# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## DESIGN, INSTALL AND MONITOR OF HYDRONIC RADIANT COOLING SYSTEM IN AN ENCLOSED CAR

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) (Hons.)

by

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FACULTY OF ENGINEERING TECHNOLOGY
2015

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TAJUK: Design, Install and Monitor of Hydronic Radiant Cooling System in an Enclosed Car

SESI PENGAJIAN: **2015/2016 Semester 1**

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# APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Refrigeration and Air-Conditioning System) (Hons.). The member of the supervisory is as follow:

…….

(Dr. Ahmed Salem Saeed bin Ghooth)



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# ABSTRACT

Maintaining a good thermal comfort is an important issue for human being. Discomfort feeling will happen if the temperature is too hot or too cold. Nowadays, moving from one place to another by using car as the mode of transportation is human daily basis. When the car that is parked under direct sunlight, the heat from the sunlight is trapped inside the car. The situation happens when the solar radiation passes through the glass but cannot escape from it and trapped inside the car. The high temperature that is trapped inside the car could cause discomfort when the driver or passenger enters the car. Besides that, the damage of the car cabinet is also affected by the high temperature. The purpose of this study is to design, monitor and install hydronic radiant cooling system, which can be relied on to remove the excessive heat trapped inside the car interior by the method of convection heat transfer. The design is based on the temperature inside the car that is measured using thermocouples. The temperature inside the car interior with completely closed ventilations could increase up to $60.85^{0}$C. Experimental work is carried to compare the temperature before and after the installation and implementation of the hydronic radiant cooling system. An average reduction of 11.48 $^{0}$C is recorded after hydronic radiant cooling system is installed. The additional benefit other than to provide comfort, the installation of the system inside the car when it is parked under the direct sun light could also to avoid damage of the car cabinet, especially the rubber parts. This can lead to a better indoor air quality inside the car as trapped heat could cause the emission of the volatile organic compound gases from the car cabinet.



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# ABSTRAK

Mengekalkan suhu yang selesa adalah perkara yang amat penting bagi manusia. Perasaan tidak selesa akan timbul apabila suhu menjadi terlalu panas atau terlalu sejuk. Di zaman kini, penggunaan kereta sebagai medium pengangkutan yang utama untuk bergerak dari suatu tempat ke suatu tempat yang lain telah menjadi kebiasaan dalam kehidupan manusia. Kereta yang diletakkan di bawah sinaran cahaya matahari secara terus akan menyebabkan haba dari sinaran tersebut terkumpul di dalam kereta. Perkara ini terlaku adalah disebabkan sinaran cahaya matahari menembusi cermin tingkat, namun sebahagiannya tidak berjaya dilepaskan semula ke persekitaran dan terperangkap di dalam kereta. Tujuan kajian ini dijalankan adalah untuk merekabentuk, membuat pemerhatian dan memasang sistem penyejukan hidronik, yang mana boleh digunakan untuk menyingkirkan lebihan haba yang terperangkap di dalam kereta menggunakan kaedah pemindahan haba secara perolakan. Reka bentuk sistem ini adalah berdasarkan nilai suhu yang terperangkap yang diukur menggunakan termogandingan suhu. Berdasarkan pemerhatian, suhu di dalam kereta yang tertutup boleh meningkat dan mencapai $60.85^{0}$C. Kerja eksperimen telah dijalankan bagi melihat perbezaan suhu sebelum dan selepas sistem penyejukan hidronik ini dipasang. Secara purata, nilai suhu yang dapat dikurangkan di dalam kereta setelah system peyejukan hidronik dipasang adalah 11.48 $^{0}$C. selain daripada memberi suhu yang selesa, pemasangan system penyejukan hidronik ini juga mempu melindungi komponen-komponen di dalam kereta daripada rosak, terutamanya komponen yang diperbuat daripada getah. Hal ini juga mampu mengelakkan daripada perlepasan gas berbahaya daripada sebatian organic yang meruap daripada komponen-komponen kereta.



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# DEDICATIONS

To my beloved parents, I acknowledge my sincere indebtedness and gratitude to them for their love, dream and sacrifice throughout my life. I am really thankful for their sacrifice, patience, and understanding that were inevitable to make this work possible. Their sacrifice had inspired me from the day I learned how to read and write until what I have become now. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to achieve my dreams Lastly, I would like to send my gratitude to any person that contributes to my final year project whether it is directly or indirectly. I would like to acknowledge their comments and suggestions, which are crucial for the successful completion of this study


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# ACKNOWLEDGMENTS

First and foremost, all praise to Allah the Almighty for giving me the strength, health, knowledge and patience to successfully complete this Finale Year Project report in the given time. I have to thank my parents for their love and support throughout my life. Thank you for giving me strength to climb the stairs and walking towards the paths of life. I would like to address my deepest appreciation to the supervisor, Dr Ahmed Salem Saeed Bin Gooth for his encouragement, comments, guidance and enthusiasm through the time developing the report. Special thanks to the friends that have been through thick and thin throughout the completion of this project. This project report might be impossible to complete without all of your help. Last but not least, thank you to everyone that directly and indirectly involved in helping me finishing this Finale Year Project report. Thank you.



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# LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| HRC | - | Hydronic Radiant Cooling |
| HVAC | - | Heating, Ventilating and Air-conditioning |
| PV | - | Photovoltaic |
| A | - | Area |
| $C_v$ | - | Specific heat capacity with constant volume |
| E | - | Sun Total Power |
| g | - | Gravity |
| h | - | Height |
| m | - | Mass |
| $\dot{m}$ | - | Mass Flow Rate |
| P | - | Pressure |
| $\Delta P$ | - | Difference in Pressure |
| $\dot{Q}$ | - | The amount of heat / heat radiation |
| R | - | Radius |
| S | - | Irradiance |
| T | - | Temperature |
| $\Delta T$ | - | Difference in temperature |
| $\dot{V}$ | - | Volume Flow Rate |
| W | - | Weight |
| $\varepsilon$ | - | Emmissivity |
| $\sigma$ | - | Stefan BoltzmannConstant |
| $\pi$ | - | Ratio of Circle Circumference to the Diameter |


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# CHAPTER 1
# INTRODUCTION

## 1.0 Introduction

In this chapter, introduction of the most important topics that involve background, problems statement, objectives, scope of the project are provided and the thesis organization of the overall chapters is provided within the same chapter.

## 1.1 Background of Research

The background of the study describes the most important subtopics such as air-conditioning system, hydronic radiant cooling system, thermal comfort, heat transfer, Stefan Boltzmann Law and photovoltaic cells.

### 1.1.1 Air-conditioning System

Generally, the purpose of air-conditioning system is to maintain the indoor air quality and to provide thermal comfort inside the conditioned space. Maintaining a good IAQ is a very important measure to prevent the spreading of diseases throughout a building. Besides that, air-conditioning provides thermal comfort to conditioned space to the occupants. Generally, the application of air-conditioning system in daily life makes residences or occupants to be more comfortable especially in a warm climate country like in Malaysia.

Commonly, air-conditioning system can be divided into two categories, which are unitary refrigerant system, and the other one is centralised system (Norain, 2014). Both of these systems are known as conventional air-conditioning system, which depending on the vapour compression cycle. In the other means, if the area to be cooled



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is larger, the energy consumption will be higher as the compressor has to be worked more to overcome the heat. However, conventional air-conditioning system is not fit for the economic due to high energy intensive and takes about 60% of overall electrical consumption.

### 1.1.2 Hydronic Radiant Cooling System

Due to the high energy intensive as the main disadvantage, a system which is an alternative to the current system that is more practical and environment-friendly is created. Created new system provides thermal comfort environment rather than the conventional air-conditioning system, and with lower energy consumption. The new system is called Hydronic Radiant Cooling (HRC) system which can be built in the line with the modern technology that typically uses chilled water as the transport medium. The Hydronic Radiant Cooling (HRC) system does not require a compressor, but need a circulation pump instead (Olesen & Bjarne, 2008)

### 1.1.3 Thermal Comfort

Human beings are always looking for their own comfort. Comfort is a feeling of human body with its tendency to accept the thermal surroundings. According to ASHRAE (Standard 55), thermal comfort can be determined by the thermal sensational scale. This scale is an important index to determine the hotness or coldness of a conditioned space. Besides that, thermal comfort is a vital as thermal comfort has become a worldwide issue that is closely related to everyday life.

### 1.1.4 Heat Transfer

Heat transfer process is the most important approach that is more focused on the current experiments. The hydronic radiant cooling system used to transfer the heat generation inside the car to the circulated chilled water. The transfer can be defined as the exchange of thermal energy between physical system that depends on the temperature and pressure. Commonly there are three modes of heat transfer. The



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modes are conduction, convection and radiation. In hydronic radiant cooling system, convection and radiation are the associated heat transfer modes. This is because the exchange of heat occurs between the warm air indoors and the circulated chilled water in the copper tubes.

### 1.1.5 Stefan Boltzmann Law

Stefan Boltzmann law is the formula used to calculate the heat energy. The heat is radiated from the blackbody depends on its temperature. Due to the different of the temperatures, Stefan Boltzmann constant can be used to calculate the energy radiated form a body.

### 1.1.6 Photovoltaic

Photovoltaic cell is a device used to convert solar energy into direct current electricity by using semi-conductor properties. It is a renewable, environment-friendly, and has a free flow of electricity, thus it is a better preference of energy.

## 1.2 Problem Statement

As a daily basis associated with a human being, they need to travel from one place to another. Generally, car is the most and available option used of transportation. Travelling by car protects human from exposure to the sun effect by the meaning of heat (solar energy), and getting wet by the rain. In Malaysia, due to the common usage of the car, the car park needed to be built at an open area due to the insufficient car parking in the building. Hence, Malaysians cannot avoid parking their cars in an open space, at middle of a sunny day, and at the peak of the sun hour. As the car parked under direct sunlight with closed windows, the heat emitted by the enclosure is trapped, and the trapped heat causes a significant increase in temperature due to the greenhouse effect. The increase in the temperature may damage the interior cabinet of the car, causing some discomfort for the passengers, and thus passengers are not able to take a seat on the hot seat. Volatile organic compound (VOC) gas can be emitted



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from plastics material, and the extreme exposure to the gas can lead to death. Besides that, extensive energy is required to overcome the heat inside the car when turning on the conventional air-conditioning system. Thus, to overcome the excessive heat inside the car by implementing the hydronic cooling system and to save more energy consumption is a significant challenge for the current project.

## 1.3 Objectives

The main objectives of this project are:

1. To design, install and monitor the hydronic radiant cooling system in a car and check for the suitability to be used in Malaysia.

2. To generate electrical power to operate water pump by determining the required amount of photovoltaic cells size.

## 1.4 Scope of Work

The scope of work under consideration for this current project is an open environment area to park the car. Car cabinet temperature is measured before and after the implementation of the HRC system. Besides that, the system is implemented in a real car, Daihatsu Charade instead of a prototype. Moreover the scope includes the designing and installing of the copper tubes inside the car and operating the photovoltaic cells system. Next, the HRC system is tested only in Fakulti Teknologi Kejuruteraan (UTeM) compound.

## 1.5 Organization of the Thesis

Chapter 1 explains the introduction of the project, which includes the background, problem statements, objectives and the work scope of the study. In chapter 2, the chapter briefly explains the review of theories, experimental works and some findings that had been done during the past research that is related to the current



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project. In chapter 3, methodology and strategy to achieve the objectives is explained in detail. The working procedure, materials and apparatus are well explained. Chapter 4 presents the result and the findings of the study, the result from the experiments that are presented in tables, figures, drawings and graphs and are discussed elaborately in the chapter. Several observations are also projected from the findings. Chapter 5 summarizes the outcomes of this experiment. The chapter also outlines several recommendations for further development and improvement on the design. Suggestions for future inventor are also provided within the chapter.



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# CHAPTER 2
# LITERATURE REVIEW

## 2.0 Introduction

Hydronic Radiant Cooling (HRC) system is a system that provides thermal comfort but it is unlike the conventional air-conditioning system, which is because this system does not rely on the use of vapour compression cycle to generate the cooling effect. This chapter will discuss on the hydronic cooling system, previous related experiment and the possibility for the system to be used in Malaysia. Besides that, some discussion regarding effect of heat trapped in a car will also be discussed. The theories and findings from the previous studies are reviewed and described to find the highlight knowledge associated with the current study

## 2.1 Conventional Air-conditioning System

Heating, ventilation and air-conditioning system (HVAC) is a system that is designed to maintain the indoor air quality and to provide thermal comfort to conditioned space. Typically HVAC system is designed as All-Air system, which means the air is to be used to perform both of the tasks mentioned previously. Based on a study conducted by California Energy Commission (2013) in an office building, at peak load, only about 10% to 20% of the supply air is outside air. This proven that only small portion of air is necessary to maintain a high level of indoor air quality. The difference volume of the air, outside and supply, is due to the recirculated air, which is necessary to keep the temperature difference between supply air and room air in the comfort range.



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` Bhatia (2012) Refrigeration system is a combination of components and equipment that is connected in a sequential order to produce the refrigerant effect. The most used refrigeration system is the Vapour Compression Cycle System (VCC). Basically, VCC typically applies the basic concept of the nature. In this system, the heat naturally moves from hot to cold. The energy which is in the form of heat is required to change the phase of a substance from liquid to gas. Next, the energy is given out by a substance changing from a gas into a liquid, thus this is why steam is particularly good at heating things on which it condenses. Besides that, the due to the change of pressure, the boiling point and the condensing point will eventually change.

Vapour Compression System has four main components, which are compressor, condenser, expansion valve and evaporator as shown in figure 2.1. VCC is alternatively compressed and expand the refrigerant gas from liquid to vapor state.

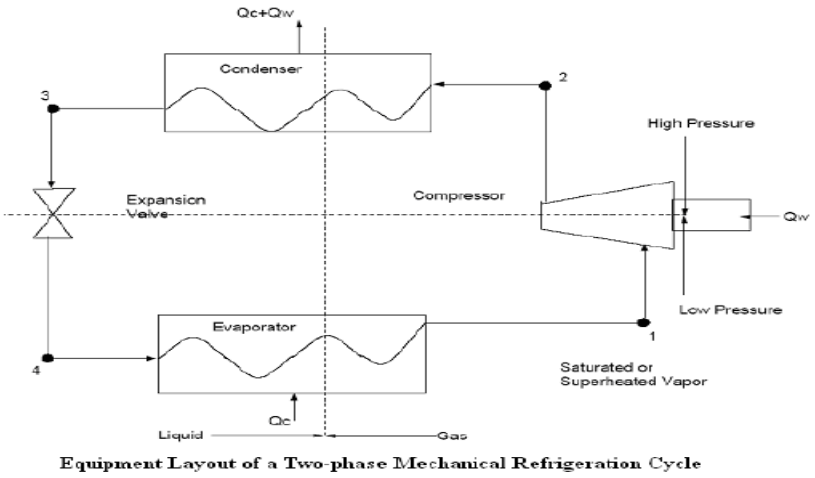


Figure 2.1: Components of vapor compression cycle

### 2.1.1 Air-conditioning System in Vehicles (Car)

Based on the book entitled A Guide to Automotive Air Conditioning Systems by Steve Rendle, published by Haynes Publishing (2000), air-conditioning system is a system which removes heat from the interior environment of the vehicles. When a vehicle is exposed to the direct sunlight whilst parked, or being driven on a hot day with closed windows, the condition inside the car will be very uncomfortable. The heat



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radiated by the sun will be absorbed by metal and glass of the roof and body panels, and then will be conducted through the body of the vehicle. Additional heat from the surface of the road, engine, exhaust system, and even the passenger can affect the amount of heat in the system. Typically, a conventional air-conditioning system can maintain the air inside a vehicle at 10 to 15˚C, which is cooler than the ambient air temperature outside the vehicle, but a vehicle air-conditioning system is not capable to produce a very cold temperature on a hot day. In an automotive air-conditioning system, the air will be cooled, cleaned and dehumidified before entering and re-entering the passenger compartments. The process of removing heat from inside the car to the outside environment is possible through some normal phenomenon; heat transfer, latent heat of vaporisation, and effect of pressure on boiling or condensation. These natural phenomena are the basic concept of air-conditioning system. The working mechanism of the vehicle air-conditioning system is stated with a high pressure liquid refrigerant in the condenser is released into the evaporator, through a device which decreases the refrigerant pressure. The decrement of pressure and partial boiling of the refrigerant lowers its temperature to the new boiling point. As the refrigerant flows through the evaporator, the passenger compartment air passes over the outside surfaces of the evaporator fins. The refrigerant then boils, absorbing the heat from the air, and cooling the air flowing into the passenger compartment. The heat from the passenger compartment is carried away by the refrigerant vapour. Next, the compressor will pump the refrigerant vapour that contains the latent or hidden heat, out from the evaporator then will force it under high pressure into the condenser. The increased pressure in the condenser will then raise the refrigerant temperature to a point higher than the outside air. As the heat transfers from hoy vapour to the cooler air, the refrigerant will then be converted back into liquid form. Finally, the liquid is now under high pressure and will be returned through the system. In the evaporator, the suction of the compressor reduces the pressure and the boiling point below the temperature of the passenger compartment, so the heat will be transferred from the passenger compartment to the boiling refrigerant. Meanwhile, in the condenser, which is pressurized by the compressor, the condensation point is raised above the temperature of the outside air, so heat transfers from the condensing refrigerant to the outside air (Steve Rendle, 2000).



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