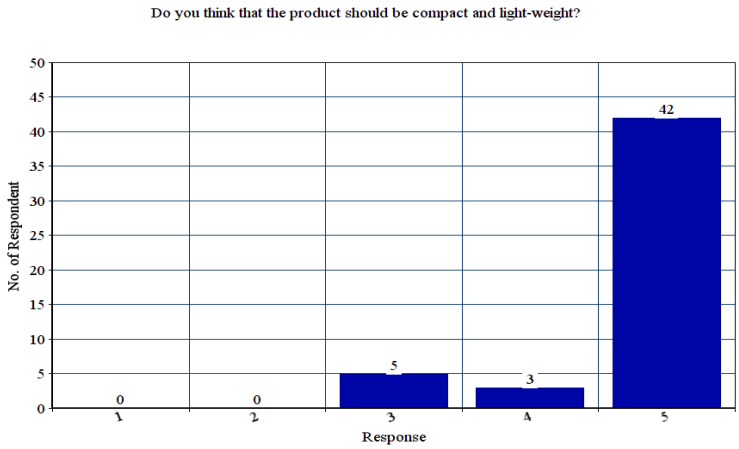


Figure 3.3: Survey Question No. 2

Question 3.

Do you think it should be user-friendly and cheap?

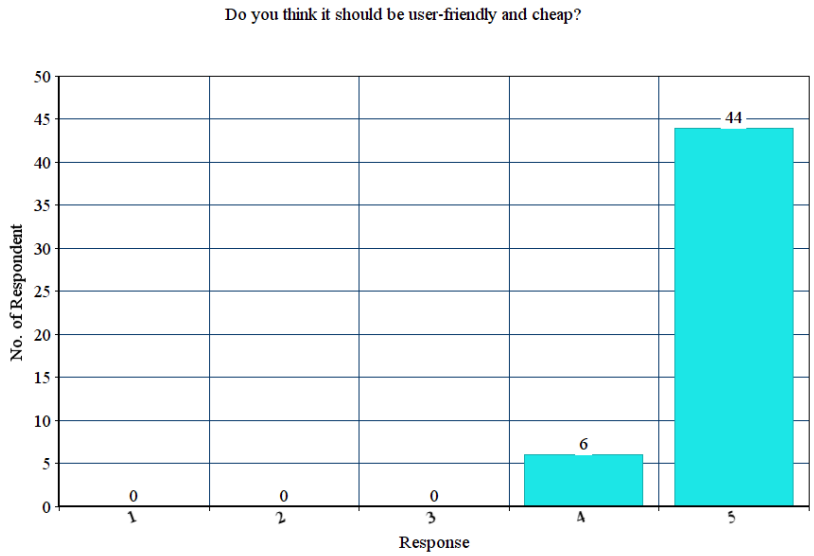


Figure 3.4: Survey Question No. 3

Question 4.

How often do you have water shortage problem in your house or district?

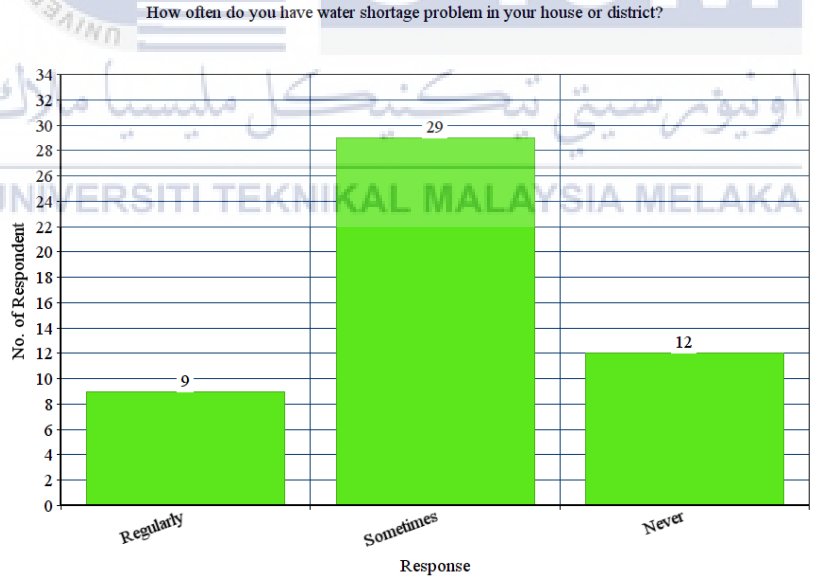


Figure 3.5: Survey Question No. 4

Question 5.

How much rain do you experience in your home area?

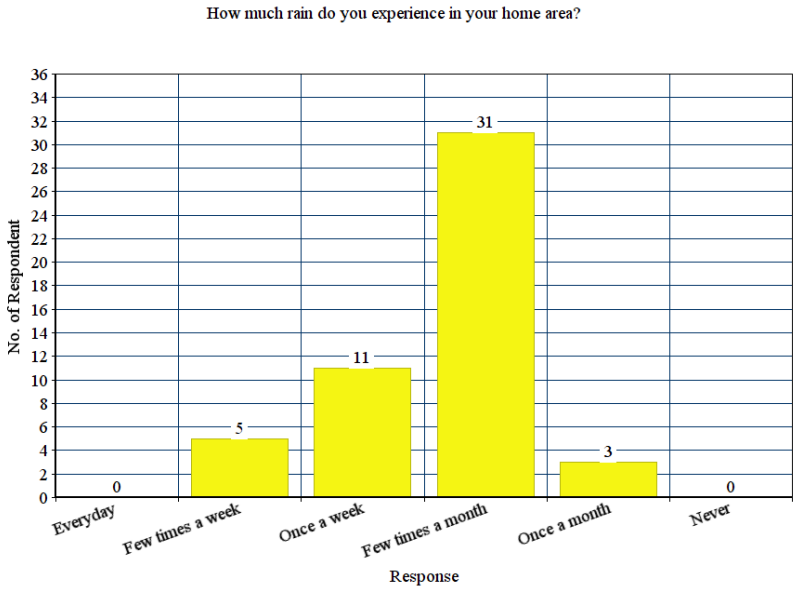


Figure 3.6: Survey Question No. 5

Question 6.

Would you buy this product to reduce your water usage?

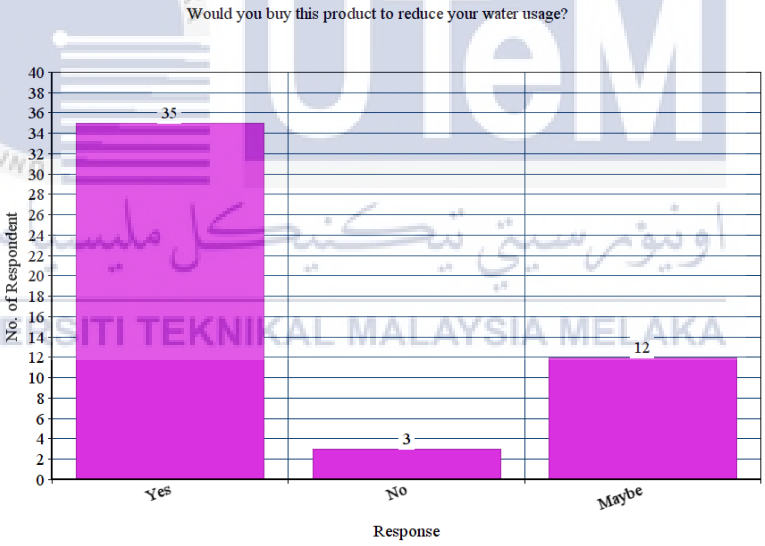


Figure 3.7: Survey Question No. 6

3.4 House of Quality (HOQ)

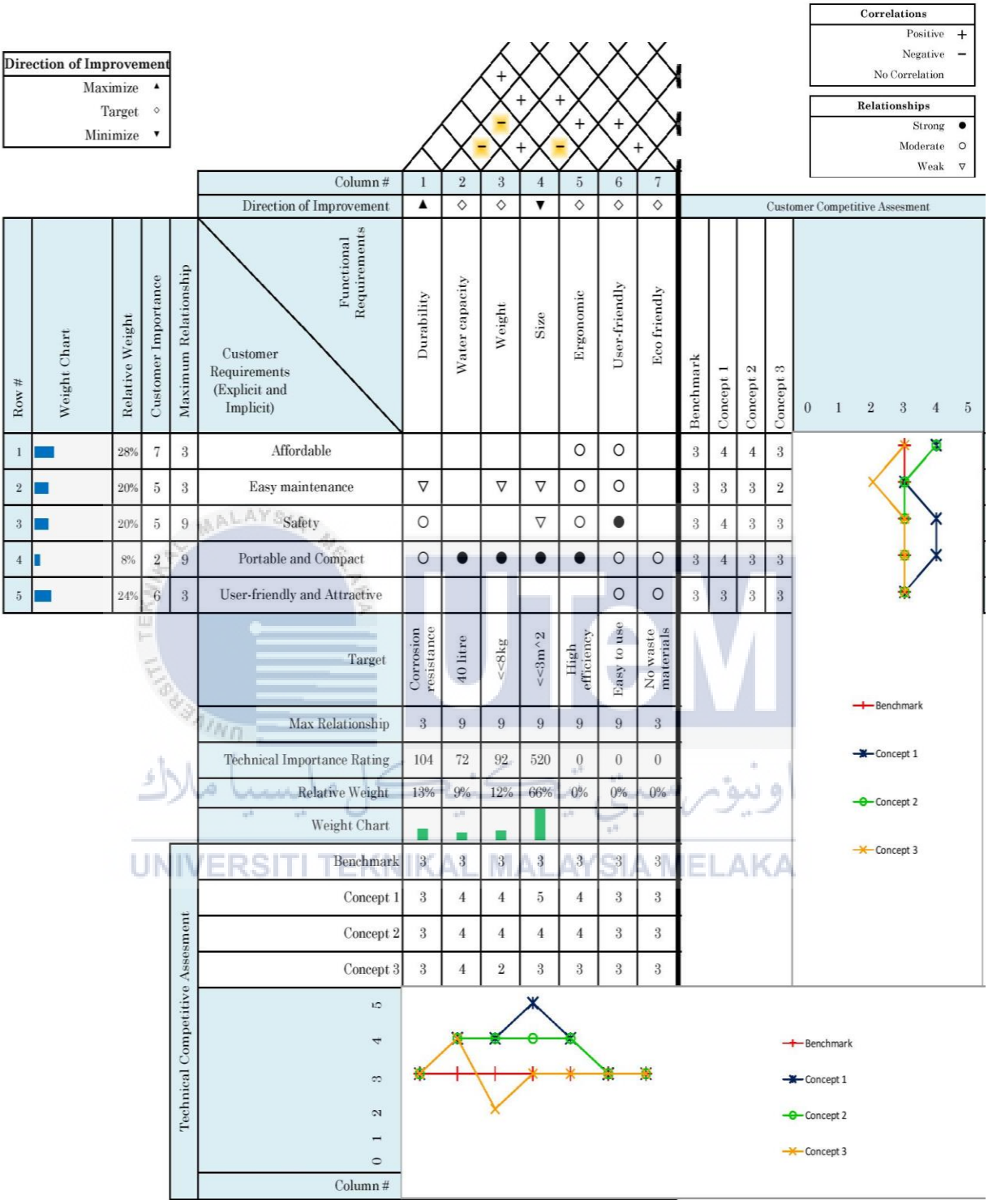


Table 3.2: House of Quality (HOQ)

3.5 Concept Generation.

In concept generation, getting the ideas is the most critical step in the engineering design process. It should start with a set of customer's needs and their target specifications. The process concludes with a variety of product alternatives from which a final design is selected.

The concept generation is based from many different views such as from the customers, respondents of surveys and many more. This allows us to create a user-friendly product that benefits other in their own way.

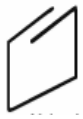
The concept generation in the production of this product is simply by acquiring the customers' needs by using a survey given to them, taking a few specifications by using the voice of customers, making an adjustments and simple modification to produce a product that is user-friendly, compact and can be used commercially by anyone.

The data gathered by the survey that had been done is then analyzed and the requirement of the customers are considered in developing the product. The data gathered are then presented in a morphological chart table. A morphological chart is a chart that provide a structured approach to concept generation to widen the area of search for solutions to a defined design problem. By using a morphological chart, it can help to generate a complete range of alternative solutions of designs for a product through a thorough and systematic analysis of the form or configuration that a product or machine might take.

From the morphological chart constructed, a design concept was made from them and was evaluated using the scoring and screening process to determine the quality and the most suitable product to be chosen and used as the final concept selection.

3.5.1 Morphological Chart

Table 3.3: Morphological Chart Table

	Option 1	Option 2	Option 3	Option 4
1. Pipe type	PVC 	Black plastic 	Galvanized iron 	
2. Gutter shapes	V-shaped 	Square 	Trapezoidal 	Wrap 
3. Tank transparency	Translucent 	Opaque 		
4. Water movement	Gravity-based	Motorized pump		
5. Mounting	Wall-mounted 	Ground-mounted 		
6. Filter orientation	90 degree 	45 degree 		

3.5.2 Concept Design

Concept design are the design made as a reference to help in the process of the final detailed design. Conceptual design usually is in the form of sketches. The design is made from the combination from the morphological charts. The combinations are picked from each option to be drawn together to create each of the conceptual design.

i) Concept Design 1.

The first conceptual design uses the combinations as shown below.

Pipe type: PVC	Gutter shape: Trapezoidal	Tank transparency: Opaque
Water movement: Gravity-based	Mounting: Wall-mounted	Filter orientation: 45 degree

- The design uses PVC pipes as they are easy to find and cheap.
- The gutter type uses trapezoidal shape for a maximum water collection.
- The tank used are opaque to preserve the water quality
- It uses a gravity-based water movement to help eliminate the use of motorized water pump
- It uses a wall mounting to hold it up on the wall that goes well to help the gravity-based water movement.
- The filter orientation uses a 45-degree orientation that can help collect optimum amount of rainwater.

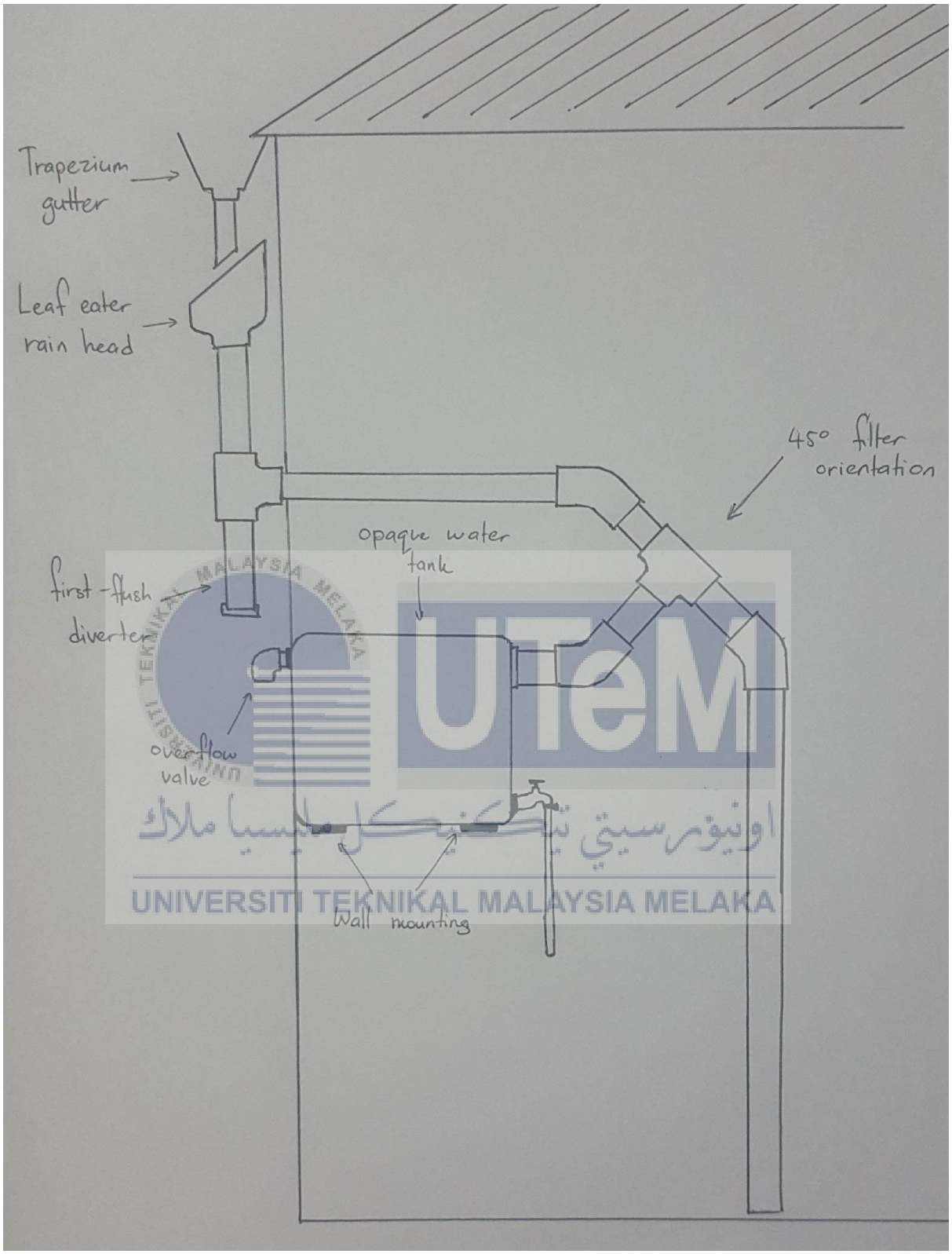


Figure 3.8 Concept Design 1

ii) Concept Design 2.

The second conceptual design uses the combinations as shown below.

Pipe type: PVC	Gutter shape: V-shaped	Tank transparency: Translucent
Water movement: Gravity-based	Mounting: Wall-mounted	Filter orientation: 45 degree

- The design uses PVC pipes as they are easy to find and cheap.
- The gutter type uses trapezoidal shape for a maximum water collection.
- The tank used translucent to help in determining the amount of water collected
- It uses a gravity-based water movement to help eliminate the use or motorized water pump
- It uses a wall mounting to hold it up on the wall that goes well to help the gravity-based water movement.
- The filter orientation uses a 45-degree orientation that can help collect optimum amount of rainwater.

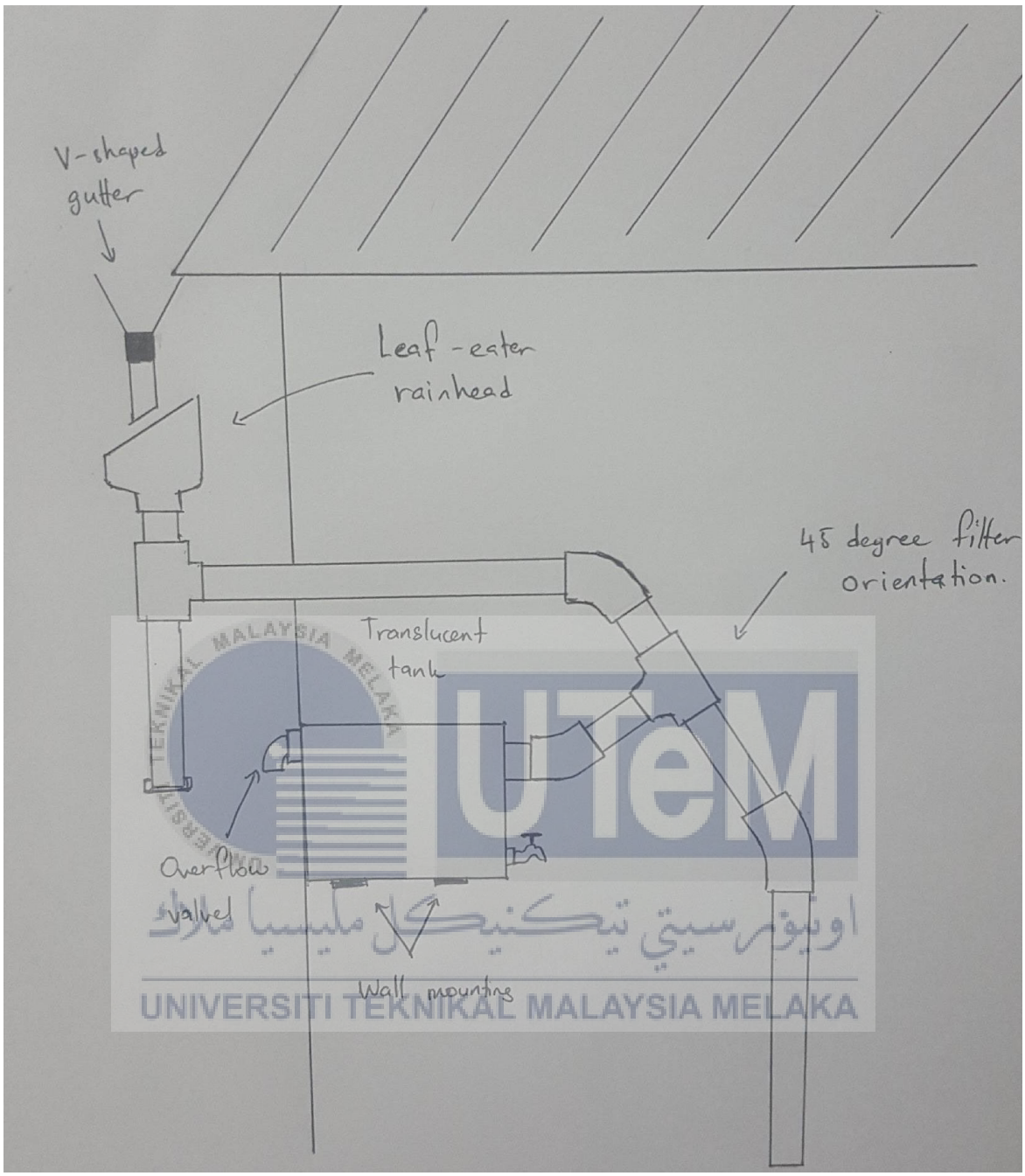


Figure 3.9 Concept Design 2

iii) Concept Design 3.

The third conceptual design uses the combinations as shown below.

Pipe type: PVC	Gutter shape: Wrap	Tank transparency: Translucent
Water movement: Motorized water pump	Mounting: Ground-mounted	Filter orientation: 90 degree

- The design uses PVC pipes as they are easy to find and cheap.
- The gutter type uses wrap shape to intercept run-off from the catchment surface.
- The tank used translucent to help in determining the amount of water collected.
- It uses a motorized water pump to help pump the water from the tank to be used.
- It uses a ground mounting to hold it on the ground and the amount of water collected can be high as they have no weight limit by being on the ground.
- The filter orientation uses a 90-degree orientation that can help collect maximum amount of rainwater.

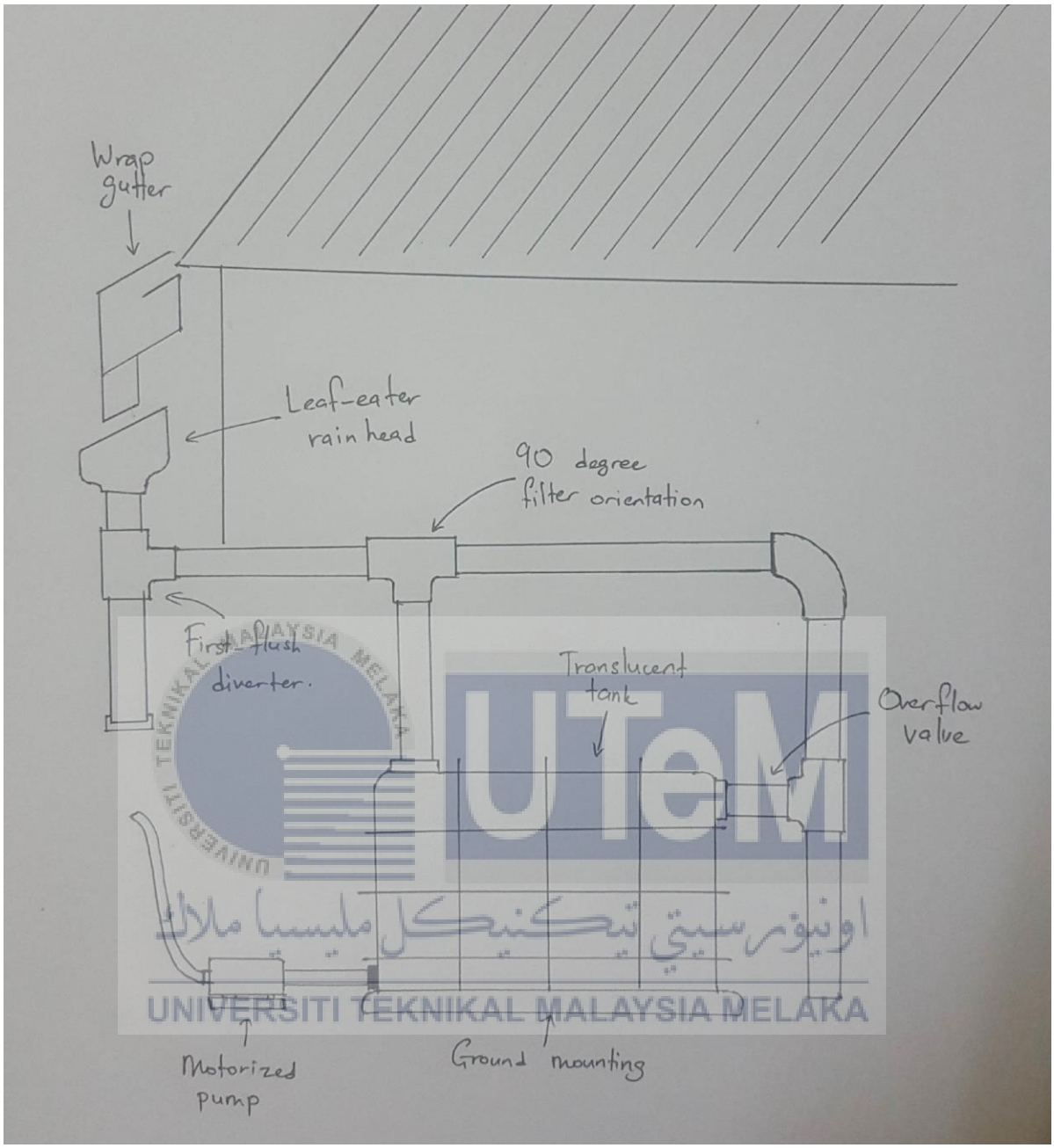


Figure 3.10 Concept Design 3

3.6 Concept Screening and Scoring.

This concept is used to evaluate concepts before investing too much energy in the detailed design work. Screening and scoring are used by reducing many ideas into smaller and more manageable set. The ideas quality in the final set depends on the quality of ideas in the initial set. Therefore, it is important to put great effort into the front-end processes of the comparison and ideation

After generating ideas, a variety of tools are used to analyze and filter the ideas to end up with something that is worth pursuing in more detail. All these techniques can be applied repeatedly as new ideas are generated or as the existing ideas are refined.

The outcomes are not always precise, i.e. a clear "winner" may not emerge. In that case, an experiment is devised (prototype) or new question(s) to use in evaluating concepts. Perhaps the group needs to conduct more internal research (brainstorming, concept sketching, cardboard mock-ups) or external research (web search, patent search, catalog search).

Concept screening.

Concept screening is used to eliminate ideas that are unworthy of pursuing. The team doing the research shall decide using simple criteria

- Are the ideas possible?
- Is the idea necessary?
- Does the technology already exist, or does it need to be refined or developed?
- If it needs to be refined or developed, does the team have the resources (skill, time, money) to do it?

The screening process may help leads to new ideas or ways to combine all the ideas. The process can be made iteratively, but it makes sense to use the screening process early in the designing process when there are several, great and excellent ideas. As the ideas are made much more detailed, other techniques used are more beneficial.

Concept Scoring.

After the specific design concepts have evolved, the concept scoring is used to establish a qualitative hierarchy of choosing the design options. The concept designs are then scored numerically using a simple scale that are relative to a benchmark.

- Create a set of criteria to evaluate (score) the concepts: 3 to 7 is criteria is a good number.
- Identify a benchmark design
- Use a simple scale: -1, 0, 1 relative to the benchmark design. (A more detailed scale -2, -1, 0, 1, 2 could be used if more detailed information on each concept is available.)
- Work across the criteria, not across the concepts. For example, suppose that cost and weight are two (of several) criteria. Rate all of the design concepts first by cost, and then by weight.
- Tally and rank the scores
- The outcome is a smaller number of design concepts that the group decides to pursue. The scoring exercise may generate additional ideas for new design concepts or for ways to combine design concepts.

The team may decide that future research is necessary. Any additional research should be focused on answering specific questions. Failure to obtain clarity should not set the team back to open-ended searches. To do so implies that the team did not learn much in the scoring process.

3.6.1 Screening Concept.

Criteria	Benchmark	Concept 1	Concept 2	Concept 3
Affordable	0	+	0	-
Easy maintenance	0	+	+	0
Safety	0	+	+	+
Portable and compact	0	+	0	-
User-friendly and attractive	0	+	+	+
Sum of "+" Sum of "0" Sum of "-"	0 6 0	5 1 0	3 3 0	2 2 2
Rank	4th	1st	2nd	3rd

Table 3.4: Screening Concept Table

3.6.2 Scoring Concept

Table 3.5: Scoring Concept Table

Selected Criteria	Weightage (%)	Concept							
		1 (Benchmark)		2		3		4	
		Rating	Weight	Rating	Weight	Rating	Weight	Rating	Weight
Affordable	20	3	0.60	4	0.80	4	0.80	3	0.60
Easy maintenance	20	3	0.60	3	0.60	3	0.60	2	0.40
Safety	25	3	0.75	4	1.00	3	0.75	3	0.75
Portable and compact	25	3	0.75	4	1.00	3	0.75	3	0.75
User-friendly & attractive	10	3	0.30	3	0.30	3	0.30	3	0.30
Total score		3.00		3.70		3.20		2.80	
Ranking		3rd		1st		2nd		4th	
Chosen for development		No		Yes		No		No	

3.7 Final Concept Selection

The final concept selected is the Concept 1. The design is simple and easy to be installed. It uses PVC pipes that is light-weight, cheap and easy to be obtained. Furthermore, the tank is wall-mounted and that will make the water movement pulled down by gravity, thus eliminating the use of water pump that will reduce the production cost. Besides that, the use of trapezoidal gutter will maximize the water collection that flows from the roof and the water that falls directly onto the gutter.

Furthermore, the orientation of the filter at 45 degree will ensure the optimum water intake into the tank and will prevent the pipes from clogging due to excess dirt that passed through the first-flush diverter. Finally, the design uses an opaque water tank that will prevent sunlight from entering and by doing so, it will stop algae from growing in the water tank and affecting the water quality.

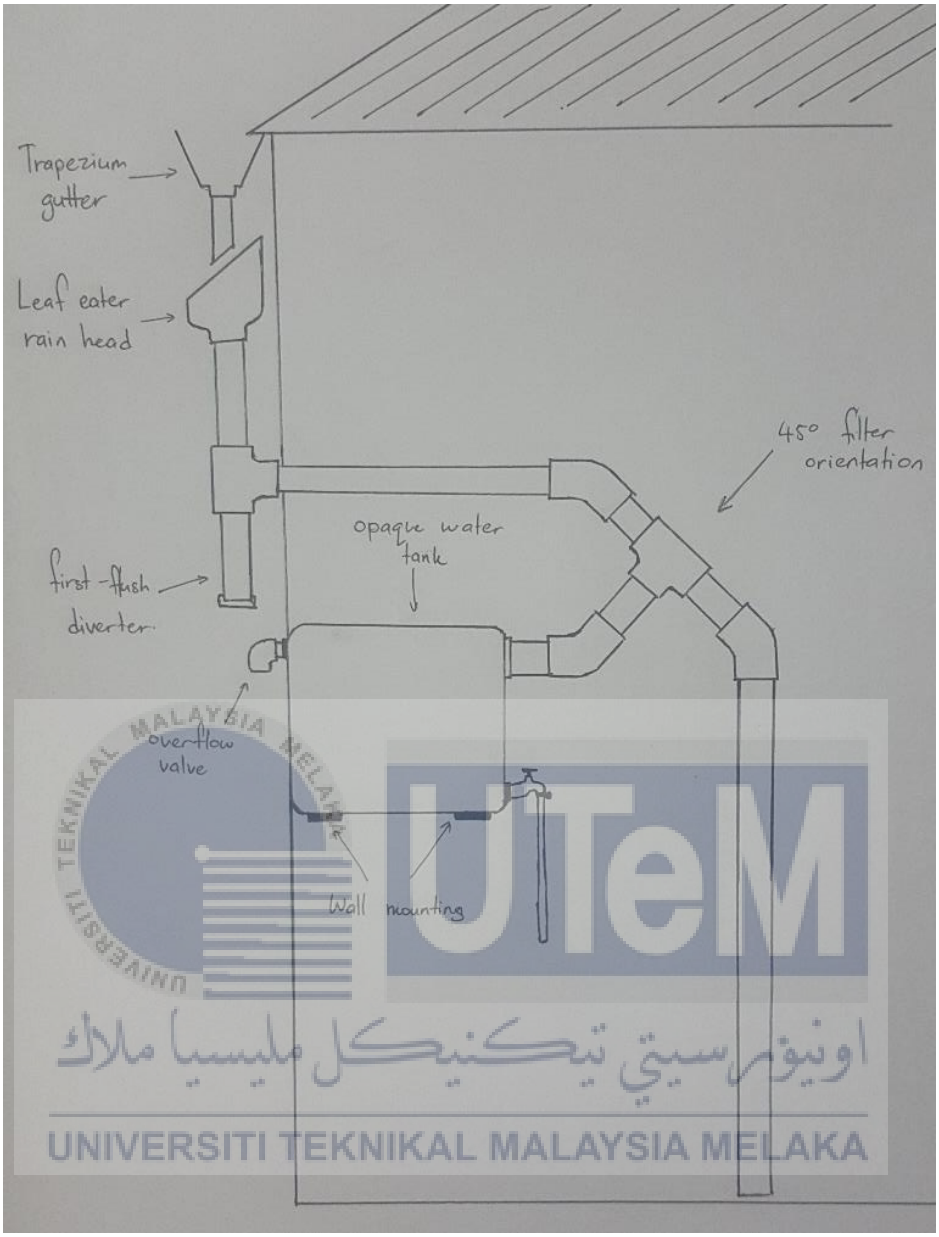


Figure 3.11: Final Concept selection from Concept 1

3.8 Material Selection & Cost Analysis

Table 3.6: Table of Material Selection & Cost Analysis

No.	Items.	Quantity.	Price per quantity. (RM)	Total price. (RM)
1.	40 Liter water tank.	1	30.00	30.00
2.	PVC pipes (4 inches).	10 feet	4.00 (per feet)	40.00
3.	Wall mounting.	1	12.00	12.00
4.	Pipe mounting.	1 set	8.00	8.00
5.	Rain head.	1	14.00	14.00
6.	Gutter.	-	-	-
7.	Filter.	1	3.00	30.00
8.	Connector.	4	1.50	6.00
9.	First-flush diverter	1 set	50.00	50.00
10.	Pipe head	1	2.00	2.00
11.	Piping tape	1	1.50	1.50
	Total	-	-	193.50

Chapter 4

FABRICATION PROCESS.

This chapter shows the fabrication process of the final product for the Rainwater Harvesting and Filtration System for Domestic Use. The product was fabricated based on the detailed design created using a Computer Aided Design (CAD) software, Fusion 360. The product is fabricated step by step by using a home-owned tools as they do not need the use of heavy machinery. Therefore, the fabrication process of this product is very efficient and does not cause pollution in any way.

4.1 Design Specifications.

The design specifications consist of the detailed design of the product for each of the parts. The detailed design also shows the orientation and position for each of the products to make the fabrication process easier. The details of each parts for the detailed design are as shown in the appendix.

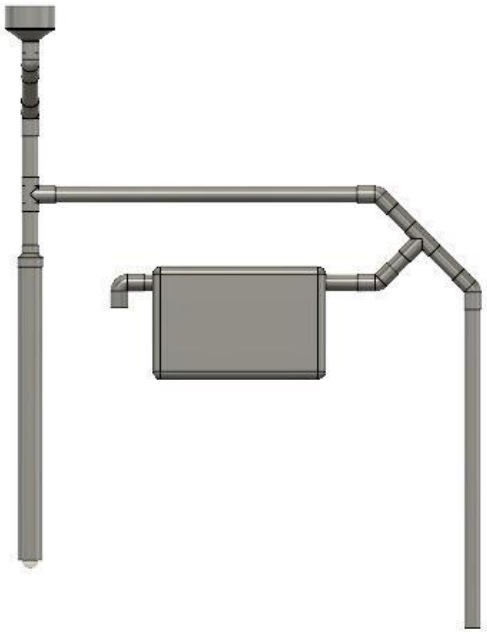


Figure 4.1: Front View of Detailed Design

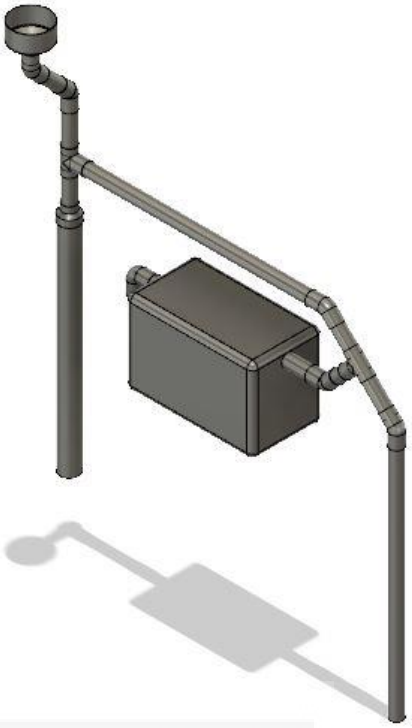


Figure 4.2: Isometric View of Detailed Design

Figure 4.1 and 4.2 show the front view and isometric view of the detailed design for the product that is going to be fabricated respectively. The product fabrication has 5 steps from the start to finish, which are;

1. Measuring.
2. Cutting.
3. Fitting.
4. Mounting.
5. Finishing.

4.2 Fabrication Process.

Measuring.

The measuring steps start by measuring all the required pipes to their exact length. Each pipe has their own length and size to ensure it can flow water smoothly through them. The PVC pipes used in this product are;

- 3 inches PVC pipe (900mm) x 1
- 2 inches PVC pipe (150mm) x 6
- 2 inches PVC pipe (200mm) x 2
- 2 inches PVC pipe (1000mm) x 2

Each of the pipes are measured, marked and labeled to make it easy to determine and differentiate each pipe. The measuring process are done by using a measuring tape and a marker pen. The pipes are then brought to the next step.

Figure 4.3: PVC pipe measuring process

Figure 4.4: PVC pipe marking process

Cutting.

The cutting process starts right after the pipes are done being measured and marked to make the cutting process easier.

Figure 4.5: PVC pipe cutting process.

The cutting process does not use any machinery or power tools to cut the pipes. The pipes are cut by using a normal hacksaw to ensure that the fabrication process of this product will not affect the environment. After the cutting process, the pipes are then brought to the fitting process.

Fitting.

The fitting process is basically a process of joining the pipes that has been cut with the joint that will be used to create a full water flow of the product. The joint used in the fitting process are;

- T-joint PVC elbow x 2
- 45-degree PVC elbow x 5
- 3 inches to 2 inches PVC pipe reducer x 1
- 3 inches PVC end cap x 1

Figure 4.6: Pipe fitting 45-degree PVC elbow.

Figure 4.7: Pipe fitting T-joint PVC elbow.

After the fitting process is finished, the fitted-out pipes are then brought to the mounting process to be mounted.

Mounting.

The mounting process is done on a piece of 5mm wood board 3 feet x 4 ½ feet that was bought at the hardware store. The mounting used are;

- ½ inch screw
- Band iron
- Metal wall bracket (for water tank)

Figure 4.8: Mounting set-up on the wooden board.

Figure 4.9: PVC pipe mounting process on the wooden board.

After the mounting for each of the pipes are put in place, the pipes are the mounted together with the wooden board to ensure that the position are correctly as measured. After that, the process is taken to the last step to undergo finishing process.

Finishing.

The finishing process is the process of refining a product before the it is considered complete. The finishing process starts by spraying the tank with black spray paint to ensure that no sunlight can enter the water tank to prevent algae growth.

Figure 4.10: Spray painting water tank.

After the finishing, everything is put together to get the final product. The final product is then brought to be tested to ensure that the product can be used in real-life situation.

Figure 4.11: Final product
after finishing.

Chapter 5

RESULTS AND DISCUSSION.

This chapter shows the results that were obtained based on the experiment conducted on the product that were fabricated. The analysis of the experiment is recorded and tabulated in this chapter. In addition, further discussion will be made according to the experimental data acquired. The results of experiment which mainly consists of the rainfall distribution and the filter mesh size will be shown in tabulated form for easier understanding and observation.

5.1 Rainfall Distribution.

The rainwater distribution in Malaysia is quite high each year. The total rainwater distribution per year is approximately 2600mm. The rain is heaviest during the monsoon season, which is between April and October. This phenomenon happens after the equinox event. Malaysia experience maximum rainfall in the form of convective rain. Figure 5.1 shows the rainfall distribution for the monsoon season in Malaysia.

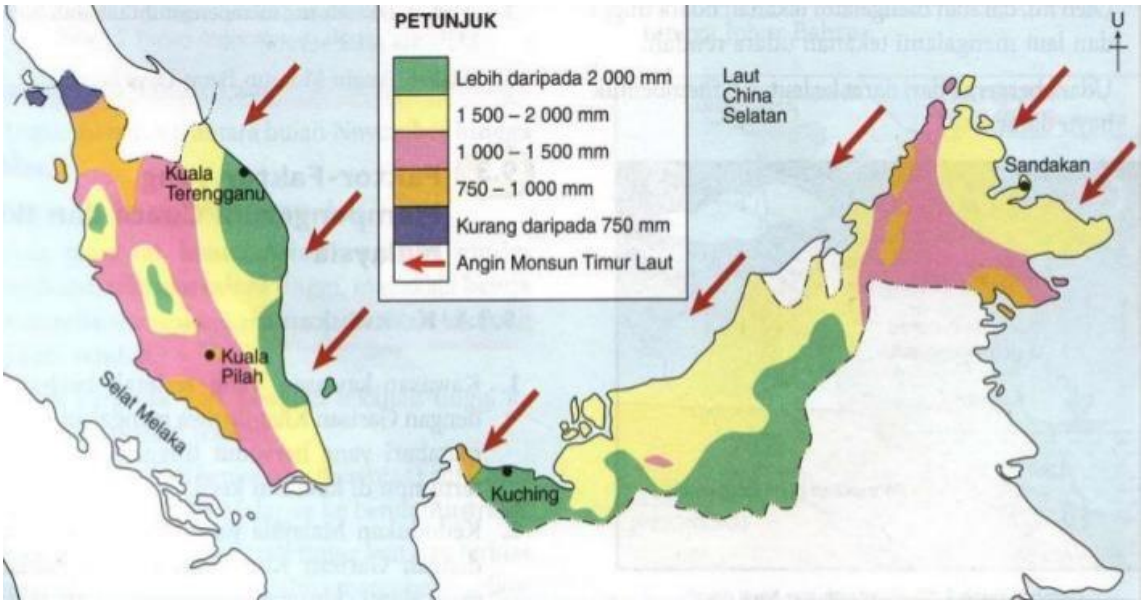


Figure 5.1: Rainfall Distribution for

Monsoon Season in Malaysia.

The rainwater collected depends on the size of the collection area and the amount of rain in inches. The amount of rainwater collected is governed by a simple formula:

1 inches of rain x 1 square foot of collection area = 0.623 gallons of rainwater

The roof area of the house used in the experiments are 22 feet wide and 30 feet long, (660 square feet). To calculate the amount of rain that can be collected, it can be done by using the formula:

N square feet of roof area x M inches of rain x 0.623 gallons = amount of rain collected

Therefore,

660 square feet of roof area x 1 inches of rain x 0.623 gallons = 411.18 gallons

411.18 gallons = 1556.49 liters

An experiment was conducted to determine the rainwater distribution throughout the month of March for the Bukit Beruang housing area. 3 glass beakers were placed on the roof every Monday for 4 weeks, starting from 4th of March until 25th of March between the times of 8 o'clock in the morning to 8 o'clock on the next morning. The water collected is measured after each time it was set-up. The results of the experiments are recorded in Table 5.1 for each of the time it was set-up. The average for the three beakers is calculated and included in the table.

Table 5.1: Results of Water Collection Experiments

Date (2019)	Beaker 1 (mm)	Beaker 2 (mm)	Beaker 3 (mm)	Average (mm)
4 March	21.0	22.0	22.0	21.7
11 March	31.0	31.0	31.0	31.0
18 March	29.0	27.0	27.0	27.7
25 March	0.0	0.0	0.0	0.0

The reading for the 25th of March is as shown because on that date, it was not raining, making the results become zero (0.0). Based on the readings, the smallest average amount of rainwater collected is 21.7 mm of rain, which is equals to 0.854 inches. Therefore, the amount of rainwater that can be collected is calculated by using the given formula:

660 square feet of roof area x 0.854 inches of rain x 0.623 gallons = 319.225 gallons

319.225 gallons = 1208.398 liters

The water tank used for this project is a 10 gallons water tank (37.85 litres), based on the calculations for the smallest amount of rainwater (21.7 mm), it yields an astonishing 319.225 gallons of water (1208.398 litres)

In conclusion, the rainwater collected depends on the rainfall distribution throughout the time of water collection and the maximum water can be stored is based on the size of the water storage tank installed. The total water collected is enough to be used for a simple daily outdoor work.

5.2 Filter Mesh Size.

The filter's mesh size is the size of the gap in a square inch of screen. The size of holes is depending on the number of mesh in a square inch of that particular screen. The example of the mesh size is as shown in Figure 5.2.

Figure 5.2: Mesh Size Example.

The size of mesh is determined by how many openings there is in between a square meter of space. There are many different types of mesh shapes such as a square mesh, round mesh and many other types. The most commonly used mesh types for rainwater harvesting system's filter is the square types mesh. They are widely used because they are easy to obtain, easy to be used and they are also quite cheap and affordable.

An experiment was conducted using 3 different mesh size as shown in Figure 5.3,Figure 5.4 and Figure 5.5. The mesh size chosen are big, medium and small. Based on many previous experiments made by researchers, it is said that the smaller the mesh size, the better the filtration process will be. But, the larger the meh size, the harder it is for the filter to get clogged and making the filter becomes unusable. The experiment conducted is to choose the best mesh size for the filter that will be used in the product. The mesh size must be small enough to filter the debris and must be large enough to ensure it is not easily clogged. The size chosen must be optimum to ensure that the water is filtered properly but at the same time, it is not clogged.

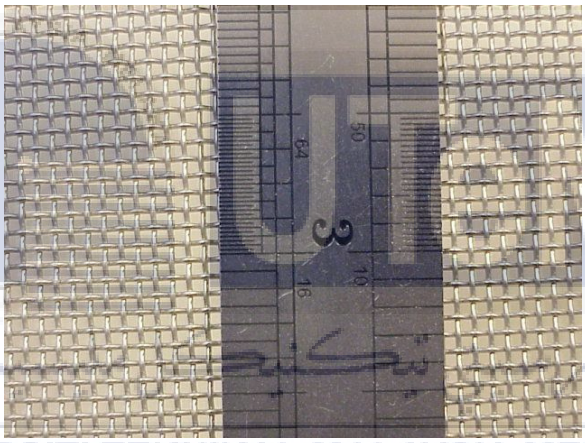


Figure 5.3: Small Mesh Size Figure 5.4: Medium Mesh Size

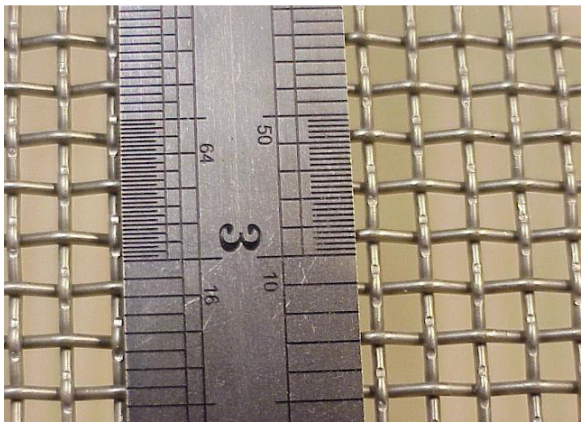


Figure 5.4: Medium Mesh Size

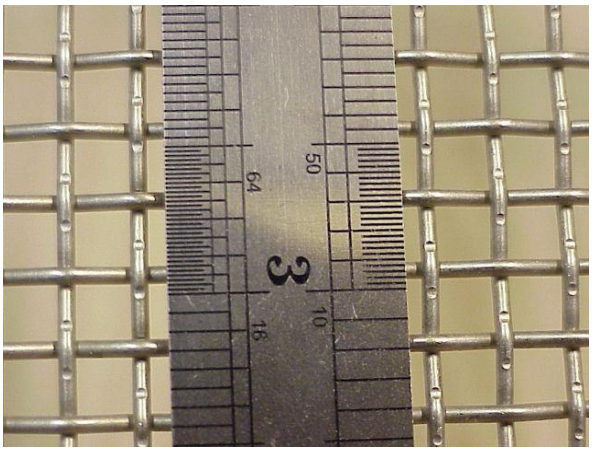


Figure 5.5: Large Mesh Size

The experiment conducted used a Styrofoam balls as debris, mixed up in normal tap water. 10 small pieces of Styrofoam balls are mixed in water, and the water is poured on the filter. The filtration performance is based on the number of Styrofoam balls that pass through the filter. The more Styrofoam balls that pass through the filter, the lower the filtration performance, and the lower the chances of the filter to be clogged. The results of the experiments are collected and tabulated as shown in Table 5.2.

Table 5.2: Results of Filtration Experiments

Mesh size. / Observations.	Small	Medium	Large
No of Styrofoam balls passes through the filter.	0/10	4/10	10/10
No of Styrofoam balls stuck on the filter.	10/10	6/10	0/10
Descriptions.	High filtration performance but needs more maintenance.	Optimal filtration performance but needs less maintenance.	Low filtration performance but needs less maintenance.

In conclusion, smaller mesh size gives the best filtration performance, but it also means that the filter needs to be maintained regularly. Therefore, the medium size mesh is the most optimum size to be used to ensure that the filtration performance is moderate and needs less maintenance.

Chapter 6

CONCLUSION AND FUTURE WORKS.

This chapter concludes about the whole project. Besides that, recommendations for the future works towards the rainwater harvesting and filtration system are added to this section. The recommendation may help the project to work better and with higher performance for its application on domestic use.

6.1 Conclusion.

In conclusion, this project is successful in harvesting rainwater and filtering it for domestic use. The product has achieved its objective on harvesting and filtering rainwater for being use for our daily lives work. The design of the prototype is optimized by adding extra features that can help enhance the filtration process and by reducing the size so that it is easier to be used and installed. The final product is tested to determine that the rainwater harvesting, and filtration process are fully functional.

The main objective of this product is to collect the rainwater and filter it for domestic use. However, along the way of this project, it was determined that there is a possibility that the product can be reduced in size and weight and also can be added an extra filter throughout the flow of the rainwater from the gutter to the water container to make it much more compact to save space and to filter the water thoroughly to ensure that the water is clean to be used for our daily work. Since the function of this product is to give us a clean water, the size reduction will not affect the collection and filtration of water in any way as they are only

to minimize the flow of water from the gutter and into the water container. The process of fabricating this prototype does not use any harmful chemicals or high-powered machinery. Therefore, the production of the product will not cause any pollution in any way.

6.2 Future Works.

For future works, it is recommended for the product to be reduced in size even more but still maintaining the current filtration process or increasing it. By doing so, it can increase the performance of the filtration process while making the product as compact as possible. The difference in every product are the filtration process and the size of the water container. The water container can be a fixed shape or a foldable shape container depending on the circumstances on using the product. A mobile type of the product can be made with a foldable water container to be used as survival kit for camping or many other purposes.

Other than that, it is recommended that the product to have a proper filter to ensure that the debris needed to be filtered out are completely absence in the water container after the filtration process. This will help to ensure that the water is perfectly clean to be used and can help prevent clogging in the water container's water outlet.

REFERENCES.

[1] Guozhen Zhang, Kun Yang, Fuping Wu, Shichao Yang, Na LiQunshu Zhu, 2012, Introduction of Rain Harvesting Treatment in Northwest Villages of China.

[2] Ola M. Surakhi, Ahmad S. Sharieh, 2017, Rooftop Rainwater Harvesting System in Amman City.

[3] Azinoor Azida Abu Bakar, Nor Syamira Hassan, 2014, The Effectiveness of Corn Cob Activated Carbon in Rainwater Harvesting Filtration System.

[4] A. Silver Vieira, M. Weeber, E. Ghisi, 2013, Self-cleaning filtration: A novel concept for rainwater harvesting systems, 78(2013), pp 67-73.

[5] Michael Veracka, MLA, 2013, Delivering Better Water Quality: Rethinking Storm Water Management.

[6] Zameer Ahmed, D. Ram Mohan Rao, K. Ram Mohan Reddy, 2011, Sustainable Storm Water Management: An Evaluation of Depression Storage effect on Peak Flow.

[7] Subhajyoti Samaddar, Norio Okada, 2008, Modelling and Analysis of Rainwater Harvesting Technology Disseminating Process Based on Social Networks Threshold Approach.

[8] Jillian Zankowski, Yixin Sun, Chiyan Poon, Emily Pas sauer, Abdalla Nassar, Khanjan Mehta, 2013, Gutter Design and Selection for Roof Rainwater Catchment Systems.

[9] Stewart, M. (2016). Piping System Design. Surface Production Operations, pp 639-730.

[10] Kelly C. Doyle , 2008, Sizing the First Flush and its Effect on the Storage-Reliability Yield Behavior of Rainwater Harvesting in Rwanda

[11] Evan M. Wanjiru, Xiaohua Xia, 2015, Energy-water optimization model incorporating rooftop water harvesting for lawn irrigation, 160(2015), pp 521-531.

[12] Huang Bing, Zhu Xiao-Min, Zheng Jin-Long, Xie Lei-Lei, Zhao Huai-Yuan, 2012, Drainage Simulating for the effect of type of urban water consumption to the combined drainage networks based on SWMM.

[13] Kishan Ramesh Kumar, Sutej Pramod Kulgod, Anish Surendan, 2016, Simulation and Analysis of Energy Harvesting from Grey water and Rain water in High rises.

[14] M. S. Nasif, G. A. Kumar, R. Roslan,, 2016, An effective optimization of rainwater harvesting system in hotel and hospital buildings.

[15] Xiaoyu Yan, Sarah Ward, David Butler, Bebhinn Daly, 2017, Performance assessment and life cycle analysis of potable water production from harvested rainwater by a decentralized system, 172(2018), pp 2167-2173.

[16] Chilka Sharma, Dr Prasad Thenkabail, 2011, Earth Observing Data and Methods for Advancing Water Harvesting Technologies in the Semi-arid Rain-fed Environemnts of India.

[17] Yie-Ru Chiu, Chao-Hsien Liaw, Chih-Yang Hu, Yao-Lung Tsai, Hsueh-Hsien Chang, 2009, Applying GIS-based Rainwater Harvesting Design System in the Water-Energy Conservation Scheme for Large Cities.

[18] A. Campisanoa, D. Di Libertoa, C. Modicaa, S. Reitanob, 2014, Potential for Peak Flow Reduction by Rainwater Harvesting Tanks, 89(2014), pp 1507-1514.

[19] Turahim Abd Hamid, Basir Nordin, 2011, Green Campus Initiative: Introducing RWH System in Kolej Perindu 3 UiTM Malaysia.

[20] Uri Nachshon, Lior Netzer, Yakov Livshitz, 2016, Land cover properties and rain water harvesting in urban environments, 27(2016), pp 398-406.

[21] Adam C Catonguay, Christian Urich, Md Sayed Ifttekhar, Ana Deletic, 2016, Modelling urban water management transitions: A case of rainwater harvesting, 105(2018), pp 270-285.

[22] Deep Shah, Purav Patel, Patrick Kudo, Aaron Steinberg, and William Herold, 2013, Feasibility of Rainwater Harvesting on Scott Laboratory.

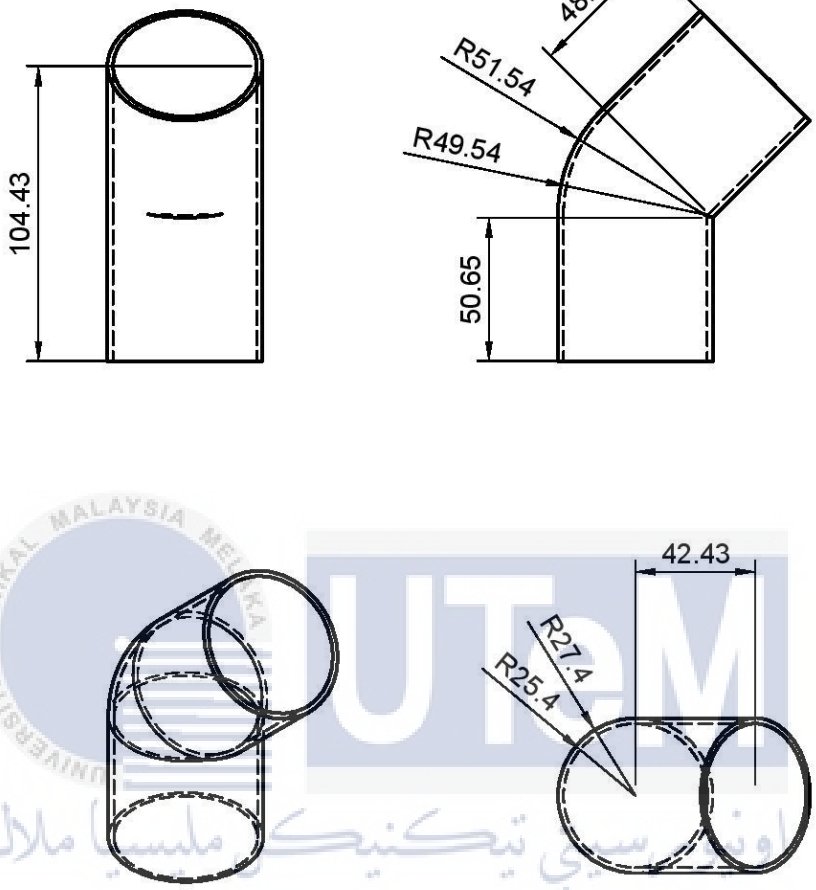
[23] Wang Xichang, 2015, An applied research in the rural landscape of rainwater collection system based on the concept of LID.

APPENDIX

Appendix A

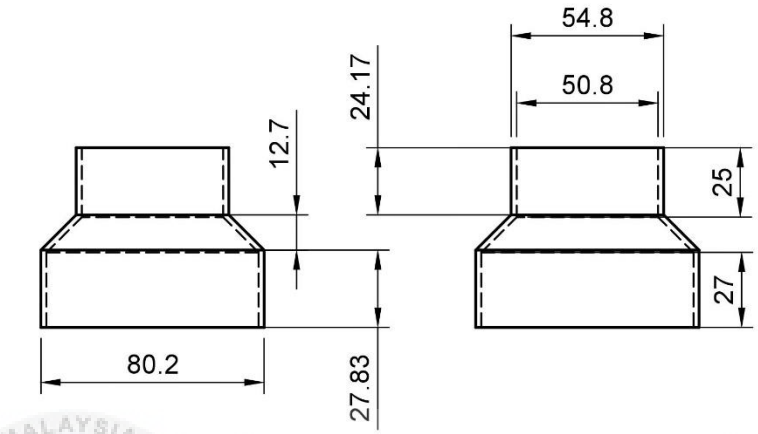
Appendix B

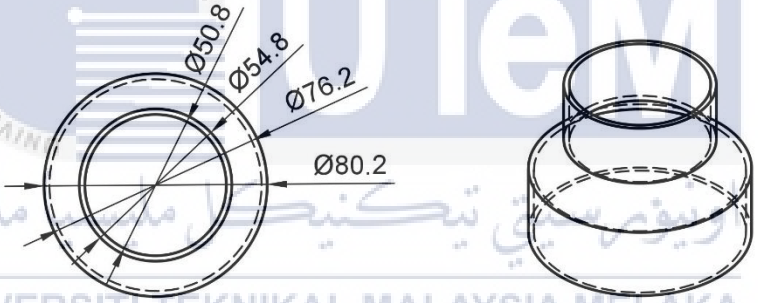
Appendix C



Dept.	Technical reference	Created by yorro_master 09/03/2019	Approved by
		Document type	Document status
		Title: 45 degree (2)	DWG No.
			Rev. / Date of issue / Sheet: 1/1

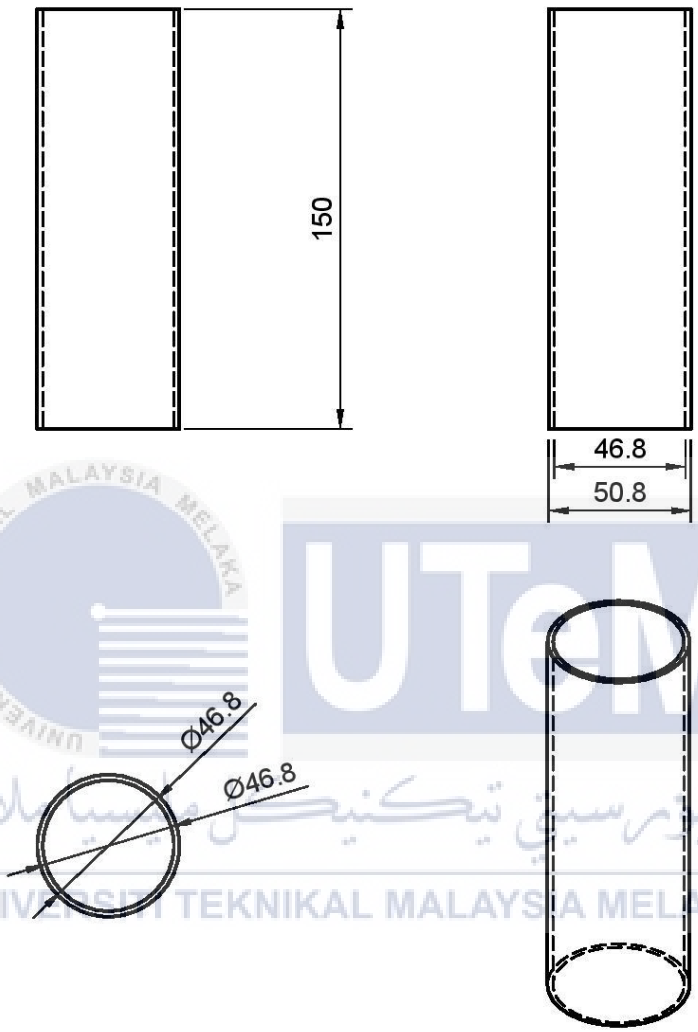
Appendix D





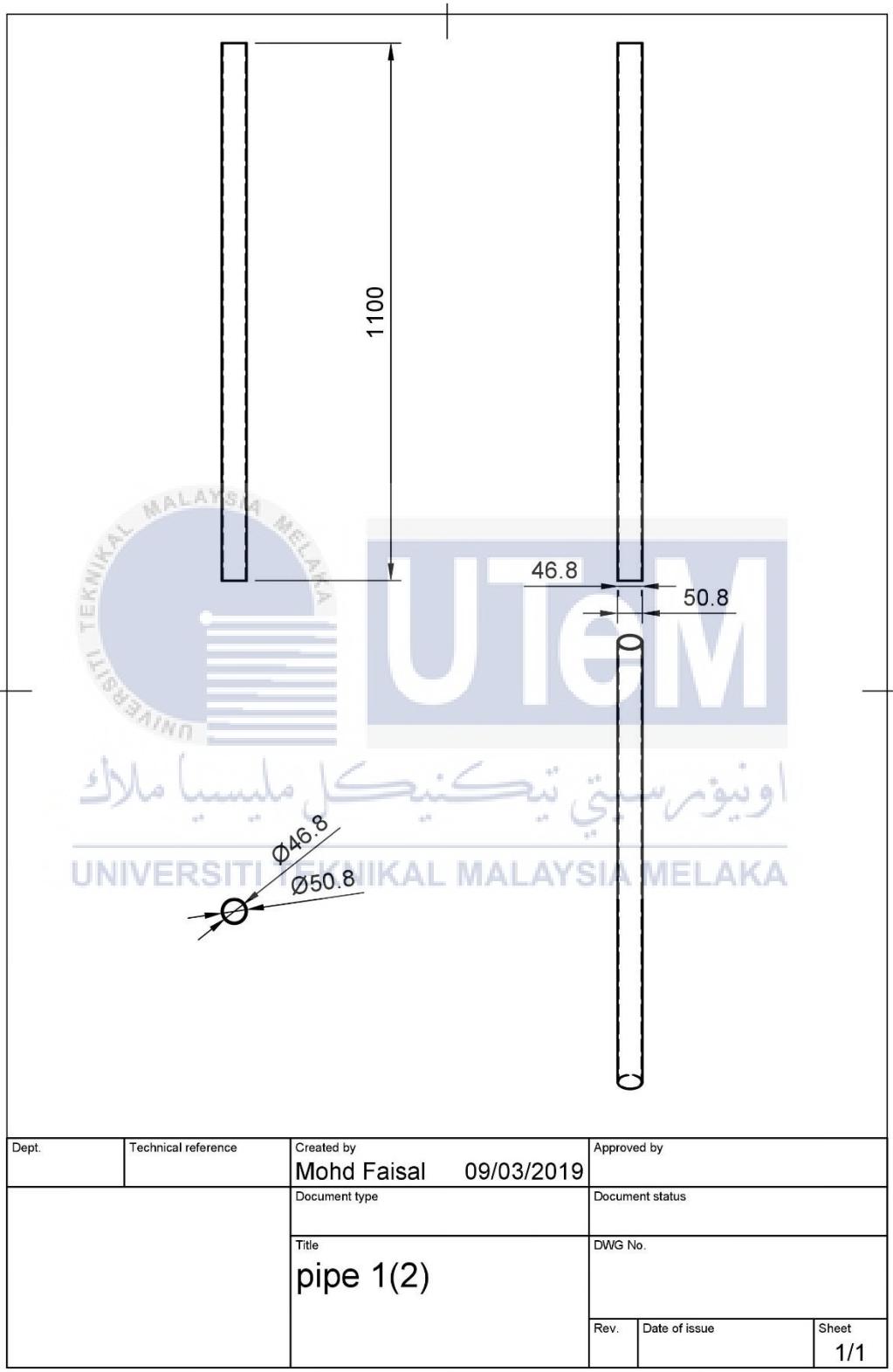
Dept.	Technical reference	Created by Mohd Faisal 08/03/2019	Approved by	
Material Type : Grey PVC		Document type	Document status	
		Title: Reducer (3 Inch to 2 Inch)	DWG No.	
			Rev. / Date of issue	Sheet 1/1

Appendix E



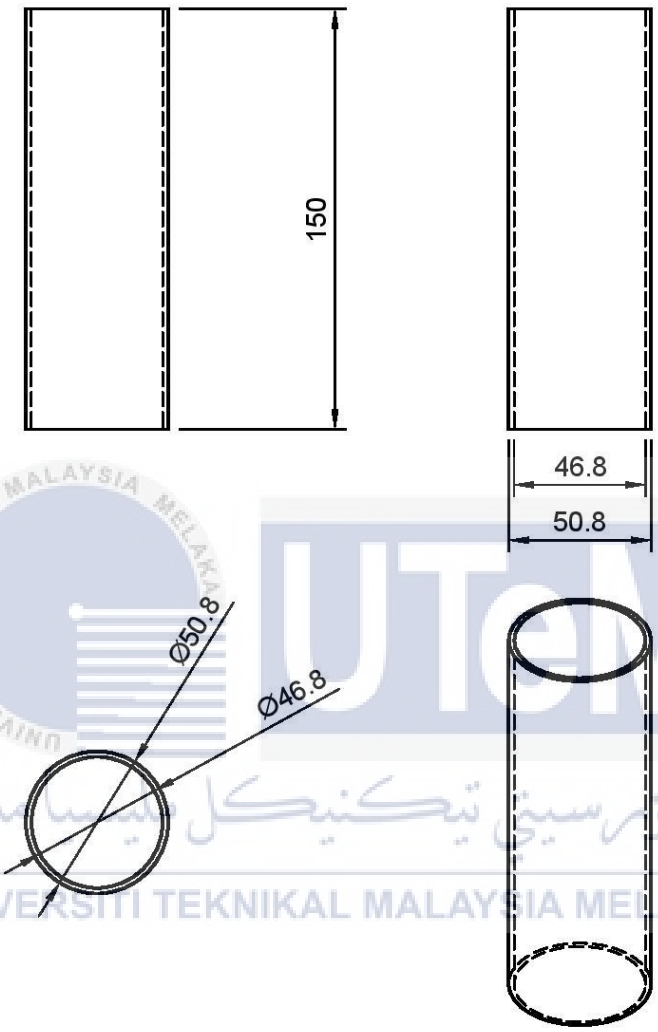
Dept.	Technical reference	Created by Mohd Faisal 09/03/2019	Approved by
		Document type	Document status
		Title middle flush	DWG No.
			Rev. / Date of issue / Sheet 1/1

Appendix F



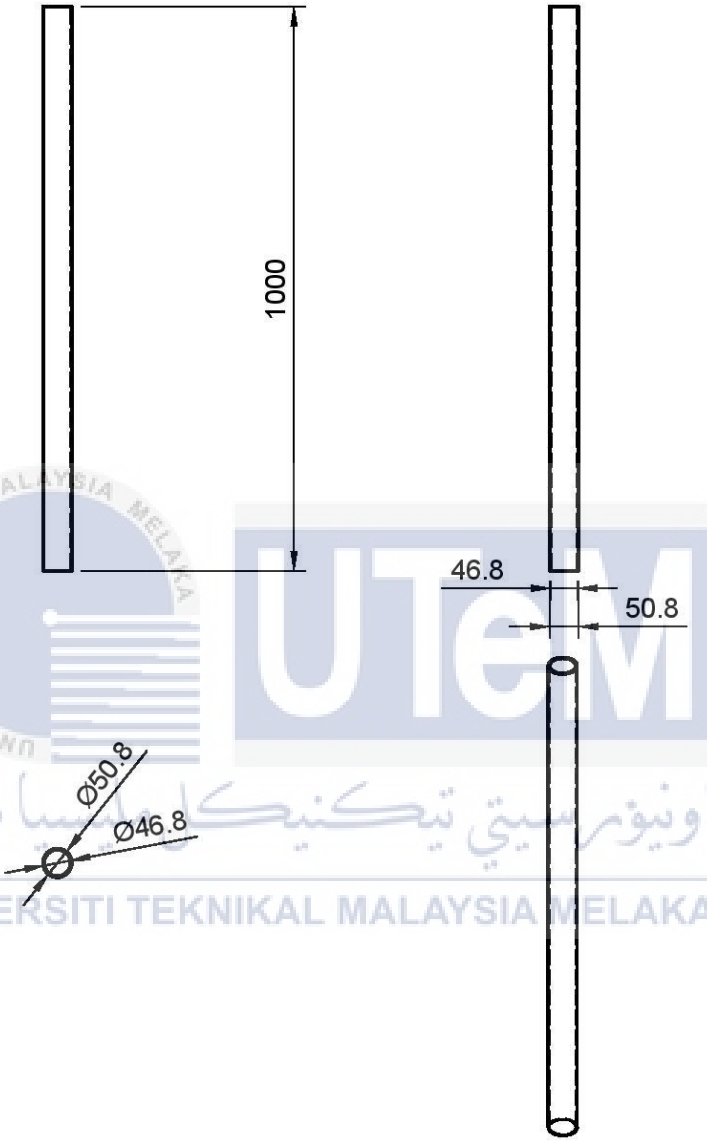
Dept.	Technical reference	Created by Mohd Faisal 09/03/2019	Approved by
		Document type	Document status
		Title: pipe 1(2)	DWG No.
			Rev. / Date of issue / Sheet 1/1

Appendix G



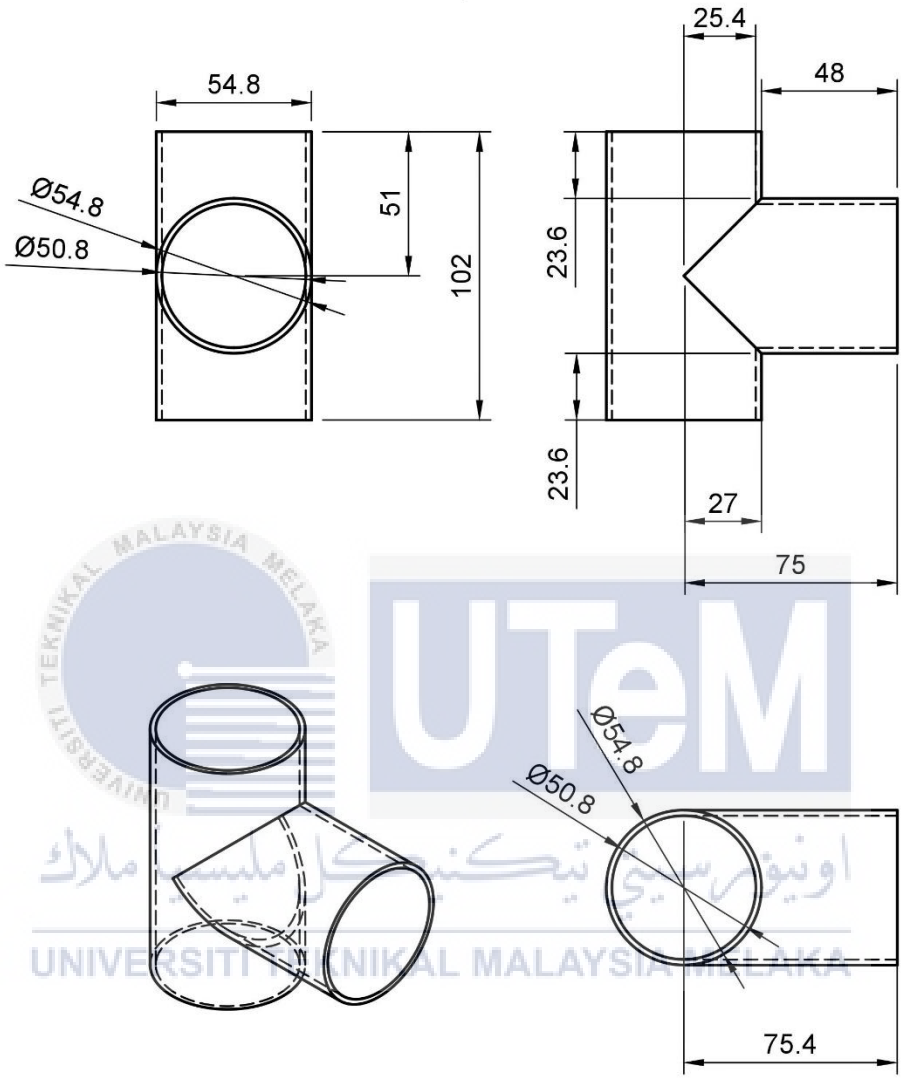
Dept.	Technical reference	Created by Mohd Faisal 09/03/2019	Approved by	
		Document type	Document status	
		Title pipe 2 (2)	DWG No.	
			Rev. / Date of issue	Sheet 1/1

Appendix H



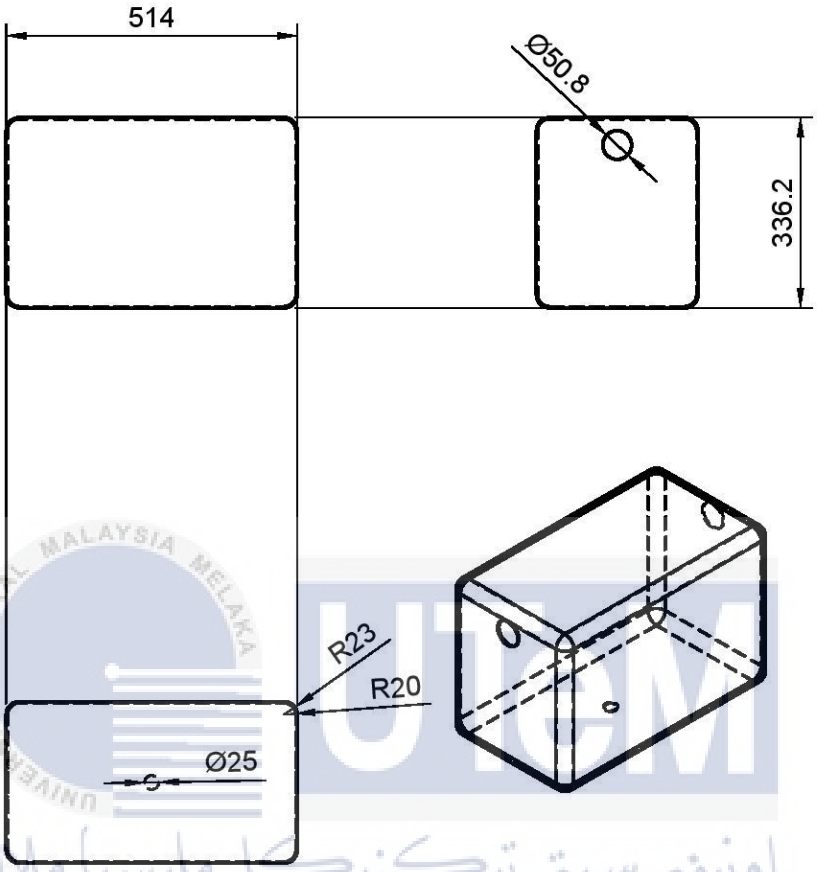
Dept.	Technical reference	Created by Mohd Faisal 09/03/2019	Approved by
		Document type	Document status
		Title pipe 3 (2)	DWG No.
			Rev. / Date of issue / Sheet 1/1

Appendix I



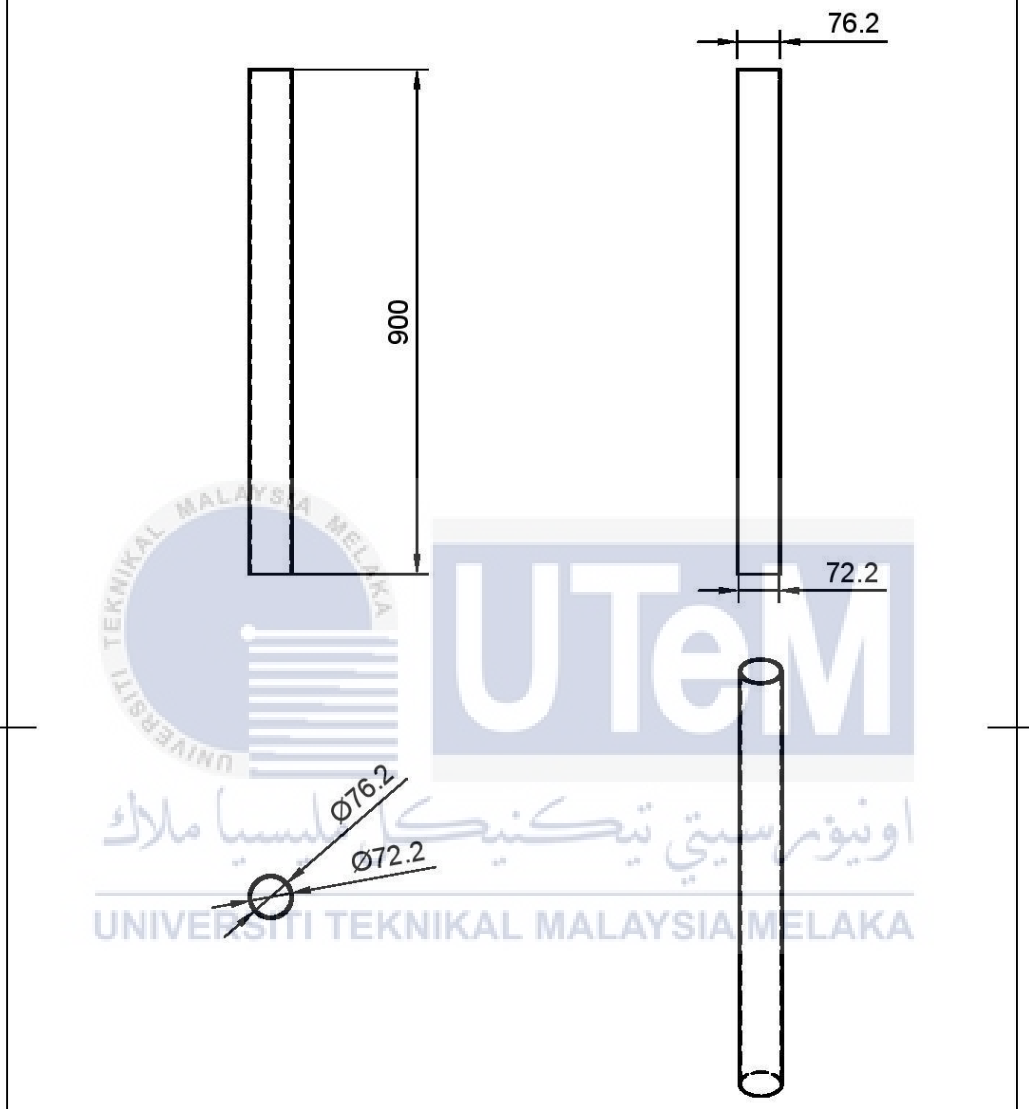
Dept.	Technical reference	Created by Mohd Faisal 09/03/2019	Approved by	
		Document type	Document status	
		Title t joint (2)	DWG No.	
			Rev. / Date of issue	Sheet 1/1

Appendix J



Dept.	Technical reference	Created by: Mohd Faisal 25/6/2019	Approved by
		Document type	Document status
		Title: Tank	DWG No.
			Rev. / Date of issue / Sheet: 1/1

Appendix K



Dept.	Technical reference	Created by yorro_master 09/03/2019	Approved by
		Document type	Document status
		Title bottom flush	DWG No.
			Rev. / Date of issue / Sheet 1/1