THE EFFECTIVENESS OF VEHICLE CABIN TEMPERATURE WITH TINTED AND HEAT ABSORBENT MATERIAL SYSTEM UNDER DIRECT SUN AT PARKING AREA

NUR RAUDAH BINTI MUHAMMAD RIDHWAN YIP
B092010395

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

2024

Faculty of Mechanical Technology and Engineering

THE EFFECTIVENESS OF VEHICLE CABIN TEMPERATURE WITH TINTED AND HEAT ABSORBENT MATERIAL SYSTEM UNDER DIRECT SUN AT PARKING AREA

Nur Raudah Binti Muhammad Ridhwan Yip

Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honors

2024

THE EFFECTIVENESS OF VEHICLE CABIN TEMPERATURE WITH TINTED AND HEAT ABSORBENT MATERIAL SYSTEM UNDER DIRECT SUN AT PARKING AREA

NUR RAUDAH BINTI MUHAMMAD RIDHWAN YIP

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours

Faculty of Mechanical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: THE EFFECTIVENESS OF VEHICLE CABIN TEMPERATURE WITH TINTED AND HEAT ABSORBENT MATERIAL SYSTEM UNDER DIRECT SUN AT PARKING AREA

SESI PENGAJIAN: SEMESTER 1 2023/2024

Saya Nur Raudah Binti Muhammad Ridhwan Yip

mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ TERHAD (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ SULIT (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☑ √ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:

4, Jalan 5, Taman Desa Muhibbah, Batu 13, Jalan Cheras, 43000 Kajang, Selangor.

Cop Rasmi:

Ts. MOHD ZAKARIA BIN MOHAMMAD NASIR
PENSYARAH KANAN
JABATAN TEKNOLOGI KEJURUTERAAN MEKANIKAL
FAKULTI TEKNOLOGI DAN KEJURUTERAAN MEKANIKAL
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Tarikh: 13 Januari 2024

Tarikh : 8 FEBRUARY 2024_

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan FYP ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this project entitled "THE EFFECTIVENESS OF VEHICLE CABIN TEMPERATURE WITH TINTED AND HEAT ABSORBENT MATERIAL UNDER DIRECT SUN AT PARKING AREA" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Author	:	NUR RAUDAH BINTI MUHAMMAD RIDHWAN YIP
Date	:	14 January 2024

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature :

Supervisor Name : Ts. MOHD ZAKARIA BIN MOHAMAD NASIR :

Date 8 February 2024

DEDICATION

Praise to the Almighty Allah, for giving me the opportunity to complete my thesis smoothly. I would like to dedicate this thesis to my beloved parents, Muhammad Ridhwan Yip Bin Abdullah and Mintana Lubis for their unconditional love and support towards my academic journey. This thesis could not have been written without Ts. Mohd Zakaria Bin Mohamad Nasir, my final year project supervisor that guide and encouraged me to give my all in this thesis till it wrapped up succesfully. Last but not least, I would like to utter my utmost gratitude to all my friends and everyone that directly or indirectly helped me through the final year project moment. Thank you so much.

ABSTRACT

Rapid climate change has heavily impacted the weather with problems such as heatwaves nowadays. The heat from this weather effects the vehicle cabin temperature that parked at open area and directly under the sun. The cabin temperature increased drastically after a vehicle parked under the sun for a long time thus cause passengers entering the vehicle cabin feel uncomfortable. This issue a heavily discussed matter where manufacturers suggested different ways to reduce the temperature, but the issue is not entirely solved. The aim of this research is to test the effectiveness of vehicle cabin temperature with tinted and heat absorbent material using a small car under direct sun at open parking area. The experiment temperature data will be collected using a Thermocouple Type K Data Logger with the thermocouple put on various location inside the vehicle cabin. The result is monitor from 10 A.M. to 3 P.M. on sunny days to investigate which area have the highest temperature. The variable concentrations of heat absorbent material will be analyzed and evaluated for each of their effectiveness in reducing the temperature build up inside the vehicle cabin. From the experiment, Concentration 1 (70% water and 30% Glycol Gel) shown the better result in absorbing latent heat on certain position inside the cabin. Concentration 1 which have the highest water content than other concentration is better in absorbing heat as water content in PEG polymer glycol gel have direct bearing to thermal energy or heat storage density.. As a conclusion, the experimental setup achieved the objective to convince the heat absorbent material can reduce heat inside the car cabin.

ABSTRAK

Perubahan iklim yang pesat telah banyak memberi kesan kepada cuaca dengan masalah seperti gelombang haba pada masa kini. Haba daripada cuaca ini memberi kesan kepada suhu kabin kenderaan yang diletakkan di kawasan lapang dan di bawah matahari. Suhu kabin meningkat secara drastik selepas kenderaan diletakkan di bawah matahari dalam tempoh yang lama sekali gus menyebabkan penumpang yang memasuki kabin kenderaan berasa tidak selesa. Isu ini merupakan perkara yang banyak dibincangkan di mana pengeluar mencadangkan cara berbeza untuk mengurangkan suhu, tetapi isu itu tidak diselesaikan sepenuhnya. Kajian ini bertujuan untuk menguji keberkesanan suhu kabin kenderaan dengan sistem bahan penyerap haba dan tingkap cermin gelap di bawah sinaran matahari langsung di kawasan parkir. Data suhu eksperimen akan dikumpul menggunakan Logger Data Thermocouple Type K dengan termokopel diletakkan di pelbagai lokasi di dalam kabin kenderaan. Hasilnya dipantau dari 10 A.M. hingga 3 P.M. pada hari yang cerah untuk menyiasat kawasan yang mempunyai suhu tertinggi. Jenis kepekatan bahan penyerap haba akan dianalisis dan dinilai untuk setiap keberkesanannya dalam mengurangkan pembentukan suhu di dalam kabin kenderaan. Daripada eksperimen, Kepekatan 1 (70% air dan 30% Glycol Gel) menunjukkan hasil yang lebih baik dalam menyerap haba pendam pada kedudukan tertentu di dalam kabin. Kepekatan 1 yang mempunyai kandungan air tertinggi berbanding kepekatan lain adalah lebih baik dalam menyerap haba kerana kandungan air dalam gel polimer glikol PEG mempunyai kaitan langsung dengan tenaga haba atau ketumpatan penyimpanan haba.. Kesimpulannya, persediaan eksperimen mencapai objektif untuk meyakinkan haba bahan penyerap boleh mengurangkan haba di dalam kabin kereta.

ACKNOWLEDGEMENT

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, for everything I received since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

My biggest appreciation goes to my main supervisor, Ts. Mohd Zakaria Bin Mohamad Nasir of Automotive Engineering Technology Department, Universiti Teknikal Malaysia Melaka (UTeM) for all his support, advice and inspiration. His constant patience for guiding and providing valuable insights will forever be remembered. Also, to my co-supervisor, Ts. Khairul Amri Bin Tofrowaih, Universiti Teknikal Malaysia Melaka (UTeM) who supported and guided my journey during PSM 1.

Last but not least, from the bottom of my heart I express gratitude to both of my parents, Muhammad Ridhwan Yip Bin Abdullah and Mintana Lubis for their encouragements and for their endless support, love and prayers. Finally, thank you to all my beloved friends and individuals who had provided me with the assistance, support and inspiration to embark on my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Heat-absorbing is a chemical reaction or compound reaction occurring or formed with absorption of heat (Heat-Absorbing, 2023). Heat absorbent material is a material that build to absorb thermal energy which is heat from the surrounding air in an enclosed space to decrease the high temperature in the space. A vehicle cabin is an example of enclosed space that trap heat inside it thus causes high temperature of the cabin.

Malaysia is a country that experienced hot weather every year especially from April to June. The hot weather is getting worse year by year due to the thinning of Earth ozone layers. The effect of thinning ozone layer and rapid climate change caused extreme and unbearable hot weather thus affecting vehicle users when their vehicle parked outside of roofed area and directly exposed to the hot sunlight.

Parking the vehicle under sunlight for a long time could increase the temperature of the vehicle cabin. The high temperature inside the cabin cause discomfort to the driver and passengers and could lead to driving fatigue due to dehydration from the high temperature. The interior components that have been exposed to heat will release benzene gas that can endangered the health of children (Condro, 2019).

A few approaches have been suggested to reduce temperature inside the vehicle cabin such as installing exhaust fan or air cooler on car windows. The other approach is by placing sunshades at vehicle windshield to reflect the heat from sunlight from entering the cabin. Opening window gap while parking under direct sunlight was also suggested to increase airflow inside the cabin and thus reduce the temperature differences between inside cabin and outdoor.

However, the suggested approaches have their own advantages and disadvantages. Using exhaust fan on vehicle windows required battery to run the device thoroughly while the vehicle is parked, this cause the heat could be channel out from the cabin but if the vehicle parked for too long the battery will be drained out quickly. Sunshades could only cover windshield area thus caused the heat could enter the cabin through windows and rear windshield. Opening window gap while park at open parking lot could led to theft or animals entering through the gap and hides inside the vehicle.

1.2 Problem Statement

The temperature inside the cabin of a vehicle is important cause it can affect the comfort of the passenger and driver. But vehicle cabin is enclosed space which the thermal properties are different from other places and conditions. In the cabin, heat from sunlight undergoes various heat transfer processes which is conduction, radiation and convection. These processes change thermal comfort of car passenger cabin during natural exposure, then people enter into the car will create instantaneous thermal shock (Qi et al., 2017). This could lead to driver feel dehydrated and fatigue when driving in hot temperature of the cabin.

During hot weather or heatwave, vehicle that parked at non-roofed area and open parking space exposed to direct sunlight for a very long period of time. Due to convection, the heat that come directly from the sunlight generates higher temperatures inside the vehicle cabin than outside cabin. The hot temperature will cause the passengers that enter the car feel uncomfortable and could led to heatstroke especially for infants or children.

The heat too caused the vehicle equipment and parts inside the cabin affected because of the radiation and Ultra-Violet rays from the sunlight. This caused the lifespan of these equipment and part shorten and causing the plastic part to fade. Moreover, if the temperature inside the cabin is too high, the vehicle air conditioning might face difficulties to cool down the cabin quickly.

1.3 Objectives

The main objectives of this study are:

1. To carryout bechmark data for small vehicle segment A park at open area with full tinted.
2. To measure the effectiveness of tinted windows with a packed glycol gel as heat absorbent material under direct sun in a segment A vehicle cabin.
3. To analyse the temperature data collected from experiments.

1.4 Scope of Research

The scope of study for this research are as follow:

a) To collect data for segment A vehicle, Perodua Kancil at open car park area with limited shades surrounding it.

b) To run experiment with different concentration of packed glycol gel material.

c) To measure the temperature distribution inside the vehicle cabin using equipment thermometer and thermocouple Type-K.

d) To evaluate the thermal comfort in vehicle cabin when using packed glycol gel along with tinted windows.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will explain the reviews that will be utilised to advance the research process through the research of materials for publishing, including journals, electronic libraries, the internet, and past year thesis papers. Literature review is a section to analyze past publications material from various researchers through a distinct of summarised information, categorization and contrast of prior case studies and journals. Moreover, this chapter will also discuss related topics to title of the research study that focused on effectiveness of vehicle cabin temperature with tinted and heat absorbent material.

2.2 Introduction to Heat Transfer Process in Vehicle Cabin

Vehicle that parked under direct sunlight without shade tends to accumulate heat inside the cabin. The solar radiation entering through the windows and windshield of a vehicle caused long wave of thermal radiation and trapped heat inside the cabin thus increasing the temperature of cabin (Issam et al., 2015). A vehicle cabin experienced process of heat transfer which can be categorized into three types of heat transfer. The types of heat transfer are conduction, convection and radiation. These processes enormously change the thermal comfort of the vehicle cabin especially during natural exposure and caused passengers that enter the cabin have instantaneous thermal shock (Chunling Qi et al., 2017).

One of the methods to study the thermal environment in a vehicle cabin is using software Computational Fluid Dynamics (CFD) simulation (Chunling Qi et al., 2017). CFD analysis is widely used for it build in equations for conduction, convection and radiation that can be used to determine the cabin temperature, heat distribution and material of the interior cabin of a vehicle (Sujith et al., 2018). The other method is using traditional experimental method utilizing the instruments including radiation, infrared thermometer and temperature and humidity recorder (Chunling Qi et al., 2017).

The temperature rise inside the cabin of a vehicle will hinder drivers from driving their vehicles comfortably. Passengers or drivers tend to turn on vehicle air conditioning system to maximum cooling just to dissipate heat inside the cabin quickly, which certainly leads to high fuel consumption (Bobba et al., 2019). In summer season, the temperature outside of vehicle cabin compared with inside of vehicle cabin show rising of more than 20℃ for periods of thirty minutes, caused children or pets left in the vehicle without ventilation or cooling suffer heat stress that could led to deaths (Al-Kayiem et al., 2010).

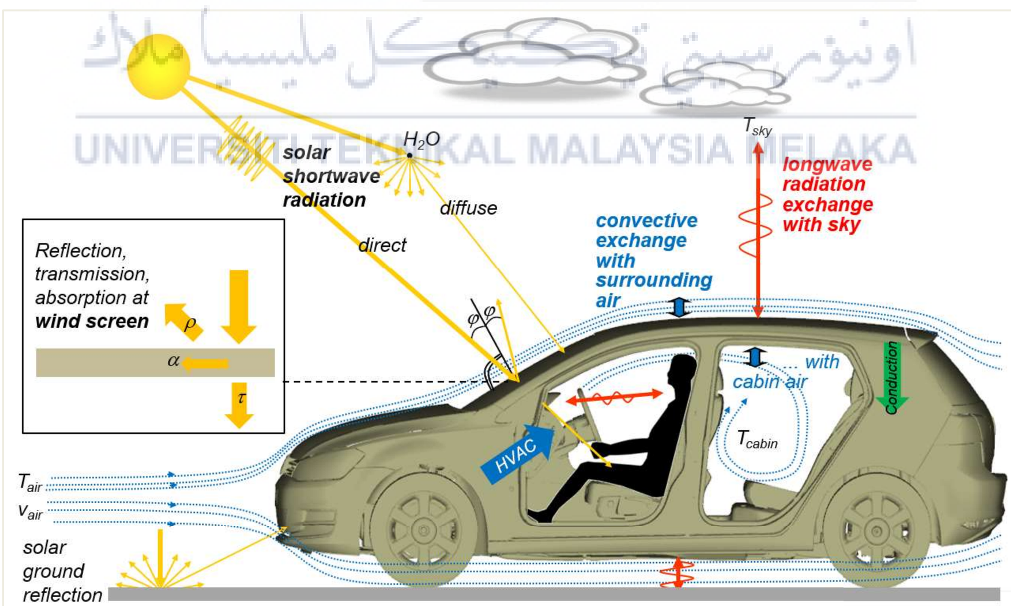


Figure 2.1 Heat Transfer Process in Vehicle

Several previous studies have been conducted to reduce the temperature of the vehicles parked in open spaces. One of the studies is conducted research using the sunshade, ventilator and window tint method. The results concluded is the use of window tint was the effective way to reduce temperature inside the vehicle cabin (Bagiyo Condro et al., 2020). The effect of using sunshades application to the interior of the vehicle windshield was quite significant during daytime and at open space. The maximum dashboard temperature was found to be 25℃ lower than the other vehicle without sunshades (Mohammed et al., 2015)

2.2.1 Heat Transfer: Conduction

Heat conduction is a heat transfer process that defines the movement of heat from one object to another object that is differ in temperature. Both objects must be in contact with each other for this process to happened. Heat conduction occurs under the influence of periodically varying temperatures or heat flux in many practical engineering problems (Xu et al., 2023)

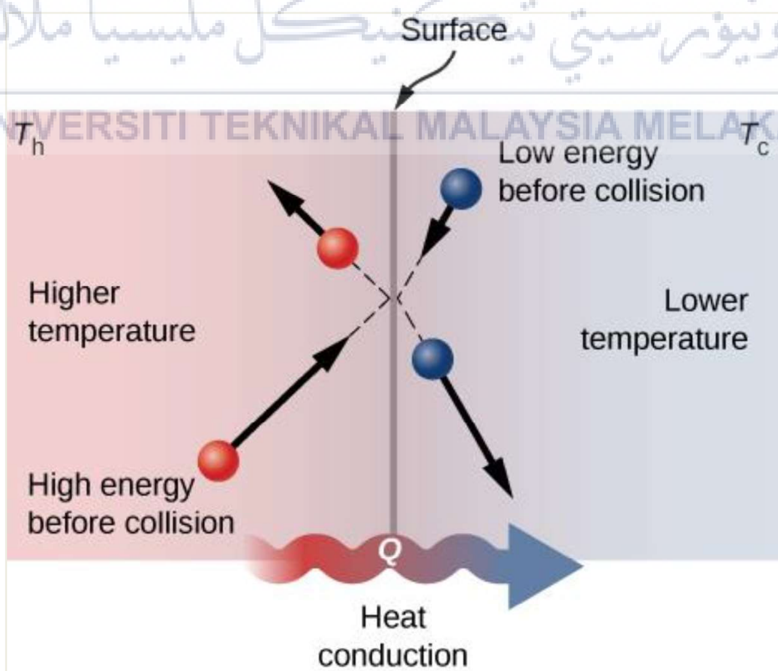


Figure 2.2 Molecules in Two Bodies During Conduction (UP2-F1, n.d.)

2.2.2 Heat Transfer: Convection

Convection is one of the processes of heat transfer involving mass movement of molecules within fluids like liquid or gas. There are two types of convection which are free convection and forced convection. Free convection is caused by the motion of fluid due to gradient of existing temperature between fluid and the solid (Mahat et al., 2016). Heat convection mainly involve hot or cold surface transferring heat to the fluid or receiving heat from the fluid in industrial application.

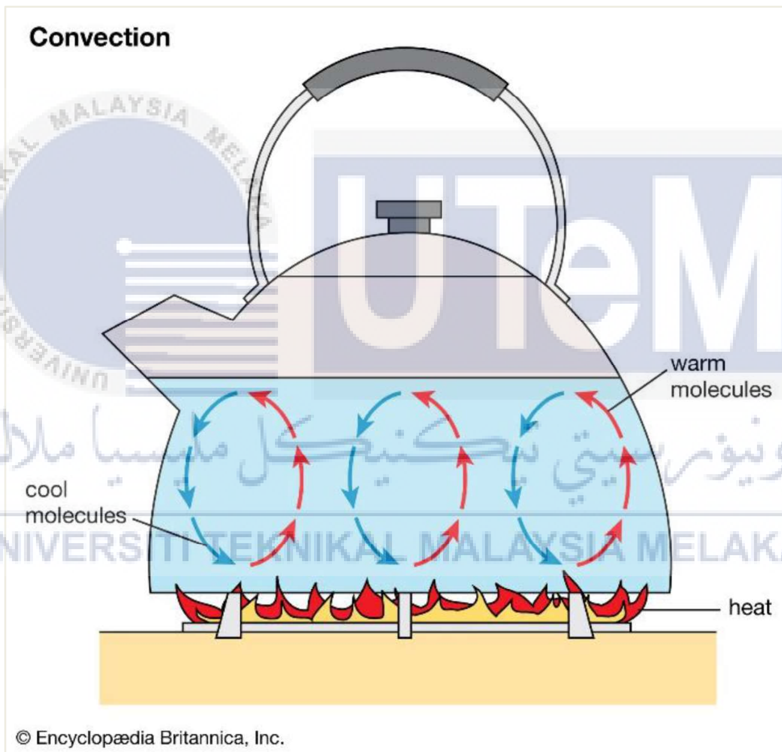


Figure 2.3 Thermal Convection in a Kettle (Britannica, 2023)

2.2.3 Heat Transfer: Radiation

The thermal motion of matter's particles produces thermal radiation, a type of electromagnetic radiation. Thermal radiation is produced when heat from the movement of charges in a material (electrons and protons in common types of matter) is transformed to electromagnetic radiation. Thermal radiation is emitted by all matter that has a temperature higher than absolute zero. Therefore, thermal radiation provides radiative access to all heat sources (Wei Li et al., 2017).

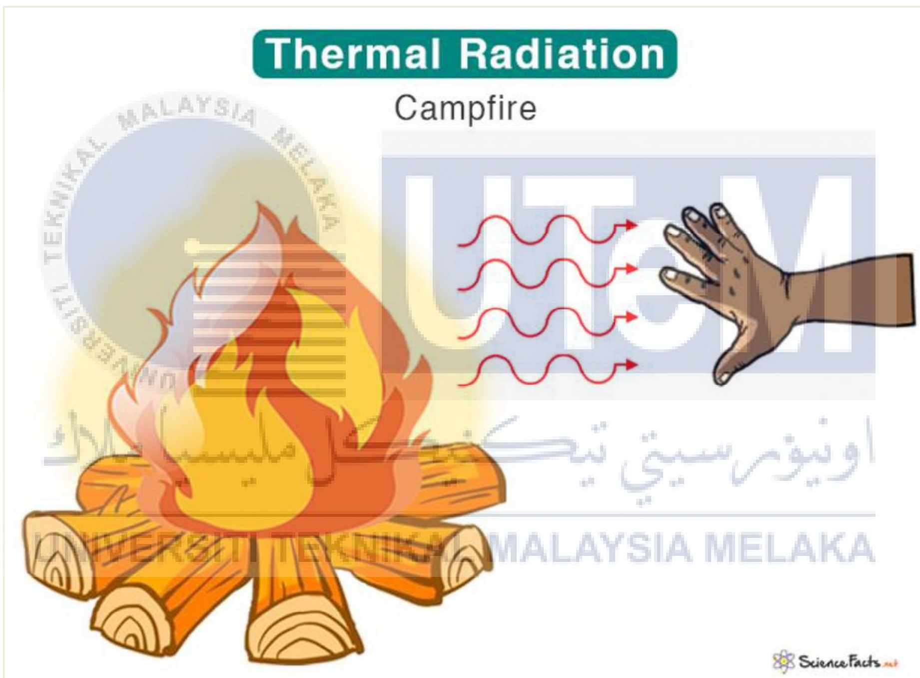


Figure 2.4 Thermal Radiation from a Campfire (Thermal-Radiation, n.d.)

2.3 Window Tint

Glass window tinting involves a variety of techniques aimed at modifying glass to counteract radiative heating effects. While the concept isn't novel for vehicle glass, ongoing developments seek to improve efficiency in reducing heat while maintaining excellent visibility. Different approaches are continuously evolving to strike a better balance between minimizing heat and ensuring clear visibility. (Marshall et al., 2019)

The installation of window tint film, a popular addition to vehicle windows and windshields, is widely offered by both dealerships and independent operators as an aftermarket feature. This tinting practice alters the outward appearance of windows by reducing their visibility, quantified through the measurement of Visible Light Transmission (VLT). VLT represents the percentage of natural daylight passing through the window, with lower VLT percentages indicating darker tints. (Isa et al., 2015)

Automotive window tints are usually made of polymer films that are placed to the inside of car windows with the intention of reducing heat and ultraviolet (UV) light transmission. These films can be bent and adjusted to match different glass dimensions since they are made of a thin, malleable polyester substance. These tints contain cyclic imino esters and heat-absorbing dyes to control the transmission of ultraviolet-visible (UV-Vis) light. In addition, a coating of adhesive, such as polyester or polyacrylate, is applied to the film to firmly adhere it to the glass. Styrene or amines are examples of additional ingredients that may be added to act as extenders, cross-linkers, or hardening catalysts. Additionally, some shades feature an abrasion-resistant coating made of polymethyl methacrylate. (Grant et al., 2020)

There are three common type of car window tint that available on the market, such as dyed window tint film, metalized window film and hybrid tinting film.. The type of tint have it different benefits and effectiveness on reducing infrared transmission, visible light transmission and ultraviolet ray from entering the car cabin.

2.3.1 Dyed Window Tint Film

Dyed window tint film is the intital type of automotive window tint that available on the market. A transparent polyethylene terephtalate (PET) film that has been dyed for a specific length of time to achieve the desired colour darkness. Infrared and visible light is absorbed by this type of window tint. From all of the film types, the dyed tint film are the least expensive and easiest to produce. (Idris & Othman, 2022)

Dyed window tint film is made of different layers of structure including scratch resistant coating, PET layer, metal layer, laminating adhesive, Ultraviolet absorber and mounting adhesive. The glass window of the car is coated with adhesive system to allow the glass and tint chemically bonded together.

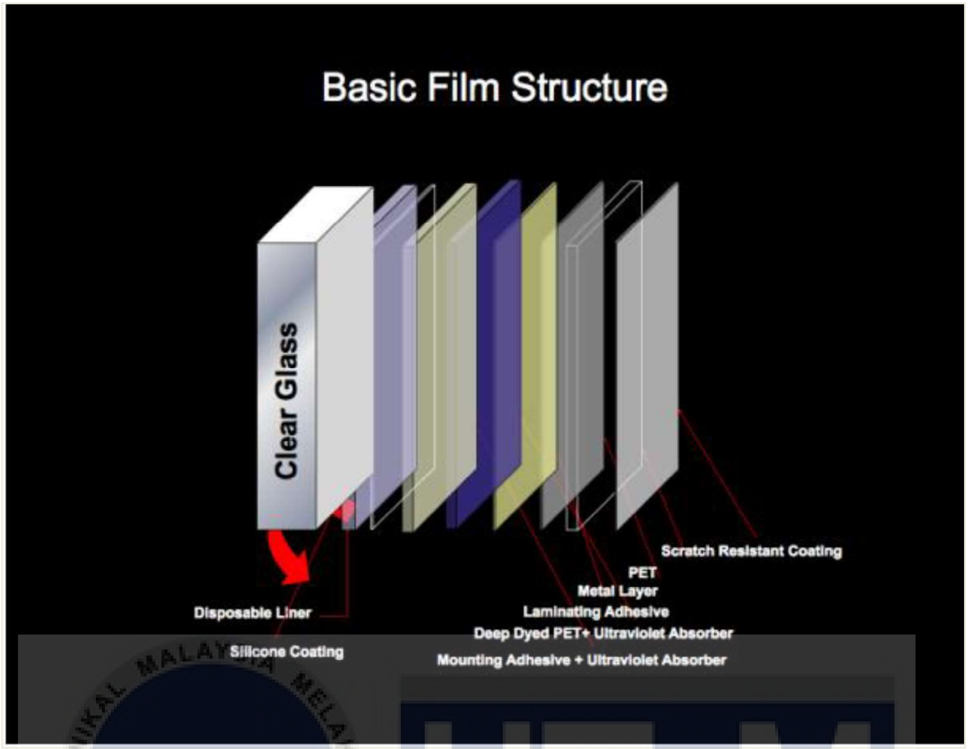


Figure 2.5 Structure of Basic (Dyed) Tint Film (All Things Tint; All Things Tint, 2013)

2.3.2 Metalized Window Tint Film

Metallised hues reflect light rather than absorb it. There are two methods for producing metallised tint film which are deposition and sputtering. The deposition procedure entails pulling the pigment through a metal ingot bath while creating a vacuum in the tank. Argon gas is then poured into the tank and heated, causing some of the metal (aluminum, nickel-chrome alloy, or copper) to be attracted to the tint's surface. The sputter process is similarly carried out in a vacuum, but it does so by generating ions that are then driven towards the metal by electromagnetic fields. When the ions collide with the metal, little groups of metal are dislodged and scattered across the film. (Murray & Zaghloul, 2013)

Figure 2.6 Example of Car with Metalized Window Tint

2.3.3 Hybrid Tinting Film

Hybrid films involve incorporating one or multiple metal layers onto dyed polyester through sputtering or vapor deposition. These added metal layers serve to reflect heat, enhancing thermal insulation and preserving color integrity. While typically cost-effective, this film type has a higher chance of disrupting wireless signals. (Murray & Zaghloul, 2013)

The tint made of base layer of dyed polyster which give the primary color and UV protection of the tint. Metal layers were added to the polyster through processes of sputtering or deposition, which the processes for metalized tint. Metal such as aluminiums are commonly used for the purpose of heat reflection, thermal insulation and color stability of the tint.

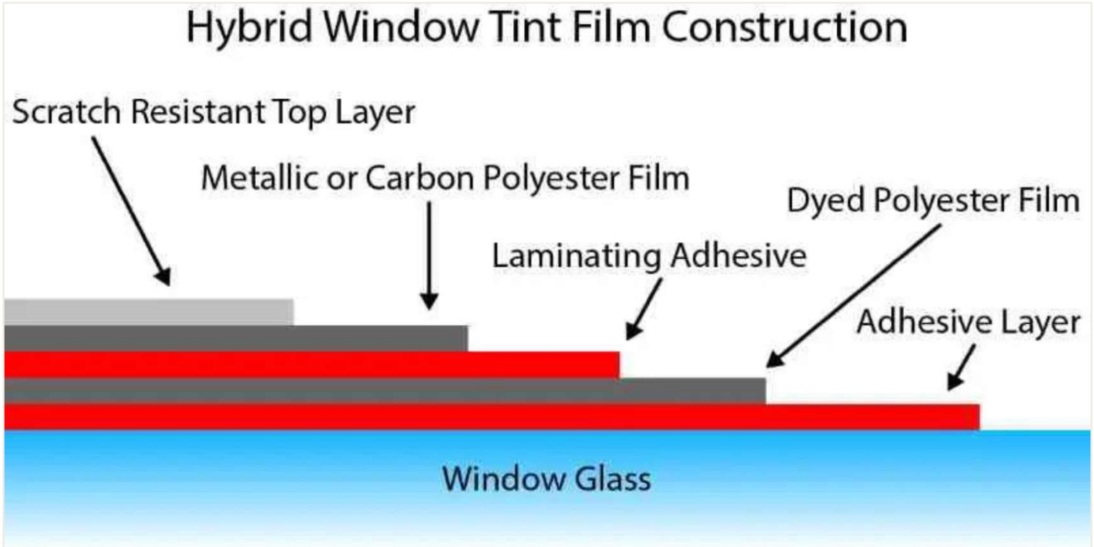


Figure 2.7 Layers of Hybrid Window Tint

2.4 Heat Absorbent Material

Heat absorbing means a chemical reaction or compound occurring or formed with absorption of heat. A heat absorbent material is a material that could absorb heat from it surrounding to reduce temperature of environment such as vehicle enclosed cabin. The material function by converting thermal radiation or conduction from inside the vehicle cabin to convection hence decrease the temperature of surrounding cabin.

2.4.1 Polyethylene Glycol

Polyethylene glycol (PEG) is a polyether compound derived from petroleum, also known as polyethylene oxide (PEO) or polyoxyethylene (POE) (Wikipedia Contributors, 2023). Polyethylene is commonly used as a heat transfer fluid for application in thermal energy storage (TES). This glycol compound is miscible with water, acetone and chloroform due to their low density and various molecular weight. PEG is a non-toxic compound, however it can give different responses if the user have allergies to any glycol polymers.

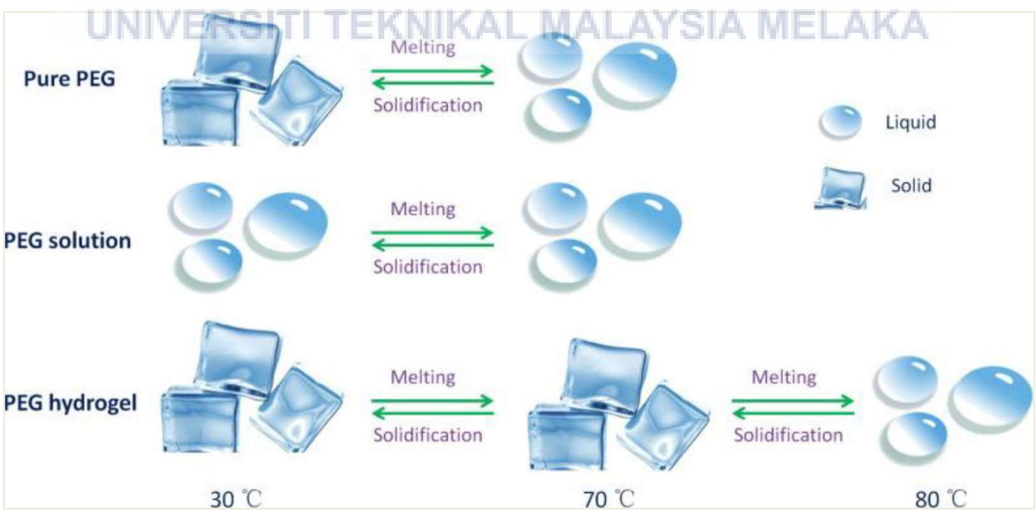


Figure 2.8 Characterization of Polyethylene Glycol (PEG) (Deng & Yang, 2017)

The figure above depicts the pure PEG polymer, PEG solution, and PEG hydrogel before and after melting. Pure PEG polymer stores and releases thermal energy through first-order phase transitions between solid and liquid fractions. The PEG solution contains a high concentration of (PEG) multimers distributed in water**.**

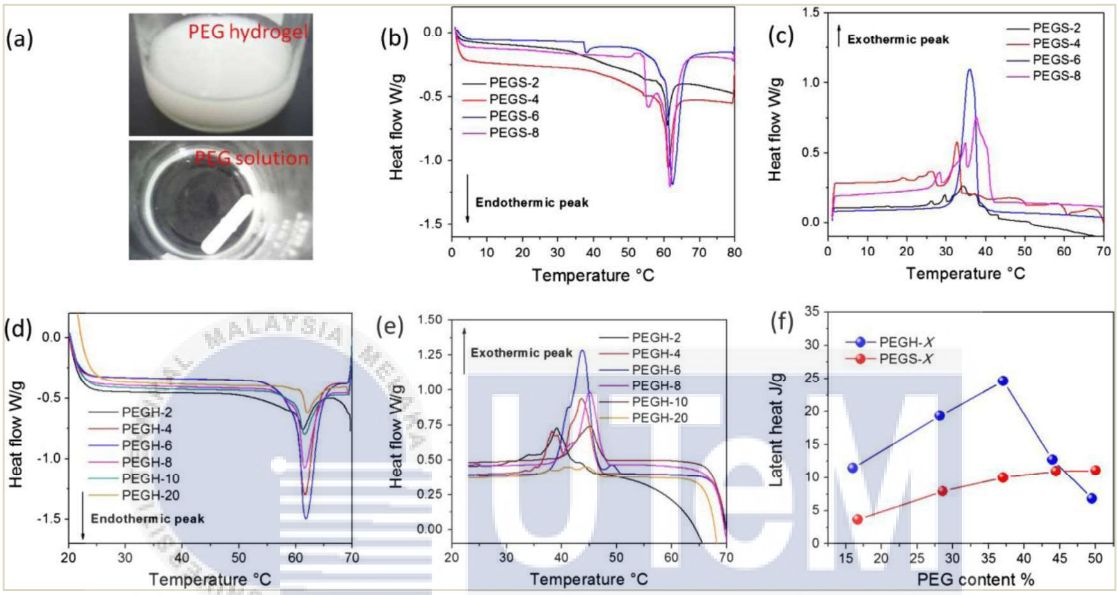


Figure 2.9 Phase Transition Temperature of PEG Hydrogel(Deng & Yang, 2017)

From the journal, the phase transition temperature of the PEG hydrogel was determined by studying the endothermic/exothermic curves shown in Figure 2.6 above. The apparent melting temperature of a PEGH sample is determined by the presence of both liquid and solid phases at a specific temperature. From the figure above, it was established that the water content of PEG polymer has a direct bearing on its thermal energy storage density. Two things influenced the D-value of the latent heat is distilled water reduced the percentage of mass of the PEG polymer without affecting its latent heat storage capacity and the water molecule broke the polymer's crystal structure.(Deng & Yang, 2017)

2.5 The Climate in Malacca

Malacca, Malaysia has a tropical climate all year round. Malacca experiences hot and humid weather with abundant rainfall with rainy season come between September and November every year. The average daytime temperature is 30 C while night-time temperature is 22 C. Malacca received average amount of annual precipitation approximately 2395 mm.

2.5.1 Monthly Weather Forecast in Malacca

The weather forecast in Malacca are demonstrate in few graphs collected from reports and data of Malaysian Meteorological Department (METMalaysia). The graphs illustrate average sunshine, precipitation, high and low temperatures and UV index in this state for a month.

2.5.2 Average Sunshine in Malacca

From the Figure 2.10 below, the highest sunshine day in Malacca is in February with average 9.7 days per month. The lowest sunshine day is in November with average 1.7 days per month as seen in the graph.

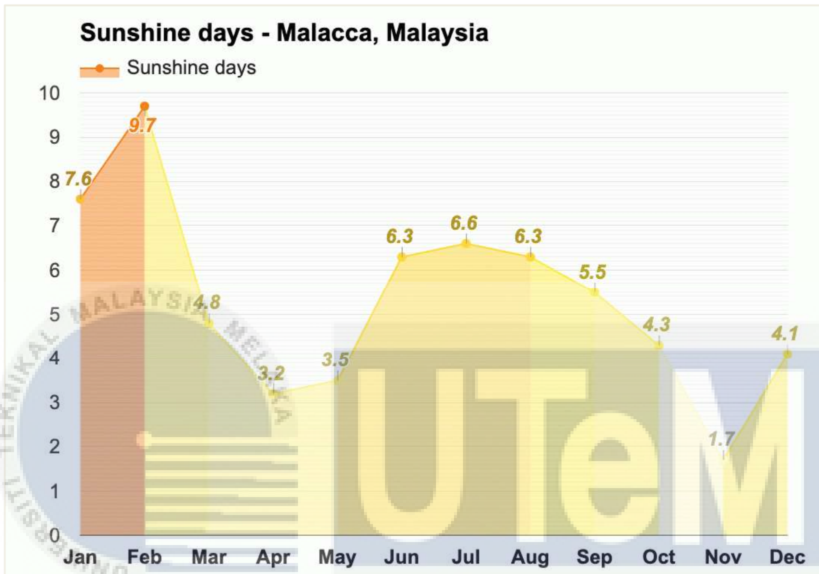


Figure 2.10 Average Sunshine in Malacca Every Month (*Melaka Climate By Month | A Year-Round Guide. World Weather & Climate Information*, 2023)

2.5.3 Average Precipitation in Malacca

From the Figure 2.11 below, November recorded as the highest precipitation per month with average 173 mm of rainfall. The lowest precipitation per month is in September with 68 mm of rainfall.

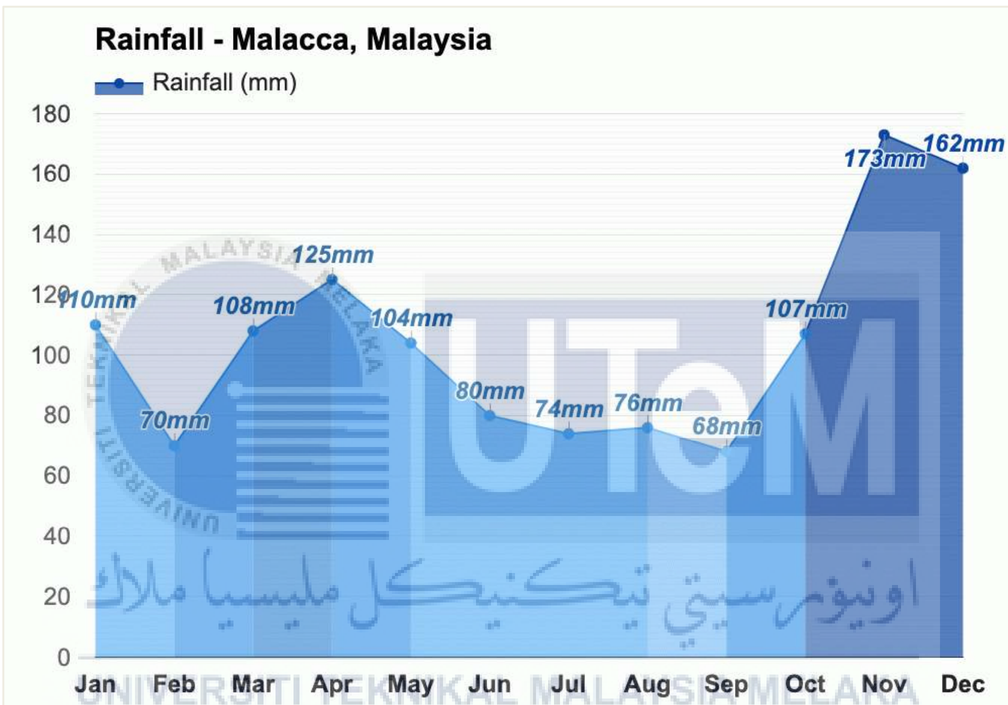


Figure 2.11 Average Precipitation in Malacca Every Month (*Melaka Climate By Month | A Year-Round Guide. World Weather & Climate Information*, 2023)

2.5.4 Average High and Low Temperature in Malacca

From the graph in Figure 2.12, the highest average high temperature in a year is from March till May with average of 31 C. While the lowest average high temperature is in December with 29.6 C. The highest average low temperature is in May with 26.5 C while the lowest average of low temperature is in January with 24.6 C.

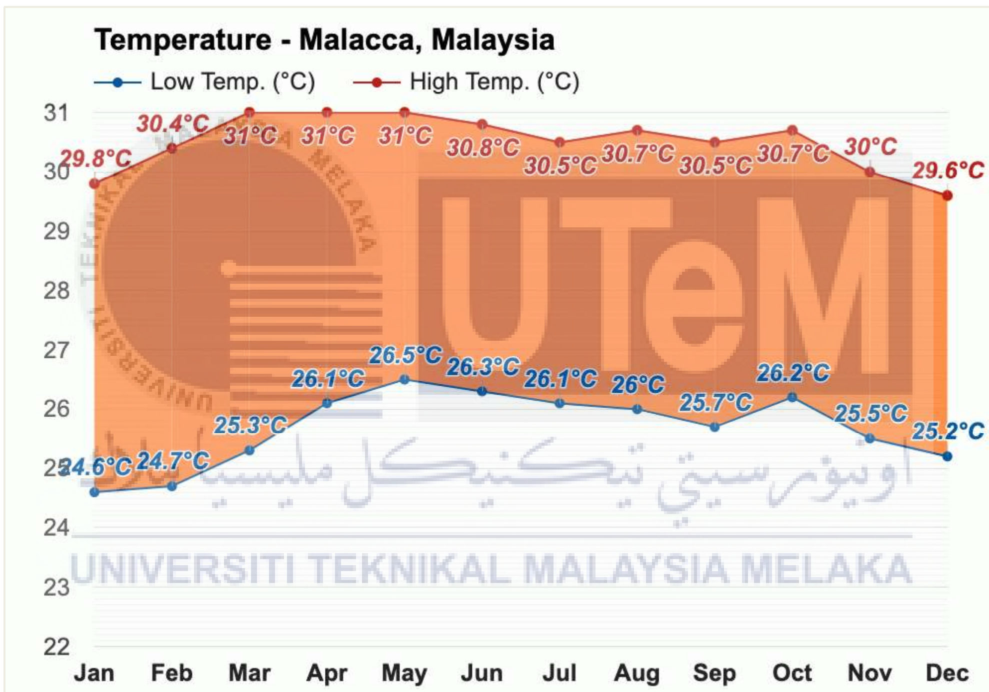


Figure 2.12 Average Temperature in Malacca Every Month (*Melaka Climate By Month | A Year-Round Guide. World Weather & Climate Information*, 2023)

2.5.5 Average UV Index in Malacca

The average UV index for the whole year which is January till December have the same UV index with average index reading of 7. The average index values are grouped into exposure categories as seen in Figure 2.13, therefore the UV index in Malacca is in high exposure categories that required protection from the sunlight.

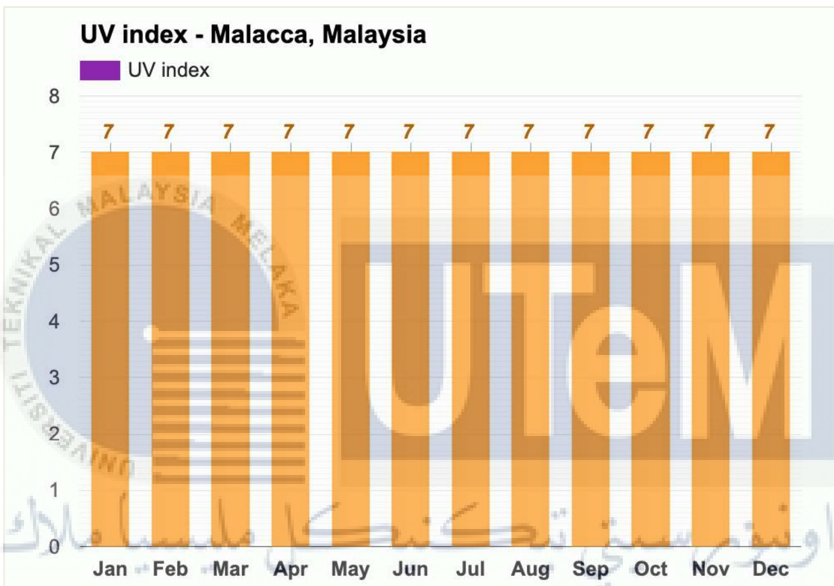


Figure 2.13 Average in UV Index in Malacca Every Month (*Melaka Climate By Month | A Year-Round Guide. World Weather & Climate Information*, 2023)

EXPOSURE CATEGORY	UVI RANGE
LOW	<2
MODERATE	3 – 5
HIGH	6 – 7
VERY HIGH	8 – 10
EXTREME	11+

Figure 2.14 Category of UV Index Values

2.6 Heat Balance Method

The Heat Balance Method addresses how mass, conduction, convection and radiation interact. Mass can be absorbing energy in one form (radiation) while giving off energy in another form (convection). With Heat Balance, heat on both sides is either entering or exiting the surface as the same time, causing thermal equilibrium (ASHRAE Heat Balance Method, 2015).

2.6.1 Equation of Heat Balance Method

The equation of Heat Balance Method is shown as below (Enggcyclopedia, 2015):

m_H : mass flow rate of the hot fluid in kg/hr
Cp_H : mass heat capacity of the hot fluid in Joules/kg^{0}C
Ti_H and To_H : Respectively inlet and outlet temperatures on exchanger hot side in ^{0}C

m_C : mass flow rate of the cold fluid in kg/hr
Cp_C : mass heat capacity of the cold fluid in Joules/kg^{0}C
Ti_C and To_C : Respectively inlet and outlet temperatures on exchanger cold side in ^{0}C

Heat lost by the hot fluid = $-Q = m_H \times Cp_H \times (To_H - Ti_H)$ … (1)

Heat gained by the cold side = $Q = m_C \times Cp_C \times (To_C - Ti_C)$ … (2)

Comparing equations (1) and (2),

$m_H \times Cp_H \times (Ti_H - To_H) = m_C \times Cp_C \times (To_C - Ti_C)$ … (3) (Heat balance equation)

2.7 Summary of Research Findings

The installation of mini air cooler and exhaust fan had a positive effect on the cooling process in the vehicle cabin by reducing the temperature slightly. The heat that could be discharged for seven hours of testing in this literature is described as great amount but with a constant of solar power needed. The temperature however could not match with the temperature of the surrounding although it can allows risk of damage to vehicle interior reduced. The result of the experiment is calculated using Origin version 6.0 which it calculate the profile of cooling effect area from the cabin and cooling power of the cooler and exhaust fan (Condro, 2019).

From literature, the opening the window and adding sunshade on thermal environment inside car cabin compartment during the parking stage do have influence on temperature differences of the cabin. With window opening gap, the temperature difference between inside and outside of cabin maintained at minimum degree Celsius. With sunshade, the temperature difference raises slightly higher than opening window gap thus could reduce thermal shock the moment passenger enters the vehicle. But the opening window gap could easily lead to a theft case to happen if the vehicle was parked at unsafe place. The sunshade that only available to cover front windshield could not prevent the heat from entering the cabin from vehicle windows. (Qi et al., 2017).

Subsequently, using cardboard pieces that sewn together as car shade to cover from front windshield, side windows and rear windscreen with part-down windows achieved a good overall performance in reducing the maximum temperature at all interior locations. Nonetheless, the cardboard car shade is not conducive and durable as heat reflect materials cause if the cardboard come in contact with rainwater, it would easily torn off and stick to vehicle windshield and windows. (Mohammed et al., 2015)

Enhancement of a dynamic structure for the cabin temperature of a truck is studied and run by three meteorological parameters, which is outdoor temperature, solar radiation and wind velocity. Smart material are implemented to reduce temperature of cabin for truck manufacturer by replacing conventional components with new one that provide better quality of performance and higher levels of comfort for passenger in the cabin. The smart materials are phase change materials, proposed solar cell system, thermo electric material and IR and UV cut automotive window glass. However, these smart material proposed in this research are costly. The thermal analysis of this research is done using CFD ANSYS with analysing material properties for thermal conductivity, specific heat, density, emissivity and others (Bobba et al., 2019).

The next literature is to study thermal effect in small passenger car cabins using three methods of tinted all windows, sunshade to cover up the main window and opening little gap on window to allow air flow through the car cabin. The three methods is recorded and analyse for comparison to have a clear view on which method is the best practice to reduce the cabin temperature after car parked under the sun. From the comparison, it is proven that combining all three methods are the best practice to reduce temperature of the cabin but the methods cannot sustain longer with current global warming situation. The data of these experiments are recorded using thermometer data logger software SE-309 (Shafie, 2023).

Vehicle window tinting includes a range of methods to alter glass and reduce the impacts of radiation heating. Even though they are well-established, continuous improvements aim to improve heat reduction while maintaining good visibility. A better balance between reducing heat and preserving visibility is the goal of many developing techniques (Marshall et al., 2019).

Widely available aftermarket car window tint films change the appearance of windows by lowering visibility, or visible light transmission (VLT). These polymer films are heat-absorbing dyes, adhesives to limit UV-Vis light transmission, and imino esters. They are flexible and adjustable to fit different windows. Abrasion-resistant coatings are present in some (Isa et al., 2015; Grant et al., 2020).

There are three popular varieties of car window tints: metalized, hybrid, and dyed films. Each has unique advantages in terms of lowering UV, visible light, and infrared radiation transmission into the vehicle cabin.

Petroleum-based polyethylene glycol (PEG) is used as a heat transfer fluid in thermal energy storage (TES). Because of its low density and variable molecular weight, PEG is miscible with water, acetone, and chloroform. It is non-toxic, however people who are allergic to glycol polymers may experience responses (Wikipedia Contributors, 2023).

The pure PEG polymer, its solution, and its hydrogel states both before and after melting are depicted in the pictures. PEG uses solid-liquid phase transitions to store and release thermal energy. Based on endothermic/exothermic curves, the phase transition temperature of PEG hydrogel indicates its melting point, which is impacted by the amount of water present. Water concentration modifies the mass percentage and crystal structure of the polymer, which in turn impacts thermal energy storage density (Deng & Yang, 2017).

Therefore, in addressing the above-mentioned issue, there is a research opportunity to test the effectiveness of three different concentrations of heat absorbing material in reducing the temperature inside of parked vehicle cabin under direct sunlight. The result from the experiments will be evaluated and compare for effectiveness of each concentration. This is the main focus of this research study. The following chapter shall discuss the proposed concentration properties that will be tested in more detail.

CHAPTER 3

METHODOLOGY

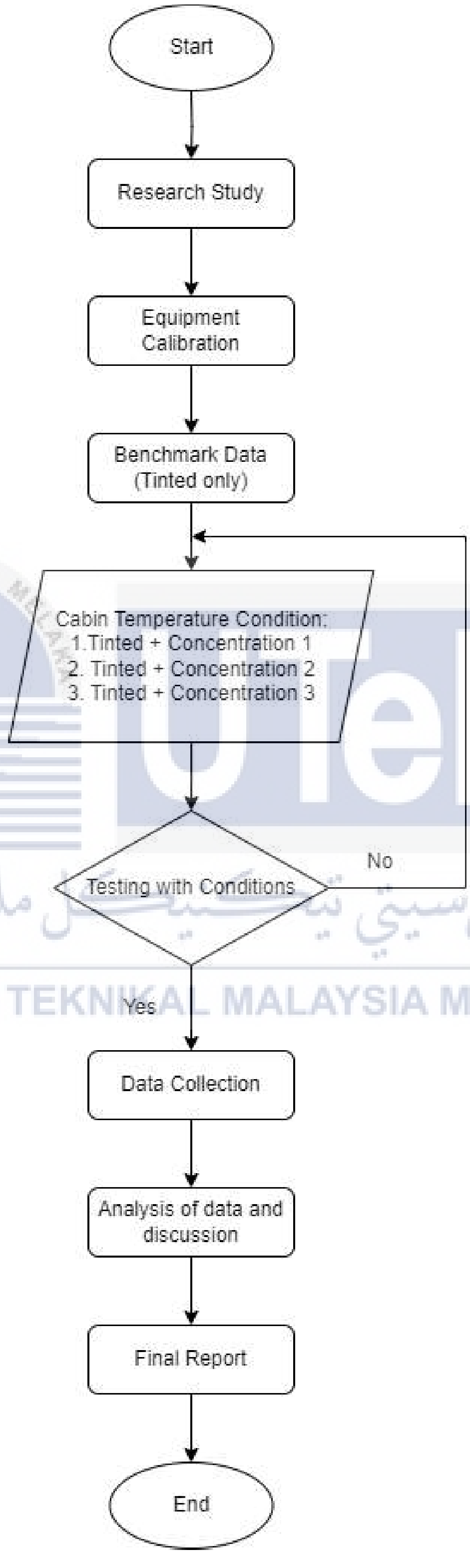
3.1 Introduction

This chapter will explain the methodology that necessary for collecting relevant information and ideas for this research. The heat convection in the vehicle cabin will be main process and focus of experimentation and viability of study. To make the research further comprehensible, the feasibility study's literature research must be finished on the main focus of this research.

Subsequently, a segment A car will be used to conduct the experiment of heat convection in vehicle passenger cabin. The position of the vehicle will be take into consideration which is west and east as a constraint of this experiment. The location for conducting the experiment will be in consideration too to ensure the accuracy of temperature data recorded from car exposed to sunlight. Following that, the benchmark data is gathered for records.

The experiment will include three different concentration of glycol gel heat absorbent material as testing. The material will be tested along with previously installed tinted windows of the car for the effectiveness in reducing the cabin temperature. The window tinted specification is checked and take into consideration along with the specification of heat absorbent material. The data collected is then analyze and a report summary is made to show the heat absorbing effectiveness of the material to reduce temperature of the cabin or vice versa.

3.2 Flow Chart



3.3 Benchmark Data Collection

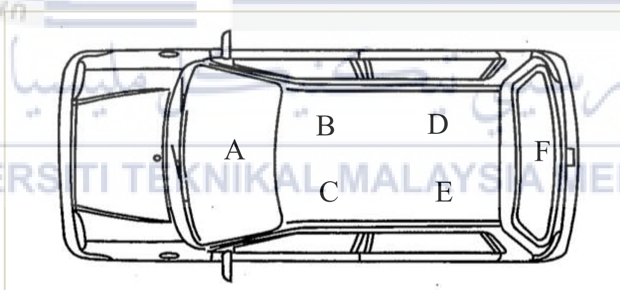
This process requires benchmark data as benchmarking for further data collection such as preliminary result and secondary result. For this experiment, a segment A car (Perodua Kancil) will be used as testing vehicle different from previous research which used segment C car.

This experiment will be carried out at open space with less shades such as trees or buildings surrounding it, for example an open space car park. All the apparatus and equipment were prepared accordingly for this experiment. The equipment are segment A car, thermocouple, thermometer, laptop, stopwatch and compass. The thermocouple type K is calibrated before using for this experiment. The time to record the data is from 10 a.m. to 3 p.m. by placing the thermocouple at six spots inside the car cabin. The data is record for every 30 minutes to observe the differences.

The information of temperature data gathered will be benchmarked and compared to future benchmarks information for comparison. The following data will be analyzed using glycol-gel material together with tinted windows. These two factors will be evaluated their effectiveness in reducing the heat build up inside the car cabin.

Table 3.1 Temperature Data Table

	TYPE OF CAR: SEGMENT A (KANCIL)						
	POSITION : WEST						
		TITLE: BENCHMARK DATA					
		THERMOCOUPLE POSITION					
	TIME	A	B	C	D	E	F
TEMPERATURE (˚C)	10:00 AM						
	10:30 AM						
	11:00 AM						
	11:30 AM						
	12:00 PM						
	12:30 PM						
	1:00 PM						
	1:30 PM						
	2:00 PM						
	2:30 PM						
	3:00 PM						



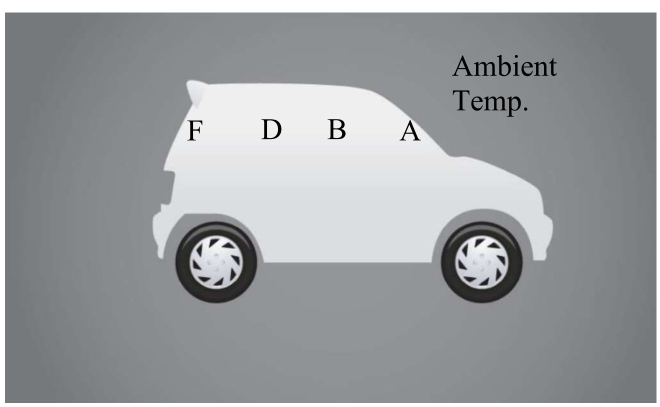


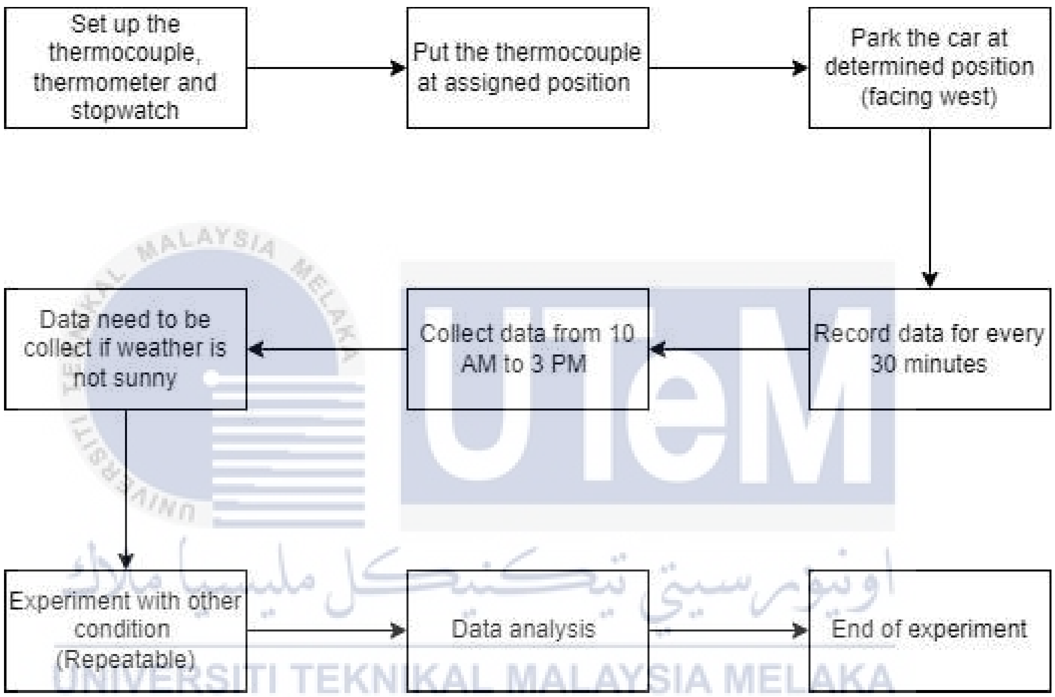
Figure 3.1 Position of Thermocouple in Car (fqemo creative., 2014)

3.3.1 Step for Collecting Experiment Data

This experiment is set up to collect data for two different situations:

1. Situation without the absorbent material (window and windshield tinted only).
2. Situation with glycol-gel material and tinted.

Table 3.2 Step for Experiment



The data for the experiments will be collected using thermometer data logger software SE-309 that provided with the thermometer data logger. The data is then analyse by plotting graphs for comparison using Originlab software for more presentable and clear view of graphs.

3.3.2 Equipment for The Experiment

Table 3.3 Equipment for Experiment

NO	EQUIPMENT/APPARATUS	IMAGE
1	Car • Type: Segment A • Brand: Perodua Kancil • Engine size: 660 cc • Wheelbase: 2280 mm • Compressor brand: Denso (scroll type) • Model year: 1996	
2	Thermometer • Range: -200 to 1370 C • Battery: 9V • Accuracy: +-0.3%rdg + 1 C	
3	Thermocouple • Type-K • Chromel and Alumel conductors • Sensibility of 39.4 microV/c at 20 C • Range: -270 to 1372 C	
4	Stopwatch • To set the time for recording temperature	

5	Compass To set the position of vehicle parking under the sun	
6	Laptop • To monitor and record the temperature data using software SE309 connecting to thermometer	

3.4 Experimental Setup

The experiment will be taking place at open space parking lot at Fakulti Teknologi dan Kejuruteraan Mekanikal (FTKM), UTeM Main Campus. The location has no buildings and trees surrounding it making the place is ideal for experiments.

Figure 3.2 Parking Lot Near FTKM Building

Figure 3.3 Car Parked Facing West

Figure 3.4 Position of The Sun at 10 A.M

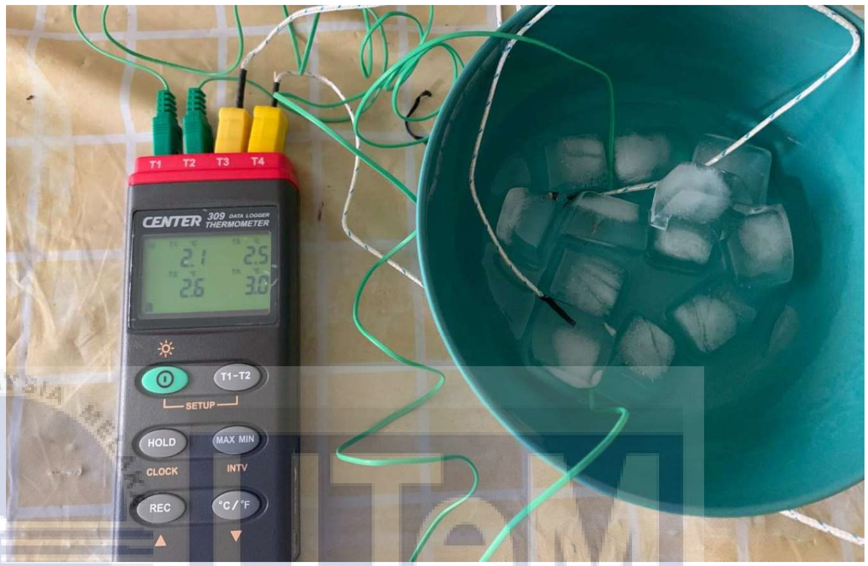
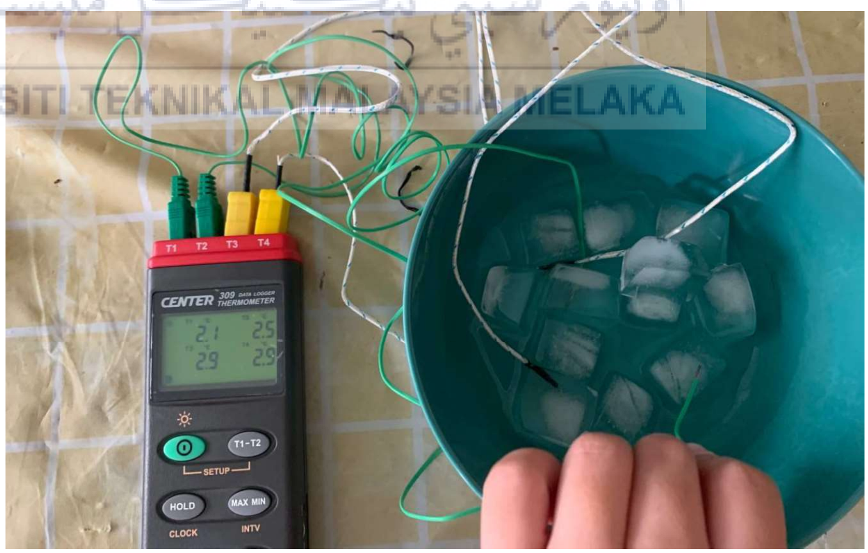
3.5 Equipment Calibration

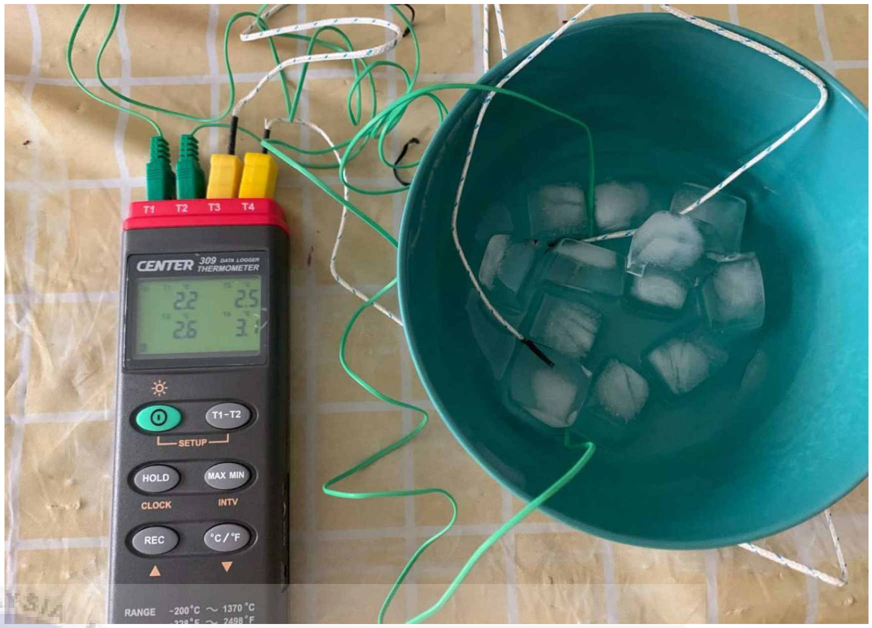
The K-type sensor must calibrate in order to determine the error between the measurement temperature and the real temperature. The calibration is done before all experiments can be start to ensure the reading from the temperature and real temperature have minimal differ.

3.5.1 Calibration in Ice Water

This calibration of thermocouple K-type sensor is made to compare the temperature that perceived from the sensor with the actual temperature of ice. The range of temperature of ice water is between 0˚C to 6˚C. The sensors are put in the ice water and the temperature data is collected for three times.

Table 3.4 Calibration for Ice Water

No	Calibration Process	Calibration Image
1	First Trial	
2	Second Trial	

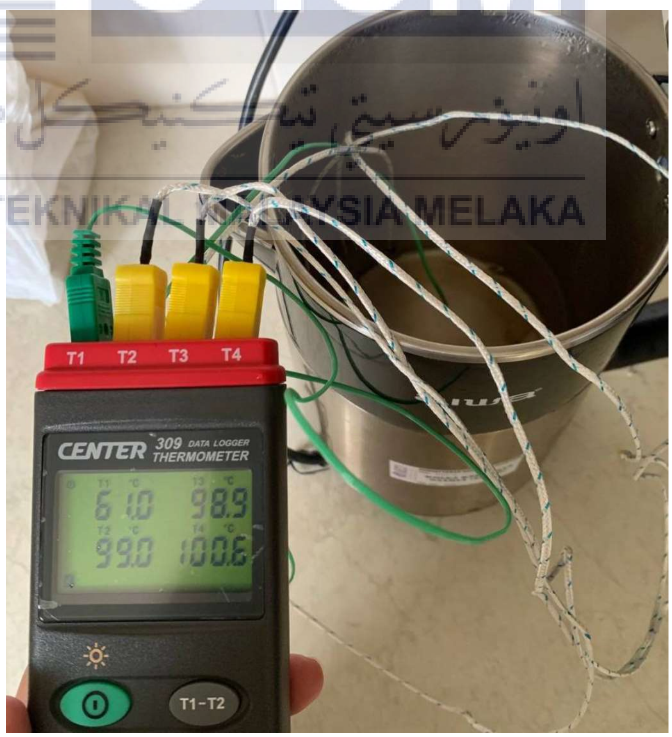
3	Third Trial	

3.5.2 Calibration in Boiling Water

This calibration of thermocouple K-type sensor is made to compare the temperature that perceived from the sensor with the actual temperature of boiling water. The range of temperature of boiling water is between ˚C to ˚C. The sensors are put in the boiling water and the temperature data is collected in three trials.

Table 3.5 Calibration for Boiling Water

No	Calibration Process	Calibration Image
1	First Trial	

2	Second Trial	
3	Third Trial	

3.6 Heat Absorbent Material and Products

A heat absorbent material which is made of glycol gel and water packed in a heat conducting membrane container will be used for this experiment. Three material will be put inside the vehicle cabin front dashboard and rear dashboard.

3.6.1 Design Improvement For Packed Glycol Gel

A new protoype design for packed glycol-gel is sketched in software Catia V6. This design is improved from previous design which is the glycol-gel is packed inside microwaveable bag. The new prototypes are designed in various shape as shown below.

3.6.2 Prototype Design A

Figure 3.5 Prototype Design A (Front View)

Figure 3.6 Prototype Design A (Top View)

This heat absorbing material is build of a glycol-based gel that mixed with water. The material mixture is stored in a cylinder container with aluminium lid. A few holes is made on the lid to allow heat from vehicle cabin absorbed by the glycol gel.

3.6.3 Prototype Design B

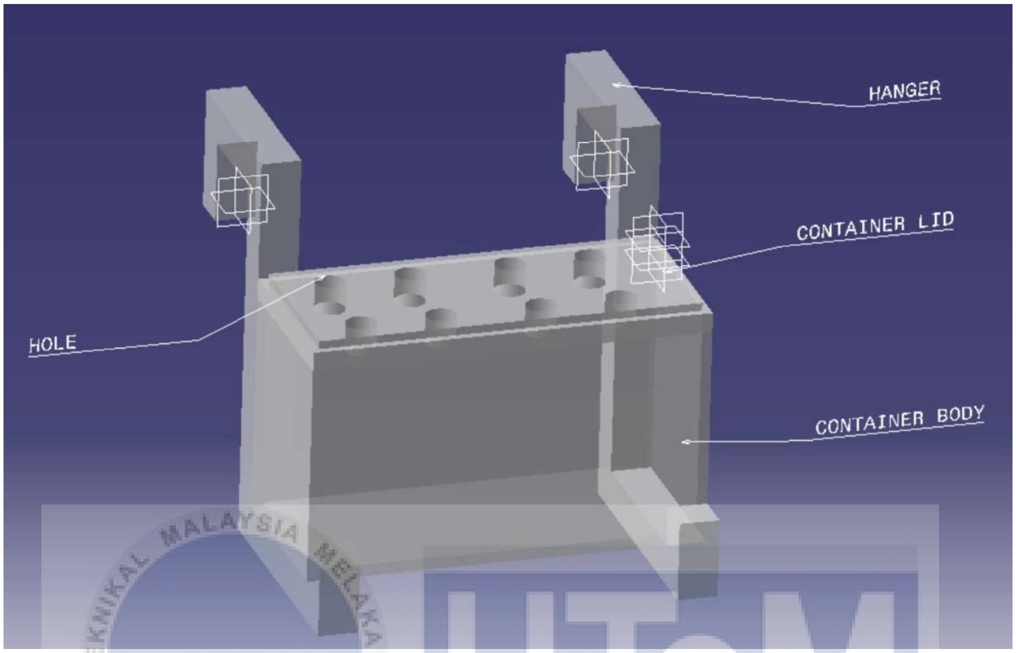


Figure 3.7 Prototype Design B (Front View)

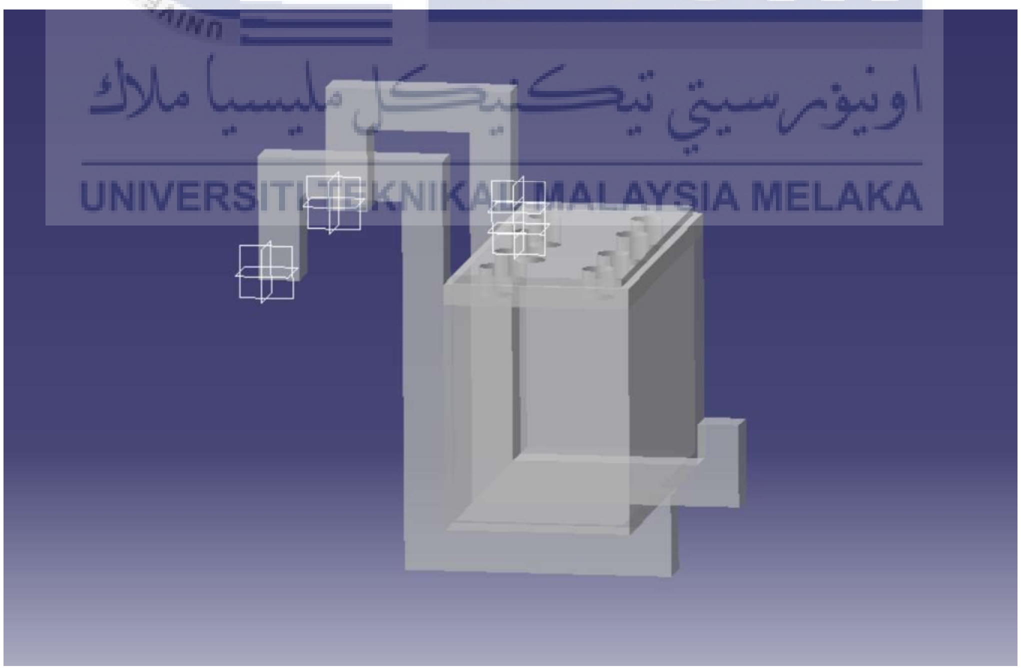


Figure 3.8 Prototype Design B (Side View)

This heat absorbing material is build of a glycol-based gel that mixed with water. The material mixture is stored in a rectangular container with aluminium lid. A few holes is made on the lid to allow heat from vehicle cabin absorbed by the glycol gel. The container is then attached to two hooks so that it can be hang on vehicle rearview mirror.

3.6.4 Product Design Specification

A Product Design Specification (PDS) is a comprehensive document that lists all of the features, attributes, and requirements that a product must have. It acts as a roadmap to direct the process of development and production, guaranteeing that the finished product satisfies user requirements and adheres to particular criteria. The PDS include functional requirements, technical specification, design criteria and safety. The table below shows PDS for Prototype A and Prototype B heat absorbent material packaging.

Table 3.6 PDS for Prototype Design A

Heat Absorbent Material Container PDS **(Prototype Design A)**	
Functionality	• Bigger surface area (lid) covered with aluminium foil to absorb heat • Can place on flat surface (E.g.: Dashboard, Arm rest)
Technical Spec.	Material: Nylon (SLS printing)/Polypropelene (PP) plastic Dimension: Diameter x Height, 150 mm x 80 mm Weight: < 60g (without the material) Tolerance: +- 0.5 mm
Design Criteria	• Minimalist design to suit car cabin aesthetic • Not easy to spill
Safety	• Not made of hamrful substance • Additional lid cover on top of aluminium foil

Table 3.7 PDS for Prototype Design B

Heat Absorbent Material Container PDS **(Prototype Design B)**	
Functionality	• Smaller surface area (lid) with holes for mixture to absorb the heat • Provided with hooks • Can hang inside the cabin (E.g.: Rearview mirror, Headrest)
Technical Spec.	Material: Nylon (SLS printing)/Glycolised Polyster, PETG (3D printing) Dimension: Length x Width x Height, 100 mm x 45 mm x 60 mm Weight: < 80g (without the material) Tolerance: +- 0.5 mm
Design Criteria	• Minimalist design to suit car cabin aesthetic • Not easy to spill
Safety	• Not made of hamrful substance • Adjustable hook

From the PDS tables above, the most suitable prototype design is Prototype Design A. Prototype Design A is chosen for its placement flexibility. The material to made this container is available widely on the market aside from it simple design. The design match the aesthetic of a car cabin to ensure there are no disruption on visual appeal. Overall, this prototype design is the most convenient for testing on experimental car.

3.7 Window Tint

Car that manufactures these days usually prepared with tinted windows that abide to specifications that guided by Jabatan Pengangkutan Jalan Malaysia (JPJ). Car without tinted windows could install it from popular manufacturers known as EcoTint, Llumar, Smart Tint and more. Window tint or reflective films are normally applied to the interior of flat glass windows to reduce the amount of infrared, visible light and ultraviolet (UV) from entering windows. Low-emissivity coating reduce the amount of visible and ultraviolet radiation entering a window, and are often applied to reduce fading of the contents of a room. (F.M., 2014)

Figure 3.9 Checking Tinted Specification (Paul Tan Automotive News, 2014)

3.7.1 Ultraviolet Rays Rejection (UVR)

UVR functions to reduce and protect cabin interior equipment for example dashboards, door trims, car seats, radio and so on. It also prevents skin related disease for passengers cause by long exposure to the sunlight. Generally, tinted films block almost 90 percent of UV rays from entering the cabin. For the experimental car, the UVR reading is 93 percent.

3.7.2 Visible Light Transmission (VLT)

VLT indicates the percentage of amount of visible light that entering through the tinted films. The VLT helps to increase cabin security because of it reduce the visibility from outside to see what inside the car cabin. The VLT percentage of this experiment car is 30 percent for rear passenger windows, 60 percent for driver side window, 70 percent for front windscreen, and 30 percent for rear windscreen.

Figure 3.10 VLT Percentage by JPJ Malaysia (Sadali., 2016)

3.7.3 Infra-red Rejection (IRR)

Infrared light is the light that causes heat when inside the car cabin, the higher percentage of IRR, the lesser heat feel inside the cabin. However, IRR could only reject wavelength range of 780 mm to 2500 nm thus could not fully rejected the infrared wavelength that usually between range of 900 nm to 1100 nm. The IRR for this experiment car windows tinted is 40 percent.

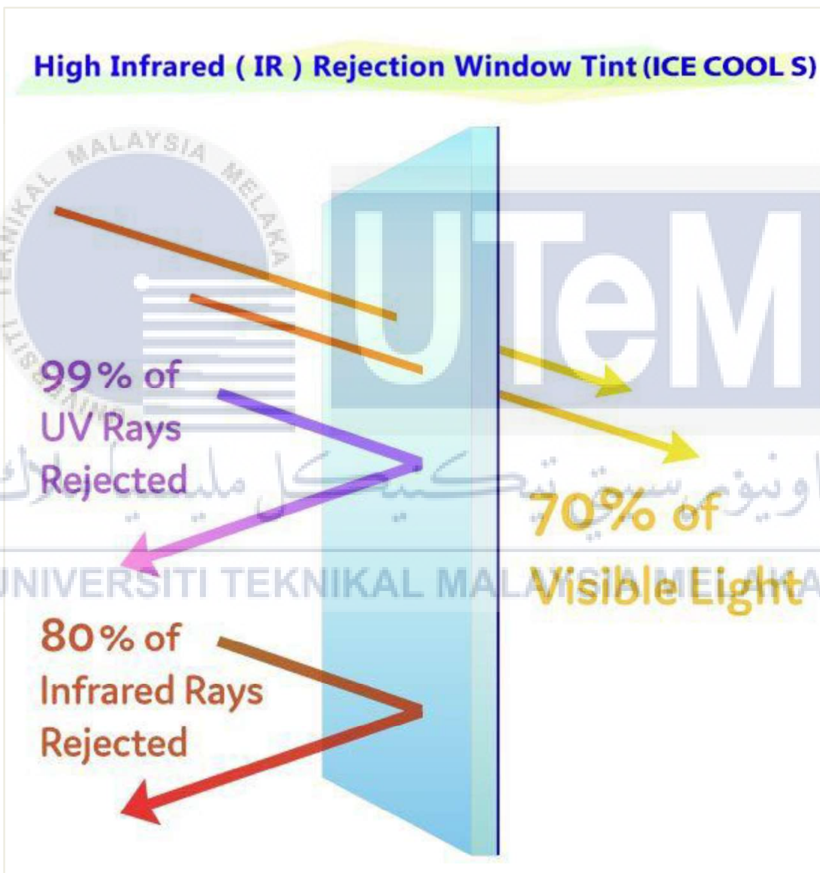


Figure 3.11 The Rays Acted on Window Tint (formosam, 2019)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the preliminary results after the experiment with it fulfilled the required testing requirement which is tinted windows. The result were obtained by placing thermocouple Type K connected to thermometer data logger to capture the temperature data of vehicle cabin at certain points. The result is recorded between 10 A.M. to 5 P.M. under direct sunlight with no buildings and trees surrounding the area. The temperature inside the vehicle cabin gradually rises over time whereas the heat transfer processes of convection, conduction and radiation take place.

4.2 Preliminary Result

4.2.1 Benchmarking Data

The benchmarking data was recorded by using thermometer with thermocouple type-K positioned at six locations inside the vehicle cabin. A laptop is connected to the thermometer to monitor and record the temperature benchmark data. The experiment was set from 10 a.m to 3 p.m with the car parked positioned to west with the sun shine from left side of the car.

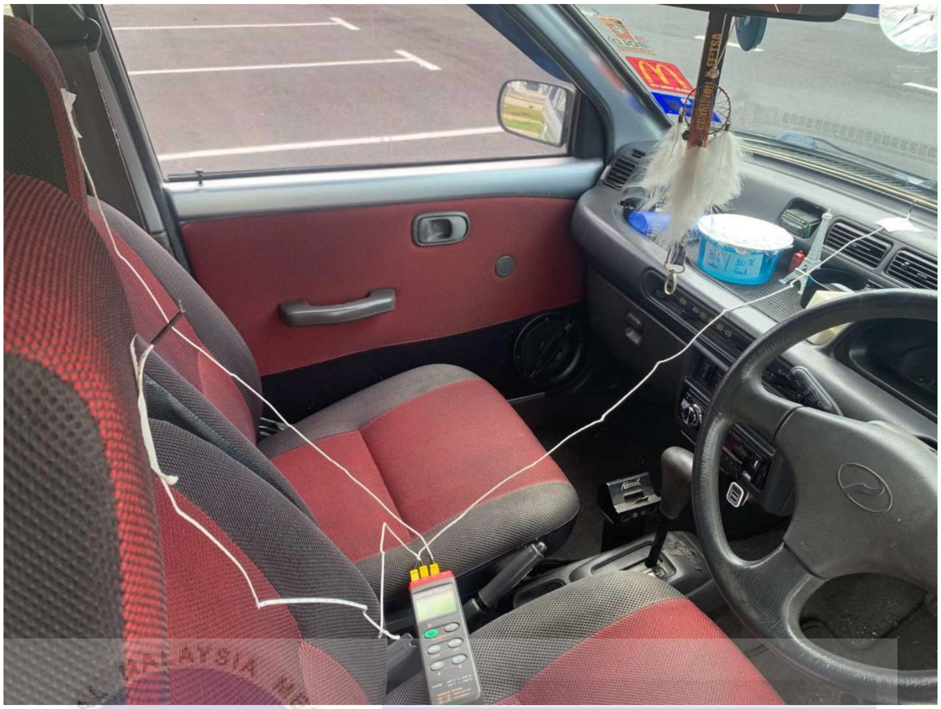


Figure 4.1 Type-K Sensors at Position A,B,C

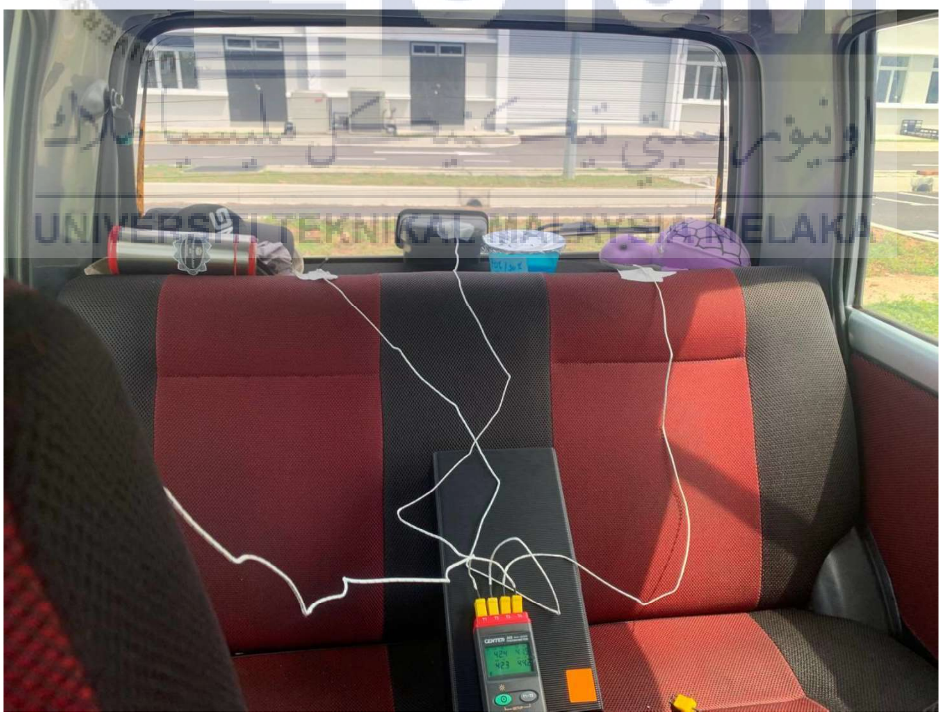


Figure 4.2 Type-K Sensors at Position D,E,F

Figure 4.3 Car Parked at FTKM Parking Lot

Table 4.1 Benchmark Data

	TYPE OF CAR: SEGMENT A (KANCIL)							
	POSITION : WEST (Sun shine from left of the car)	LOCATION: FTKM Parking Lot						
		AMBIENT TEMP. (˚C)	**TITLE: BENCHMARK DATA**					
			THERMOCOUPLE POSITION					
	TIME		A	B	C	D	E	F
TEMPERATURE (˚C)	10:00 AM	30.0	40.3	40.0	40.2	39.7	39.1	40.4
	10:30 AM	30.2	49.6	48.2	48.3	47.0	47.5	46.5
	11:00 AM	30.8	50.7	53.8	53.8	49.2	44.7	48.5
	11:30 AM	30.5	53.4	51.9	48.1	49.2	49.3	50.4
	12:00 PM	32.5	50.1	46.8	47.0	45.4	46.4	45.4
	12:30 PM	33.5	58.1	48.3	46.9	45.1	45.2	46.6
	1:00 PM	33.5	53.1	47.1	46.3	50.1	48.4	50.5
	1:30 PM	32.0	47.3	42.9	43.2	43.0	43.7	44.4
	2:00 PM	31.5	46.3	42.7	43.0	43.1	43.8	44.1
	2:30 PM	31.2	40.7	38.4	37.8	37.3	37.5	38.1
	3:00 PM	31.0	39.3	38.1	37.0	38.1	38.8	38.4

4.3 Secondary Result

4.3.1 Heat Absorbent Material Data

Heat Absorbent Material is made of glycol-based gel mixed with water. This material were separated to three mixture with different concentrations. The first glycol gel and water mixture, Concentration 1 consist of 70% of water (490 ml) and 30% of glycol (210 ml). The second concentration, Concentration 2 consist of 50% of water (350 ml) and 50% of glycol (350 ml). Concentration 3 have different volume of water with 30% (210 ml) while the glycol gel is 70% (490 ml).

The heat-absorption mixture is stored in a microwaveable container with capacity of 700 ml. The container lid is replaced with aluminium foil and a few of holes were punched on the foil. The aluminium foils act as heat-conducting membrane to effectively allow the glycol gel and water mixture to absorb the ambient heat near the position of the container.

The design that chosen for experiment of concentrations of glycol gel is Prototype Design A. The design is chosen for it wide surface area to store the glycol gel-water mixture thus increase the heat absorbing capabilities of the material. The dimension of this container design for container body and container lid are shown on figures below.

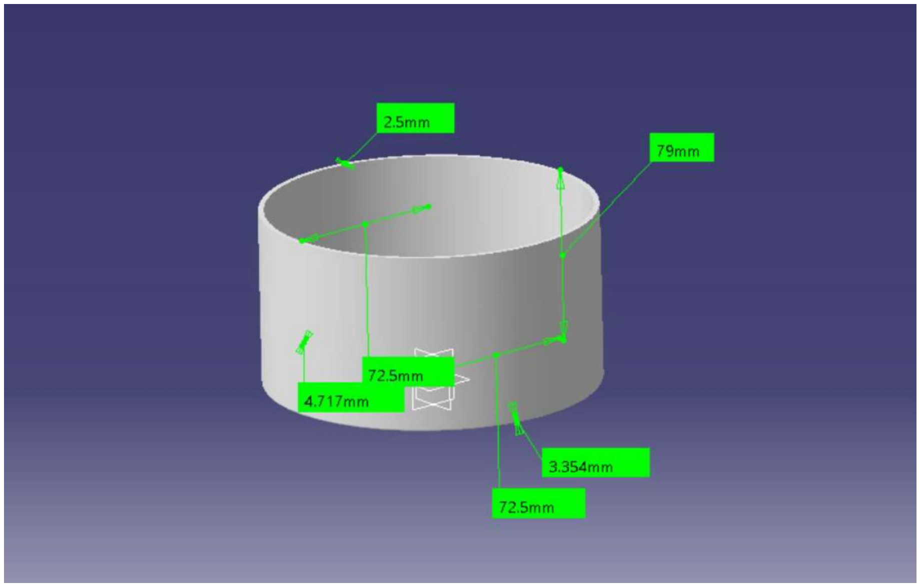


Figure 4.4 Dimension of Prototype Design A Container Body

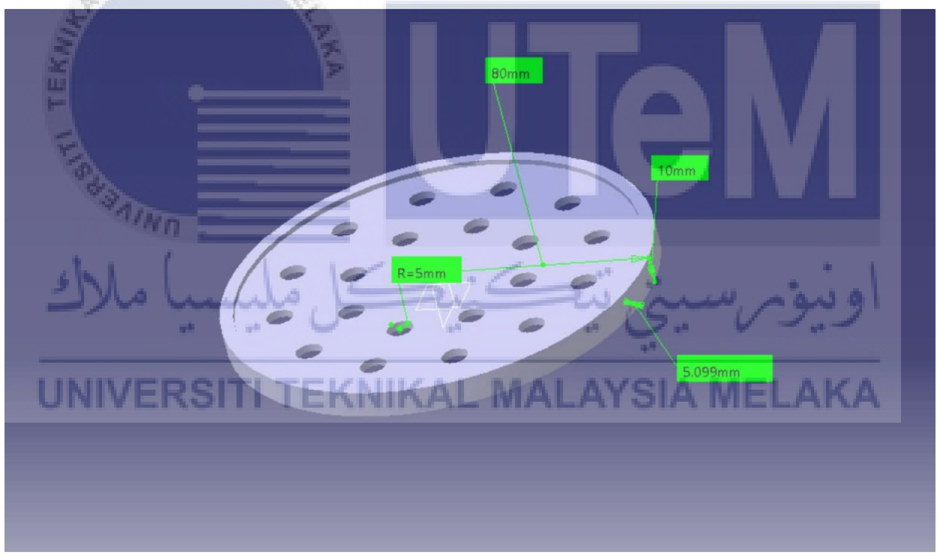


Figure 4.5 Dimension of Prototype Design A Container Lid

Figure 4.6 Container Design A contain Mixture of Glycol Gel and Water

The thermocouple type-K sensors are put in the positions of A, B, C, D, E and F before the heat absorbing material is placed. The process of setting up is executed to guarantee that the temperature obtained at that point is added to the position within our benchmark data. The graphic below depicts the location of the heat-absorbing material.

Figure 4.7 Placement of Heat Absorbent Material at Front Dashboard

The container contain heat absorbing mixture is placed near the position of thermocouple at point A, which is at car front dashboard. Front dashboard is the position where the highest temperature recorded from benchmark data. The mixture's role is to effectively absorb the accumulated ambient heat at the front dashboard.

Figure 4.8 Placement of Heat Absorbent Material at Rear Dashboard

The Heat Absorbing Material is also placed on rear dashboard, which is near the position of thermocouple point F. From the benchmark data that obtained, rear dashboard accumulate average more heat than passengers and driver seat thus increasing the temperature at that point. The mixture will reduce the heat accumulated at this area.

4.3.2 Heat Absorbent Material Data: Concentration 1 (70% Water, 30% Glycol)

A new set of data are gathered to shows the advantages and consequences of the Heat Absorbing Material inside the vehicle cabin, which absorbed heat from 10 a.m. to 3 p.m. After the type-k thermocouple and heat absorbing mixture container is positioned, the material is then evaluated on how effectively it absorbs heat from the surroundings to compare with the previous benchmark data.

The data tabulated below is for the heat absorbing mixture of Concentration 1. The hike of the temperature from 10 a.m. to 3 p.m. are presented in table. The temperature disparity demonstrates the effect of the heat absorbing mixture to absorb ambient heat as thought possible. Temperature for point A and F where the heat absorbing mixture is placed are highlighted on the table.

Table 4.2 Glycol Gel Mixture Concentration 1 (70% water, 30% glycol)

		TYPE OF CAR: SEGMENT A (KANCIL)						
	POSITION : WEST (Sun shine from left of the car)	LOCATION: FTKM Parking Lot						
		AMBIENT TEMP. (˚C)	**TITLE: CONCENTRATION 1**					
			THERMOCOUPLE POSITION					
	TIME		A	B	C	D	E	F
TEMPERATURE (˚C)	10:00 AM	28.0	32.5	31.6	30.6	32.3	32.3	33.1
	10:30 AM	28.0	36.4	35.4	35.9	35.3	35.0	35.7
	11:00 AM	29.0	36.3	35.7	35.7	36.2	36.0	36.5
	11:30 AM	30.0	38.0	38.2	37.4	36.5	36.3	36.5
	12:00 PM	30.0	39.3	38.1	37.9	37.0	37.2	37.4
	12:30 PM	30.0	40.0	38.4	38.2	37.9	38.2	38.5
	1:00 PM	31.0	37.4	36.9	39.5	39.2	39.1	39.8
	1:30 PM	31.0	38.6	37.5	39.7	40.1	39.7	40.5
	2:00 PM	30.0	40.4	38.6	39.9	38.3	38.4	38.6
	2:30 PM	30.0	38.9	37.2	37.4	38.6	38.9	39.1
	3:00 PM	30.0	40.7	39.8	41.2	40.4	40.1	40.7

4.3.3 Heat Absorbent Material Data: Concentration 2 (50% Water, 50% Glycol)

The data tabulated below is for the heat absorbing mixture of Concentration 2. The peak of the temperature from 10 a.m. to 3 p.m. are presented in the table as well. Temperature for point A and F where the heat absorbing mixture is placed are highlighted on the table.

Table 4.3 Glycol Gel Mixture Concentration 2 (50% water, 50% glycol)

	TYPE OF CAR: SEGMENT A (KANCIL)							
	POSITION : WEST (Sun shine from left of the car)	LOCATION: FTKM Parking Lot						
		AMBIENT TEMP. (˚C)	TITLE: BENCHMARK DATA					
			THERMOCOUPLE POSITION					
	TIME		A	B	C	D	E	F
TEMPERATURE (˚C)	10:00 AM	29.0	36.3	36.2	38.1	38.1	38.5	40.1
	10:30 AM	30.0	45.7	46.3	46.7	38.7	39.7	42.3
	11:00 AM	30.0	47.2	47.1	46.9	40.8	42.0	41.8
	11:30 AM	31.0	44.3	44.8	45.3	42.4	44.7	44.5
	12:00 PM	31.0	45.8	45.4	46.6	45.3	43.5	44.8
	12:30 PM	32.0	45.4	43.2	44.3	42.7	40.4	44.6
	1:00 PM	32.0	44.1	40.9	43.8	41.4	40.0	42.9
	1:30 PM	31.0	40.3	41.9	46.1	40.9	42.3	41.6
	2:00 PM	31.0	44.3	44.2	47.1	41.7	42.4	41.8
	2:30 PM	30.0	45.4	43.2	44.8	42.0	41.9	42.2
	3:00 PM	31.0	42.5	45.9	43.0	47.7	47.0	47.6

4.3.4 Heat Absorbent Material Data: Concentration 3 (30% Water, 70% Glycol)

The data tabulated below is for the heat absorbing mixture of Concentration 3. The peak of the temperature from 10 a.m. to 3 p.m. are presented in the table as well. Temperature for point A and F where the heat absorbing mixture is placed are highlighted on the table.

Table 4.4 Glycol Gel Mixture Concentration 3 (30% water, 70% glycol)

	TYPE OF CAR: SEGMENT A (KANCIL)							
	POSITION : WEST (Sun shine from left of the car)	LOCATION: FTKM Parking Lot						
		AMBIENT TEMP. (˚C)	TITLE: BENCHMARK DATA					
			THERMOCOUPLE POSITION					
	TIME		A	B	C	D	E	F
TEMPERATURE (˚C)	10:00 AM	29.0	45.2	38.6	42.0	39.5	40.6	41.6
	10:30 AM	30.0	42.9	43.9	45.0	44.6	46.0	45.3
	11:00 AM	30.0	46.1	43.9	41.4	44.0	46.2	45.9
	11:30 AM	31.0	50.4	47.6	45.0	44.0	46.3	44.3
	12:00 PM	31.0	46.1	46.1	47.4	49.0	49.5	49.6
	12:30 PM	32.0	50.3	50.1	51.4	46.4	48.3	47.5
	1:00 PM	32.0	46.3	43.2	44.1	50.6	49.8	50.8
	1:30 PM	32.0	45.7	44.1	47.7	45.5	45.3	44.5
	2:00 PM	32.0	45.5	44.7	44.3	44.9	44.1	44.5
	2:30 PM	31.0	46.1	44.8	44.9	43.3	43.3	43.6
	3:00 PM	31.0	44.9	45.5	44.6	43.3	44.9	49.3

From all the results above, the comparison for peak temperature difference between 12 p.m. to 2 p.m. can be made. The temperatures from three different concentrations at point A, front dashboard and point F, rear dashboard are compared with benchmark data. The comparison for all data is presented on Table 4.5 below.

Table 4.5 Comparison of Result of Peak Temperature at Position A (Front Dahsboard) and F (Rear Dashboard)

Car Position	Temperature Vs Time							
Car facing West, Sun rises from East and sets at West	Benchmark		Concentration 1		Concentration 2		Concentration 3	
	12 pm	A: 50.1 ℃ F: 45.4 ℃	12 pm	A: 39.3 ℃ F: 37.4 ℃	12 pm	A: 45.8 ℃ F: 44.8 ℃	12 pm	A: 46.1 ℃ F: 49.6 ℃
	12.30 pm	A: 58.1 ℃ F: 46.6 ℃	12.30 pm	A: 40.0 ℃ F: 38.5 ℃	12.30 pm	A: 45.4 ℃ F: 44.6 ℃	12.30 pm	A: 50.3 ℃ F: 47.5 ℃
	1 pm	A: 53.1 ℃ F: 50.5 ℃	1 pm	A: 37.4 ℃ F: 39.8 ℃	1 pm	A: 44.1 ℃ F: 42.9 ℃	1 pm	A:46.3 ℃ F: 50.8 ℃
	1.30 pm	A: 47.3 ℃ F: 44.4 ℃	1.30 pm	A: 38.6 ℃ F: 40.5 ℃	1.30 pm	A: 40.3 ℃ F: 41.6 ℃	1.30 pm	A: 45.7 ℃ F: 44.5 ℃
	2 pm	A: 46.3 ℃ F: 44.1 ℃	2 pm	A: 40.4 ℃ F: 38.6 ℃	2 pm	A: 44.3 ℃ F: 41.8 ℃	2 pm	A:45.5 ℃ F: 44.5 ℃

The data tabulated above indicates that there is a temperature differences for each of concentration of glycol gel and water mixture. The significant difference can be observed at the peak times of 1 p.m. where the Concentration 1 mixture that placed at point A recorded temperature of 37.4 ℃ compared with benchmark data temperature of 53.1˚ C. The differences recorded valued at 15.7˚C. While at point F, the difference of both benchmark and Concentration 1 temperatures are 10.7 ˚C.

Concentration 2 mixture recorded temperature of 44.1 ˚C at point A compared with 53.1 ˚C without the heat absorbent material. The temperature differences of 9 ℃ are recorded while at point F the value differ for 7.6 ˚C. The temperature of point F with heat absorbent material is 42.9 ˚C while without the material is 50.5 ˚C.

For the Concentration 3, the temperatures between the concentration and benchmark data show vague differences, where at point A the differences is 6.8 ˚C and point F is -0.3 ˚C. The heat absorption for Concentration 1 and Concentration 2 shown to perform well in reducing the temperature at front dashboard and rear dashboard with temperature ranging from 6.8 ˚C to 15.7 ˚C.

4.4 Result Analysis

After gathering all the data, the initial data is examined to fulfill the benchmarking criteria. The graph illustrates a rise in ambient temperature between 12 to 1 p.m.., causing an increase in the temperature inside the vehicle cabin as well. The maximum temperature at 12.30 p.m. for the Position A which is the front dashboard reached 58.1 ºC, while at 1 p.m., the Position F which is the rear dashboard recorded a peak temperature of 50.5 ºC.

This indicates that during the afternoon, the front dashboard experienced heightened temperatures due to the sun's impact on the front windshield. Conversely, as the evening approached and the car was parked, the rear dashboard heated up due to the heat amplification by the back window. The graph presented below showcases the temperature plotted against time, encompassing data from 10 a.m. to 3 p.m. This timeline is chosen because the temperature after 3 p.m. dropped rapidly due to change of weather.

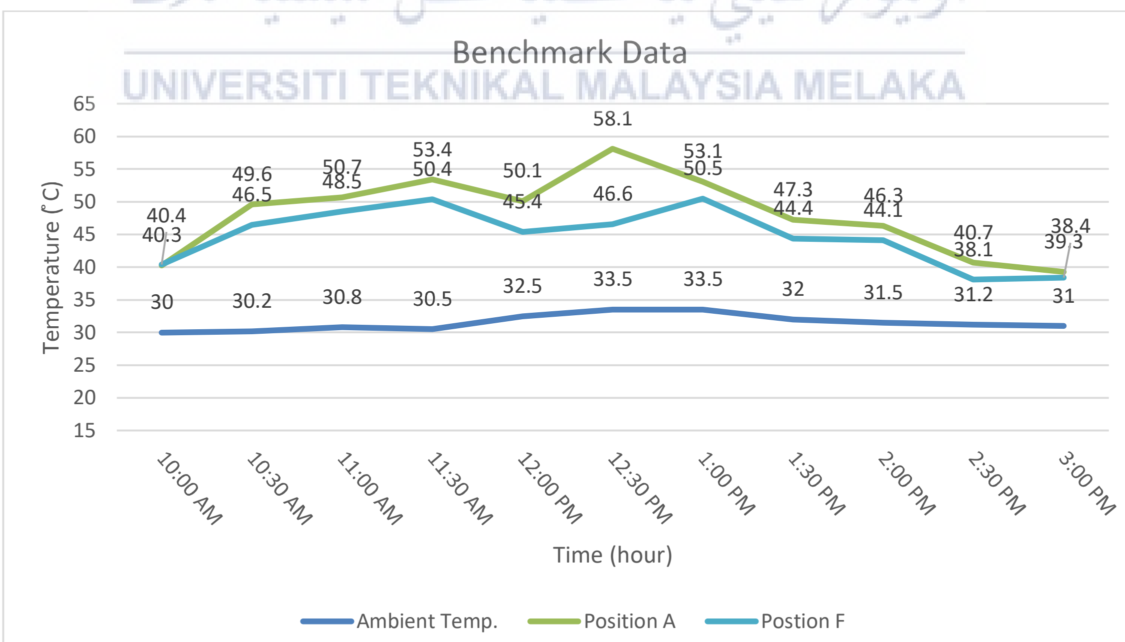


Figure 4.9 Vehicle Cabin Temperature vs Time Graph for Benchmark Data

4.4.1 Result Analysis for Concentration 1 (70% Water, 30% Glycol)

The graph below depicts the data collected for temperature at Position A and Position F compared with ambient temperature, benchmark temperature of Position A and Position F. The heat absorbent material of Concentration 1 performs it roles to absorb the heat surrounding the area of each positions. The actual temperature shown contrast difference from the benchmark temperature, proven the effectiveness of Concentration 1 in abated the surplus heat in vehicle cabin.

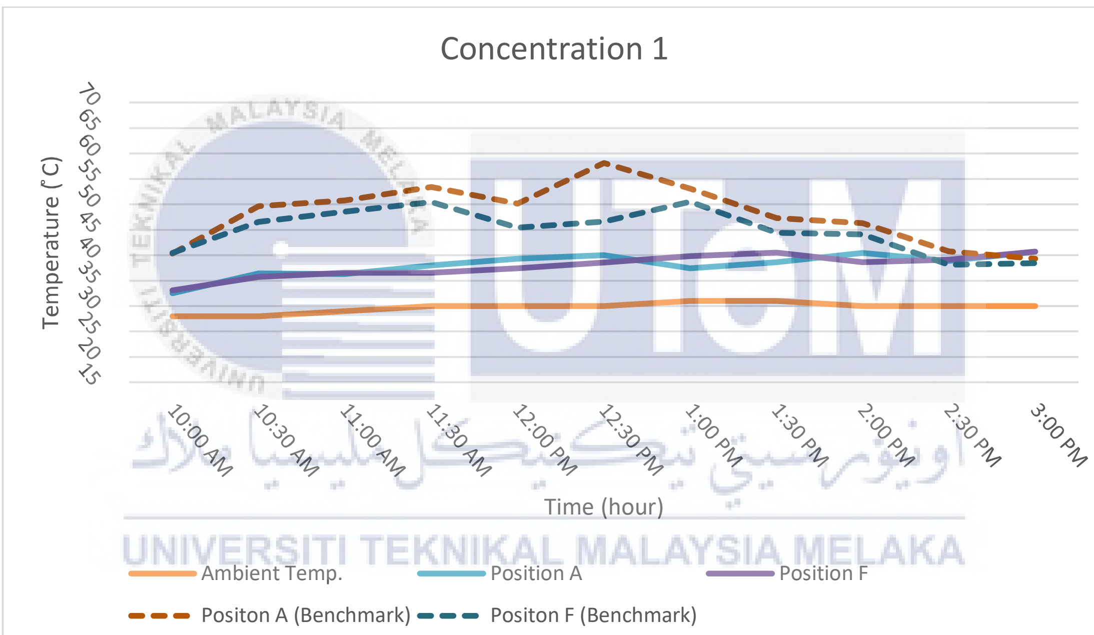


Figure 4.10 Cabin Temperature vs Time with Comparison Between Benchmark and Concentration 1

Position A, front dashboard thermocouple sensor is represented in light blue line and Position F, rear dashboard or speaker board sensor is represented in purple line. In relation to graph on Figure 4.7, position A experience lower heat loss than position F. This is caused by the position of the car parking facing West where the Sun will rise from East thus the sun shine to the rear windscreen in the morning. However, between 1 p.m. to 2 p.m., the differences of temperature affected by heat absorbing material Concentration 1 effectively enhancing passenger comforts in car cabin by decreasing the excessive heat. Specifially, at 12.30 p.m., the heat percentage different from position A is 31.15% while at position F at 1.30 p.m. is 8.78%.

4.4.2 Result Analysis for Concentration 2 (50% Water, 50% Glycol)

The graph displays temperature data for Position A and Position F in comparison to both ambient temperature and benchmark temperature at those positions. Concentration 2 of the heat-absorbent material effectively functions to absorb heat around these areas. The observed temperature slight differences with the benchmark, showcasing how Concentration 2 somewhat effectively mitigates excess heat within the vehicle cabin.

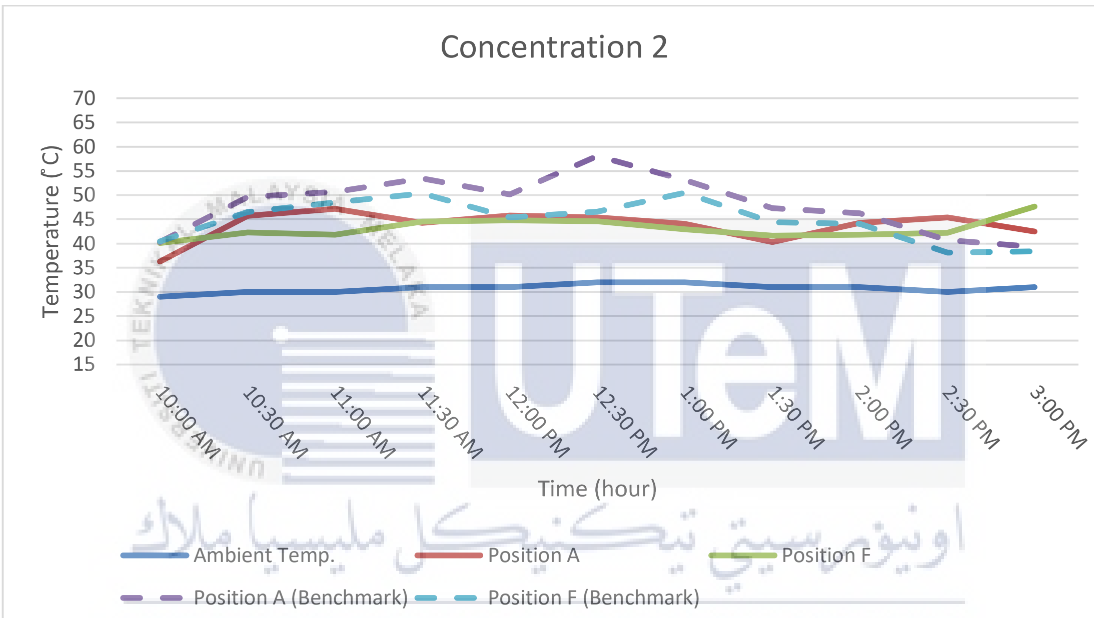


Figure 4.11 Cabin Temperature vs Time with Comparison Between Benchmark and Concentration 2

The temperature readings from the front dashboard sensor (Position A, red line) and the rear dashboard sensor (Position F, green line) indicate that Position A average experiences lower heat loss compared to Position F. This is due to the car's parking orientation, facing West, allowing morning sunlight to shine on the rear windscreen. However, between 12 p.m. and 1 p.m., the impact of Concentration 2 of the heat-absorbing material becomes evident, enhancing passenger comfort by effectively reducing excessive heat within the car cabin. Specifically, at 12:30 p.m., the heat percentage difference from Position A is 21.86%, while 30 minutes later at Position F, it registers at 15.05%.

4.4.3 Result Analysis for Concentration 3 (30% Water, 70% Glycol)

The graph presents temperature data for Position A and Position F, comparing it against both ambient temperature and benchmark temperatures at these specific locations. Concentration 3 of the heat-absorbent material demonstrates little effective heat absorption in these areas. The observed temperatures diverge from the benchmark figures, indicating Concentration 3's poorly manage excess heat within the vehicle cabin.

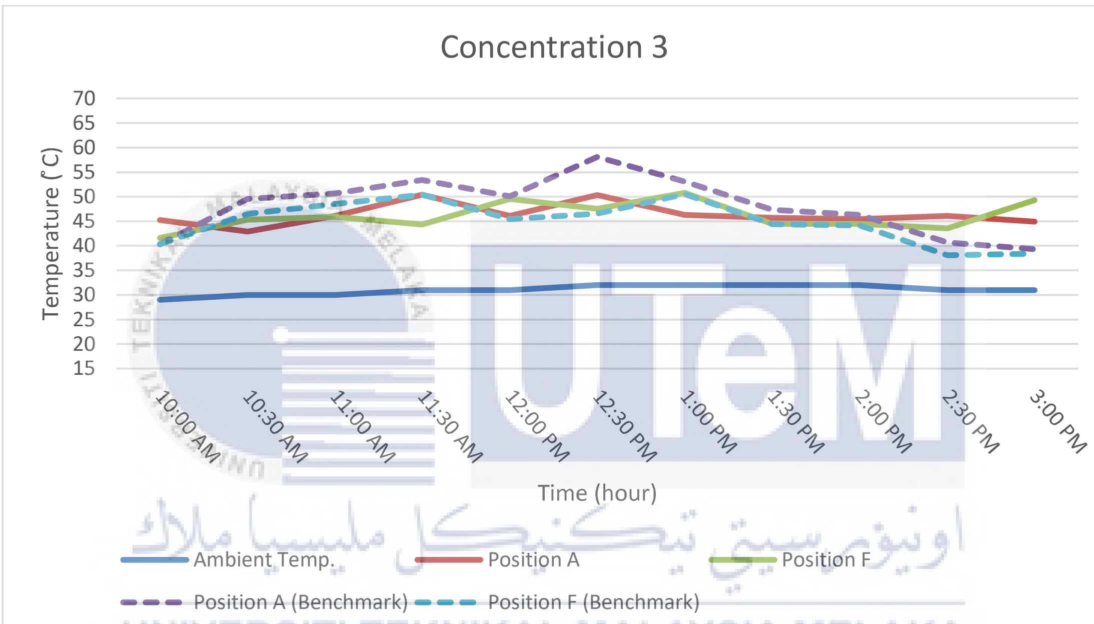


Figure 4.12 Cabin Temperature vs Time with Comparison Between Benchmark and Concentration 3

The temperature analysis of sensors placed at the front (Position A, red line) and rear (Position F, green line) dashboards reveals that Position A consistently records similar heat loss compared to Position F. However, between noon and 1.30 p.m., Concentration 3 of the heat-absorbing material slightly impacts passenger comfort by mitigating excessive heat within the car cabin. Specifically, at 12:30 p.m., the heat percentage difference between Position A and Position F is 13.43%, with Position F experiencing a slightly lower heat different percentage of 0.22% at 1.30 p.m.

4.4.4 Comparison of Concentration 1, 2 and 3

The positioning of different concentrations of heat absorbent material in both position A and F, respectively the front dashboard and rear speaker board areas demonstrates a significant reduction in heat. This highlights the efficacy of this strategy. The various concentrations of the heat absorbent material, comprising a glycol gel and water mixture, plays a pivotal role.

The ratio for Concentration 1 which composed of 70% water and 30% glycol gel, which is 490 ml water and 210 ml glycol respectively, packed in a 700 ml capacity microwave safe container. For Concentration 2 which made of half of water and glycol gel have equal volume of 350 ml. While Concentration 3 have the highest volume of glycol gel with 70% (490 ml) and 30% (210 ml) of water. These different type of concentrations give various result in showcasing enhanced heat absorption capabilities.

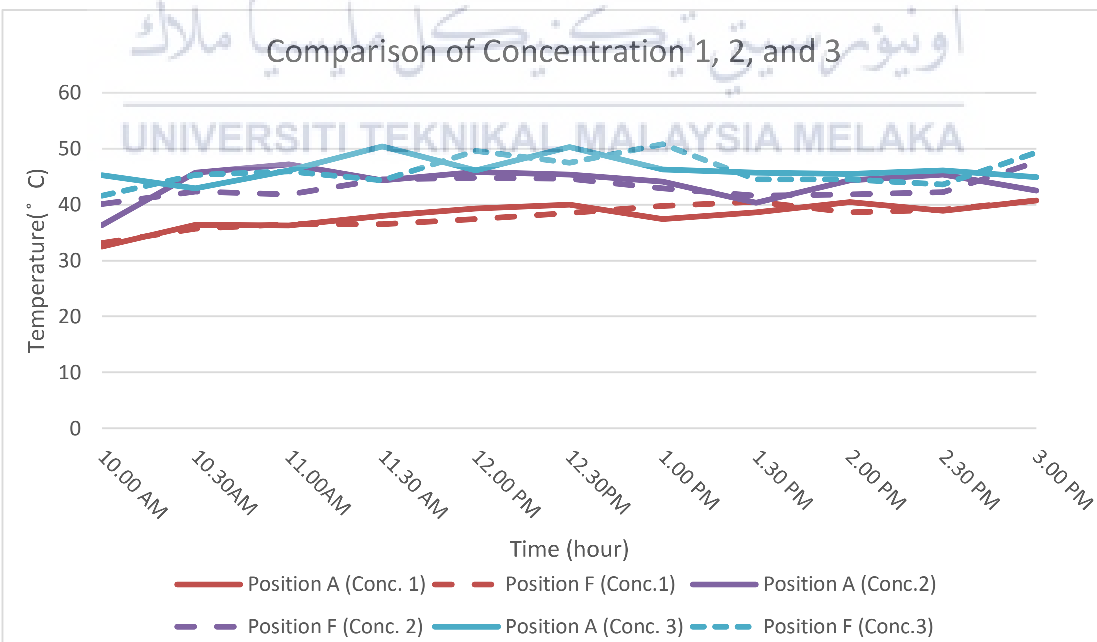


Figure 4.13 Comparison of Concentration 1,2 and 3 for Position A (Front Dashboard) and F (Rear Dashboard)

The comparison for three type of concentrations are present on Figure 4.11 above. From the graph, the Concentration 1 which represented using orange line for both Position A and F compared to Concentration 2 (purple line) and Concentration 3 (blue line). The heat absorption rate for these concentrations shown vague differences from each other.

From all of the result presented, Concentration 1 demonstrates the better heat absorption capabilities than other concentrations for front dashboard. However, the concentration with stable heat absorption capabilities for both front and rear dashboard is Concentration 2. The percentage of temperature differences between Concentration 2 and benchmark shows significant yet consistent heat absorption. Concentration 3 conversely display a poor result compared with other two concentrations. The percentage difference for rear dashboard (Position F) with benchmark have little impact on reducing heat inside the car cabin.

Concentration 1 with 70% of water content mixed with glycol gel absorb heat more effectively. The amount of water content for this glycol gel-water mixture affected the heat absorption efficiency as water content in PEG polymer glycol gel have direct bearing to thermal energy or heat storage density. Water is known for it heat capacity ability without undergoing rapid increase in temperature.(Kusmono et al., 2020) Although the water content in the mixture decreased from vaporization however the heat absorbent capabilities of the glycol gel is unaffected. This properties allow the heat absorbent material to perform its role in absorbing and reducing heat accumulated inside the vehicle cabin. (Deng & Yang, 2017)

The varying concentration levels of glycol yield different effects due to its inherent cooling properties that resist high boiling temperatures and effectively absorb surrounding heat. Furthermore, the microwaveable container apart from withstanding high heat, it functions as a permeable membrane facilitating heat transfer into the absorbent material. The container aluminium lid have larger surface area correlates with its improved ability to absorb ambient or excess heat, thereby enhancing the comfort level within the passenger car cabin for passengers.(Zulkhairi Iskandar, 2023)

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

Upon the project's conclusion, preliminary findings reveal an intriguing correlation between our accumulated research insights and the outcomes of our experimental study. A key revelation stems from the examination of certain scholarly journals, indicating that the front dashboard and rear dashboard endure the highest temperature levels, primarily due to the wide surface area of the Front Windshield and Rear Window, surpassing that of other windows in the vehicle. The confined car cabin experiences significant heating, especially when exposed to direct sunlight in an open setting, triggering the heat transfer of convection, conduction, and radiation forces.

From all the collected data analysis, barring any weather-related anomalies, the performance of the Heat Absorbent Material Concentration 1 is fulfilled well according to our devised plan. This concentration efficiently reduces the accumulation of excessive heat within the car cabin, substantially amplifying the comfort level experienced upon entering the vehicle. As a result, the meticulous examination of heat differential based on our benchmark data serves as compelling evidence affirming the membrane is suitable as a heat conductor.

Moving forward, the forthcoming phase of integration with HVAC systems aims at achieving the utmost efficacy of the heat absorbent material. This recommendation seeks to enhance the material's capacity to regulate heat dynamics within the vehicle cabin more comprehensively and smoothly.

5.2 Recommendation

Integrating the heat absorbent material with ventilation systems involving merging these materials with the vehicle's existing Heating, Ventilation and Air Conditioning (HVAC) infrastructure to optimize the thermal comfort within the car cabin. One of the suggestion is to embedding the heat absorbent material, which is the glycol gel and water mixture within the components of HVAC system. For example, the heat absorbent material can be integrate within the air ducts, vents, or air filter. The material can intercept and absorb the heat air passed through these channels before released to cabin.

To improve airflow patterns within the cabin and help absorb heat more efficiently, the heat-absorbing material can be redesigned in a more practical and compact manner. This can be accomplished by arranging the material in a way that minimizes heat retention and encourages more even air circulation. The suggestion to apply the heat absorbent material is on heat exchangers in the system.

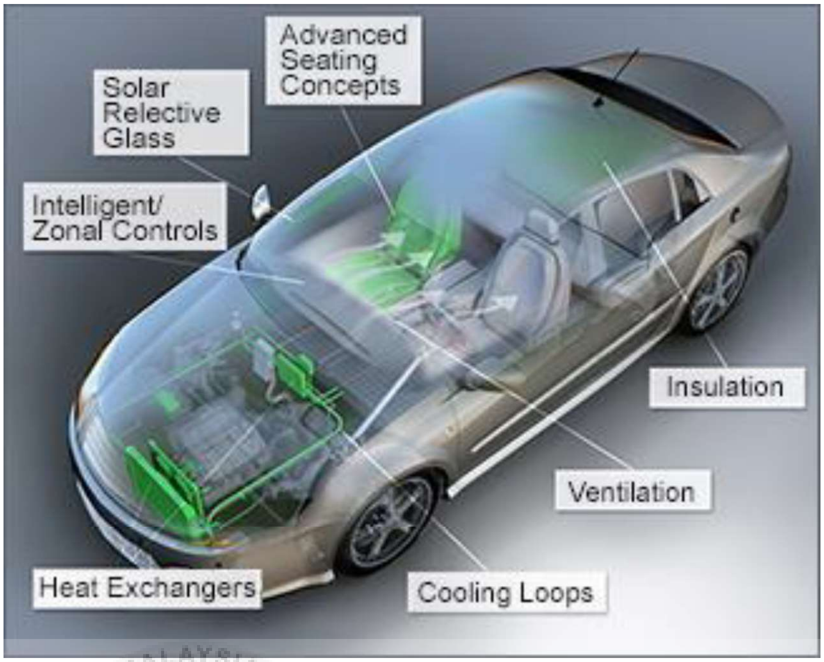


Figure 5.1 Suggestion to Reduce Heat Accumulated in Vehicle Cabin (Lustbader, 2020)

This recommendation can be implemented on future vehicle especially on hot tropical countries. It is more functional and complement the vehicle interior design than designing different casing or container to put the heat absorbent material mixture. Other than that, it can also be produced as template by automotive manufacturers to offer potential buyers an optional feature aimed at enhancing their comfort.

REFERENCES

Al-Kayiem, H. H., Sidik, M. F. B. M., & Munusammy, Y. R. A. L. (2010). Study on the thermal accumulation and distribution inside a parked car cabin. *American Journal of Applied Sciences*, *7*(6), 784–789. https://doi.org/10.3844/ajassp.2010.784.789

All Things Tint; All Things Tint. (2013). *What exactly is Window Film?* https://solarshieldmn.wordpress.com/2013/10/14/what-exactly-is-window-film/

Bobba, S., Leman, Z., Zainuddin, E. S., & Sapuan, S. M. (2019). Study of interior temperature distribution and implementation of smart materials in the truck cabin during summer conditions. *Materials Today: Proceedings*, *18*, 361–374. https://doi.org/10.1016/j.matpr.2019.06.313

Britannica, T. E. of E. (2023). *convection. Encyclopedia Britannica*. Britannica. https://www.britannica.com/science/convection

Condro, B. (2019). Automotive Experiences. *Automotive Experiences*, *2*(2), 41–46.

Deng, Y., & Yang, L. (2017). Preparation and characterization of polyethylene glycol (PEG) hydrogel as shape-stabilized phase change material. *Applied Thermal Engineering*, *114*, 1014–1017. https://doi.org/10.1016/j.applthermaleng.2016.11.207

F.M., N. (2014). *methods in reducing car cabin interior Experimental Comparison Study of the Passive Methods in Reducing Car Cabin Interior Temperature*. *September*, 1–6.

formosam. (2019). *Clear Film | 포모사엠 - Formosa M. 포모사엠 - Formosa M.* https://www.formosam.com/en/clear-film/?ckattempt=1

fqemo creative. (2014). *Perodua Kancil. Behance.* https://www.behance.net/gallery/19996255/Perodua-Kancil

Grant, B., Sauzier, G., & Lewis, S. W. (2020). Discrimination of automotive window tint using ATR-FTIR spectroscopy and chemometrics. *Forensic Science International*, *313*, 110338. https://doi.org/10.1016/j.forsciint.2020.110338

Idris, S. N., & Othman, S. A. (2022). The Application of Natural Dye on Tinted Vehicle Films - A Review. *Journal of Physics: Conference Series*, *2169*(1), 0–5. https://doi.org/10.1088/1742-6596/2169/1/012005

Isa, M. H., Musa, M., Rahman, M. K., Ariffin, A. H., Hamzah, A., Solah, S., Soid, N. F., Ilyas, R., Voon, W. S., & Malaysian Institute of Road Safety, R. (2015). *A study on automotive tint glazing in Malaysia* (Issue MRR 159). https://www.miros.gov.my/1/publications.php?id_page=19%0Ahttps://trid.trb.org/view/1401566

Kusmono, Hestiawan, H., & Jamasri. (2020). The water absorption, mechanical and thermal properties of chemically treated woven fan palm reinforced polyester composites. *Journal of Materials Research and Technology*, *9*(3), 4410–4420. https://doi.org/10.1016/j.jmrt.2020.02.065

Lustbader, J. (2020). Ford AZTECS Vehicle - Thermal Testing: Cooperative Research and Development Final Report. *U.S Department of Energy, National Renewable Energy Laboratory*, *June*. www.nrel.gov/publications.

Mahat, R., Najat, W., Azman, W., Mahyuddin, A., Kassim, R., & Darul Takzim, J. (2016). Review on Convection Heat Transfer Using Porous Media. *Malaysian Journal of Industrial Technology*, *1*(1), 25–30.

Marshall, G. J., Mahony, C. P., Rhodes, M. J., Daniewicz, S. R., Tsolas, N., & Thompson, S. M. (2019). Thermal Management of Vehicle Cabins, External Surfaces, and Onboard Electronics: An Overview. *Engineering*, *5*(5), 954–969. https://doi.org/10.1016/j.eng.2019.02.009

Melaka Climate By Month | A Year-Round Guide. World Weather & Climate Information. (2023). Weather and Climate. https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,melaka,Malaysia

Mohammed, I., Aljubury, A., Farhan, A. A., & Mussa, A. (2015). Experimental Study of Interior Temperature Distribution Inside Parked Automobile Cabin. *Journal of Engineering*, *21*(3).

Murray, B. P., & Zaghloul, A. I. (2013). Shielding effectiveness of tinted automotive films. *IEEE Antennas and Propagation Society, AP-S International Symposium (Digest)*, *June*, 1144–1145. https://doi.org/10.1109/APS.2013.6711232

Qi, C., Helian, Y., Liu, J., & Zhang, L. (2017). Experiment Study on the Thermal Comfort inside a Car Passenger Compartment. *Procedia Engineering*, *205*, 3607–3614. https://doi.org/10.1016/j.proeng.2017.10.211

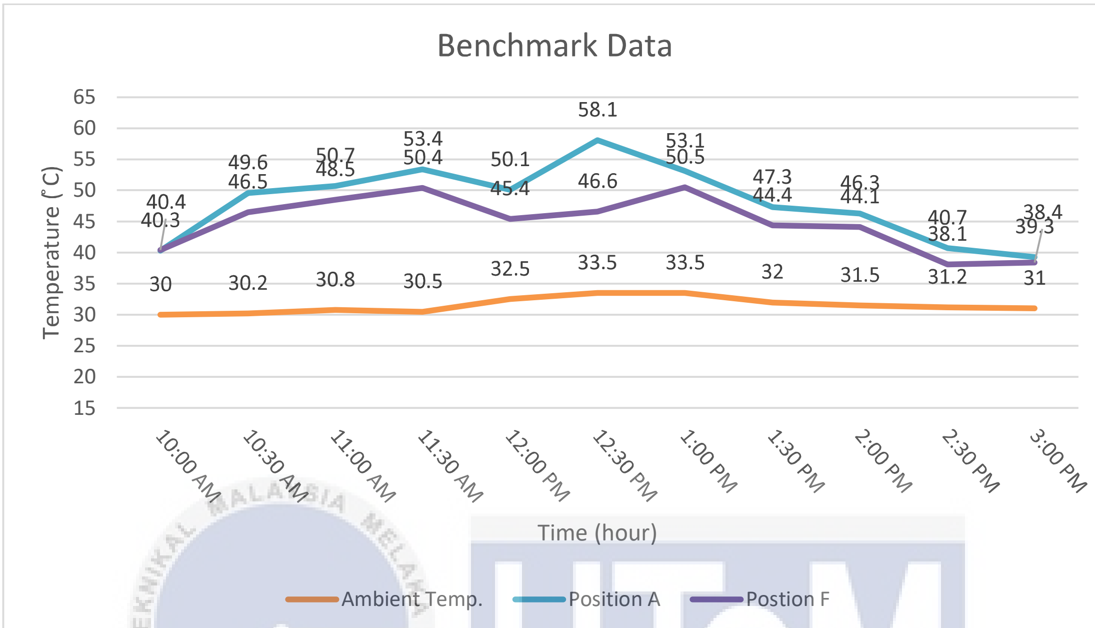
Sadali., I. (2016). *puspakom-cermin-gelap-850×534. Paul Tan's Automotive News.* https://paultan.org/2016/01/15/puspakom-tawar-25-peringkat-pemeriksaan-kenderaan-persendirian-sukarela-secara-percuma-sempena-cny/puspakom-cermin-gelap-850x534/

Shafie, H. (2023). *Experimental Study The Heating Effect Of Small Passenger Car Cabin Parking At Open Place Area By Using Tinted, Sunshade And Natural Airflow*.

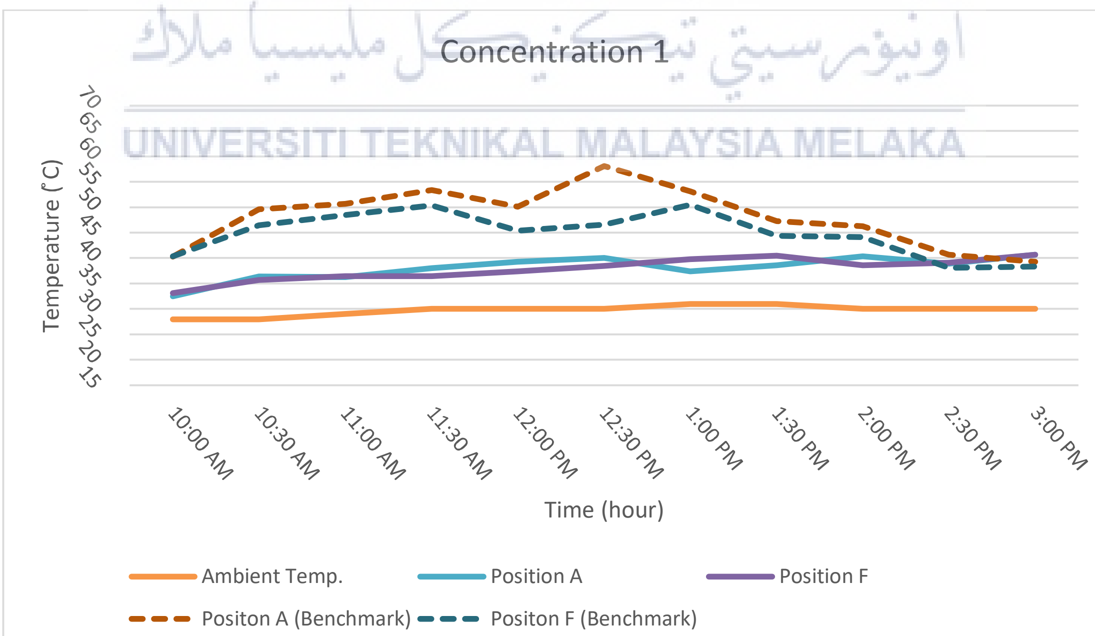
Xu, X., Li, G., Zhao, Y., & Liu, T. (2023). Analytical solutions for heat conduction problems with three kinds of periodic boundary conditions and their applications. *Applied Mathematics and Computation*, *442*. https://doi.org/10.1016/j.amc.2022.127735

Zulkhairi Iskandar, Z. (2023). Experimental Study On Thermal Effect Using New Abrsorbent Material In Passenger Compartment. *Experimental Study On Thermal Effect Using New Abrsorbent Material In Passenger Compartment*, *4*(1), 88–100.

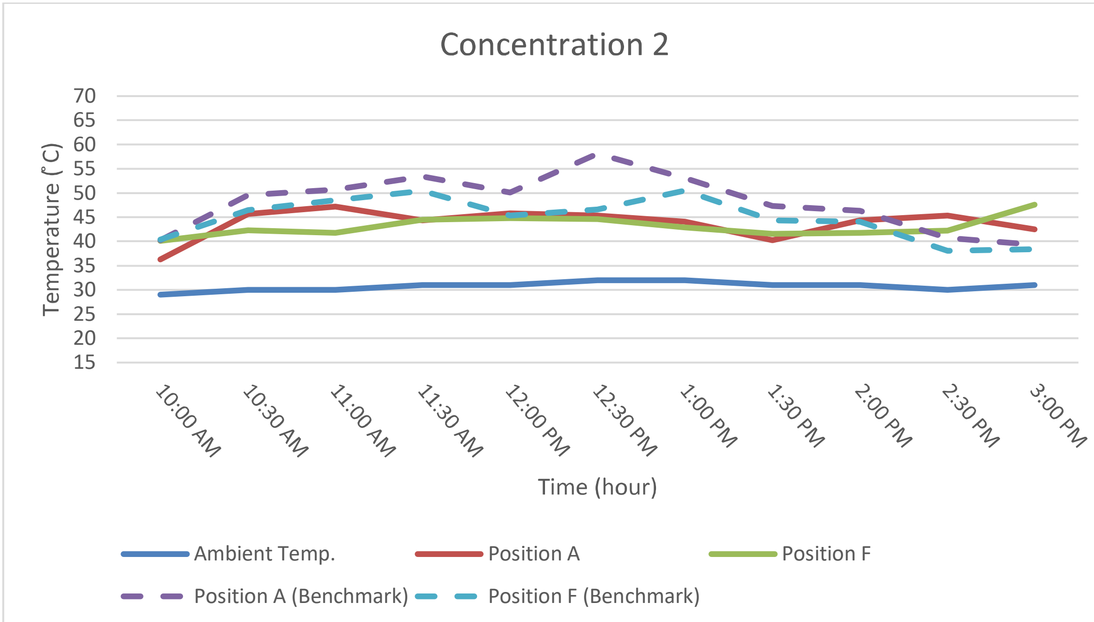
APPENDICES



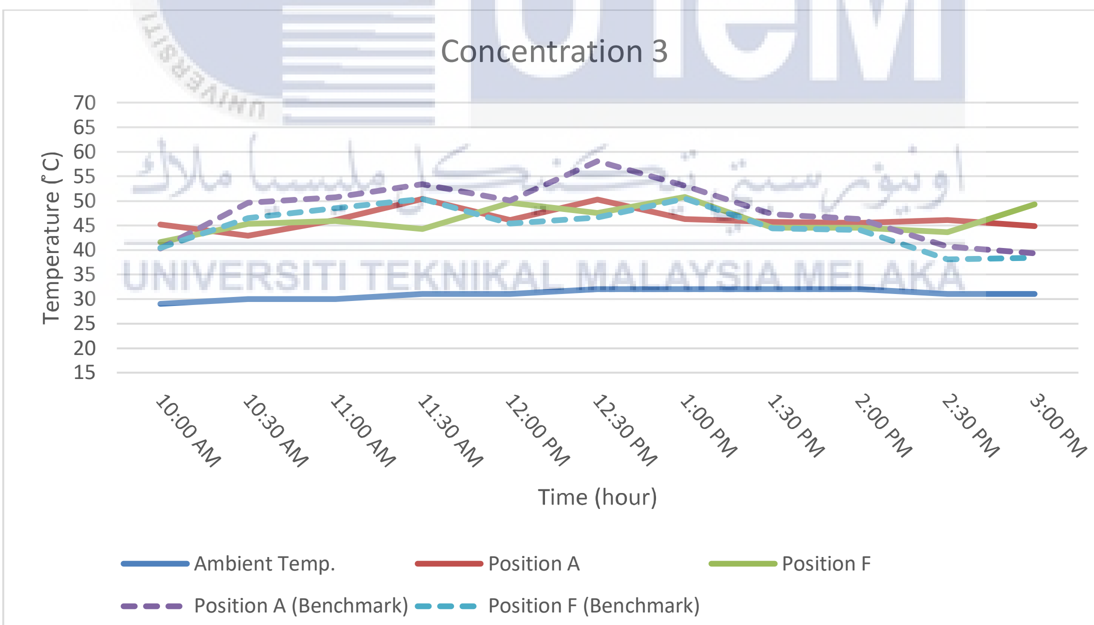
APPENDIX 1 Graph of Benchmark Data



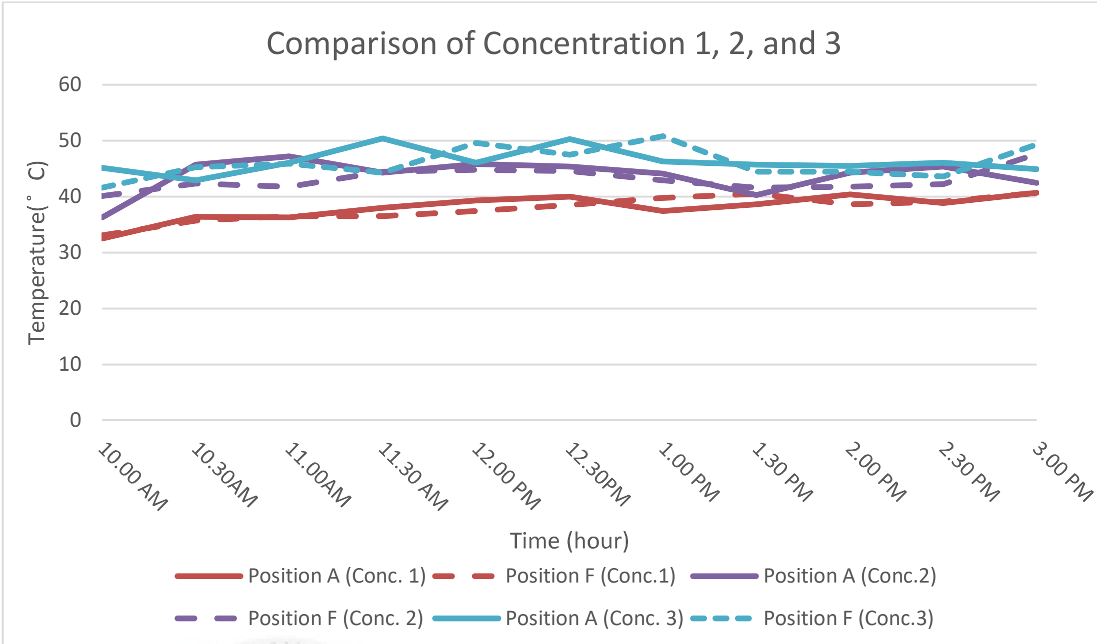
APPENDIX 2 Graph of Concentration 1 Data



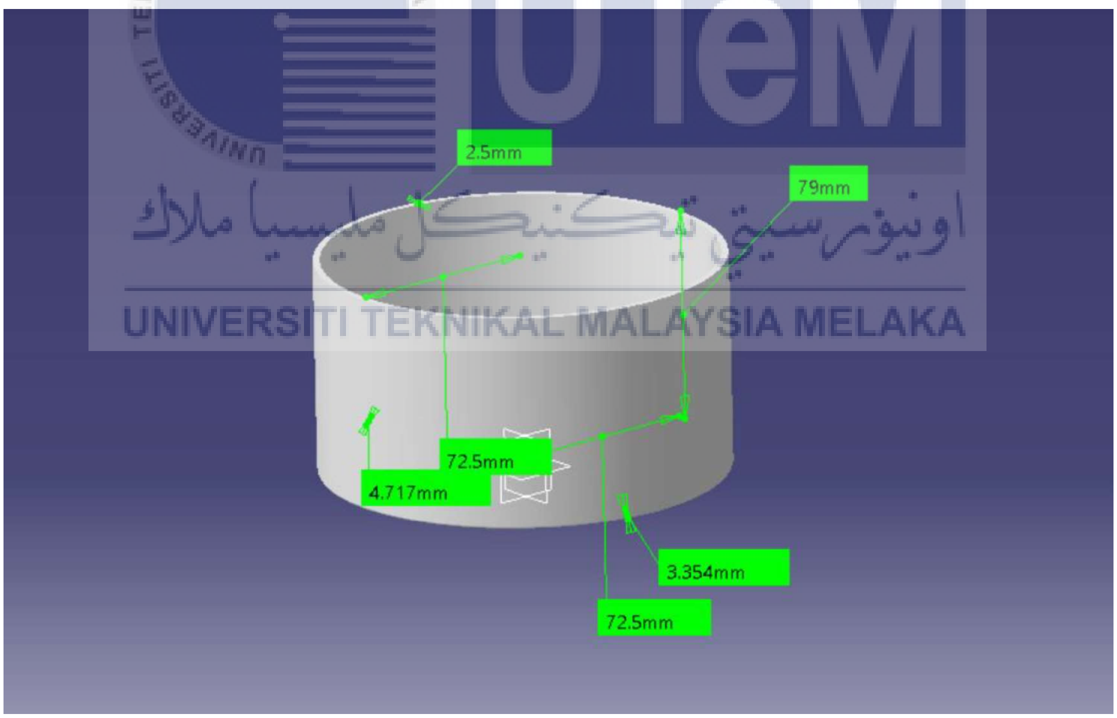
APPENDIX 3 Graph of Concentration 2 Data



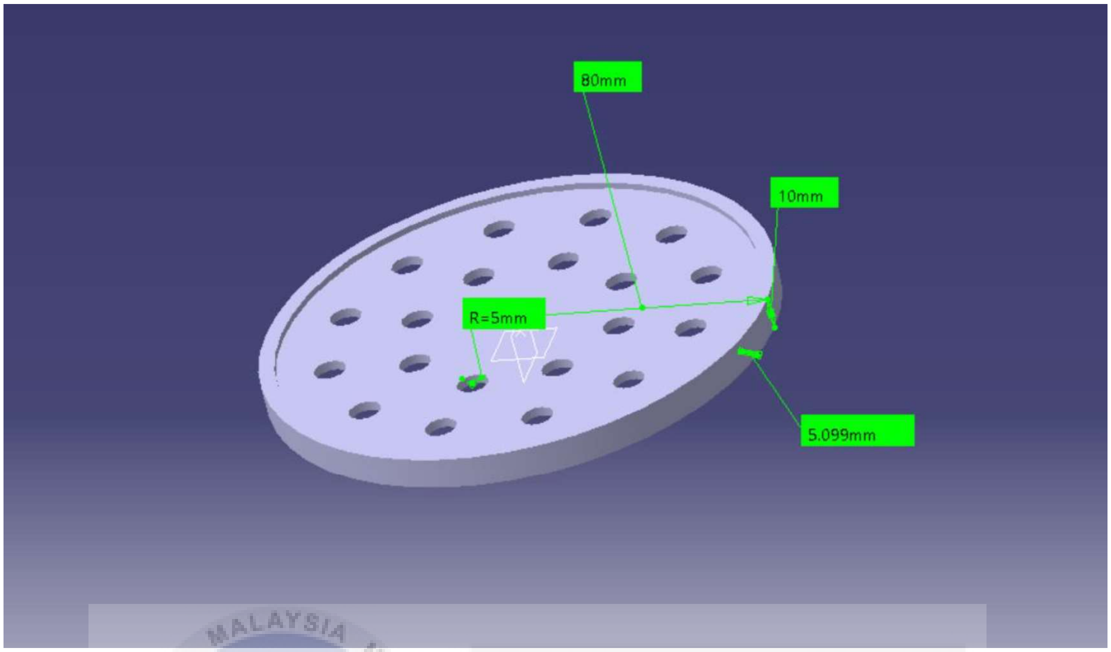
APPENDIX 4 Graph of Concentration 3 Data



APPENDIX 5 Graph of Comparison Data Concentration 1,2 and 3



APPENDIX 6 Dimension of Container Body for Prototype Design A



APPENDIX 7 Dimension of Container Lid for Prototype Design A

APPENDIX 8 Gantt Chart for PSM 1 and PSM 2

Gantt Chart for PSM 1

No	**Activities**	**Academic Week(s)**													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Confirming PSM Title														
2	Preparing Front Page, Abstract and Introduction														
3	Literature Review (Chapter 2)														
4	Preminilary Result														
5	Methodology														
6	Calibration of Tools (Thermometer)														
7	Report Writing														
8	Presentation of Progress for PSM 1														
9	Submission of Report														

Gantt Chart for PSM 2

No	**Activities**	**Academic Week(s)**													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Research Study														
2	Data Collection (Benchmark Data)														
3	Equipment Calibration														
4	Cabin Temperature Data Collection														
5	Result Verification														
6	Result and Analysis														
7	Final Report Writing														
8	Presentation of PSM 2														
9	Submission of Report														

PSM_2_RAUDAH

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

PAGE 28

PAGE 29

PAGE 30

PAGE 31

PAGE 32

PAGE 33

PAGE 34

PAGE 35

PAGE 36

PAGE 37

PAGE 38

PAGE 39

PAGE 40

PAGE 41

PAGE 42

PAGE 43

PAGE 44

PAGE 45

PAGE 46

PAGE 47

PAGE 48

PAGE 49

PAGE 50

PAGE 51

PAGE 52

PAGE 53

PAGE 54

PAGE 55

PAGE 56

PAGE 57

PAGE 58

PAGE 59

PAGE 60

PAGE 61

PAGE 62

PAGE 63

PAGE 64

PAGE 65

PAGE 66

PAGE 67

PAGE 68

PAGE 69

PAGE 70

PAGE 71

PAGE 72

PAGE 73

PAGE 74

PAGE 75

PAGE 76

PAGE 77

PAGE 78

PAGE 79

PAGE 80

PAGE 81

PAGE 82

PAGE 83

PAGE 84

PAGE 85

PAGE 86

PAGE 87

PAGE 88

PAGE 89

PAGE 90

PAGE 91

PAGE 92

PAGE 93

PAGE 94

PAGE 95

PAGE 96

PAGE 97

PAGE 98