DEVELOPMENT OF A LOW-COST FOOD SCRAP AND GREASE SEPARATOR

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LEE ZHEN SHENG

A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Mechanical Engineering with Honours

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May 2023

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"DEVELOPMENT OF A LOW-COST FOOD SCRAP AND GREASE SEPARATOR"** was prepared by **LEE ZHEN SHENG** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Mechanical Engineering with Honours at Universiti Tunku Abdul Rahman.

Approved by,

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Supervisor	:	Dr. Wong Hong Mun
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ACKNOWLEDGEMENTS

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Wong Hong Mun for his invaluable advice, guidance and his enormous patience throughout the development of the research.

In addition, I would also like to express my gratitude to my loving parents and friends who had helped and given me supports emotionally and practically.

ABSTRACT

The purpose of this project is to develop a low-cost food scrap and grease separator, a device that separates food scrap and grease from the leftover food and also the food preparation process. It is to prevent the presence of food scraps, fats, oil, and grease in the drain which can cause clogging which can lead to flooding. One of the main reasons that caused floods hit Malaysia in many places in the year 2021 is the clogged drainage system. To be low cost, a simple design is selected. However, it is important to mention that simple design does not mean only the most basic functions should be retained. Features that have the potential to increase the willingness of target groups to adopt the product is also important and should be considered to add to the product. Hence, the detachable baffles are the feature that was added to the prototype. Through experiments and testing conducted, the results obtained have met the expectation, which is no oil droplets were observed from the discharged flow collected, and most of the oil separated remained in two different sections of the grease separator. Hence, the feature added does not reduce the effectiveness of the prototype but provides convenience in the more thorough discharge of oil and the cleaning process. Thence, it is believed that the added feature would increase the willingness of target groups to adopt this product. Lastly, the total cost of material used to fabricate the prototype is RM 420.27.

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LIST OF SYMBOLS / ABBREVIATIONS

l	length, mm
h	height, mm
w	width, mm
Mt	mass, 1000 kg
ml	volume, milliliters
s	time, second
FOG	fat, oil, and grease
MSW	Municipal Solid Waste
OFMSW	Organic Fraction of Municipal Solid Waste
PVC	Polyvinyl chloride

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

In Malaysia, floods occur every year. In recent years, the situation of floods in Malaysia has become more and more serious, especially the number and severity of floods that occurred between the end of the year 2021 and the beginning of the year 2022, which have affected the lives of people across the country to varying degrees. According to the statistics made by the department of statistics Malaysia, the total losses caused by the floods is about 6.1 billion Ringgit Malaysia in monetary terms, this is also equivalent to 0.4 percent of the nominal Gross Domestic Product (MAHIDIN, 2022). A news report from the New Straits Times stated that despite the environmental and climate change problems, the clogged drainage system is one of the reasons that caused the floods, found by the Environment and Water Ministry (New Straits Times, 2021). The water channel of the clogged drains or blocked drains was narrowed, or completely blocked at worse. Therefore, they do not function as it should be, there is no time for the rainwater to be drained to other place and caused flood. Sewer is a part of a drainage system. A study stated that around 70% of the sewer blockage that occurs in Malaysia is due to fats, oils and grease (FOG) (Otsuka et al., 2020). According to the sustainability report 2010 published by Indah Water Konsortium Sdn Bhd (IWK), there were 22184 blockage enquiries received by IWK in the year 2010 (ANG, 2011). Thence, it can be concluded that there are about 15529 cases of sewer blockage due to FOG in the year 2010 alone. However, this is only the enquiries received by IWK, the actual situation may be more.

FOG refers to fats, oils, and grease. They usually come from the foodstuffs preparation process such as oil used for frying, or after finished eating foodstuffs such as food scraps. Those cooking oil and food scraps that consist of meat fats will become the FOG that blocks the sewer when they are poured or dumped into the sewer. As times goes by, the FOG will become thicker and thicker until the water unable to pass through because the FOG will become solidified after it cooled down (FOG is the biggest cause of blocked drains, 2017). Therefore, the sewer is blocked, and a lot of negative impact will come after. For example, foul smell, overflow of the sewer, flash flood and others. These problems will require a large amount of money to solve the problem, and the money comes from the taxpayers. However, the same consequences will also happen to the drain when the oil and food scraps were being poured and dumped into the drain by irresponsible people.

Until here, it is not difficult to notice that the problem of food scraps exist and it already impact the environment and the quality of life. Besides the drain and river, food scraps will also end up under the ground due to the major disposal of the solid waste in Malaysia is through landfill method. Consequently, the food scraps will decompose under the anaerobic environment formed by landfilling and the organic substances in the food scraps will release greenhouse gases such as methane that is way more powerful in the ability of trapping the heat in the atmosphere. Yet, before carrying out a better food scrap disposal method, the more important is to collect the food scraps because it is not supposed to be in the drain whether any method of disposal be chosen. Moreover, separating food scraps from the other waste enables it to have better usage that will bring benefits such as reducing greenhouse gas emissions, quality of the soil can be improved from nutrients that consist of the food scraps through composting, and it can also decrease the need for landfilling (State of Vermont, n.d.). Hence, a food scrap separator device could provide help in this situation.

In the River of Life project, a study on water quality was carried out. The study document stated that one of the sources of river pollution is food and beverages (Md Nasir, 2014). Just think about how these things flow into the river and cause pollution, other than just dumping or pouring directly into the river, nothing more than through a drain or sewer. Hence, it can be seen that the food scraps that have been dumped into the drain or sewer are already causing a very serious problem in Malaysia. A news report from The Straits Times stated that the main cause of the clogged drain is the stall owners of those restaurant and coffee shops connect the pipe from the sink straight to the drains, and then all wastewater from the kitchens flows into the drains directly (The Straits Times, 2016). According to the news from The Star, solving this problem will cost the local government or relevant authorities a huge amount of money including the piping and drainage works, but it has the other way with lower cost, that is to let the stall owners or restaurant owners install a food scrap and FOG trap device (Chen, 2016).

Next, the problem comes to the willingness of those stall owners and restaurant owners to purchase and install a food scrap and FOG trap device. The cost of the food scrap and FOG trap device is definitely a factor they will take into account, and it will critically affect they willingness. Therefore, by developing a low-cost food scrap and FOG trap device may help to solve or improve this situation on the front line.

The food scrap and FOG trap device will be referred as food scrap and grease separator in this study. Hence, this study is to develop a low-cost food scrap and grease separator. As the name implies it is a device which is able to collect the food scrap and separate the grease from the wastewater that flows through the device and comes out with lower grease content wastewater.

1.2 Importance of the Study

The outcome of this study is a low-cost food scrap and grease separator. Therefore, this study might be able to provide a reference on the design of a low-cost food scrap and grease separator. Thence, it might help to reduce the cost of the product as companies can modify the reference designs to facilitate production, allowing for mass production. Hence, the willingness of stall owners and restaurant owners to purchase and install the food scrap and FOG trap device could be increased. Then, the presence of food scrap and FOG in drains and sewers could be decreased because they will be collected before goes into the drain. Subsequently, the sewer blockage able to decrease also. The food scraps separated will be able to facilitate subsequent handling, and it will bring advantages.

1.3 Problem Statement

Due to various reasons, the leftover food produced after consumers eat in the restaurants, hawker centers, and food stalls along the road was being disposed of by direct dumping into the drain. This move will have many negative impacts on the environment such as affecting the appearance of the city that will leave a bad impression on those who see it, producing and emitting an unpleasant odor, attracting pests, and causing hygienic and health hazards. Moreover, the fats, oils, and grease sourced from the food scraps will cause the blockage of the drains and sewer pipes, and once the problem has occurred, it requires a lot of human and material resources, especially money from the government or relevant unit to solve it.

There are various food scrap separators and grease separators on the market, but they are two separate devices. However, the adoption of food scrap separators and grease separators is low because they are expensive. Even if it is adopted, it cannot perform its useful role due to lack of maintenance. For example, the separated grease is not discharged but solidifies in the grease separator so that the grease separator cannot further separate the grease from the further input stream. The lack of maintenance is due to the discharge of the grease often not thorough, and the maintenance work such as cleaning the device is inconvenient. Moreover, the inconvenient maintenance work also causes the low adoption of the grease separator.

1.4 Aim and Objectives

The aim of this project is to increase the willingness of the target group to adopt a food scrap and grease separator.

The objectives of this project are:

(i) To design and develop a low-cost food scrap and grease separator.

(ii) To increase the user-friendliness of the low-cost food scrap and grease separator by adding minimal features to it.

(iii) To determine the effectiveness of the prototype fabricated.

1.5 Scope and Limitation of the Study

The target group of the low-cost food scrap and grease separator is mainly structured by the owner of hawker food stalls in the hawker centers and owners of food stalls in the small restaurants, which is more precisely referred to as “Kopitiam”. Due to its low cost, it can also be adopted for food stalls along the roadside and for household use.

In order to achieve a low-cost product, the design will try to be as simple as possible to meet the basic concept of low cost. Besides, the materials for constructing the prototype will be selected through their cost-effectiveness and convenience to obtain. The tools used for machining the prototype will be selected through the workshop's existing tools. Although the goal is to develop a low-cost food scrap and grease separator, the product will still have the features as it should. For example, the ease of installation of the product and the ease of the product maintenance such as cleaning of the product and the discharge of the fats, oils, grease, and solids in the product.

Based on this project required to make a prototype, all the materials needed will be selected and purchased from the products that are already on the market and processed into prototype, therefore the cost estimated in this project will have a difference when it comes to mass producing or this product. Machining of this prototype will be carried out by the student who successfully registered for this project title in the institution workshop. Hence, the labor cost, machining cost, and overhead cost will not be included and calculated.

1.6 Contribution of the Study

The outcome of this study is a low-cost food scrap and grease separator that improved in terms of user-friendliness. As such, it provides an additional alternative to commercial food scrap and grease separators. Besides, its improved user-friendliness is believed that it could increase the willingness of target groups to adopt a food scrap and grease separator. Thence, it has the potential to promote the adoption of food scrap and grease separators. By doing so, the negative impact caused by food waste, fats, oil, and grease can be reduced.

1.7 Outline of the Report

This report has 5 chapters. It starts with introduction, which is the chapter 1. It stated the background of this study. Then, the literature review had stated in chapter 2. Chapter 3 will be focusing on the development of the prototype for this study, and the experiments and testing conducted also included. Chapter 4 mainly discusses on the results obtained from experiments and testing to gain a better understanding of the prototype to improve user-friendliness. Lastly, chapter 5 summarizes the conclusions of the discussion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the literature review was carried out to understand more about the situation of food waste in Malaysia which includes the generation and the disposal of the food waste. Furthermore, the understanding of the sewage system and the stormwater drainage system in Malaysia were also carried out.

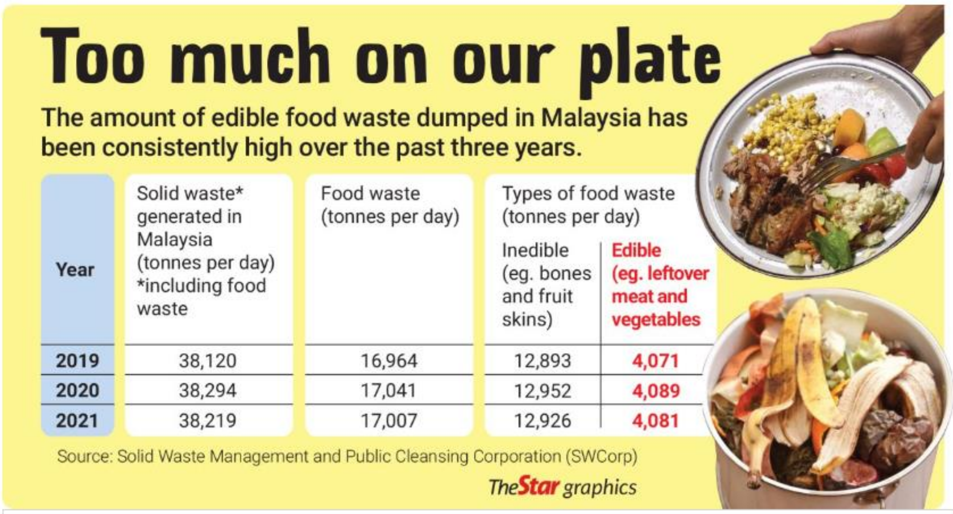
2.2 Municipal Solid Waste

Municipal solid waste (MSW) is also known as rubbish or garbage. According to the data obtained from the Organization for Economic Cooperation and Development (OECD), the total municipal waste increased from 652 Mt in the year 2000 to 732 Mt in the year 2020 (Municipal waste (indicator), 2022). Hence, it can be said that the scenario of the increase in municipal waste occurs globally. Whereas in Malaysia, the municipal solid waste generated over the past ten years before the year 2012 increased by more than 91%, which is caused by the rapid growth of population, urbanization, and industrialization (Dinie, Samsudin and Mat Don, 2013). Therefore, the handling method of municipal waste is important to face the problem of increasing municipal solid waste because it may cause unnecessary waste of resources to solve the problem if the method is ineffective. Moreover, organic waste including food waste and processed kitchen waste occupied most of the waste in Malaysia stated in a study on the evolution of solid waste management in Malaysia (Periathamby, Hamid and Khidzir, 2009). Thence, the handling of food waste and also the fats, oil, and grease that are source from the food waste is crucial.

2.2.1 Proportion of Food Waste in Municipal Solid Waste

The largest proportion of the overall waste composition in Malaysia is municipal solid waste (Moh and Abd Manaf, 2014). As food waste was considered a kind of municipal solid waste in Malaysia, the proportion of food waste can be calculated by dividing the amount of food waste by the amount of solid waste (Wahidah and Ghafar, 2017). From the data obtained from the Solid

Waste Management and Public Cleansing Corporation (SWCorp), the proportion of food waste in MSW in the year 2021 is 44.5%, furthermore about 76% of it was inedible and 24% still can be consumed (YUEN, 2022). The data is shown in Figure 2.1.



Year	Solid waste* generated in Malaysia (tonnes per day) *including food waste	Food waste (tonnes per day)	Types of food waste (tonnes per day) Inedible (eg. bones and fruit skins)	Edible (eg. leftover meat and vegetables)
2019	38,120	16,964	12,893	4,071
2020	38,294	17,041	12,952	4,089
2021	38,219	17,007	12,926	4,081

Figure 2.1: Amount of Solid Waste and Food Waste in Malaysia (YUEN, 2022).

2.2.2 Analysis of Organic Fraction of Municipal Solid Waste (OFMSW)

Basically, OFMSW is a mixture of waste such as garden waste and kitchen waste, whereas its definition will differ due to different regions or nations (Campuzano and González-Martínez, 2016). In a study, OFMSW constitutes 70% of the municipal solid waste composition (Albanna, 2013). A review conducted shows the analysis results of OFMSW from physical, chemical, and bromatological characteristics aspects in different countries and cities. Food waste which is included in the OFMSW has a density of 513 kg/m^3 (Campuzano and González-Martínez, 2016).

The other result related to the food waste in the OFMSW is the analysis of the bramatological characteristics. The average percentage of fat, oil, and grease sourced from the food waste in OFMSW was stated in the percent of the volatile solids (%VS) as 17.5±6.6%VS (Campuzano and González-Martínez, 2016). However, the source of the fat, oil, and grease can be animal or botanic. The data is shown in Table 2.1.

Table 2.1: Bramatological characteristics of OFMSW (Campuzano and González-Martínez, 2016).

Country	City	Fat, oil, grease	Protein	Raw fibre	Lignin	Carbohydrates				
						Cellulose	Hemi-cellulose	Starch	Free sugars	Total
China	Guangzhou	15.6	23.1	13.6	–	–	–	–	–	61.4
Colombia	Bucaramanga	–	–	19.9	5.2	6.4	2.9	–	–	–
Denmark	Lyngby	20.5	30.0	–	–	–	–	–	–	–
	Copenhagen	13.8	14.9	26.4	–	–	–	13.8	8.0	–
	Vejile	12.5	12.5	32.5	–	–	–	16.3	6.3	–
	Kolding	18.3	18.3	15.9	–	–	–	20.7	11.0	–
	Aalborg	16.5	17.5	17.3	–	–	–	18.8	10.0	–
	Kolding	18.0	19.2	19.2	–	–	–	15.4	5.9	–
	Grinsted	–	–	36.6	18.5	5.0	13.1	–	–	–
France	Rennes	–	–	41.8	3.8	23.4	14.6	–	–	–
India	Indore	9.6	7.7	37.8	9.6	17.5	10.7	–	–	–
Ireland	Cork	19.9	18.9	–	–	–	–	–	–	61.9
Italy	Padova	20.7	17.4	22.9	5.4	12.0	5.5	17.4	22.0	62.0
	Udine	6.09	14.61	–	–	–	–	–	–	35.0
	Milano	–	–	22.6	7.1	11.2	4.3	–	–	–
Mexico	Mexico City	17.5	15.2	39.5	13.5	21.1	5.1	–	–	52.9
Turkey	Ankara	26.0	13.3	–	–	–	–	–	–	63.2
United Kingdom	Luton	14.8	21.3	–	–	–	–	–	–	–
	Eastleigh	15.2	18.3	–	–	–	–	–	–	–
USA	New York	35.0	26.6	19.6	–	–	–	–	–	52.1
	Arizona (city not specified)	–	11.7	71.9	14.6	51.9	12.6	–	–	–
Average		17.5 ± 6.6	17.7 ± 5.5	29.2 ± 15.0	9.7 ± 5.3	18.6 ± 15.0	8.6 ± 4.6	17.1 ± 2.5	10.5 ± 6.0	55.5 ± 10.1

(–) indicates no data available.

2.3 Food Waste Handling Method

By looking at the ways in which food waste are disposed of around the world, landfill and composting seem to be the most common method to be used. Food waste that is under municipal solid waste is categorized as solid waste. Hence, the Malaysia Solid Waste and Public Cleansing Management Act 2007 (Act 672) can be applied to food waste disposal. From Act 672, disposal can be done by any means such as incineration, demolition, deposition, and decomposition (Nagapan and Rahman, 2012). However, the management of municipal solid waste in Malaysia is relatively poor and unorganized (Dinie, Samsudin and Mat Don, 2013).

2.3.1 Landfill

In Malaysia, landfill is the most often disposal method that is carried out due to the approach is straightforward, the cost required is low, and the landscape-restoration effect (Ahmad et al., 2019). However, the landfill method has its drawbacks which will pollute the environment. There is information to show that 70% of the municipal solid waste which consists of about 50% of food waste was disposed through landfilling in Malaysia (Nadzri, 2013). The organic substance in the food waste will decompose and release greenhouse gases such as methane due to the anaerobic environment created by landfill (What should you do with your food scraps?, 2016). Notably, the ability to trap heat in the atmosphere of methane is 25 times more powerful than carbon dioxide (Importance of Methane | US EPA, 2022). Moreover, 25% of global warming nowadays is caused by methane produced by human activity (Methane: A crucial opportunity in the climate fight, n.d.). Besides that, as the waste decomposed, a liquid will be formed, leachate. It will pollute the land and groundwater due to its toxicity (The problem with landfill, 2013). Consequently, the source of clean water will be polluted, and aquatic life will also be in danger. Anyway, the disposal through landfilling will be more and more difficult since the population growth will lead to scarcity of land, and the price of the land will rise due to the high demand for land. Meanwhile, the maximum capacity of most landfills is about to or already overstepped (Moh and Abd Manaf, 2014).

2.3.2 Incineration

Incineration is also a method to dispose the food waste in municipal solid waste. It is a process of disposing of substances at high temperatures, in other words, burning the waste in a combustion chamber. However, this method will consume a lot of energy to carry out since the content of the food waste is high (Zhang et al., 2014) (Lim et al., 2016). Other than that, burning the waste will produce greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) which will cause the greenhouse effect and pollutes the air (Hwang et al., 2017). Hence, it is banned in many countries (Zhang et al., 2014).

2.3.3 Backyard Composting

Since yard waste such as leaves and grass clippings can be composted into compost, which is an organic substance that can be added to the soil to improve the quality of the soil for better plant growth (Compost vs. Fertilizer, Explained, n.d.). Likewise, some of the food scraps can be added into it as compost material such as fruits, rice, and vegetable (Backyard Composting of Yard, 2017).

However, food waste composting is proved that it is effective for kitchen waste and good results were obtained in recent studies (Cerda et al., 2018). Therefore, this method is highly valued, and many studies were conducted due to its potential of producing valuable products. Despite this, it is also able to reduce the emission of methane from food waste (Hu, 2020). Yet, this method will take a relatively long time to process the food waste.

2.3.4 Anaerobic Digestion

Anaerobic digestion is a biological process by which bacteria break down the organic substance in an oxygen deficit environment (How Does Anaerobic Digestion Work? | US EPA, 2022). Furthermore, anaerobic digestion technology was proposed as a new method to obtain renewable energy from the OFMSW, but it does not fully implement in food waste management due to some technical, economic, and social issues (Xu et al., 2018) (Xu, Li and Wang, 2015). From a report published by the Business for Social Responsibility (BSR), the percentage of food waste that is processed through anaerobic digestion is less than 2% in the United States (BSR, 2014). Importantly, one of the challenges to adopting anaerobic digestion in food waste management is that the recycling rate of food waste from the consumer end is low (Xu et al., 2018).

2.4 Sewerage System

Sewage is also known as wastewater which includes industrial wastewater, domestic wastewater, and stormwater. A sewerage system means the infrastructure which carries the sewage to a wastewater treatment plant, river, or sea through sewers. There are three types of sewerage system, they are combined sewerage system, separate sewerage system, and partially combined or partially separate sewerage system (ROHIT, 2018).

2.4.1 Combined Sewerage System

In a combined sewerage system, the sanitary wastewater will mix with the stormwater in a sewer forming the sewage after collecting from the drain along the road and the buildings. The sewage will flow to the public sewage treatment plant under normal circumstances due to the dam could still completely divert the sewage to the sewer that leads to the sewage treatment plant. When heavy rain is coming, the increasing stormwater might cause the sewage level in the sewer to surpass the height of the dam and the overflow of the sewage will happen. The overflow of the sewage will flow into the river or sea (Thompson, 2020). Hence, it will damage the environment and the aquatic life in the rivers.

2.4.2 Separate Sewage System

In order to reduce the pollution in the rivers, a separate sewage system is being introduced. In a separate sewerage system, the sewers are being differed into two types, that is storm sewer and sanitary sewer. The storm sewer only collects the stormwater, and it ends up diverting the flow into rivers without any treatments being carried out (ROHIT, 2018). Whereas the sanitary sewer will divert the flow into the wastewater treatment plant to treat the sanitary wastewater. Then, the treated wastewater will be discharged into the rivers. As a result, the damage caused to the river is reduced.

2.4.3 Partially Combined or Partially Separate Sewerage System

A partially separate sewerage system is a combination of the combined sewerage system and separate sewerage system to obtain the advantages of both systems (ROHIT, 2018). In this system, the main two sewers are the same as the separate sewerage system. Some of the storm drains will be connected to the sanitary sewers for solid waste flushing purposes.

2.4.4 Sewerage System in Malaysia

The government of Malaysia introduced sewerage systems in the year 1963, for example, mechanically connected systems, individual or communal septic tanks, Imhoff tanks, and oxidation ponds to improve public health (Sewerage Systems, n.d.). However, the main sewerage system being used in Malaysia is the connected sewerage system and the individual or communal septic tanks (Objective & Systems, n.d.).

In Malaysia, the number of individual septic tanks is at estimated over one million because it is an affordable solution for sewage disposal (IST and Connected, n.d.) (Sewage Treatment Plant, n.d.). The septic tank consists of two chambers that are linked together in series (IST and Connected, n.d.). Solid that comes with the sewage will undergo sedimentation and form sludge at the bottom of the first chamber due to gravity, whereas the oil and grease will float on the surface and form a scum layer in the first chamber due to their lower density (IST and Connected, n.d.). Then the effluent between the scum layer and the sludge will flow into the second chamber for further sedimentation process (IST and Connected, n.d.). Lastly, the effluent will then discharge from the septic tank and flow into the drain. Therefore, the sewage goes into the drain or waterways without being processed in a wastewater treatment plant. Furthermore, Figure 2.2 shows an inspection chamber and a filter installed in front of and after the septic tank respectively. The sewage will flow into the inspection chamber before flowing into the septic tank, and the effluent will flow into the filter before flowing into the drain. The inspection chamber provides an access point that enables the removal of blockage and maintenance. However, the septic tank can only treat the sewage partially and it will also cause odor and health problems if it is overloaded (IST and Connected, n.d.) (Sewage Treatment Plant, n.d.). Moreover, the septic tank requires regular maintenance in order to work effectively.

In contrast, the connected sewerage system directly linked the sewage outlet from the user to the sewage treatment plant through a network of underground sewer pipes (IST and Connected, n.d.). Yet, there is a premise to adopting this system, that is the inspection chamber has to be outside of the user's building. Similar to the individual septic tank, one or more inspection chambers are connected to the sewerage pipelines of the user's building depending on the number of toilets and kitchens in the user's building (IST and Connected, n.d.). Then, it will be the sewage outlet connected to the public sewage treatment plant via the public sewerage pipelines (IST and Connected, n.d.). Hence, if any blockage occurs, the inspection chamber allows the checking and clearing work to be done.

Despite this, to further improve public health and solve the environmental problem, drastic changes must be made in sewage management in Malaysia including the whole sewerage infrastructure (Sewage Treatment Plant, n.d.). It is because wide urban areas adopt individual septic tanks that could only treat the sewage partially and still discharge effluent that still has a high organic content (Sewage Treatment Plant, n.d.).

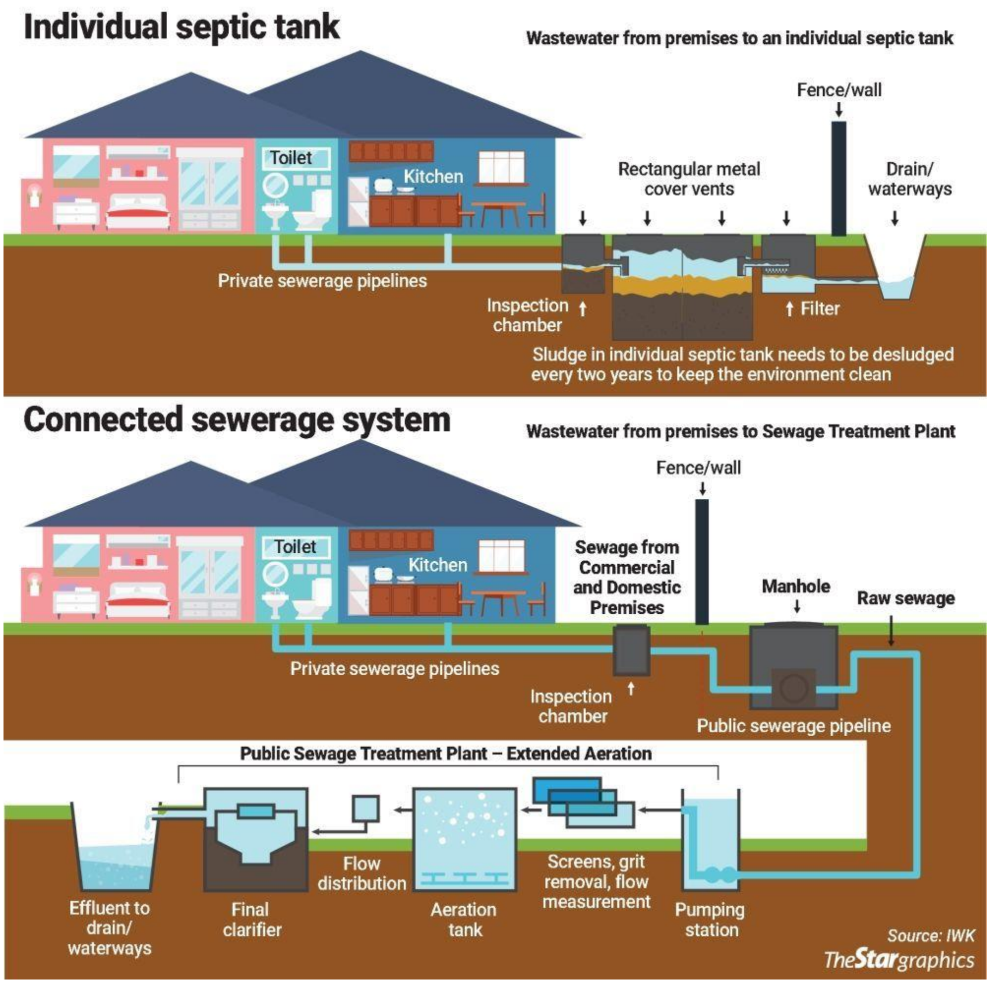


Figure 2.2: Main Sewerage Systems in Malaysia (The Star, 2021).

2.5 Household Waste Separation in Malaysia

In the year 2013, the government of Malaysia implemented the separation of organic waste and recyclable waste from household waste through the Solid Waste Management Act and Public Cleansing 2007 (Thi, Kumar and Lin, 2015). However, the effect does not meet the expectation due to the weak enforcement and the lack of resources allocated (Thi, Kumar and Lin, 2015). Therefore, a suitable low-cost device could help in this situation. Moreover, public awareness about the disadvantage of increasing food waste has to be raised also.

2.6 Advantages of Separating Household Kitchen Waste

A recent study stated that the sorting of food waste is one of the available approaches to improve the sustainable management of municipal solid waste (Yu and Li, 2020). From the conclusion of the study, complete house kitchen waste separation is the best household kitchen waste management strategy in view of environmental performance and economical benefit (Xu et al., 2018). As every 20% separation of the household kitchen waste, it would result in reducing the net carbon emission from 5% to 7%, reducing the emission of acidic gas by 3.1% to 3.5%, and a decrease in cumulative energy demand by about 2.1% to 2.2% (Xu et al., 2018). However, due to the social cost, the economic performance of separating household waste is subpar. Hence, two main factors that could affect the performance were found to lower the social cost of separating the household kitchen waste for better performance. The two factors are the proportion of food waste in municipal solid waste and the water content in the household kitchen waste (Xu et al., 2018). As a result, the first choice to manage the household kitchen waste is to drain the water content of the household kitchen waste to 60% with the source of household kitchen waste reduced by 20% and reduce the separation rate should be lower than 20% to reduce the social cost until it is acceptable to the people (Xu et al., 2018).

Importantly, the fact that collecting food waste and reducing the water content of the food waste brings a lot of benefits. Not to mention, as food scrap is included in food waste, similar effects can be obtained by collecting the food scraps and separating the food scraps from water. Therefore, the development of a low-cost food scrap and grease separator is meaningful and practical.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

In this chapter, the methodological approach to develop a low-cost food scrap and grease separator will be shown. Since this is a developing project, the steps will start with conceptual design, following by embodiment design, detail design, fabrication and testing of the prototype, and lastly the reflection of this project.

3.2 Workflow of the project

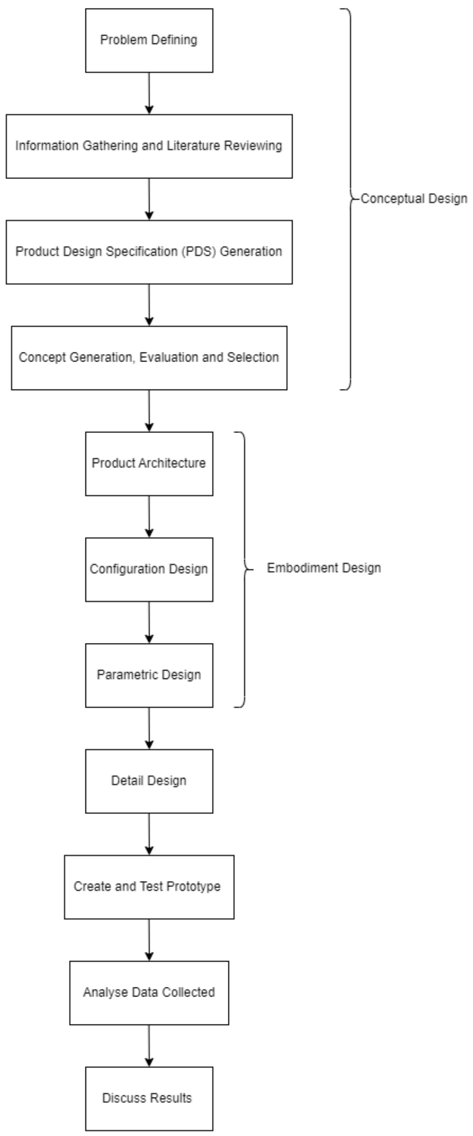


Figure 3.1: Workflow of the Project

3.3 Design boundary limit

The target customer of this low-cost food scrap and grease separator are the owners of hawker food stalls in the hawker centers and owners of food stalls in small restaurants as main. However, the food stalls along the roadside and household market will be treated as minor target markets. Hence, the commercial sinks that are being adopted by the food stalls either in the hawker centers or small restaurants for washing the dishes will be used as the dimension reference for the low-cost food scrap and grease separator. Figure 3.2 shown one of the commercial sinks available on the market.

The common material of the commercial basin is stainless steel, with dimensions of 1200 mm in length, 600 mm in width, and 800 mm in height. Therefore, the dimension of the low-cost food scrap and grease separator shall not exceed any dimensions of the commercial basin respectively.

Figure 3.2: Commercial sink available on the market.

3.4 Design Parameter

3.4.1 Design Requirements

Table 3.1: Design Requirements of the Low-Cost Food Scrap and Grease. Separator.

Customer Requirements	Description
Low cost	Simple design which can also be produced by simple manufacturing process at the same time to minimize the manufacturing cost for a low selling price product.
Simple installation	The installation of the device should be convenient and easy for ordinary people to avoid any extra installation fees needed to be paid for the device set up.
User friendly	Avoid complicated operations of the device.
Easy to clean	The device should be able to clean easily to avoid any foul smell and further consequences.
Easy to maintain	The product should require as less maintenance as possible for convenience adopt to use. It should be able to operate at atmospheric pressure.
Long service life	The material selected for the product should be durable to maximize the service life of the design.
Safe to use	The product should not have any sharp edges to avoid any harm caused by the product during installation, operation, and maintenance.

3.4.2 Engineering Characteristics

Table 3.2: Engineering Characteristics and its Description.

Engineering Characteristics	Description
Short set up time	Roughly the installation of the device takes an hour of set up time at most.
Device size	Length ≤ 2 m, Width ≤ 1.5 m, Height ≤ 1.8 m.
Device weight	Weight of machine should below 15 kg.
Device performance	At least no clearly visible drop of grease and food particles in the output flow.
Operating pressure	1 atm

3.4.3 Engineering Constraint

Table 3.3: Engineering Constraint of the Low-Cost Food Scrap and Grease Separator.

	Unit	Constraint
Length of the product	mm	1200 mm
Width of the product	mm	600 mm
Height of the product	mm	800 mm

3.5 Product Design Specification

3.5.1 Product Identification

Low-Cost Food Scrap and Grease Separator

Basic Function:

- To collect the solid food scrap left by customers after finished their meal
- To separate the grease from the liquid food scrap
- To collect the grease separated from the liquid food scrap

Special Features:

- Plug and play device; Easy installation; Easy to operate

Key Performance Targets:

- The non-presence of the food scrap content of the wastewater discharge
- The low presence of the grease content of the wastewater discharge

Service Environment:

- Hawker centre
- Small restaurant

User Training Requirement:

- Easy to operate, user’s manual will also be provided so that customer can know the procedure to operate the device.

3.5.2 Market Identification

Market Target:

- Owners of hawker food stalls in the hawker centers.
- Owners of food stalls in small restaurants.

Competing Products:

- Food scrap collector
- Grease trap

Branding Strategy: Inexpensive and effective plug-and-play food scrap separator and grease separator.

3.5.3 Physical Description

A solid food scrap separator device and a grease separator device that can use with commercial basins.

Estimated Device Dimension (L x W x H): 600 mm x 500 mm x 800 mm

Estimated Device Weight: 15 kg

Device Material: Aluminium sheet, acrylic sheet, metal wire mesh, PVC pipes, ball valve, slotted angle bar, food tray, and industrial storage box.

3.5.4 Financial Requirements

Target manufacturing cost: RM500

Warranty Policy: 3 years

3.5.5 Life Cycle Targets

Useful life or shelf life: 8 years

Maintenance:

Table 3.4: Maintenance Schedule with Action.

Action	Schedule
Discharge of grease separated	Once a day in use
Cleaning work	Once a month, or more often if needed

Reliability: 5 years

End-of-Life Strategy: Refurbishment or recycling of the worn parts during the end life of the product is the cheapest regarding costs for the customer.

3.5.6 Social, Political, and Legal Requirements

Safety and Environment regulations will be followed

Standards: Comply with ISO9001 and ISO20484, Occupational Safety and Health Act 1994 (OSHA)

3.5.7 Fabricating Specifications

- The equipment and resources needed to fabricate the product are easy to reach.
- The prototype will be designed for real-world tolerance. The custom parts of the whole assembly line should be able to fabricate easily. Moreover, the design should be able to accommodate to the variation as when tolerance stack up, parts of the operation might add up to a huge obstacle.

3.6 Function Structure

Figure 3.3 shows the function structure of the low-cost food scrap and grease separator. The functions of the low-cost food scrap and grease separator are represented graphically with inputs and outputs. The “blocks” in the figure represent the process undergoing at a certain state, whereas the “arrows” represent the inputs and outputs of a certain state which includes energy, material, and signal. Hence, the "blocks" can also refer to as functions and the "arrows" can also refer to as flows.

Firstly, the leftover food from the customers will be poured into the food scrap separator. So, the leftover food will pass through 3 layers of strain tray with different sizes of meshes due to gravity. The uppermost strain tray will have the largest size of the holes, then the following strain tray will have a smaller size of the holes, and the lowest strain tray will have the smallest size of the holes. Hence, the food scrap will be filtered out by size from larger to smaller. The purpose of having layers of strain tray is to avoid the food scrap accumulating and blocking the holes which will cause the liquid from the leftover food unable to flow from the food scrap separator to the grease separator. Besides, it can also roughly distribute the food scraps that can be used by size depending on the leftover food of the stall. For example, the chicken bones will mainly remain in the upper strain tray and the rice will remain in the lowest strain tray.

After that, the remaining will be the liquid from the leftover food. It will pass through layers of strain tray and flow into the grease separator. Then, the liquid from the leftover food will be slowed down by the baffles in the grease separator. Here, the grease in the liquid from the leftover food will float to the surface of the solution due to its density is lower than the density of water. Besides that, those tiny suspended particles in the liquid from the leftover food will be precipitated at the bottom of the grease separator. Hence, the separation of grease and the sedimentation of tiny suspended particles from the liquid from the leftover food will be undergone simultaneously. The accumulated grease can be discharged through the grease discharge pipe when the ball valve of the grease discharge pipe is opened, whereas the sediments can be discharged when the cleaning of the grease separator is being carried out. Next, the processed liquid will be discharged through the outlet pipe and flow into the drain. Therefore, the basic working mechanism is being explained, and it is similar to the fundamental working mechanism of a household septic tank.

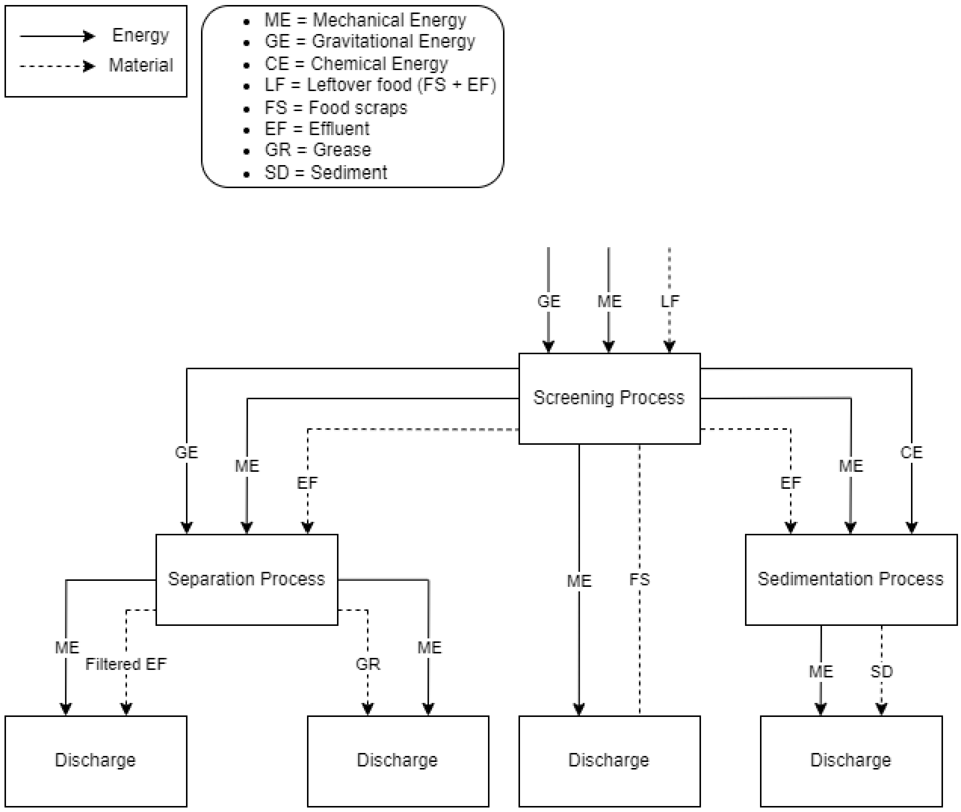


Figure 3.3: Function Structure of the Low-Cost Food Scrap and Grease Separator.

3.7 Embodiment Design

3.7.1 Product Architecture

Figure 3.4 shows the element clustering of the low-cost food scrap and grease separator. Different from the function structure, the "blocks" in the figure represent the components of the low-cost food scrap and grease separator instead of the functions. Each of the components was designed to serve for particular purpose respectively. Hence, the components can be separated into different modules respectively as shown in Figure 3.4.

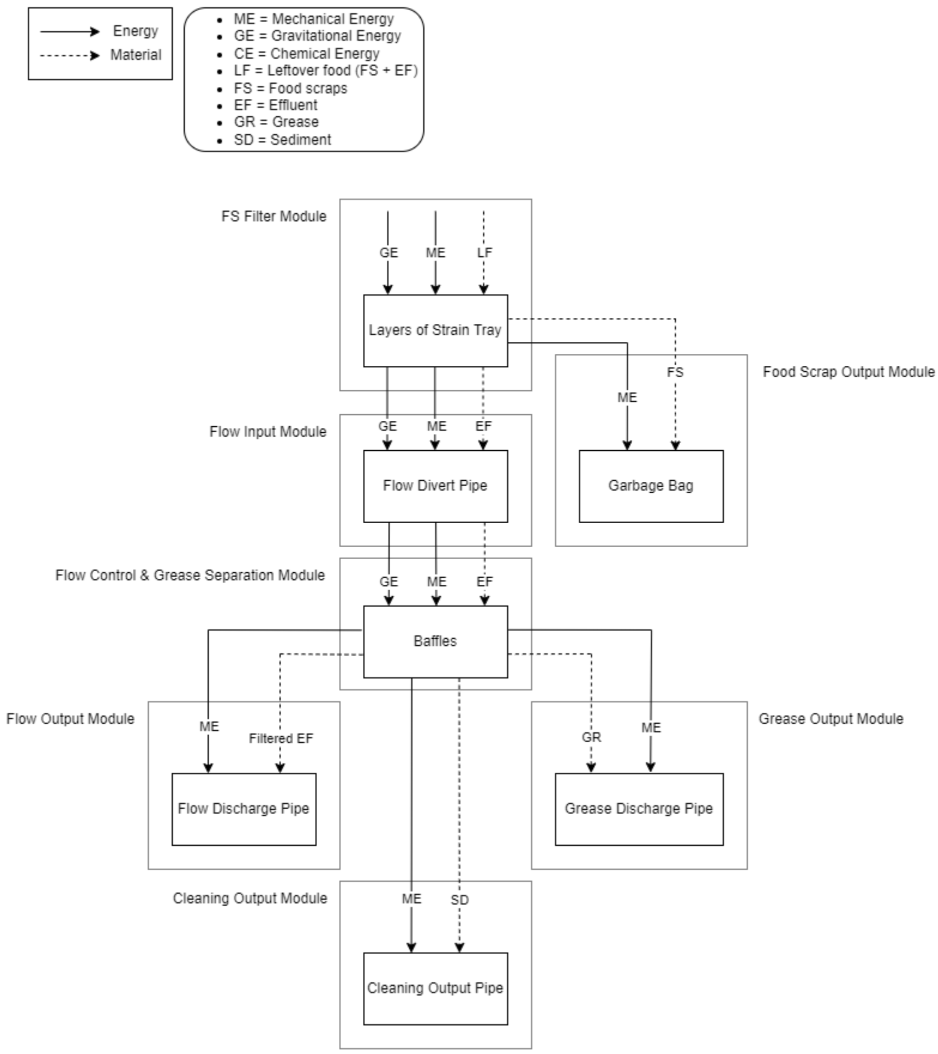


Figure 3.4: Element Clustering of the Low-Cost Food Scrap and Grease Separator.

To further establish the product architecture, two different modular architectures had sketched out as shown in Figure 3.5 and Figure 3.6.

For modular architecture 1 in Figure 3.5, the leftover food will pass through layers of strain trays which are stacked together above the cover of the grease separator. Therefore, the food scraps will be filtered out and stay in the strain trays. Then, the effluent will flow into the grease separator. The effluent will pass through layers of baffles, and the velocity of the flow will be slowed down. Hence, the grease could be separated because it will float up to the surface due to its density is lower than the density of water. After that, the filtered effluent will be discharged from the grease separator.

For modular architecture 2 in Figure 3.6, the leftover food will pass through layers of strain trays which using the concept of drawers. By doing so, the food tray can be taken out individually for the food scraps to unload. Hence, the food scraps will be filtered out and stay in the strain trays. Then, the effluent will flow into the grease separator through a pipe. The effluent will have to pass through the grease separator with some obstacles which are layers of baffles. Therefore, the velocity of the flow will be slowed down. Hence, the grease could be separated because it will float up to the surface due to its density is lower than the density of water. After that, the filtered effluent will be discharged from the grease separator.

By considering adaptability, the modular architecture 1 will not be chosen. It is because, for the modular architecture 1, the strain trays are stacked above the cover of the grease separator. Therefore, if the model of the stainless-steel commercial basin adopted by the small restaurant or the food stall has side stretchers, the space required to place the device will be larger, and it will cause inconvenience to the end user. Thus, the modular architecture 2 will be more suitable.

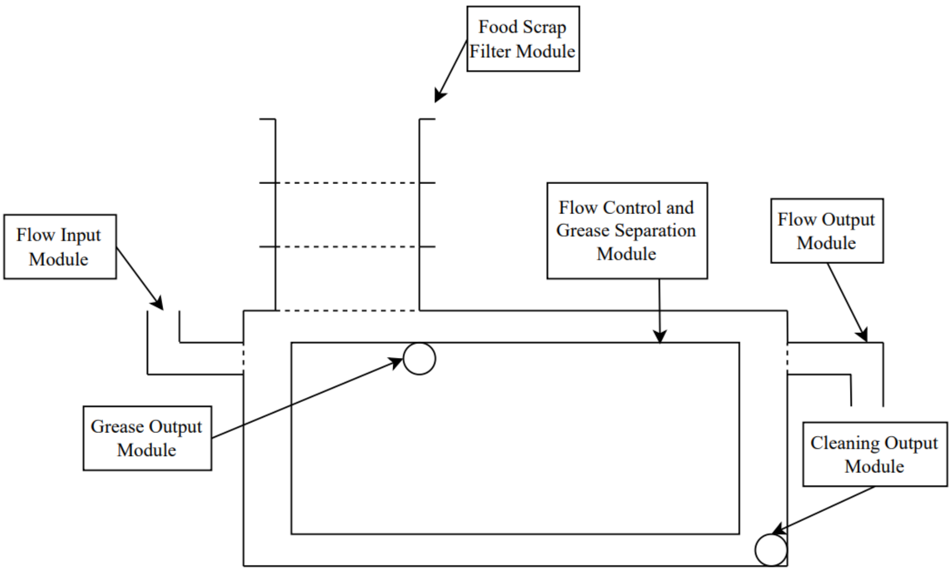


Figure 3.5: Modular Architecture 1.

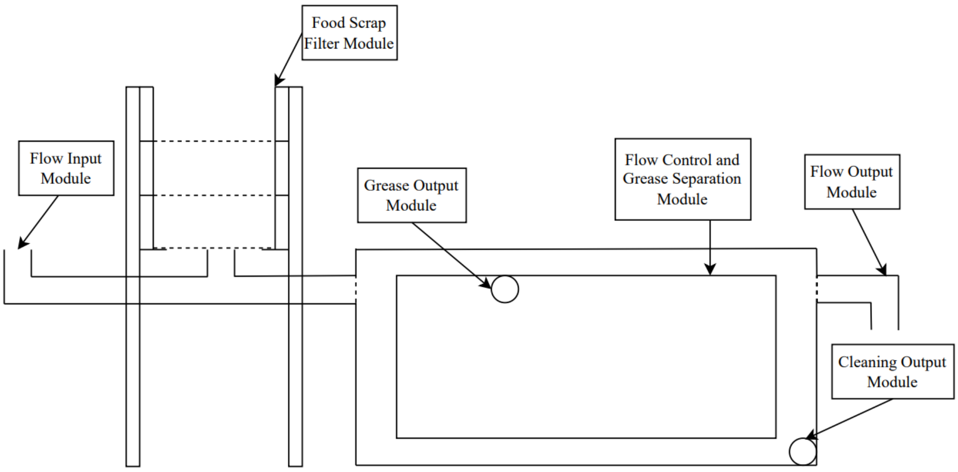


Figure 3.6: Modular Architecture 2.

3.7.2 Configuration Design

In the low-cost food scrap and grease separator, the main components that need to be carried out configuration design are the strain drawer of the food scrap separator and the baffle of the grease separator.

The function of the strain drawer is to screen out the food scrap from the leftover food and let the liquid from the leftover food pass through it. Therefore, the concept chosen to solve this design problem is to let the liquid from the leftover food pass through holes of the strainer, then the food scraps will be separated out due to their size are larger than the holes. Thence, the possible configurations could be a perforated metal sheet or metal wire mesh. Both configurations are shown in Figure 3.7. However, the metal wire mesh was chosen for the prototype because it is less expensive and allows a more thorough passing of the food scraps for which are smaller than the mesh size, making the distribution of the food scraps more even.

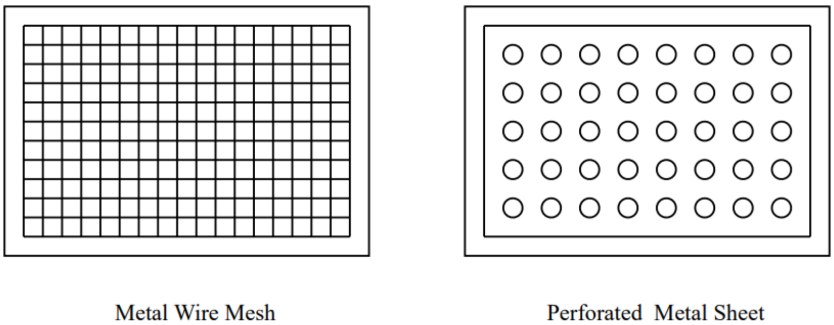


Figure 3.7: Possible Configurations for Strain Drawer Design.

The function of the baffle is to slow down the velocity of the liquid from the leftover food in order to let the grease able to be separated from it with water and for those tiny, suspended particles to precipitate at the bottom of the grease separator. Therefore, the concept chosen to solve this problem is to let the liquid from the leftover food collide with the baffles, and the flow will be diverted to other directions than the front. Besides, the number of baffles needed will also be considered in the design. Hence, there are three possible configuration and design of the baffles shown in Figure 3.8, Figure 3.9, and Figure 3.10. However, the baffles will be detachable as user-friendliness feature.

The first configuration for baffles design is shown in Figure 3.8. The baffles were a cuboid with four fillet edges, and there are holes on the lower part of the baffles to allow the liquid to pass through the baffles. The size of the holes for the baffles are from large to small as the baffle gets further from the input hole for the liquid of leftover food.

The second configuration for baffles design is shown in Figure 3.9. The design of the baffles is simple, just a cuboid with four fillet edges. However, the baffles in second configuration will be shorter than the baffles in the first configuration. Hence, the flow will only pass through above or below the baffles depends on the position of the baffles are installed.

The third configuration for baffles design is shown in Figure 3.10. The design of the baffles is complicated. Besides the fillet edges, the baffles design is curved. The way of the flow will pass through the baffles is same as the second configuration.

However, the second configuration was chosen due to its simplicity, which means a higher manufacturability. Moreover, the flow path is longer compared to the first configuration, allowing better separation effect of oil.

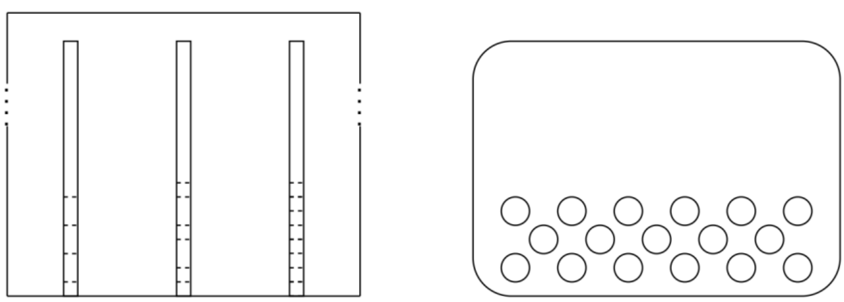


Figure 3.8: First Configuration for Baffles Design.

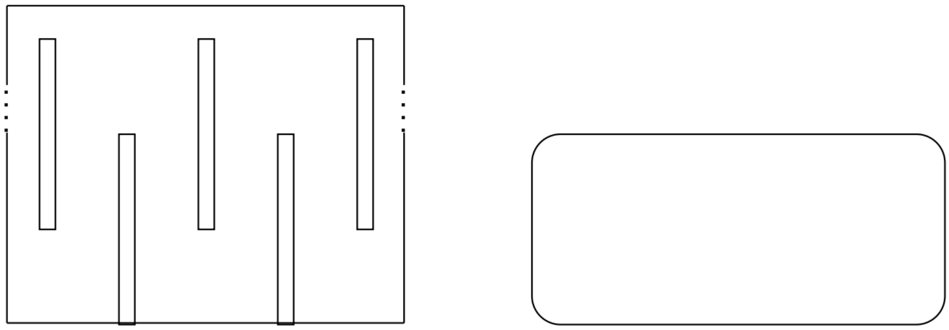


Figure 3.9: Second Configuration for Baffles Design.

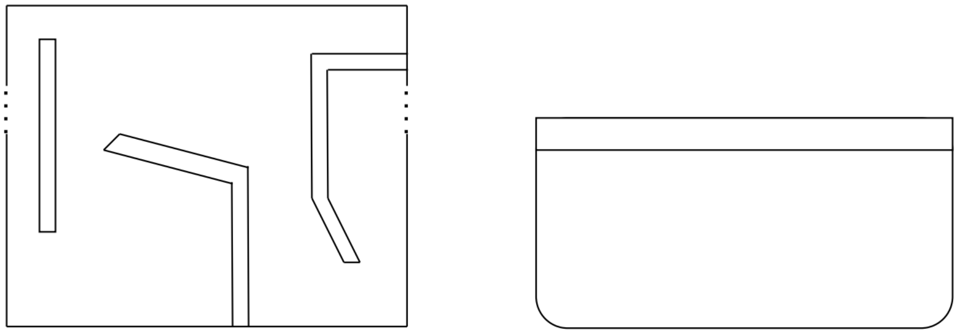


Figure 3.10: Third Configuration for Baffles Design.

3.7.3 Parametric Design

Since most parts of the prototype will be purchasing standard parts that are available on the market, therefore the tolerance for the prototype should follow the ISO tolerance stated in ISO 2768. Considering the machining skills and the status of the machines in the workshop, a coarse tolerance class was chosen.

Table 3.5: Tolerance of the Low-Cost Food Scrap and Grease Separator.

Food Scrap Separator	
Height	800 mm ± 2.0 mm
Width	600 mm ± 2.0 mm
Length	500 mm ± 3.0 mm
Hole for diverting pipe	50 mm ± 1.0 mm
Grease Separator	
Height	600 mm ± 2.0 mm
Width	500 mm ± 2.0 mm
Length	600 mm ± 3.0 mm

Table 3.6 (Continue)

Hole for flow discharge pipe	50 mm ± 1.0 mm
Hole for grease discharge pipe	20 mm ± 1.0 mm
Hole for cleaning output pipe	30 mm ± 1.0 mm

3.8 Detail Design

3.8.1 Engineering Drawing Set

Appendix A: Engineering Drawings

3.9 Prototyping and Testing Plan

3.9.1 Product Key Functionalities

The product's key functionality is to separate and collect the solid food scrap left by customers after finishing their meal and to separate the grease from the liquid food scrap.

3.9.2 Materials and Prototyping Process

Roughly, the materials used to build the prototype include aluminium plates, acrylic sheets, metal wire meshes, PVC fittings, ball valves, slotted angle bars, plastic food trays, and an industrial container. The slotted angle bars were used to construct the main framework of the food scrap separator, whereas the industrial container is the main framework of the grease separator. The aluminium plates were used to fabricate support plates for the metal wire meshes fastened to the strain trays, whereas the acrylic sheets were for baffles fabrication. The metal wire meshes and the plastic food trays were used to fabricate the strain trays. Lastly, the PVC fittings were used for input and discharge purposes with the control of the ball valves.

The prototyping process included cutting, bending, and drilling. The aluminium plates were cut into the dimension required by the metal shearing machine and then bent through a manual sheet metal bending machine. After that, the holes required were drilled through the bench drilling machine with the respective diameter of the drill. Until this point, they were ready to be used for assembly. Besides, an industrial storage box was opened with some holes for the installation of pipes that allow the inlet and discharge of the flows. Moreover, pockets were cut out from the food trays and installed with different mesh sizes of metal wire mesh to act as strain trays.

3.9.3 Testing Plan

Two experiments were done to determine the effectiveness of the grease separator, and one testing was done to determine the effectiveness of the food scrap separator and the grease separator.

3.9.3.1 Experiment 1

The idea behind this experiment is to simulate the flow of liquid from the leftover food into the grease separator and observe whether the liquid from the output flow contains oil droplets. In this experiment, three mixtures with different cooking oil-water mixing ratios were made. The mixtures were shacked well just before being poured into the grease separator. First, the mixture that had the lowest oil content among the three mixtures was poured into the grease separator that was pre-filled with water which was just about to allow the discharge of flow once a solution has entered. The discharged flow was collected and observed for the oil droplets. At the same time, the time for the discharge of output flow to completely flow out after the mixtures were poured. Then, the same procedure was conducted for the mixture that had the second lowest oil content among the three mixtures, and lastly for the mixture that had the highest oil content among the three mixtures. However, there was no discharge of the oil from the grease discharge pipe throughout the experiment.

3.9.3.2 Experiment 2

This experiment was conducted after experiment 1. The idea behind this experiment is to simulate the flow from the basin when the washing of the dishes is in progress and observe whether the liquid from the output flow contains oil droplets. First, the faucet was opened to allow the flow of water. After the water flow was stabled, a measuring cup was used to catch the water and a timer was set to start at the same time as the measuring cup started to catch the water. The timer was stopped when the water reached the level of 1000 ml stated on the measuring cup. The time required for the water flow to fill up 1000 ml was recorded. Then, the water flow was diverted into the grease separator through a basin flexible drain hose. The timer was set to zero and started again as the water flow was being diverted. After that, the timer was stopped when the flow starts to discharge at the flow discharge pipe. The time required for the flow to have an output at the flow discharge pipe after the flow was diverted into the grease separator is called retention time. The retention time was recorded. After the water flow has been diverted into the grease separator for 2 minutes, the faucet was turned off. The discharged liquid was collected and observed for the oil droplets. The same steps were taken for another two different flow rates. After experiment 2, the thickness of the oil layer for each section of the grease separator was measured.

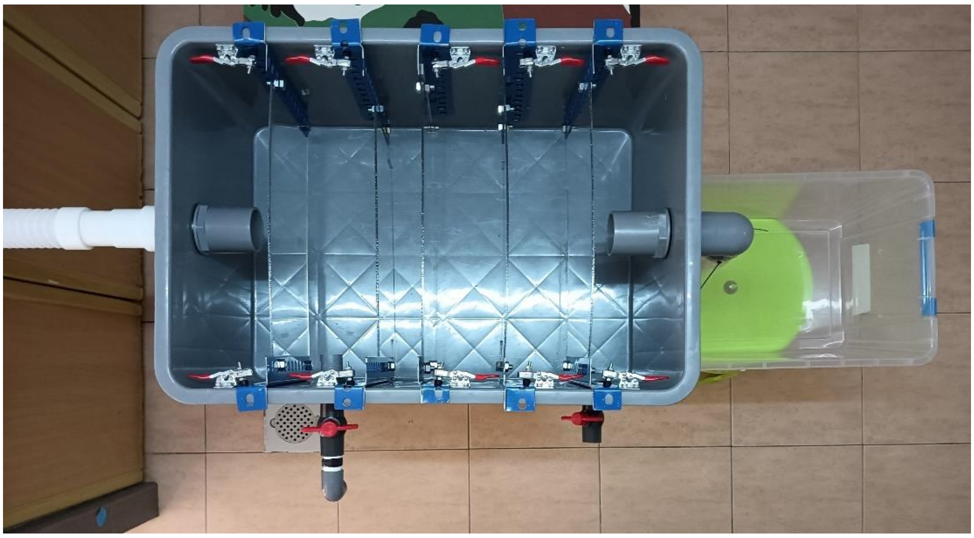


Figure 3.11: Top View of the Setup for Experiment 1 and Experiment 2.

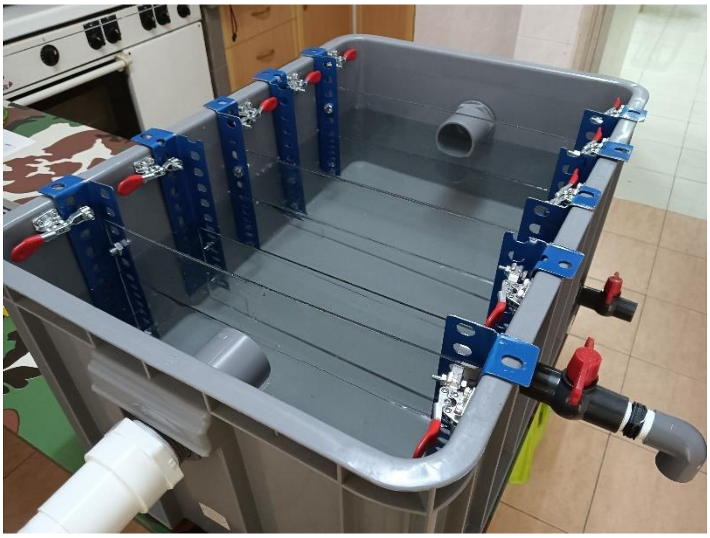


Figure 3.12: Water Level of the Grease Separator Before Experiment.

3.9.3.3 Testing

The aim of this testing is to test how well the food scrap and grease separator will work in an actual working environment. First, the food scraps were collected from a food stall in a restaurant and brought to the place where the experiment is carried out. Then, the food scrap and grease separator were set up. After that, the food scraps collected were poured into the food scrap separator. The situation of the food scrap and grease separator was observed after the discharge was completed.

Figure 3.13: Food Stall that Provides the Leftover Food.

Figure 3.14: Setup of Food Scrap and Grease Separator for Testing.

3.10 Prototype Fabricated

The prototype of the food scrap and grease separator was done as shown in Figure 3.15. The prototype can be divided into two main parts, the food scrap separator, and the grease separator. These two main parts are connected by a basin flexible drain hose. It is to allow the liquid from the leftover food to flow from the food scrap separator to the grease separator for the grease separation process.

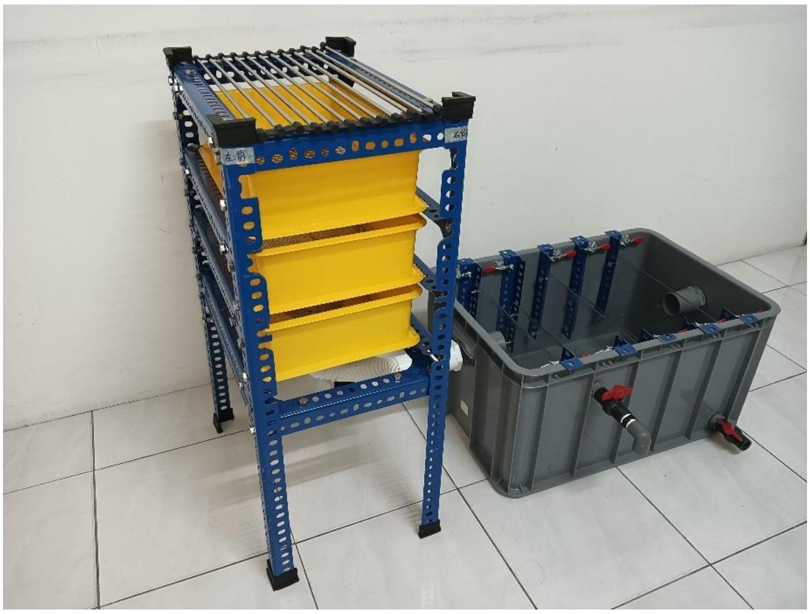


Figure 3.15: Prototype Fabricated.

3.10.1 Food Scrap Separator

The food scrap separator was made from slotted angle bars, rubber bases, corner plates, plastic food trays, metal wire meshes, metal wire mesh frame, metal wire mesh frame connectors, metal wire mesh frame spacers, and stainless steel foldable dish mat drainer. The fastening method used for the main framework is bolts and nuts. The stainless steel foldable dish mat drainer was added for the temporary storage of dishes to allow liquid to drain from leftover food. The rubber bases were installed to prevent it from scratching the ground and people. The food scrap separator fabricated has a length of 320 mm, width of 472 mm, and height of 780 mm, which is smaller than the targeted dimensions in the parametric design, makes it more space-saving.

Figure 3.16: Front View of the Food Scrap Separator Fabricated.

3.10.1.1 Strain Trays

The strain trays were made from plastic food trays, three different sizes of metal wire mesh, metal wire mesh frames made from aluminum plates, metal wire mesh frame connectors, and metal wire mesh frame spacers. The metal wire meshes, frames, frame connectors, and frame spacers were fastened to the food trays using bolts and nuts. The bottom of the plastic food trays was being cut for the food scraps smaller than the hole of the metal wire mesh of the respective layer and fluid from the leftover food to pass through. For the bottom layer of the strain trays, only a hole is opened for the installation of the stainless steel sink strainer. It is different from the other two because it was required to direct the fluid from the leftover food to the grease separator. A drawer design was adopted for the convenience of the discharge of food scraps since the amount of the food scraps will be different due to the different sizes of food scraps. There are three layers of strain trays instead of one layer because the original idea was to prevent the larger food scraps at the bottom covered the holes of the metal wire mesh, making it slow or even impossible for liquid to pass through. The sizes of the three metal wire meshes are 12 mm x 12 mm, 4 mm x 4 mm, and 1 mm x 1 mm from coarse to fine respectively.

Figure 3.17: Different Sizes of Metal Wire Meshes Compared to 20 cents.

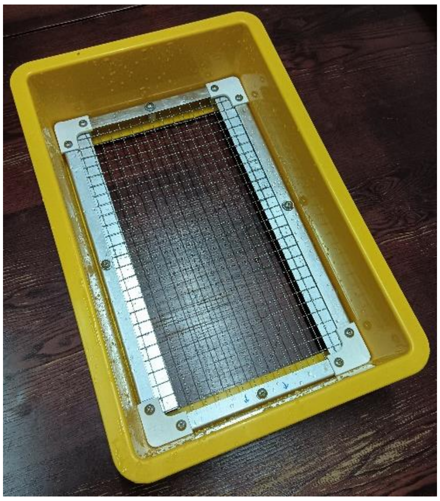


Figure 3.18: Top Layer of the Strain Trays.

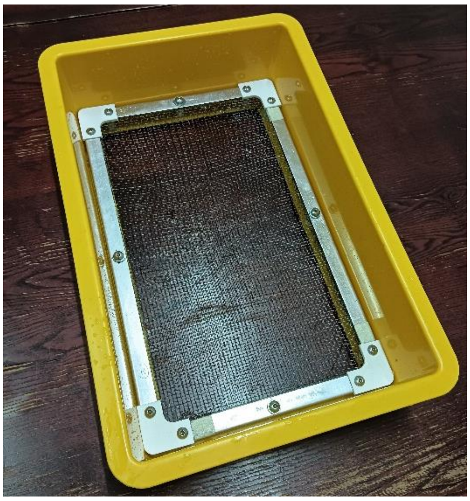


Figure 3.19: Middle Layer of the Strain Trays.

Figure 3.20: Bottom Layer of the Strain Trays.

3.10.2 Grease Separator

The grease separator was made from an industrial container, various kinds of PVC fittings, acrylic sheets, slotted angle bars, and quick-release toggle clamps. The baffles were attached with slotted angle bars using bolts and nuts, and they were fixed by quick-release toggle clamps to realize the detachable function. The quick-release toggle clamps were fastened to the industrial container by bolts and nuts. There are two ball valves, one is for the discharge of the grease separated and another one is for the discharge of whole liquid in the grease separator, which usually will only be used when being cleaned.

Figure 3.21: Front View of the Grease Separator.

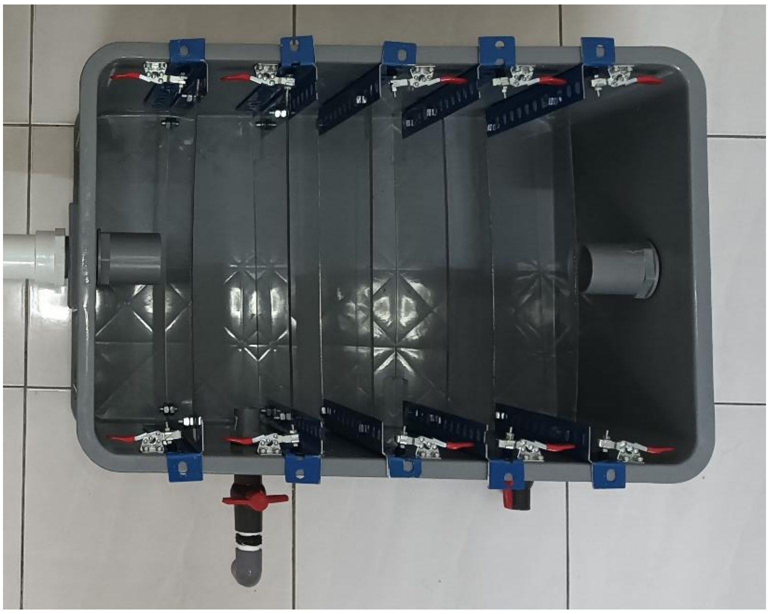


Figure 3.22: Top View of the Grease Separator.

3.10.2.1 Baffles

The baffles are divided into two types, upper baffle, and lower baffle. The design of the upper baffle is just a simple cuboid with four fillet edges and holes for attachment with the slotted angle bars. The design of the lower baffle is slightly more complex because it has to fit with the inner fillet of the industrial container to maximize the impossibility of liquid passing through from the bottom of the lower baffles. At the same time, it has to leave space and holes for the slotted angle bar for attachment purposes. The fabrication of baffles used acrylic sheets with a thickness of 3 mm, and it is cut through a laser cutting machine.

Figure 3.23: Lower Baffle.

Figure 3.24: Cutting of the Acrylic Sheets through Laser Cutting Machine.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results and Discussions for Experiments and Testing

The results and discussions for the experiments and testing are separated into three sections. Each section will focus on the respective experiment or testing done. The results consist of qualitative data and quantitative data. Hence, the interpretation of data will be carried out according to two kinds of data.

4.1.1 Experiment 1

This section will focus on the results obtained from experiment 1.

Table 4.1: Time Required for Discharge of Output Flow to Completely Flowing Out After the Mixtures Being Poured Respective to the Mixtures Poured into the Grease Separator.

No.	Mixture Input			Time Required for Discharge of Output Flow to Completely Flowing Out After the Mixtures Being Poured (s)
	Oil (ml)	Water (ml)	Ratio (Oil : Water)	
1	300	1700	3 : 17	260
2	600	1400	3 : 7	306
3	900	1100	9 : 11	343

Table 4.2: Oil Droplets Observed from the Discharged Flow Respective to the Mixtures Poured into the Grease Separator.

No.	Mixture Input			Oil Droplets Observed from the Discharged Flow
	Oil (ml)	Water (ml)	Ratio (Oil : Water)	
1	300	1700	3 : 17	None
2	600	1400	3 : 7	None
3	900	1100	9 : 11	None

Figure 4.1: Discharged Flow Collected After Mixture 1 Poured into the Grease Separator.

Figure 4.2: Discharged Flow Collected After Mixture 2 Poured into the Grease Separator.

Figure 4.3: Discharged Flow Collected After Mixture 3 Poured into the Grease Separator.

The results obtained from experiment 1 were shown in Table 4.1, Table 4.2, Figure 4.1, Figure 4.2, and Figure 4.3. There were no oil droplets observed from the discharged flow after all mixtures had been poured into the grease separator. Hence, it can be concluded that the prototype of the grease separator fabricated is effective in separating the oil from the mixtures poured into it. The total volume of the oil poured is 1800 ml, with a total volume of water which is 4200 ml. The total volume of the mixtures is 6000 ml. However, the results obtained is only a reference for the ability of oil separation of the fabricated prototype.

From Table 4.1, the time required for the discharge of output flow to completely flow out after the mixtures were poured increased as the oil content increased. It is because the increase in the oil content increased the viscosity of the mixture. Therefore, the discharge flow rate was decreased due to the increased viscosity. In other words, the fluid that flows into the grease separator will have a longer time staying inside of it, which will require space for it to stay. Hence, the design of the baffles has to consider the height of the upper baffles to prevent overflow of the fluid causing it to malfunction. This is important because overflow will also cause extra cleaning for the working environment and the inconvenience will decrease the willingness of the owners of food stalls in small restaurants to adopt the grease separator.

4.1.2 Experiment 2

This section will focus on the results obtained from experiment 2.

Table 4.3: Thickness of Oil Layer at Different Sections.

Section	Distance	Thickness of Oil Layer
	(mm)	(mm)
1	0.0	14
	95.5	14
2	98.5	12
	289.5	12
3	292.5	0.5
	483.5	0.5
4	486.5	0
	580.0	0

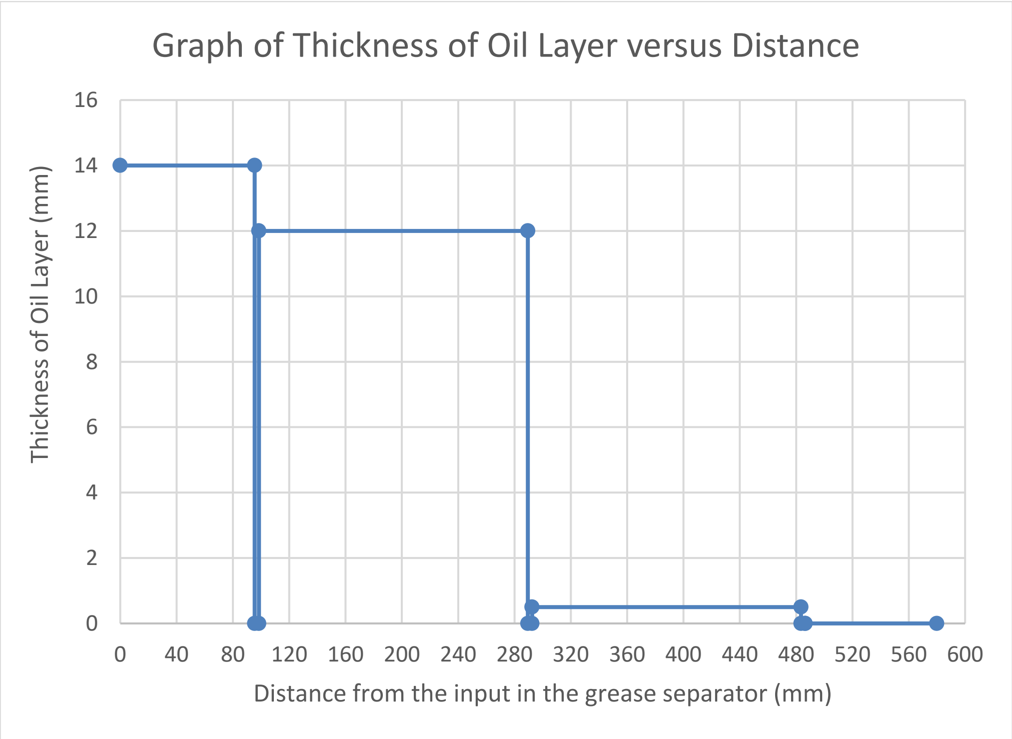


Figure 4.4: Graph of Thickness of Oil Layer versus Distance.

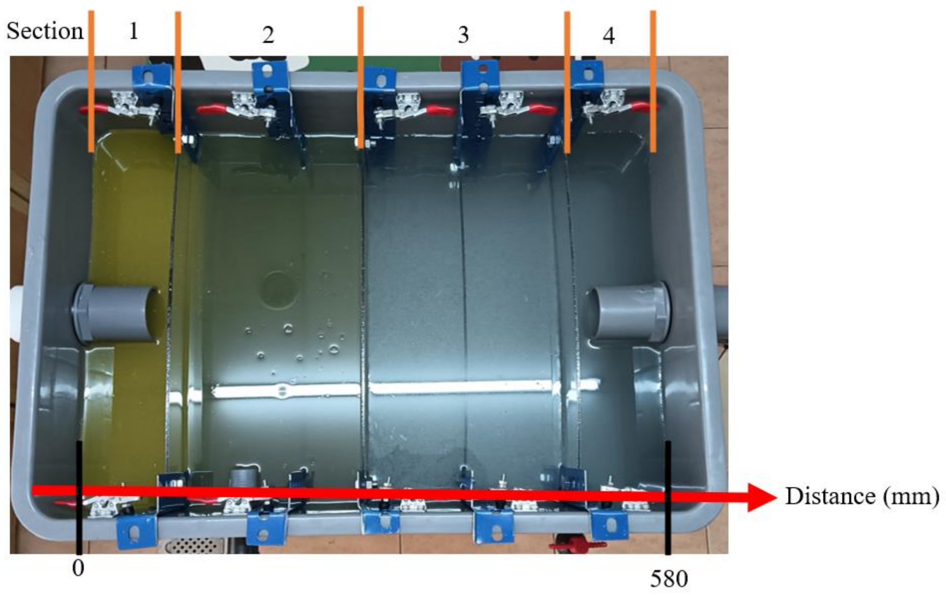


Figure 4.5: Grease Separator Labelled with Section and Distance.

Table 4.4: Data Collected from Experiment 2.

Volume of the Measuring Cup	Time Required to Reach the Level of 1000 $\boldsymbol{ml}$ Stated on the Measuring Cup	Input Flow Rate	Retention Time
$(\boldsymbol{m^3})$	**(s)**	$\left(\mathbf{1 \times 10^{-5}}\ \frac{\boldsymbol{m^3}}{\boldsymbol{s}}\right)$	**(s)**
0.001	69	1.4493	110.56
0.001	21	4.7619	29.88
0.001	9	11.1111	13.49

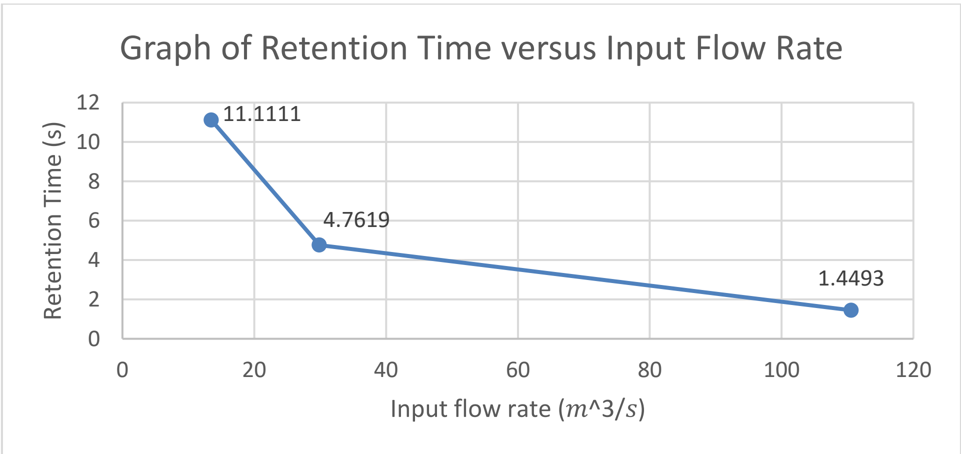


Figure 4.6: Graph of Retention Time versus Input Flow Rate.

Table 4.5: Observation of Oil Droplets for Different Input Flow Rates.

Volume of the Measuring Cup	Time Required to Reach the Level of 1000 $\boldsymbol{ml}$ Stated on the Measuring Cup	Input Flow Rate	Oil Droplets Observed from the Discharged Flow
$(\boldsymbol{m^3})$	(s)	$(1 \times 10^{-5}\ \frac{m^3}{s})$	
0.001	69	1.4493	None
0.001	21	4.7619	None
0.001	9	11.1111	None

Figure 4.7: Discharged Flow Collected for Lowest Flow Rate.

Figure 4.8: Discharged Flow Collected for Second Lowest Flow Rate.

Figure 4.9: Discharged Flow Collected for Highest Flow Rate.

The results obtained from experiment 1 were shown in Table 4.3, Table 4.4, Table 4.5, Figure 4.4, Figure 4.6, Figure 4.7, Figure 4.8, and Figure 4.9. From Figure 4.7, Figure 4.8, and Figure 4.9, it can be seen that there were no oil droplets observed from the discharged flow for all input flow rates. Hence, it can be concluded that the prototype of the grease separator fabricated is effective to retain the oil separated from water with a flow rate of 11.11×10^{-5} $\frac{m^3}{s}$ for two minutes. However, the time for the water flow was set to two minutes flow due to the limited volume of the container box for the collection of the discharge liquid. In fact, the process of washing dishes lasts for a long time.

Figure 4.4 shows the graph of the thickness of the oil layer versus distance, where the distance starts from the input end of the inner cavity of the industrial container, and at the distance 580 mm, it is the discharge end of the inner cavity of the industrial container. The sudden drop to zero and rise from zero of the thickness of the oil layer is due to the place being installed with upper baffles, which have zero presence of the oil layer. The distance having the same thickness of the oil layer is because the distance is located in the same section, the surface of the liquid did not isolate by upper baffles. Figure 4.4 shows a downward trend in steps, indicating that the thickness of the oil layer is decreased from section to section, which is as expected. This result shows most of the oil will be remained in section 1 and section 2 after being separated. Hence, the detachable baffle between section 1 and section 2 is useful for a better oil discharge effect, since the baffle between section 1 and section 2 can be detached and proceed to the discharge of oil separated. The existing products on the market have only one oil discharge hole and it is usually located after the first upper baffle. This will cause the FOG to remain on the surface of the water in section 1 and the performance of the grease separator will be degraded once it solidified. Separated oil that remained in section 3 is far lower than in section 1 and section 2. Whereas there are no observable oil droplets in section 4.

4.1.3 Testing

This section will focus on the results obtained from testing. The results obtained are qualitative only.

Figure 4.10: Top Layer of the Strain Trays After Testing.

Figure 4.11: Middle Layer of the Strain Trays After Testing.

Figure 4.12: Bottom Layer of the Strain Trays After Testing.

Figure 4.13: Discharged Flow Collected from Testing.

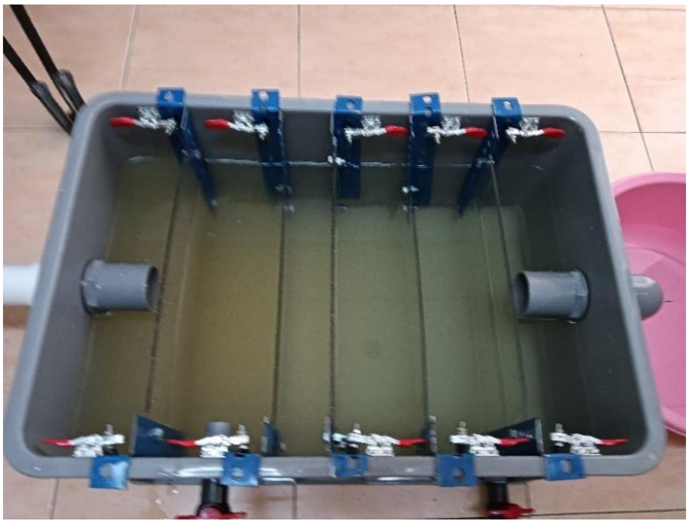


Figure 4.14: Condition of Grease Separator After Testing.

The results obtained from testing were shown in Figure 4.10 to Figure 4.14. From Figure 4.10, it can be seen that most of the food scraps were stranded in the top layer of the strain trays such as cooked sliced meat, various noodles, greens, anchovies, cooked minced meat, sliced mushrooms, chili, chopped green onions, short rice noodles, sliced edible tree fungus, and chopped coriander. From Figure 4.11, it can be seen that there are only some anchovies, cooked minced meat, sliced mushrooms, chili, chopped green onions, short rice noodles, sliced edible tree fungus, and chopped coriander. From Figure 4.12, it can be seen that the food scraps stranded are chili seeds and finely chopped chili.

The food scraps that are stranded in the top layer and middle layer are kind of repetitive, but the amount is different. The results mean that three layers of strain trays may be excessive. The top layer and the middle layer of the strain trays can be replaced by a food tray that has a larger capacity, equipped with the metal wire mesh used by the second tray. In this way, the number of times of taking out those food scraps can be reduced, and the convenience is increased. However, by intuitively, most of the various noodles should pass through the top layer of the strain trays, but it did not. This is because the noodles settle at the bottom of the container with other food scraps such as cooked cuts of meat. When poured, it falls with those and caused it stranded on the top layer.

From Figure 4.13, there are no oil droplets observed from the discharged flow collected from testing. This represents the prototype fabricated has the ability to deal with the real working environment to a certain extent. From Figure 4.14, the liquid in the grease separator gradually changes from cloudy to clear. This proves that the liquid from leftover food had flown into the grease separator and was trapped inside it. This indicates the oil from the leftover food has time to separate due to the different densities of water and oil.

4.1.4 Summary

The results obtained from experiment 1, experiment 2, and testing are as expected. Experiment 1 which simulates the flow of liquid from the leftover food into the grease separator has no oil droplets in the discharged flow proves that the prototype fabricated is able to separate the oil from the liquid from the leftover food. Experiment 2 which simulates the flow from the basin when the washing of the dishes is in progress into the grease separator also results in no oil droplets in the discharged flow. This indicates that the prototype fabricated has the ability to retain the oil from a flow rate of $11.11 \times 10^{-5}\ \frac{m^3}{s}$ to some extent. The thickness of the oil layer for each section of the grease separator measured after experiment 2 shows that most of the oil separated will remain in the water surface of section 1 and section 2 of the grease separator. Hence, the detachable baffle between section 1 and section 2 can be detached, and the oil discharge is more thorough. This discovery is meaningful for the detachable baffles feature which is an innovation focused on a better oil discharge for the grease separator to increase the willingness of the owners of the hawker food stall to adopt the grease separator. Moreover, even though the experiment did not test the cleaning of the grease separator, but the detachable baffles feature is believed that it could make the cleaning process more convenient.

From the results obtained through the testing, the design of the food scrap separator can be improved. Most of the food scraps were stranded in the top layer of the strain trays, and the type of food scraps stranded in the top layer and the middle layer has not much difference. Therefore, it is more convenient and reasonable to replace the top layer and the second layer of strain trays into one strain tray which has a larger capacity, equipped with the metal wire mesh used by the second tray. However, there are no oil droplets observed from the discharged flow collected, this means that the prototype fabricated has the ability to deal with the real working environment to a certain extent.

4.2 Cost of Fabrication

Table 4.6 shows the material cost that was used to fabricate the prototype for low-cost food scrap and grease separator. The cost can only be used as a reference since the cost for a factory to bulk purchase will be different from the end-user. The total cost of material used to fabricate the prototype is RM 420.27. A similar volume of grease separator available on the market is having a price of RM 650 as shown in Figure 4.15. The volume of prototype fabricated and is $580\ mm \times 390\ mm \times 295\ mm$, whereas the similar volume available on the market is $610\ mm \times 305\ mm \times 305\ mm$. A food scrap separator on market cost 875 USD as shown in Figure 4.16.

Table 4.6: Cost of Materials Used to Fabricate Prototype.

No.	Item	Quantity	Unit Price (RM)	Shipping Fee (RM)	Subtotal (RM)
1.	Industrial Container	1	60.76	19.20	79.96
2.	Slotted Angle Bar (3 feet)	8	3.30	15.00	85.92
3.	Slotted Angle Bar (2 feet)	9	2.20		
4.	Slotted Angle Bar (1 feet)	10	1.10		
5.	Corner Plate	26	0.22		
6.	Rubber Base	8	1.00		
7.	Food Tray	3	11.90	8.00	43.7
8.	Sink Strainer	1	3.33	5.60	15.49
9.	Stainless Steel Dish mat Drainer	1	6.56		
10.	Stainless Steel 0.24 mm Wire Mesh	1	12.00	5.60	17.60
11.	Barbecue Grate	1	5.90	-	5.90
12.	GI Netting	1	5.00		5.00
13.	A1 Acrylic Sheet	1	78.50		99.50
14.	A3 Acrylic Sheet	1	21.00		
15.	Ball Valve	2	2.30		4.60
16.	Sealing Tape	2	0.80		1.60
17.	Basin Flexible Drain Hose	1	6.15		6.15
18.	PVC 90-Degree Elbow	1	1.90		1.90
19.	PVC Tank Connector	2	7.00		14.00
20.	PVC PT elbow	1	2.50		2.50
21.	UPVC PT Socket	1	2.50		2.50
22.	PVC Elbow	1	1.60		1.60
23.	PT Elbow	1	1.00		1.00
24.	PVC Socket	1	1.60		1.60
25.	Toggle Clamp	3	8.05	5.60	29.75
				Total	420.27

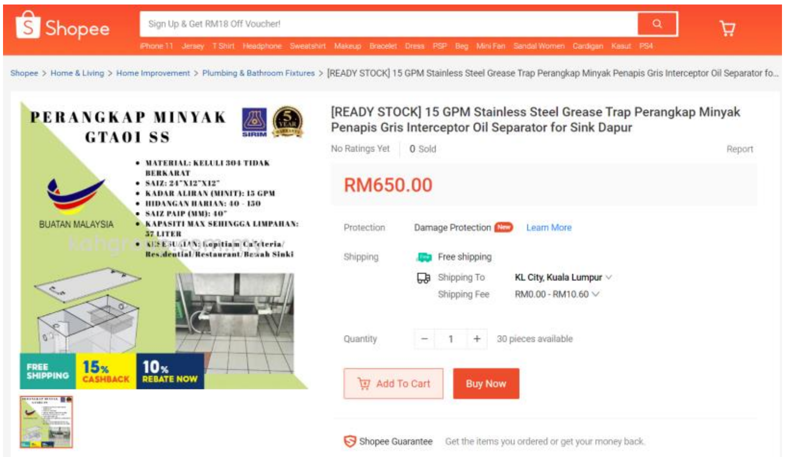


Figure 4.15: Grease Separator Available on Market.

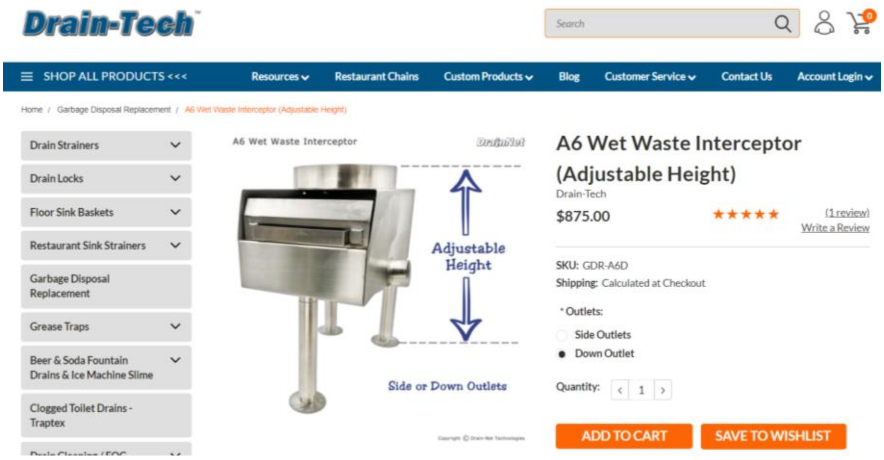


Figure 4.16: Food Scrap Separator Available on Market.

4.3 Comparison with Product on Market

As mentioned in the problem statement, there are food scrap separators and grease separators on the market, but they are two separate devices. The baffles of the grease separators on the market are all fixed by welding or integrated with the grease separator as a whole. This caused inconvenience for maintenance work such as cleaning to be done. Also, the discharge of the grease is not thorough because there is at most one grease discharge valve for grease separators on the market. Therefore, the detachable feature for the baffles is introduced in this project to provide a more thorough grease discharge and convenience for maintenance work. These are the advantages of the designed grease separator in this project. However, the disadvantage is the number of components is more than grease separators on the market.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, a low-cost food scrap and grease separator was designed, and a prototype has been fabricated. Two experiments and one test were conducted to determine the effectiveness of the prototype fabricated.

The results obtained from the experiments and testing were as expected. There are no oil droplets observed from the discharged flow obtained from experiments and testing. For such a result, it is undoubtedly a success. Besides, most of the oil separated remained in section 1 and section 2. This result proves that the detachable baffles can provide a more thorough oil discharge by simply removing the baffle between section 1 and section 2.

It is important to highlight that the innovative feature of the detachable baffles make this design stand out from the existing product available in the market. It is believed that this feature could increase the willingness of the owners of small restaurants to adopt the food scrap and grease separator through a more thorough oil discharge and a more convenient cleaning process. At the same time, it fits the concept of low cost without involving any electronic equipment. The concerns about increased assembly costs can be addressed by letting buyers do their own assembly since the assembly of the prototype is through bolts and nuts.

However, there is still a lot of room for improvement in this project. Throughout the fabrication of the prototype, the improvement of the food scrap separator has been made. The strain tray support plates were removed from the design to make it more compact for space-saving. Unfortunately, more improvement cannot be done due to the time constraint of this project.

5.2 Recommendations

For prototyping, the material selected to fabricate the prototype of the grease separator should be transparent if possible. This is for a better observation of the inner condition of the grease separator fabricated. Besides, if possible, the dimensions of the prototype of the grease separator fabricated should be as close as possible to the products available on the market. If the funds are sufficient, it is better to purchase one of the products available on the market and conduct experiments and testing with the prototype fabricated and the product purchased to increase comparability.

For the experiments, experiments conducted should be using flow control equipment to control the flow of the mixtures to obtain a more reliable result. Besides, a larger discharged flow collector should be used to observe the impact of long-time water flow on the ability of the grease separator fabricated to separate the oil from the mixture and liquid from the leftover food.

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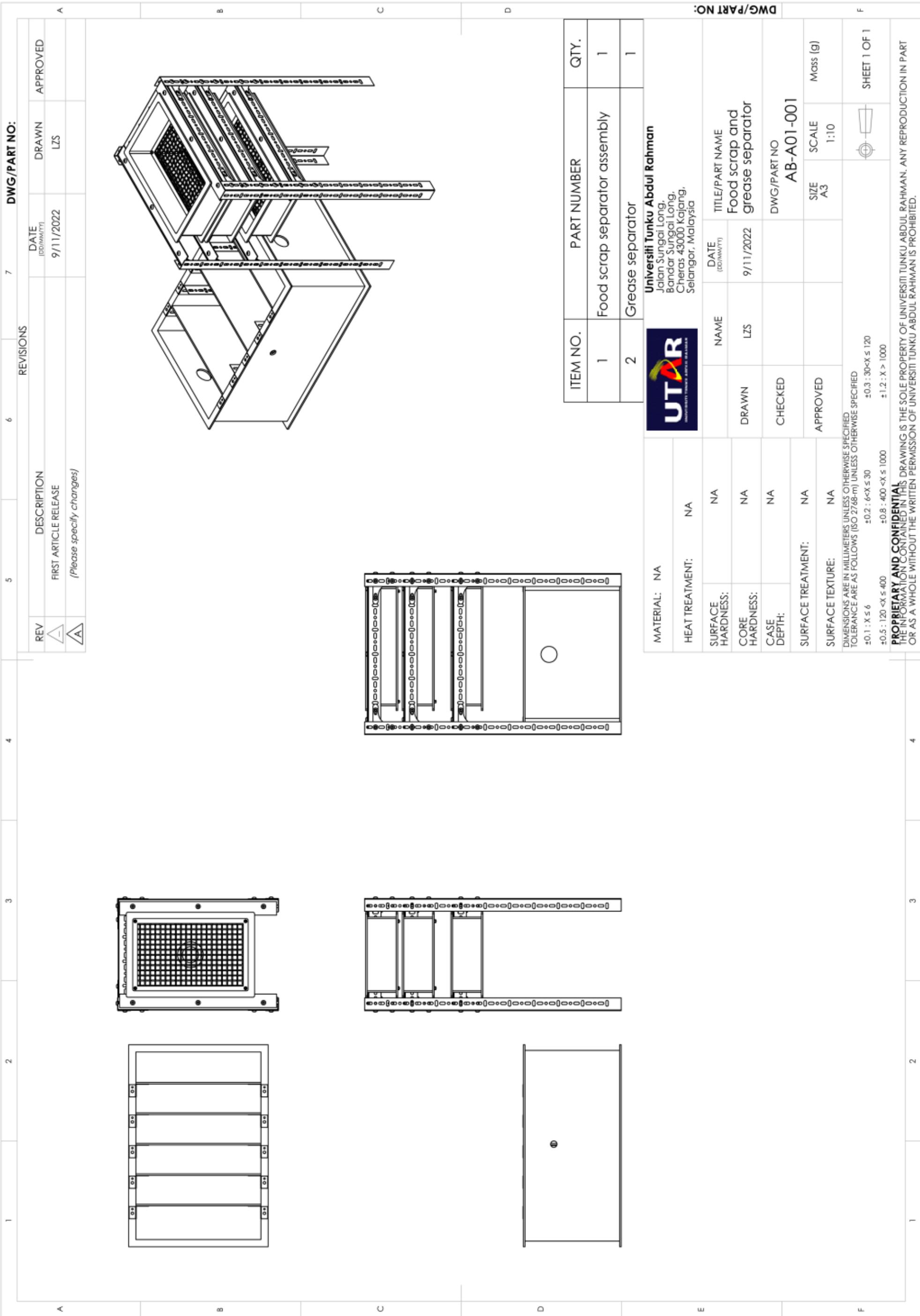
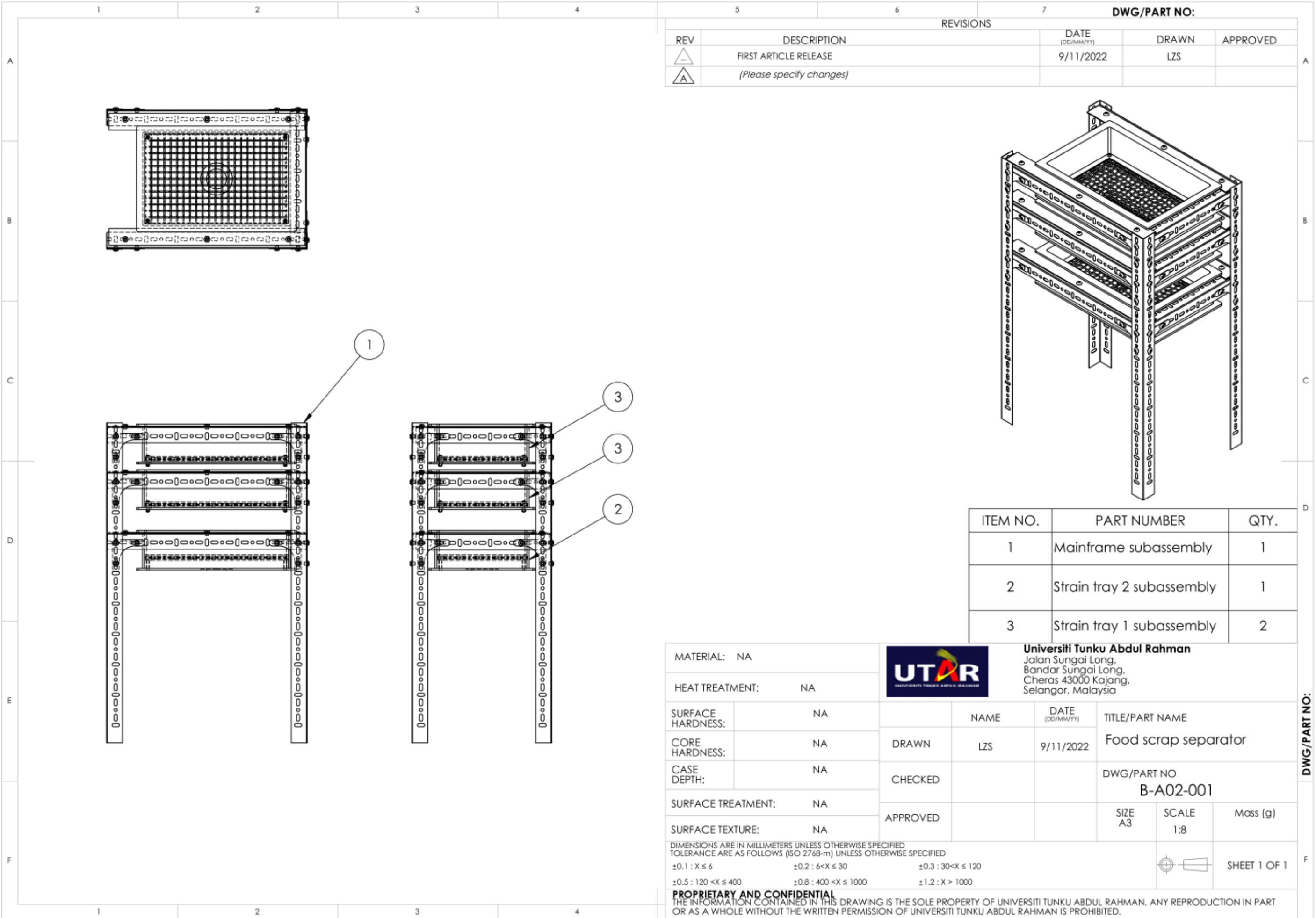
APPENDICES

Appendix A: Engineering Drawings

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9/11/2022
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ITEM NO.
PART NUMBER
QTY.
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2
Strain tray 2 subassembly
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2
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HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
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Universiti Tunku Abdul Rahman
Jalan Sungai Long,
Bandar Sungai Long,
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9/11/2022
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Food scrap separator
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SIZE A3
SCALE 1:8
Mass (g)
SHEET 1 OF 1
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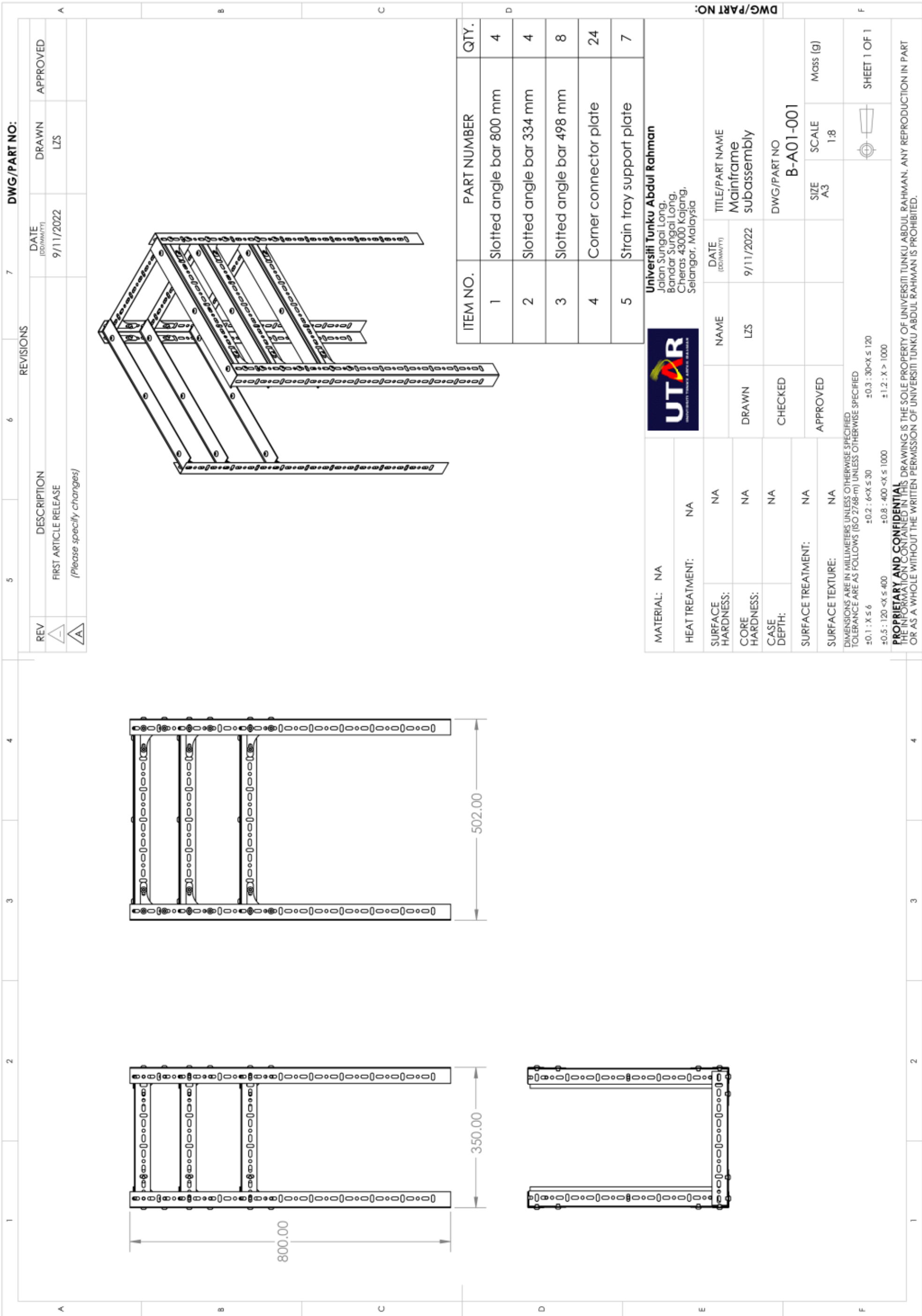
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCE ARE AS FOLLOWS (ISO 2768-m) UNLESS OTHERWISE SPECIFIED
±0.1 : X ≤ 6
±0.2 : 6<X ≤ 30
±0.3 : 30<X ≤ 120
±0.5 : 120 <X ≤ 400
±0.8 : 400 <X ≤ 1000
±1.2 : X > 1000
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF UNIVERSITI TUNKU ABDUL RAHMAN. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF UNIVERSITI TUNKU ABDUL RAHMAN IS PROHIBITED.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4
3
Slotted angle bar 498 mm
8
4
Corner connector plate
24
5
Strain tray support plate
7
Universiti Tunku Abdul Rahman
Jalan Sungai Long,
Bandar Sungai Long,
Cheras 43000 Kajang,
Selangor, Malaysia
MATERIAL: NA
HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
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9/11/2022
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APPROVED
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B-A01-001
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SCALE
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Mass (g)
SHEET 1 OF 1
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCE ARE AS FOLLOWS (ISO 2768-m) UNLESS OTHERWISE SPECIFIED
±0.1 : X ≤ 6
±0.2 : 6<X ≤ 30
±0.3 : 30<X ≤ 120
±0.5 : 120 <X ≤ 400
±0.8 : 400 <X ≤ 1000
±1.2 : X > 1000
PROPRIETARY AND CONFIDENTIAL
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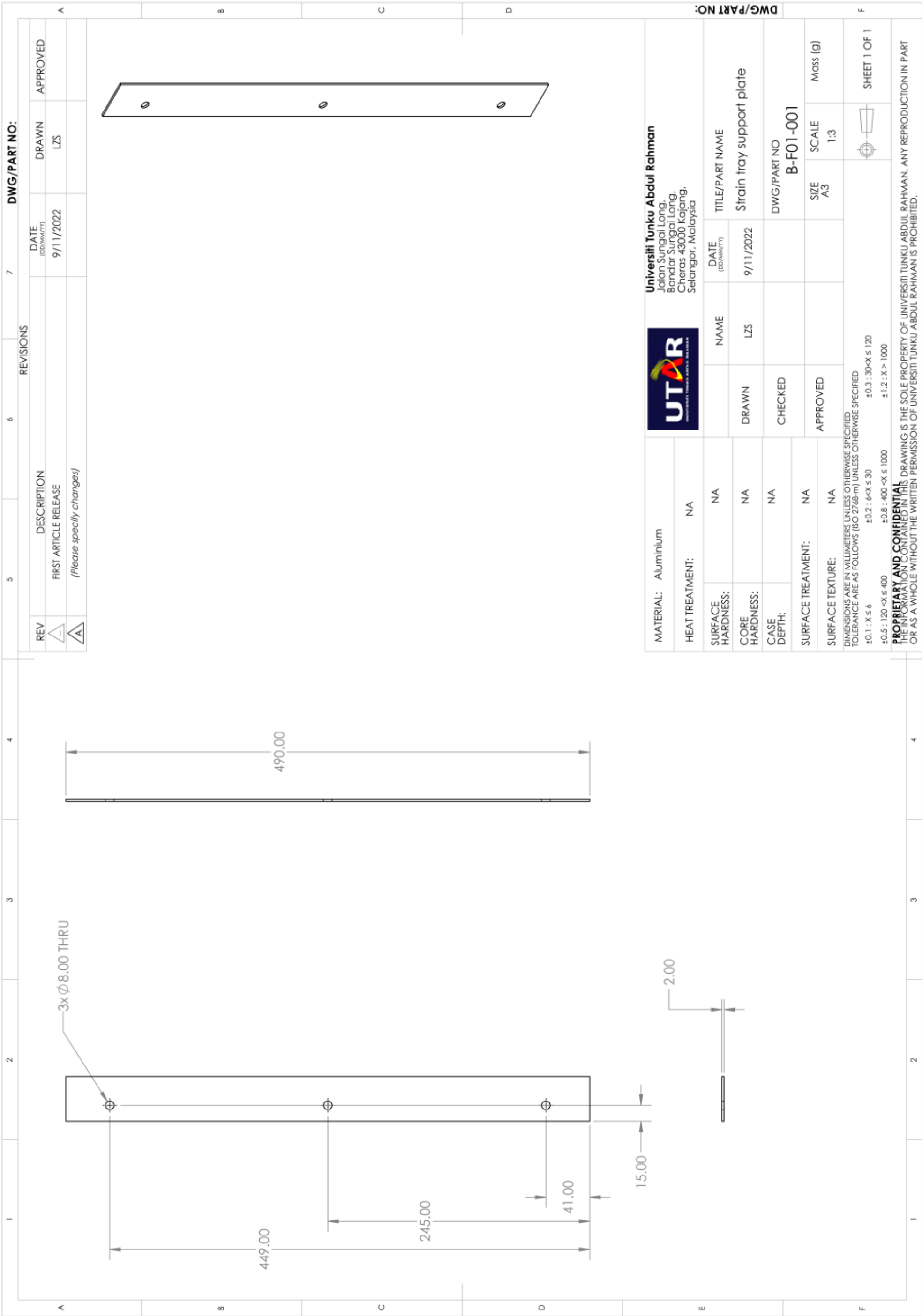
502.00
350.00
800.00



DWG/PART NO:
REVISIONS
REV
DESCRIPTION
DATE (DD/MM/YY)
DRAWN
APPROVED
FIRST ARTICLE RELEASE
9/11/2022
LZS
(Please specify changes)
490.00
3x ⌀8.00 THRU
2.00
15.00
41.00
245.00
449.00
MATERIAL: Aluminium
HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
Universiti Tunku Abdul Rahman
Jalan Sungai Long,
Bandar Sungai Long,
Cheras 43000 Kajang,
Selangor, Malaysia
NAME
DATE (DD/MM/YY)
DRAWN
LZS
9/11/2022
CHECKED
APPROVED
TITLE/PART NAME
Strain tray support plate
DWG/PART NO
B-F01-001
SIZE A3
SCALE 1:3
Mass (g)
SHEET 1 OF 1
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCE ARE AS FOLLOWS (ISO 2768-m) UNLESS OTHERWISE SPECIFIED
±0.1 : X ≤ 6
±0.2 : 6<X ≤ 30
±0.3 : 30<X ≤ 120
±0.5 : 120 <X ≤ 400
±0.8 : 400 <X ≤ 1000
±1.2 : X > 1000
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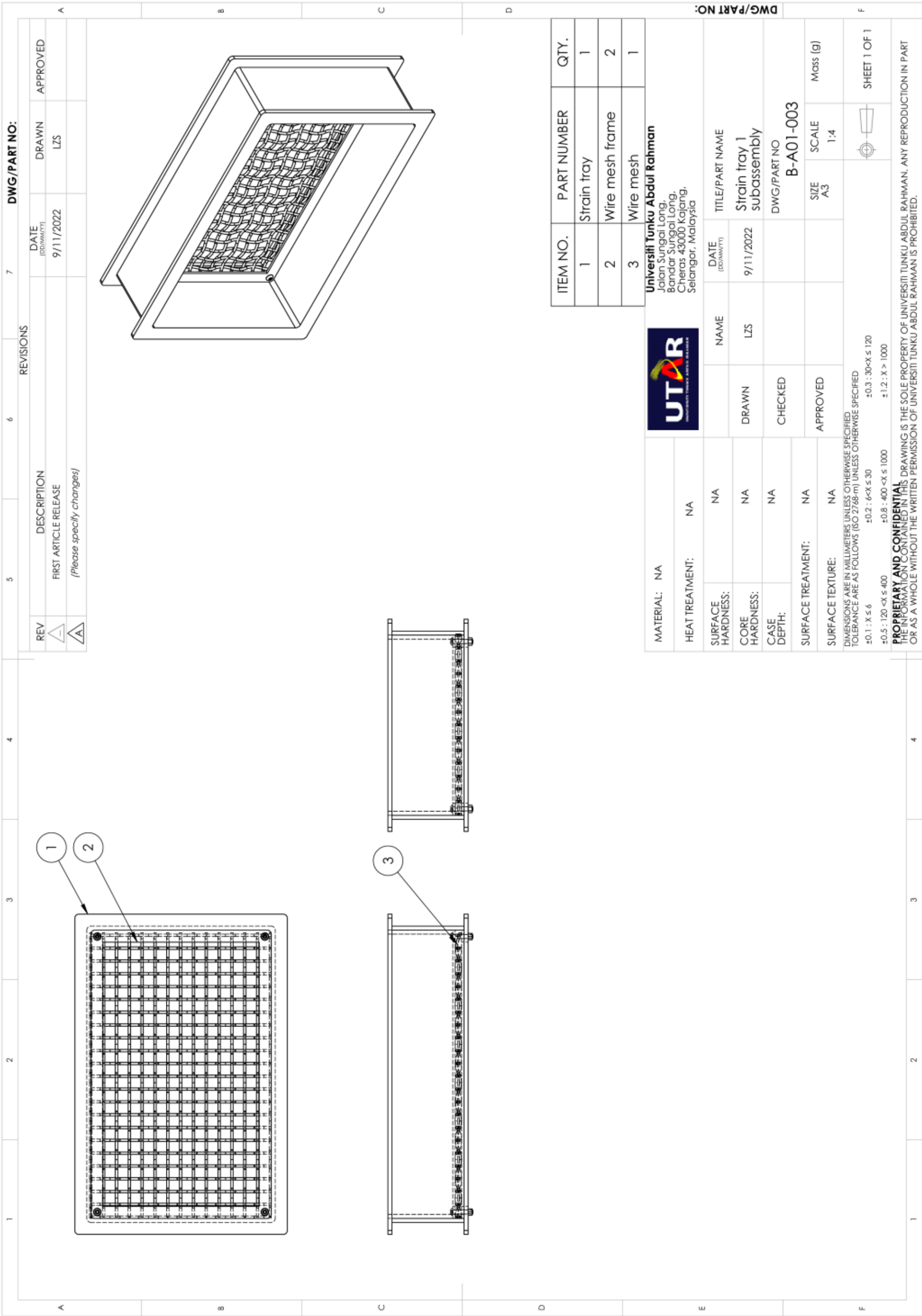

DWG/PART NO:
REVISIONS
REV
DESCRIPTION
DATE (DD/MM/YY)
DRAWN
APPROVED
FIRST ARTICLE RELEASE
9/11/2022
LZS
(Please specify changes)
ITEM NO.
PART NUMBER
QTY.
1
Strain tray
1
2
Wire mesh frame
2
3
Wire mesh
1
Universiti Tunku Abdul Rahman
Jalan Sungai Long,
Bandar Sungai Long,
Cheras 43000 Kajang,
Selangor, Malaysia
UTAR
MATERIAL: NA
HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
NAME
DATE (DD/MM/YY)
DRAWN
LZS
9/11/2022
CHECKED
APPROVED
TITLE/PART NAME
Strain tray 1 subassembly
DWG/PART NO
B-A01-003
SIZE A3
SCALE 1:4
Mass (g)
SHEET 1 OF 1
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCE ARE AS FOLLOWS (ISO 2768-m) UNLESS OTHERWISE SPECIFIED
±0.1 : X ≤ 6
±0.2 : 6<X ≤ 30
±0.3 : 30<X ≤ 120
±0.5 : 120 <X ≤ 400
±0.8 : 400 <X ≤ 1000
±1.2 : X > 1000
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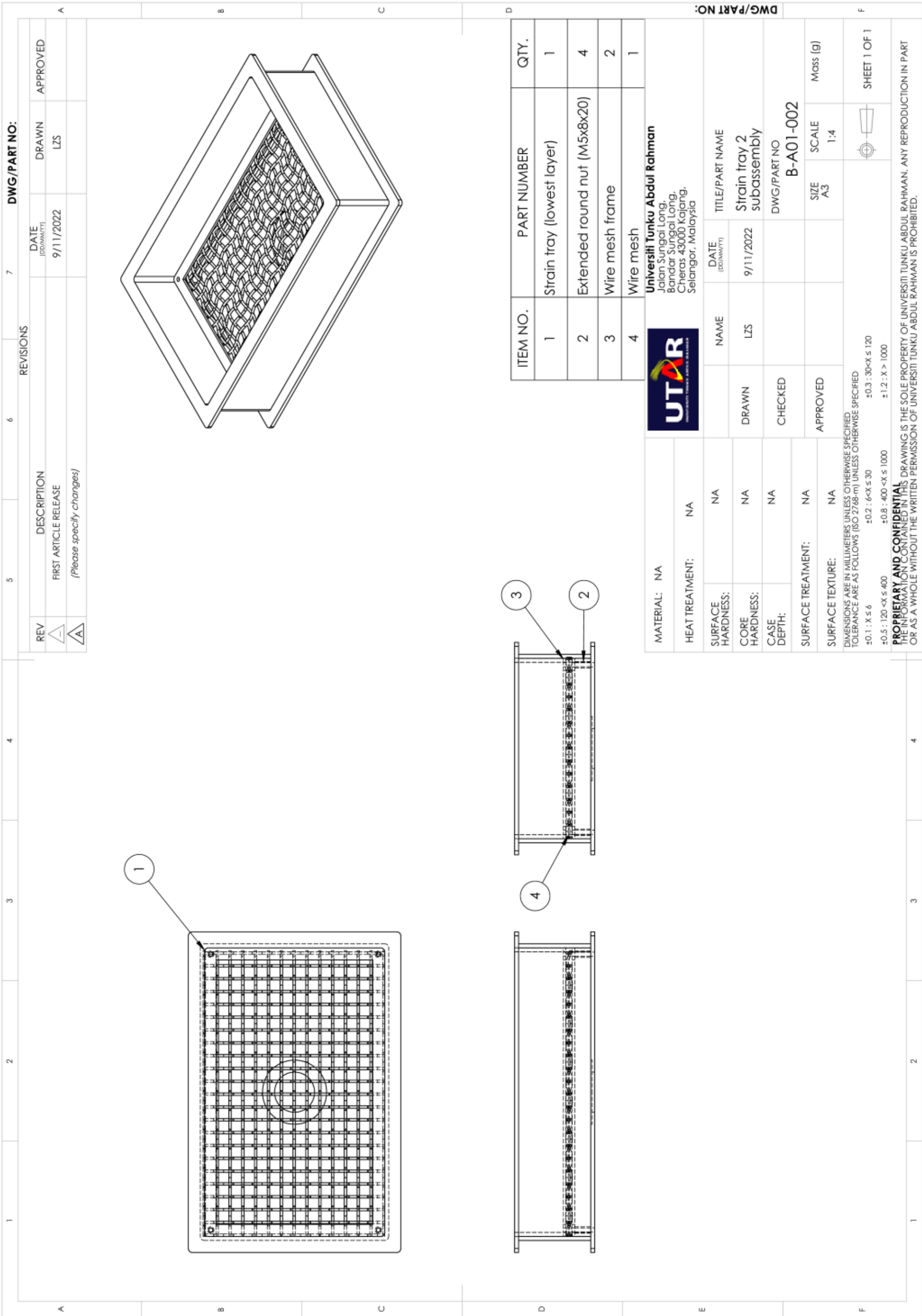
DWG/PART NO:
REVISIONS
REV
DESCRIPTION
DATE
DRAWN
APPROVED
FIRST ARTICLE RELEASE
9/11/2022
LZS
(Please specify changes)
ITEM NO.
PART NUMBER
QTY.
1
Strain tray (lowest layer)
1
2
Extended round nut (M5x8x20)
4
3
Wire mesh frame
2
4
Wire mesh
1
Universiti Tunku Abdul Rahman
Jalan Sungai Long,
Bandar Sungai Long,
Cheras 43000 Kajang,
Selangor, Malaysia
MATERIAL: NA
HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
NAME
DATE
DRAWN
LZS
9/11/2022
CHECKED
APPROVED
TITLE/PART NAME
Strain tray 2 subassembly
DWG/PART NO
B-A01-002
SIZE A3
SCALE 1:4
Mass (g)
SHEET 1 OF 1
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCE ARE AS FOLLOWS (ISO 2768-m) UNLESS OTHERWISE SPECIFIED
±0.1 : X ≤ 6
±0.2 : 6<X ≤ 30
±0.3 : 30<X ≤ 120
±0.5 : 120 <X ≤ 400
±0.8 : 400 <X ≤ 1000
±1.2 : X > 1000
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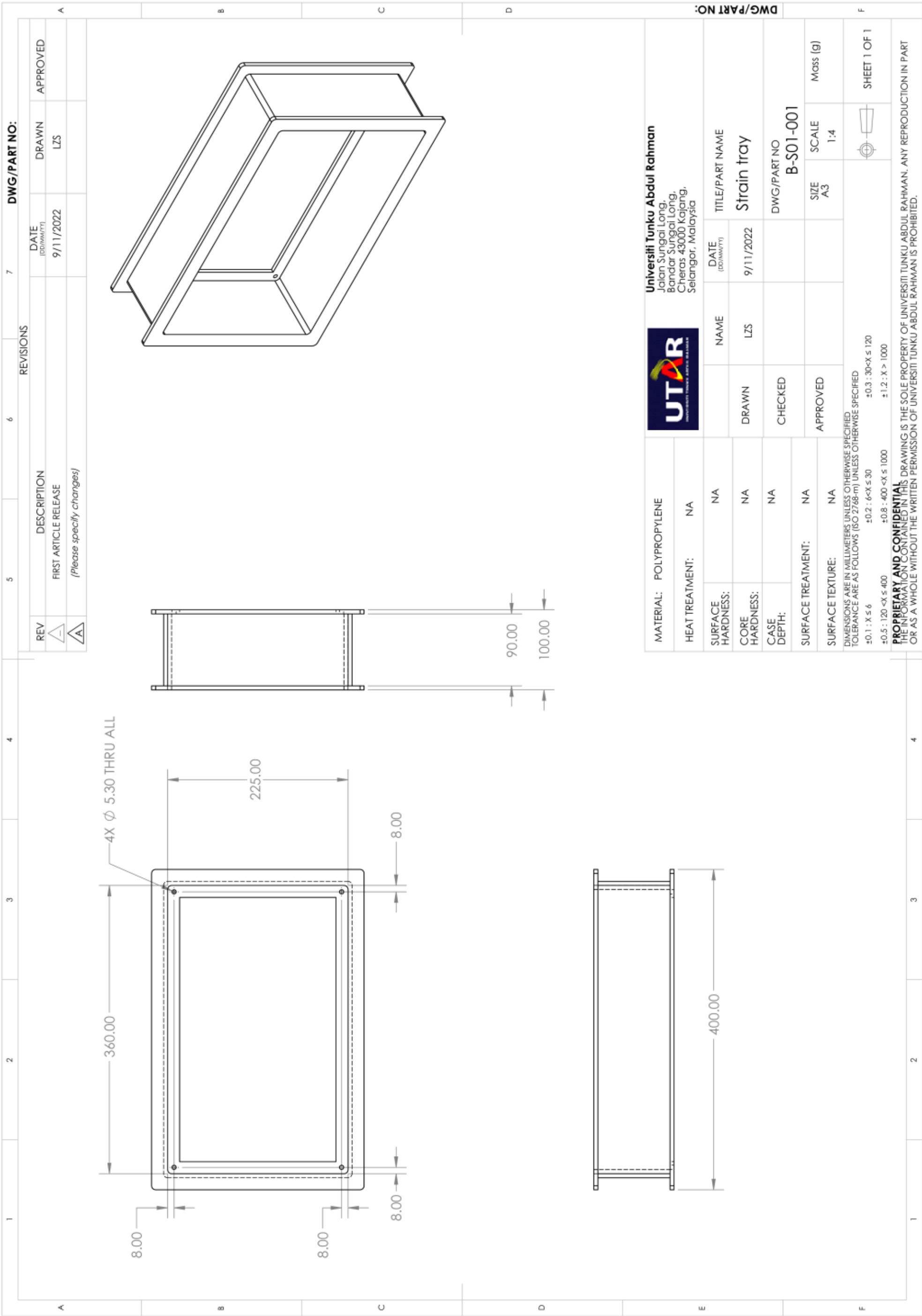

DWG/PART NO:
REVISIONS
REV
DESCRIPTION
DATE (DD/MM/YY)
DRAWN
APPROVED
FIRST ARTICLE RELEASE
9/11/2022
LZS
(Please specify changes)
4X ⌀ 5.30 THRU ALL
225.00
360.00
8.00
8.00
8.00
8.00
90.00
100.00
400.00
MATERIAL: POLYPROPYLENE
HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
Universiti Tunku Abdul Rahman
Jalan Sungai Long, Bandar Sungai Long, Cheras 43000 Kajang, Selangor, Malaysia
NAME
DATE (DD/MM/YY)
DRAWN
LZS
9/11/2022
CHECKED
APPROVED
TITLE/PART NAME
Strain tray
DWG/PART NO
B-S01-001
SIZE A3
SCALE 1:4
Mass (g)
SHEET 1 OF 1
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCE ARE AS FOLLOWS (ISO 2768-m) UNLESS OTHERWISE SPECIFIED
±0.1 : X ≤ 6
±0.2 : 6<X ≤ 30
±0.3 : 30<X ≤ 120
±0.5 : 120 <X ≤ 400
±0.8 : 400 <X ≤ 1000
±1.2 : X > 1000
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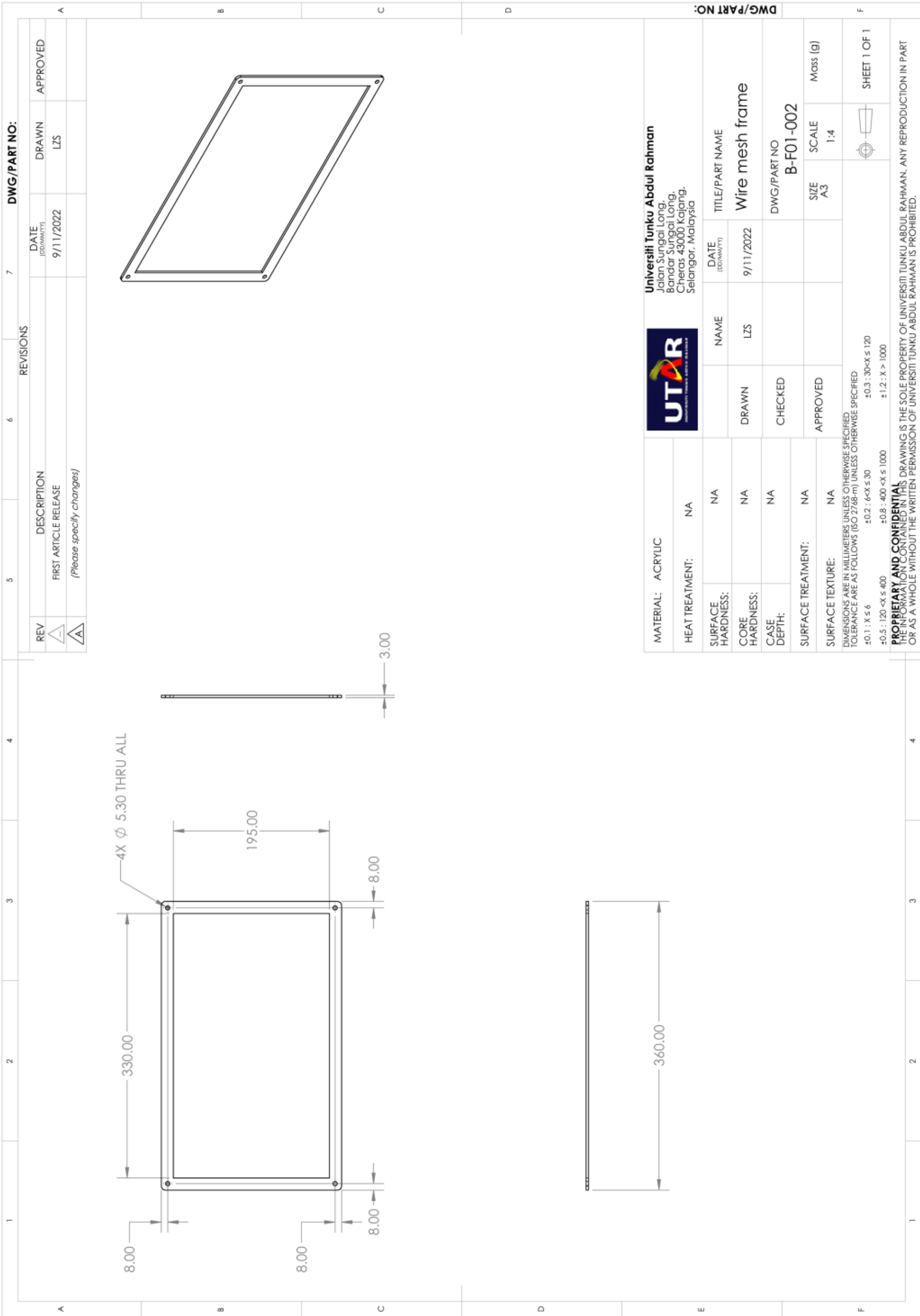
DWG/PART NO:
REVISIONS
REV
DESCRIPTION
DATE (DD/MM/YY)
DRAWN
APPROVED
FIRST ARTICLE RELEASE
9/11/2022
LZS
(Please specify changes)
4X ∅ 5.30 THRU ALL
195.00
330.00
360.00
3.00
8.00
8.00
8.00
8.00
MATERIAL: ACRYLIC
HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
Universiti Tunku Abdul Rahman
Jalan Sungai Long,
Bandar Sungai Long,
Cheras 43000 Kajang,
Selangor, Malaysia
UTAR
NAME
DATE (DD/MM/YY)
DRAWN
LZS
9/11/2022
CHECKED
APPROVED
TITLE/PART NAME
Wire mesh frame
DWG/PART NO
B-F01-002
SIZE A3
SCALE 1:4
Mass (g)
SHEET 1 OF 1
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCE ARE AS FOLLOWS (ISO 2768-m) UNLESS OTHERWISE SPECIFIED
±0.1 : X ≤ 6
±0.2 : 6<X ≤ 30
±0.3 : 30<X ≤ 120
±0.5 : 120 <X ≤ 400
±0.8 : 400 <X ≤ 1000
±1.2 : X > 1000
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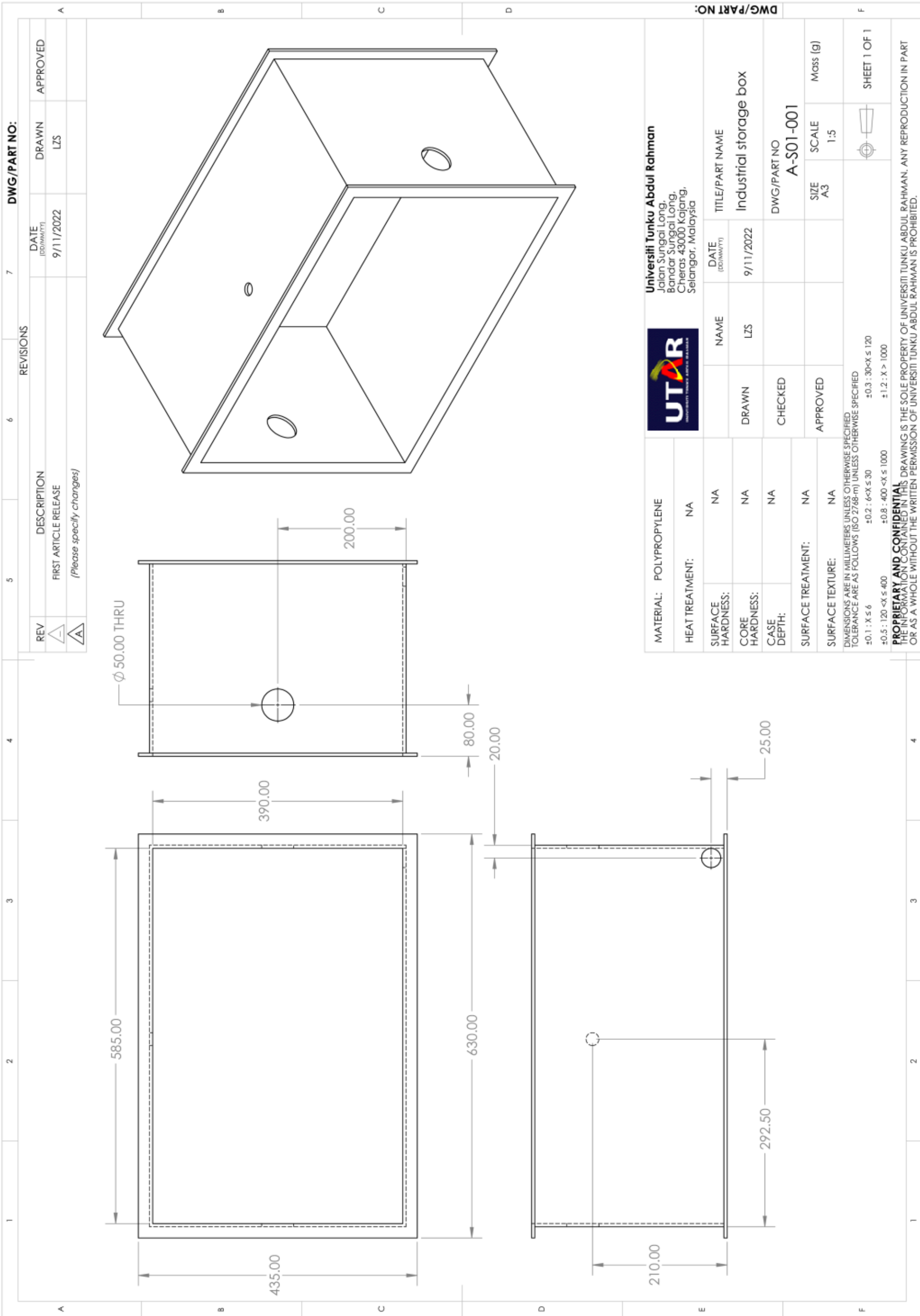

DWG/PART NO:
REVISIONS
REV
DESCRIPTION
DATE
DRAWN
APPROVED
FIRST ARTICLE RELEASE
9/11/2022
LZS
(Please specify changes)
Ø 50.00 THRU
200.00
80.00
20.00
390.00
25.00
585.00
630.00
292.50
435.00
210.00
MATERIAL: POLYPROPYLENE
HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
Universiti Tunku Abdul Rahman
Jalan Sungai Long,
Bandar Sungai Long,
Cheras 43000 Kajang,
Selangor, Malaysia
NAME
DATE
DRAWN
LZS
9/11/2022
CHECKED
APPROVED
TITLE/PART NAME
Industrial storage box
DWG/PART NO
A-S01-001
SIZE A3
SCALE 1:5
Mass (g)
SHEET 1 OF 1
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
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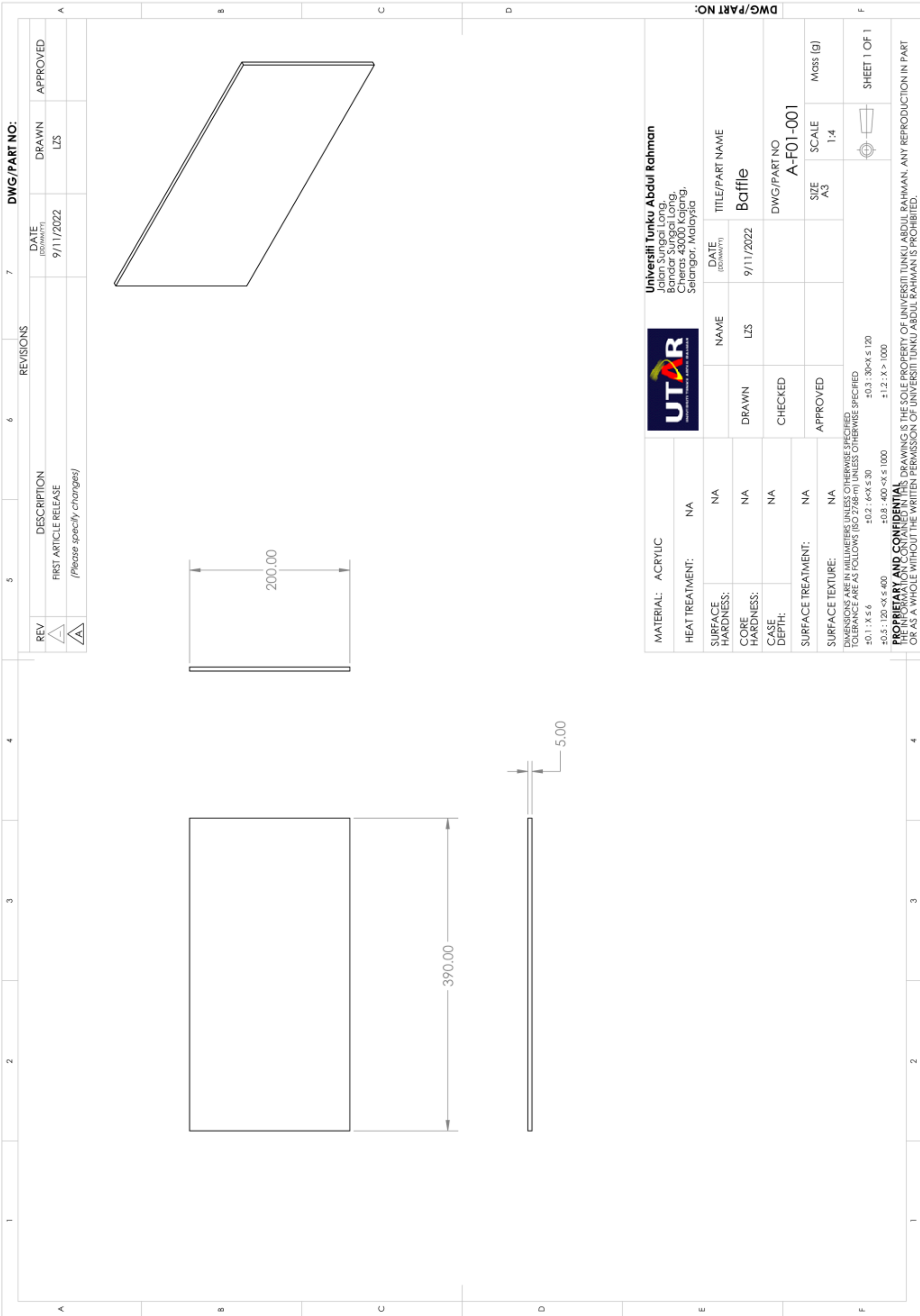
DWG/PART NO:
REVISIONS
REV
DESCRIPTION
DATE (DD/MM/YY)
DRAWN
APPROVED
FIRST ARTICLE RELEASE
9/11/2022
LZS
(Please specify changes)
200.00
390.00
5.00
MATERIAL: ACRYLIC
HEAT TREATMENT: NA
SURFACE HARDNESS: NA
CORE HARDNESS: NA
CASE DEPTH: NA
SURFACE TREATMENT: NA
SURFACE TEXTURE: NA
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCE ARE AS FOLLOWS (ISO 2768-m) UNLESS OTHERWISE SPECIFIED
±0.1 : X ≤ 6
±0.2 : 6<X ≤ 30
±0.3 : 30<X ≤ 120
±0.5 : 120 <X ≤ 400
±0.8 : 400 <X ≤ 1000
±1.2 : X > 1000
Universiti Tunku Abdul Rahman
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Bandar Sungai Long,
Cheras 43000 Kajang,
Selangor, Malaysia
NAME
DATE (DD/MM/YY)
DRAWN
LZS
9/11/2022
CHECKED
APPROVED
TITLE/PART NAME
Baffle
DWG/PART NO
A-F01-001
SIZE A3
SCALE 1:4
Mass (g)
SHEET 1 OF 1
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