PERFORMANCE INVESTIGATION OF VEHICLE AIR CONDITIONING SYSTEM UNDER DIFFERENT AMBIENT CONDITION

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A report submitted
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DECLARATION

I declare that this project report entitled "Performance Investigation of Vehicle Air Conditioning System Under Different Ambient Condition" is the result of my own work except as cited in the references.

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

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

Signature	:	....
Supervisor’s Name	:	....
Date	:	....

DEDICATION

To my beloved father and mother.

ABSTRACT

This study investigate the performance of vehicle air conditioning system under different ambient condition. An ambient temperature play an important role in affecting the performance of vehicle air conditioning system. This is because the impact of the global warming that is happening today due to increased of fuel consumption will cause increased an ambient temperature, even affecting the vehicle's air conditioning system. The objective of this study is to determine the best coefficient of performance of air conditioning systems between three different ambient temperatures which are 28^{o}C, 33^{o}C and 38^{o}C by taking into account several parameters such as system temperature, system pressure, cooling capacity and compressor work. The compressor speed and blower inlet air temperature are kept constant where at 1500 rpm and 30^{o}C respectively. The experiment was conducted by using a test rig that consist of actual componenet used in Proton Wira passenger car. During the experimental works, the test rig should be stabilized of around 10 minutes before the data is taken for another 10 minutes with time interval of 20 seconds. The recorded data are temperature and mass flow rate. The results showed that an ambient temperature at 33^{o}C produced higher COP at 4.97.

ABSTRAK

Kajian ini menyiasat prestasi sistem penyaman udara kenderaan di bawah keadaan ambien yang berbeza. Suhu ambient memainkan peranan penting dalam memberikan kesan terhadap prestasi sistem penyaman udara kenderaan. Hal yang demikian kerana kesan pemanasan global yang berlaku pada masa kini disebabkan oleh peningkatan penggunaan bahan bakar akan menyebabkan berlakunya peningkatan suhu ambien, malah mempengaruhi sistem penyaman udara kenderaan. Objektif kajian ini adalah untuk menentukan pekali prestasi terbaik sistem penyaman udara antara tiga suhu ambien yang berbeza iaitu 28^{o}*C, 33*^{o}*C dan 38*^{o}*C dengan mengambil kira beberapa parameter seperti suhu sistem, tekanan sistem, kapasiti penyejukan dan kerja pemampat. Kelajuan pemampat dan suhu udara masuk blower tetap di mana masing-masing 1500 rpm dan 30*^{o}*C. Eksperimen dijalankan dengan menggunakan rig ujian yang terdiri daripada komponen sebenar yang digunakan di dalam kenderaan penumpang Proton Wira. Semasa eksperimen dijalankan, rig ujian perlulah distabilkan sekitar 10 minit sebelum data diambil untuk 10 minit lagi dengan selang waktu 20 saat. Data yang direkodkan adalah suhu dan kadar aliran jisim. Keputusan menunjukkan bahawa suhu ambien pada 33*^{o}*C menghasilkan COP yang lebih tinggi pada 4.97.*

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Syukur Alhamdulillah and thanks to Allah S.W.T. for giving me courage and strength to complete my final year project.

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Besides that, special thanks to laboratory assistant which is Encik Asjufri that help me and my friends a lot during the experiment for this project. He not only helps but also proposes to use best and accurate method even to provide new knowledge in the vehicle's air-conditioning system. He also provided guidance on the use of equipment and the installation of each tool used during the experiment.

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LIST OF ABBREVIATION

VCRC	Vapor Compression Refrigeration Cycle
COP	Coefficient of Performance
CO_2	Carbon Dioxide

LIST OF SYMBOL

Qc	Condenser Heat Rejection (kJ/s)
Qe	Cooling Capacity (kJ/s)
Wc	Compressor Work (kJ/s)
Qa	Heat Absorb by Air (kJ/s)
$\dot{m}$	Refrigerant Mass Flow Rate (kg/s)
T	Temperature (^{o}C)
N	Compressor Speed (rpm)

CHAPTER 1

INTRODUCTION

1.1 Background

Air conditioning system in a car is needed especially in Malaysia as the weather in this country is hot and always humid. Many factors can affect the thermal comfort inside a cabin compartment of a typical land vehicle. One of the factors is ambient condition.

Ambient condition is a state where it involves the humidity at surrounding, air movement and temperature. It affects the efficiency of the air conditioning system due to the fact that heat load of the air conditioning system significantly depends on the surrounding condition. Apart from that, vehicular thermal comfort is vital as a result of driver and passenger should feel comfortable when in the vehicle and can improve health and safety during driving. There are several factors affecting the thermal comfort such as air temperature, air speed and humidity.

The air conditioning system in the vehicle needs to work stronger due to the increased of an ambient conditions to provide the ideal temperature in the cabin compartment. The inclusion of heat and its transfer rate into the vehicle system depends on the ambient temperature difference where if the ambient temperature is lower then it causes more cooling to be done by the heat exchanger while high ambient temperatures causes reducing of compressor efficiency. This indicates that ambient condition can affects the performance of the air conditioning system in the vehicle.

1.2 Problem Statement

One of the energy used to produce internal combustion engine is the fossil fuel. As a result of elevated fuel consumption, it causes pollution to air and global warming. Global warming takes place when the ozone layer serves to absorb most sun's ultraviolet radiation and block the damaging ultraviolet achieving the surface of the earth that will reduce the ozone layer. This ozone layer is placed above the atmosphere that is a blanket of gases that covers the planet Earth and is maintained by means of its gravity. The gas that accountable for the global warming is the carbon dioxide which carbon dioxide can be discovered in the vehicle air conditioning system.

As a way to reduce this pollution problem, an ambient temperature cannot be control but the vehicle can be operate at specified ambient temperature where at that condition the efficiency is the best. If the consumer know the best operating time of the air conditioning system, the journey or travel activity can be planned during its best operating time. This ambient temperature plays an important role in reducing global warming and provide thermal comfort for drivers and passengers in the vehicle. Besides that, ambient temperature is differ based on the condition of place and relates with the condenser where higher ambient temperature cause the higher condensing temperature and contributes to the higher consumption. So, this experiment is conduct to ensure which condition of the ambient temperature is the excellent in reducing pollution, operates in efficient way and the most important is to maximize the coefficient of performance for the vehicle air conditioning system.

1.3 Objectives

The objectives of this study are:

a) To determine the system temperature, system pressure, cooling capacity and compressor work at different ambient condition.

b) To justify the best coefficient of performance of the air conditioning system.

1.4 Scope of Project

In this study, there are three scope of projects that should be considered and one of it is the method use for this project. The experiment method for this study is a procedure that have been carried out to collect the data and doing the analysis to get the required result based on different ambient condition. Besides that, experiment is the handy way to learn more due to the fact it take a look at the understanding about the ongoing experiment and it's primarily based on the hands-on things to do to gain result or progress of the project.

Second is the variables covered that includes the variables fixed, manipulated variables and control variables. In this vehicle air conditioning system, the main variable that need to be manipulate is the ambient temperature as it as it will test the overall performance of air conditioner when the compressor is driven using engine power in the car. Variables fixed is something that want to remain constant or not change during the experiment which can be describe as the operation of air conditioning system in a car using internal combustion engine. The control variables is the variables that should be calculate in this experiment which encompasses within the objectives to be achieved. From the manipulate variables, the changes can be observed and easy to figure out the conclusion that will give result about the performance of air conditioner.

Lastly, the validity result. This result will show among the different condition, which one is the best to obtain the best coefficient of performance of the air conditioning system whether in morning, afternoon, evening and night. When the results are obtained, awareness of the amount of energy released by the air conditioner can be portrayed at different times. It is to ensure that the energy produces enough to accommodate the car users with a certain amount without wasting energy.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review is organized into several section. The first section briefly review the air conditioning system and actual VCRC system as a basic principle of a typical air conditioning system. Second is the main components included in the air conditioning system. Then, the working principles followed by the thermodynamic analysis. Next, the effect of an ambient condition to the efficiency of vehicle air conditioning system and finally, the summary of chapter 2.

2.1.1 Impact of using the Vehicle Air Conditioning System to the Environment

Air conditioners in the vehicle illustrate many implications to the environment where the air conditioners emit high amounts of energy and can cause additions to climate change. Vehicles burn more fuel and produce more greenhouse gases where greenhouse gases is the gas that absorbs infrared radiation emitted from the earth surface and re-emitted in all directions by atmosphere that cause warm to the earth surface and lower the atmosphere (Russell and John, 2006).

The fuel produced by the car is also routed to the environment without any filtering that gives poor air quality which will cause in increasing the respiratory ailments like asthma and can increase the risk to get cancer. When the usage of fuel is lower, the impact for the environment can be reduce by control the use of air conditioners by not wasting the excess energy provided to passengers when generating the air conditioning system.

2.1.2 Basic Air Conditioning System

Air conditioning in the vehicle is an accessory that can provide comfort to passengers. The air conditioner can not only cool the temperature in the vehicle but also be able to treat ventilation for temperature and humidity. There are two basic types of air conditioners system used in the vehicle. The only difference is the type of device that can reduce the refrigerant pressure but the way and the concept it works together is the same with each other (Mike and John, 2000).

The first type of system is to use the expansion valve system. Expansion valve system used to control the pressure and temperature levels in the air conditioner to determine the amount of refrigerant that enters the evaporator.

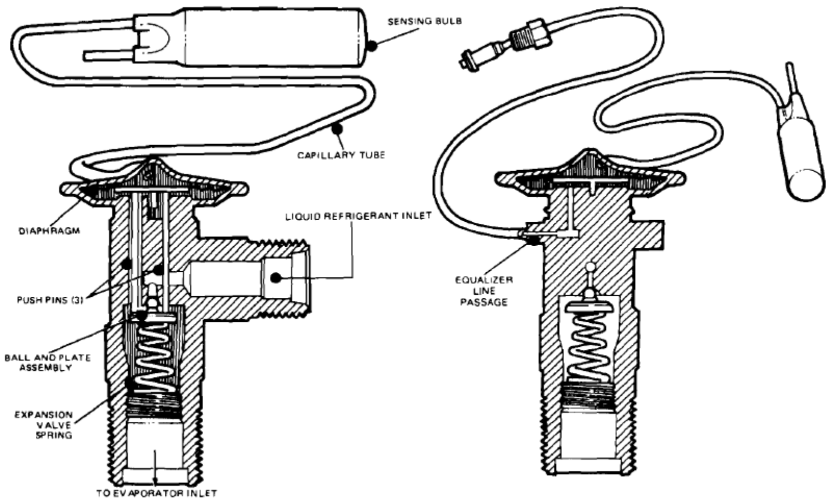

Figure 2.1: Expansion Valve (Mike and John, 2002).

The second type of the system is to use the fixed orifice tube system. The fixed orifice tube function is similar to the expansion valve which is to control the amount of refrigerant that goes into the evaporator but it has a fixed size and cannot change the rate of refrigerant inclusion into the evaporator as can be made by expansion valve where expansion valve can adjust the rate of refrigerant enter to the evaporator because if too much refrigerant enters the evaporator, the evaporator will be too cold and there may be freezing.

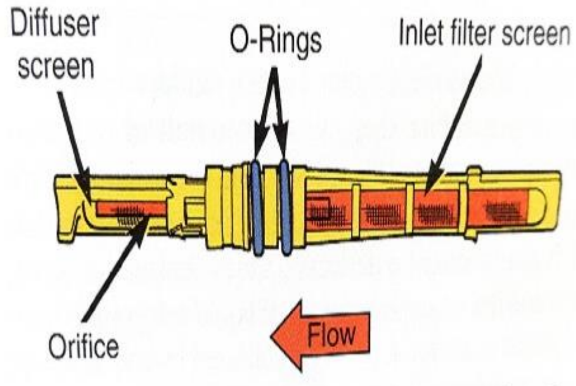

Figure 2.2: Orifice Tube (Mark, 2018).

2.2 Main Components of Air Conditioning System

Air conditioning systems have five of the main components that work with each other to provide thermal comfort to the occupant. The components are:

2.2.1 Compressor

Compressor is the most important component and located beside the engine of the vehicle (Khiril, 2015). Compressor also known as the heart of the air conditioning system as it works to compress the refrigerant gases. In addition, the compressor also controls temperature production and moves the hot temperature to the condenser.

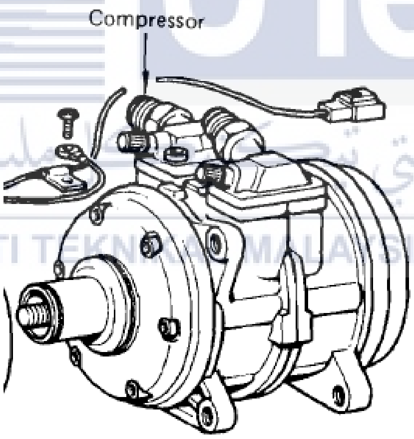

Figure 2.3: Compressor (Mike and John, 2000).

2.2.2 Condenser

Typically, the condenser is located at front of the vehicle radiator and is known as a mini radiator. Condenser works to convert hot gas to cold. When the hot gas comes out of the compressor and enters the condenser, the condenser will turn into a liquid and move to the air conditioner dryer or accumulator (Khiril, 2015).

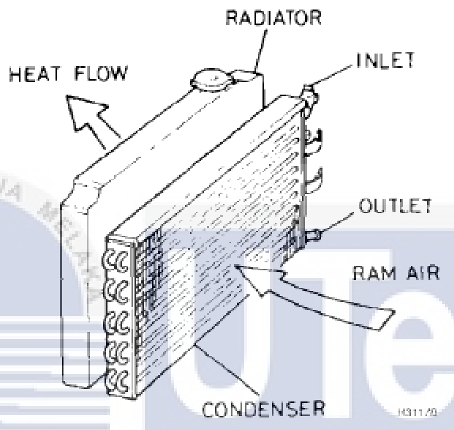

Figure 2.4: Condenser (Mike and John, 2000).

2.2.3 Dryer or accumulator

Dryer or accumulator depending on the type of vehicle used. These components located in the engine compartment (Mike and John, 2000). Dryers are available in vehicles using the expansion valve while the accumulator is in the vehicle using the orifice tube. The function for this dryer is similar to the accumulator function which both filters the dust, remove the moisture and liquid from entering the air conditioner system as when the liquid enters the compressor designed only to handle gas and non-liquid, the compressor will be damaged.

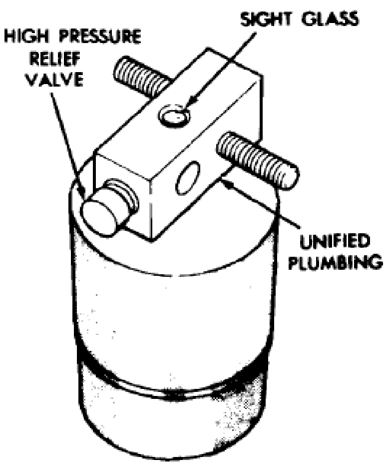

Figure 2.5: Dryer (Mike and John, 2000).

2.2.4 Expansion valve or orifice tube

Orifice tube is located in refrigerant line while the expansion valve is usually attached to the evaporator (Mike and John, 2000). The function of these devices are to control the amount of refrigerant that enters the evaporator by controlling the temperature and pressure of the air conditioning system.

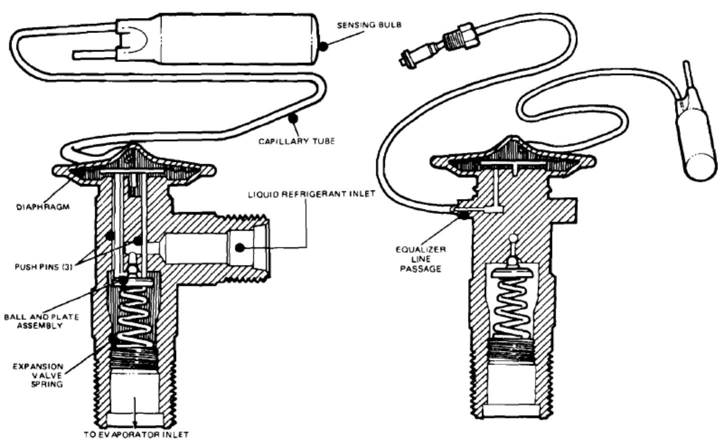

Figure 2.6: Expansion Valve (Mike and John, 2000).

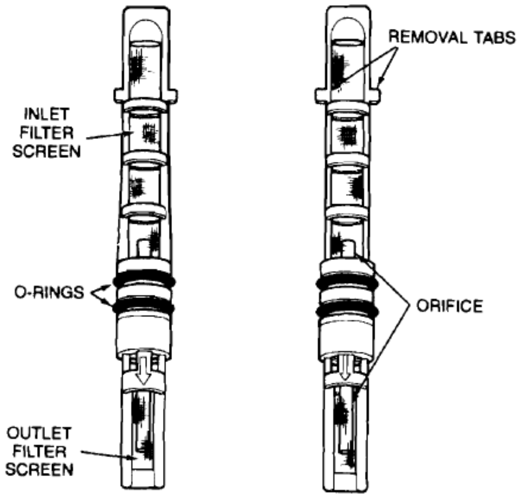

Figure 2.7: Orifice Tube (Mike and John, 2000).

2.2.5 Evaporator

The evaporator is the last component that gives complete cooling to the vehicle system. The evaporator is also responsible for removing the moisture in which the cold air found in the evaporator is blown into the vehicle cabin to provide the coolness required by passengers. This evaporator is located inside the passenger compartment.

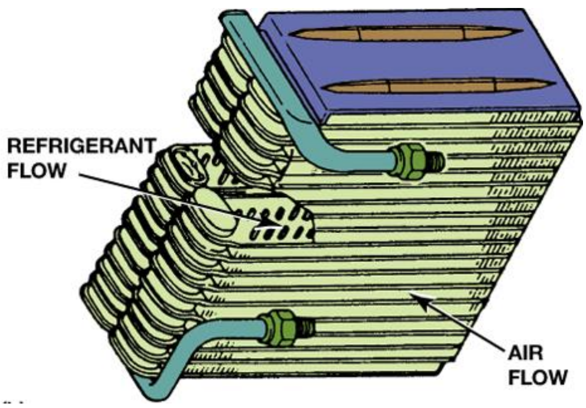

Figure 2.8: Evaporator (Halderman, 2018).

2.3 Working Principle of Air Conditioning System

Air conditioning system works when air conditioner inside the vehicle is turned on. The shaft inside the compressor start to turn and then compressed the refrigerant that coming into the compressor. After that, the compressed refrigerant will go to the condenser where that time the refrigerant is in gas condition. The refrigerant leaves the compressor and start to being in high pressure. The high pressure of the refrigerant goes to condenser and the condenser will cooling down the refrigerant.

Once the refrigerant leaves the condenser, the refrigerant change from gas condition into liquid condition. Then, the refrigerant will enter the dryer or accumulator and goes to expansion valve or orifice tube depends on the car that being used. As the refrigerant passes through expansion valve or orifice tube, the refrigerant will turning into the gas. The refrigerant goes to the evaporator and at this point, it said that the refrigerant is in low pressure and going to cool down. Evaporator will absorb the cool refrigerant that flowing over it and blow the cool refrigerant inside the cabin compartment. The cycle will keep repeating after the refrigerant leaves the evaporator as long as the air conditioner is turned on.

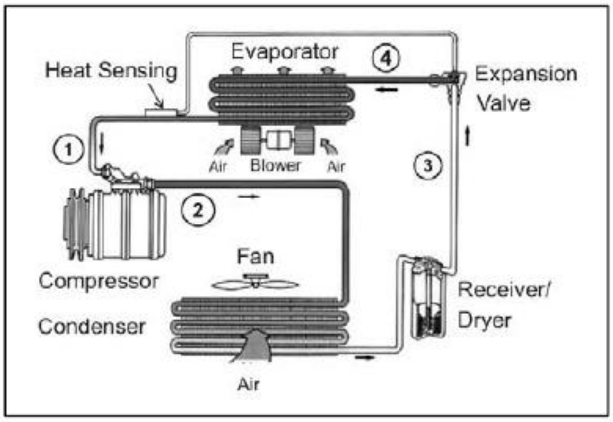

Figure 2.9: Flow of the vehicle air conditioning system (Muji et al.,2017).

2.4 Thermodynamic Analysis of Vehicle Air Conditioning System

Vehicle air conditioning system operates based on the vapor compression refrigeration cycle (VCRC) that consist of the compressor, condenser, evaporator, expansion and fans. Figure 2.10 shows the cycle of vehicle air conditioning system based on thermodynamic analysis.

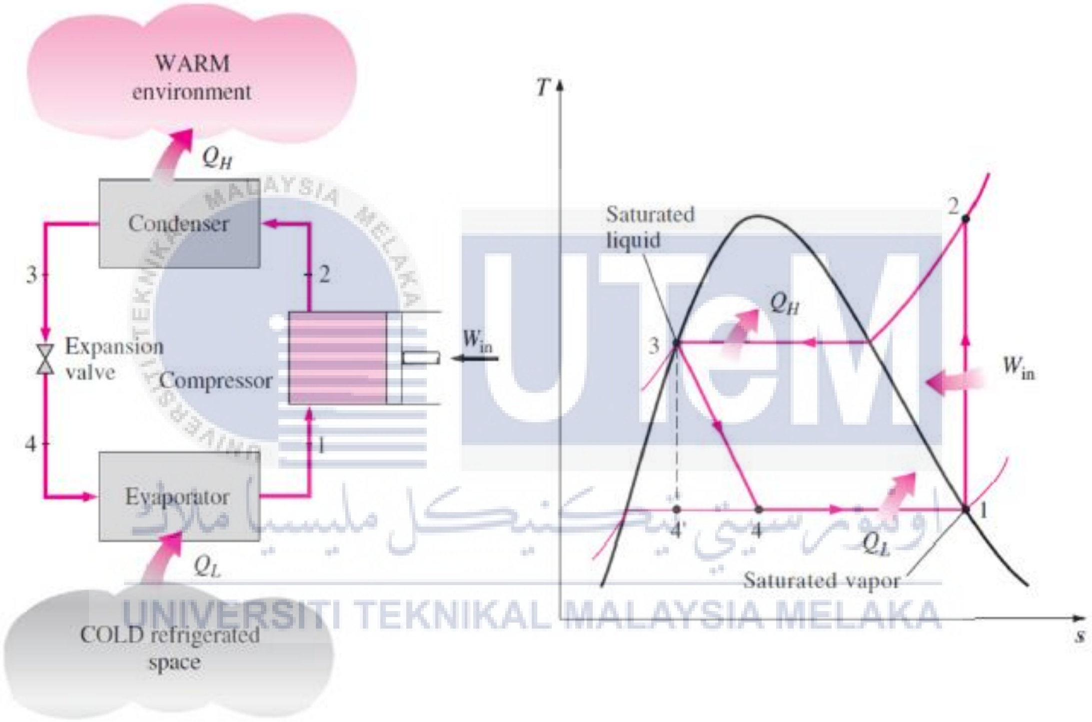

Figure 2.10: Schematic of basic vapor compression refrigeration cycle (Farshid Bagheri, 2016).

The compressor circulates and compress the refrigerant gas from the evaporator and then pumps the high pressure and high temperature gas into the condenser which is typically installed near the car radiator. Gas is condensed when passing through the condenser and causes latent and sensible heat to be rejected to the secondary flow. The gas change phase from superheated gas to gas-liquid mixture or even sub-cooled liquid which then enters the expansion valve that makes the temperature and pressure drop.

Pressure and temperature drop drastically due to the throttling through the expansion valve where low pressure and low temperature two phase refrigerant flows to evaporator. The cooling impact on an air conditioning and refrigeration system show up in the evaporator where the refrigerant works. The heat from the secondary flow is absorbed by the evaporator and cools it down and then the evaporated refrigerant that in saturated or superheated gas state being absorbed by the compressor that will completing one cycle of the system (Farshid Bagheri, 2016).

$$Qc = h2 - h3 \text{ (kJ/kg)} \quad (2.1)$$

$$Qe = h1 - h4 \text{ (kJ/kg)} \quad (2.2)$$

$$Wc = h2 - h1 \text{ (kJ/kg)} \quad (2.3)$$

2.5 The Effect of Ambient Condition to the Efficiency of the Vehicle Air Conditioning System

Ambient condition refer to temperature, humidity and velocity of surrounding air of the system. The condition of the ambient can affect the efficiency of the vehicle air conditioning system. However, this study only consider ambient temperature as the factor that can affect the thermal comfort. In this case, the performance of condenser will be affected with different ambient condition. Consequently, the performance of the air conditioning system varies with differ temperature of the air flowing to the condenser. This is because, the ambient air will flow to the condenser with different ambient condition, where the heat load is rejected to the ambient air. In general, the entire system will be affected as well as the performance of the air conditioning system (Russel and John, 2006).

The air conditioning is widely used in vehicle system which consumes huge mechanical power to supply cooling or heating demand to the cabin space. The purpose of this system is to provide comfort condition to the driver and passenger. The efficiency of the air conditioning system is characterized by the coefficient of performance (COP) which define as the ratio between the cooling capacity to the input power consumption where,

$$COP = Qe/Wc \tag{2.4}$$

Few factors can influence the performance of the air conditioning system. One of them is an ambient condition. Table 2.1 shows the method used to control the ambient temperature by previous researcher.

Table 2.1: Method of controlling an ambient temperature by previous researcher.

Author	Method	Input	Output	Result
Zulkhairie et al., 2016.	Test rig.	Pressure, temperature, air flow and air velocity.	COP, cooling load and compressor power consumption.	The rises of air flow to the condenser inlet will reduce the power consumption and increase in COP.
Hisamudin et al., 2016.	Experimental rig.	Speed compressor, ambient temperature and internal load.	Energy consumption of compressor and COP.	COP will decrease with increase of compressor speed.
Chung et al., 2012.	Wasted heat from electric devices.	Outdoor temperature and volume flow rate of coolant water of electrical devices.	Heating capacity, compressor work and COP.	Increase in outdoor temperature will decrease the COP but COP increase when water flow rate on condenser side increase.

Hazwan et al., 2018.	Three-stage coil heaters.	Outdoor temperature.	Cooling capacity, power consumption and COP.	As outdoor temperature increase will decrease the COP and cooling capacity.
Abdalla Gomaa, 2017.	Test rig.	Speed compressor and condensing temperature.	Cooling capacity and COP.	Increase in compressor speed will decrease the COP but when condensing temperature increase, it will decrease the cooling capacity and the COP.
Rahul and Farkade, 2017.	Test rig.	Ambient temperature.	COP, refrigeration capacity and compressor discharge temperature.	Increase in ambient temperature will increase the discharge temperature and energy consumption but decrease in COP and refrigeration capacity.

Based on the Table 2.1, most of the previous researcher stated that when the ambient temperature higher cause the COP of the air conditioning system to be lower while when the compressor speed increase, the COP will drop. This is because the compressor need to work hard than usual due to the higher in ambient temperature but give the negative impact to the performance of the air conditioning system.

When an ambient temperature increase, the energy consumption will increase because the vehicle requires more energy to give the cooling temperatures required by the air conditioning system in cabin compartment but it will give lower COP. Ambient temperature is one of the important factors in determining the cooling of air conditioning systems in vehicles because high or low ambient temperatures will have different effects on compressor speed, cooling capacity, COP, energy consumption and others.

2.6 Summary of this Chapter

This chapter concludes that the methods studied by previous researchers can be used in experimenting. Vehicles that will be used to test and get every parameter to be sought are Proton Wira but after researching every method studied by earlier researchers found that the Proton Wira vehicle was also used to conduct experiments. The difference between experiments to be carried out in this project with previous studies is in determining parameters because the parameters sought are to get the best performance when ambient conditions are different.

In addition, there are also the same search parameters but the methods used in the building system and the possibility that the method can also be used in experiments using the vehicle. As long as the method can give a good result in the experiment conducted then the method can be used even in different circumstances.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, all steps have been listed to achieve the objective of the study. This procedure is conducted to investigate and evaluate the effect of different ambient condition to the performance of vehicle air conditioning system. Figure 3.1 shows step by step of the overall project chart representing the process or workflow and indicates the steps taken to complete the research conducted to ensure that this method is not contrary to the objectives and scope of the study.

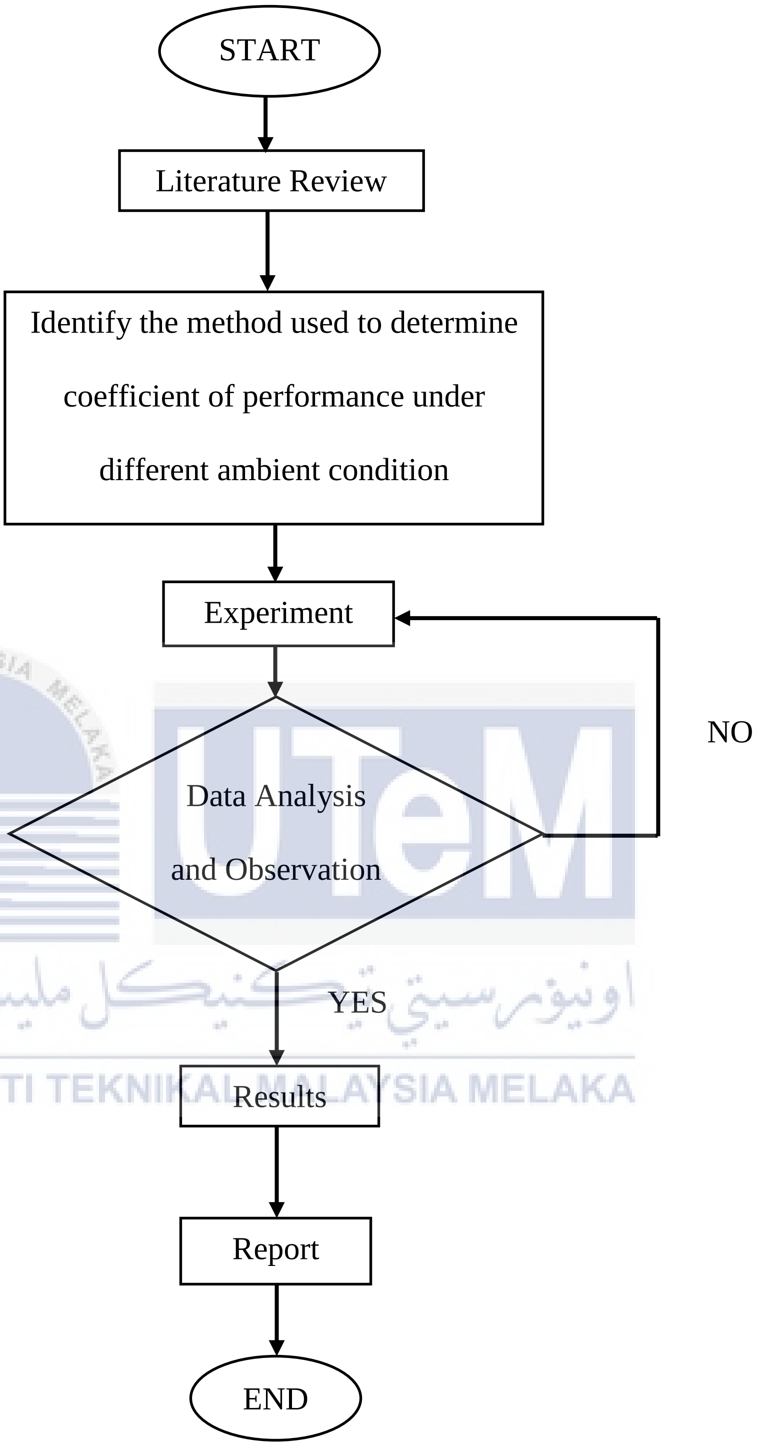

Figure 3.1: Flow Chart of the Methodology.

3.2 Process Flow

The process begins with researching journals, articles or books on the topics given to be able to understand more about the entire study. The first step is to identify the methods used to determine the coefficients of performance under different ambient conditions. This is very important because in order to get good results, the methods and parameters used before conducting the experiment should be known. The air conditioning system in the vehicle is very complicated if all aspects are taken into account, therefore the focus is only given to the ambient condition that related to the coefficient of performance of the vehicle air conditioning system.

Then, experiments are conducted based on the methods studied from journals, books or articles to ensure that this study can be carried out. This experiment requires an equipment to control and measure an ambient temperature at different condition to determine system temperature, system pressure, cooling capacity and compressor work and from that, the best performance of the vehicle air conditioning can be obtained.

The data obtained from the experiments need to be analyzed so that the results reach the study of this experiment and if the data is not achieved as desired, then the other experiments need to be done again to get the correct and best results. So, by learning the method at first from the journals, books or articles, some of the other related methods may be taken as references and used for other experiments as to replace the failed method of the previous experiment.

The results achieved are seen in terms of ambient conditions where to achieve high and good performance as well as the efficiency, the temperature at different condition and time can affect all the parameters in this study.

3.3 Method of Study

There is many experimental method that can be used to investigate the performance of vehicle air conditioning system under different ambient condition. Among the method is experiment, simulation and analytical. These method is recommended through the journals, books or articles. Below is an explanation of the methods that can be used in this study.

3.3.1 Vapor Compression and Transcritical Cycle Simulation Models

This experiment uses a semi-theoretical cycle model to assess the performance of CO2 and R134a of vehicle air conditioning system. The R134a system consists of compressors, condensers, expansion devices, and evaporators while the CO2 system is equipped with a liquid line/suction line heat exchanger. When both system are used, an efforts have been made to produce a fairly comparable performance where components in both systems are equals and differences in thermodynamic and transport characteristics are considered in the simulation.

The analysis indicates that R134a has a better coefficient of performance than CO_2 where CO_2 has inconsistency coefficient of performance that depends on the compressor speed and ambient temperature. Coefficient of performance differences are greater at ambient speed and ambient temperatures. The huge entropy generation in gas coolers is the main reason for lower CO_2 performance shown in the calculation of entropy generation.

3.3.2 Experimental Test Rig

The vehicle air conditioning system consists of R134a refrigeration system with variable speed compressors, condensers, thermostatic expansion valves and evaporators were conducted experimentally and theoretically. The compressor is powered by a three-phase electric current through the frequency inverter which allows the compressor to operate at the necessary speed.

This experiment contains two air duct in which the evaporator and condenser have been placed and the duct containing the evaporator has a predetermined cross section area and length. All the measuring instrument reading were recorded after the experiment reached a steady state condition which took about 45 minutes and this experiment is performed with standard parameters such as cooling capacity, compressor power, coefficient of performance, pressure ratio and condenser heat load.

3.4 Experiment Parameter

This experiment focuses on finding out the best coefficient of performance in Proton Wira vehicle system model under different ambient condition. The setup of the experiment consist of the compressor, condenser, dryer, expansion valve and evaporator using the R134a as a working fluid. The experiment that will conduct is to determine the system temperature, system pressure, cooling capacity and compressor work. The temperature is measured by the thermocouple while the pressure is measured using pressure gauge. The compressor speed and temperature at the inlet of blower in this experiment is fixed according to given RPM and temperature. Figure 3.2 shows the schematic diagram of the experiment.

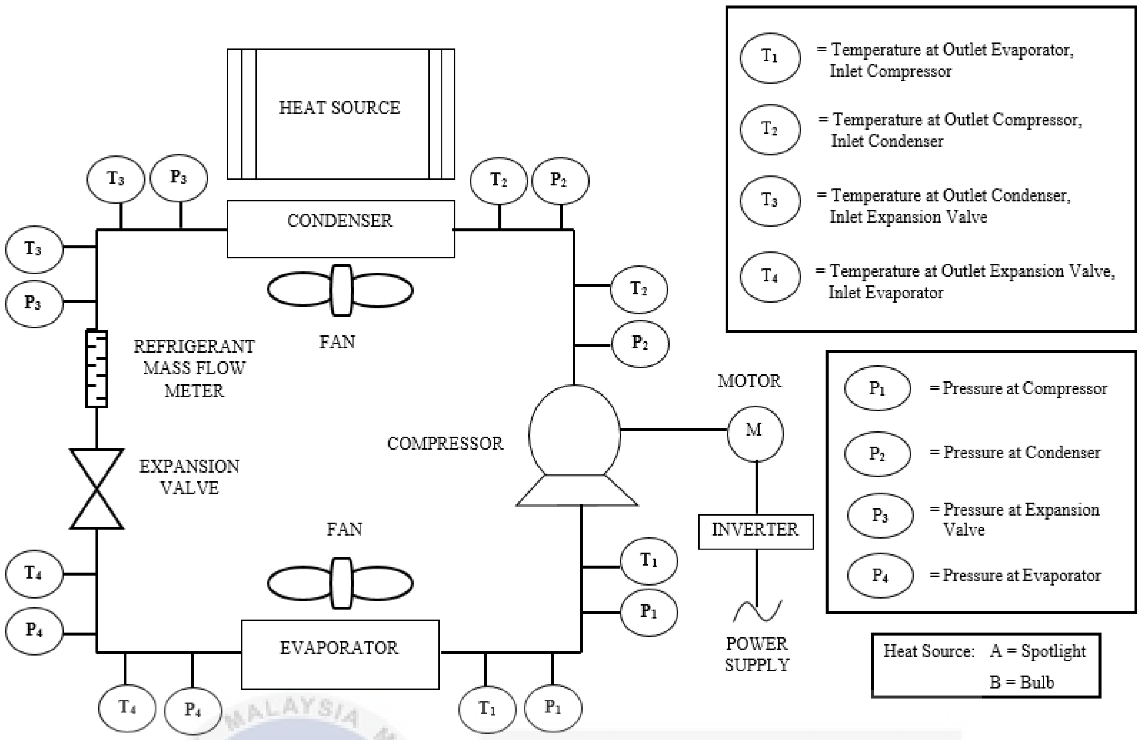

Figure 3.2: Schematic Diagram of the experiment.

3.5 Method to Control an Ambient Temperature

The ambient temperature needs to be control to get the difference required temperature. There are several method to control an ambient temperature at the inlet of the condenser which are using the heater, spotlight or bulb. For this experiment, the bulb and spotlight are selected as one of the methods to control an ambient temperature because the bulb is very cheap and the spotlight is already available in the lab. Besides that, the use of bulb and spotlight only requires a bulb conversion if the bulb burn and the work of conversion is very easy to carry out in a short time.

3.6 Method to Calculate the Enthalpy

Enthalpy is important in calculating the coefficient of the performance (COP) in the air conditioning system because it tells the difference in heat gain or loss in the system. In addition, this experiment required the enthalpy value to calculate all the data obtained from the experiments performed. Some methods have been identified to calculate the enthalpy which are using the Refprop software, thermodynamic table and the pressure-enthalpy diagram.

Method using the Refprop software is easy to use but there is a lack of it where it can only get data for the enthalpy but the graph plotted are not exactly accurate if the scale is entered incorrectly. The thermodynamic table is also the good method to be used but limited because some of the value cannot be find in the table and need to make an interpolation to get the accurate value. Additionally, to use the thermodynamic table requires the right skills because if the data is found incorrectly will cause the whole value to be incorrect.

In this experiment, the pressure-enthalpy diagram has been chosen as an effective method for calculating an enthalpy. This is because the enthalpy value can be easily found when the data obtained from an experiments such as pressure and temperature are plotted directly in the diagram.

3.7 Volume of Refrigerant R134a

In vehicle air-conditioning system, the refrigerant R134a is used to assist in the cooling process and without the refrigerant, the vehicle system cannot be cool effectively. The test rig in this experiment only able to pump the refrigerant by 10 psi and if more than that, it will make the system not smooth because the load is too heavy and the motor cannot afford to swivel the speed. This test rig is limited in the use of refrigerant unlike a real vehicle system that requiring 30 psi to allow the vehicle to obtain the required cooling capacity to provide thermal comfort to the user.

3.8 Experiment Procedures

The experiment started by using the test rig that is used to collect all the data needed based on Proton Wira component as shown in Figure 3.3. The measuring instrument known as Pico Technology TC-08 thermocouple data logger (Figure 3.4) is used to measure the temperature at which the thermocouple is placed. The Pico Technology TC-08 thermocouple data logger is able to collect data every hour, minutes and second by setting the PicoLog Recorder Software that is being installed in the laptop. Besides that, to measure the rpm of the compressor, the Digital Tachometer HT-4200 is used as in Figure 3.5.

Figure 3.3: Test rig.

Figure 3.4: Pico Technology TC-08 thermocouple.

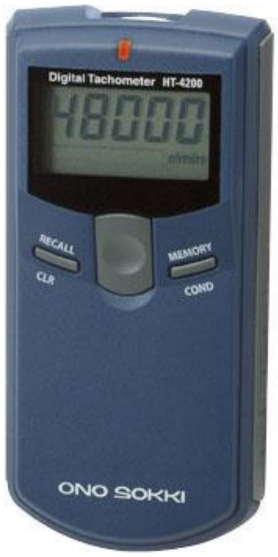

Figure 3.5: Digital Tachometer HT-4200.

Before experiment begin, the test rig is being placed at the inside of the air conditioning laboratory according to the time and temperature that the experiment being run, so that the desired temperature will obtain which is 28 ºC, 33 ºC and 33 ºC. If the test rig is placed inside of the lab at time between 9.00 am to 11.00 am, the ambient temperature is cold and if the test rig is placed at the outside of the lab between 2.00 pm to 4.00 pm, an ambient temperature will be hot.

Experiment setup is done by placing the thermocouple at the inlet of the condenser (Figure 3.6) and outlet of the condenser (Figure 3.7) to measure an ambient temperature while to measure the temperature at the inlet of the blower, the thermocouple was placed at the inlet of blower as in Figure 3.8. Another thermocouple was placed at the outlet of the blower (Figure 3.9) to measure the temperature of the air conditioning for the test rig.

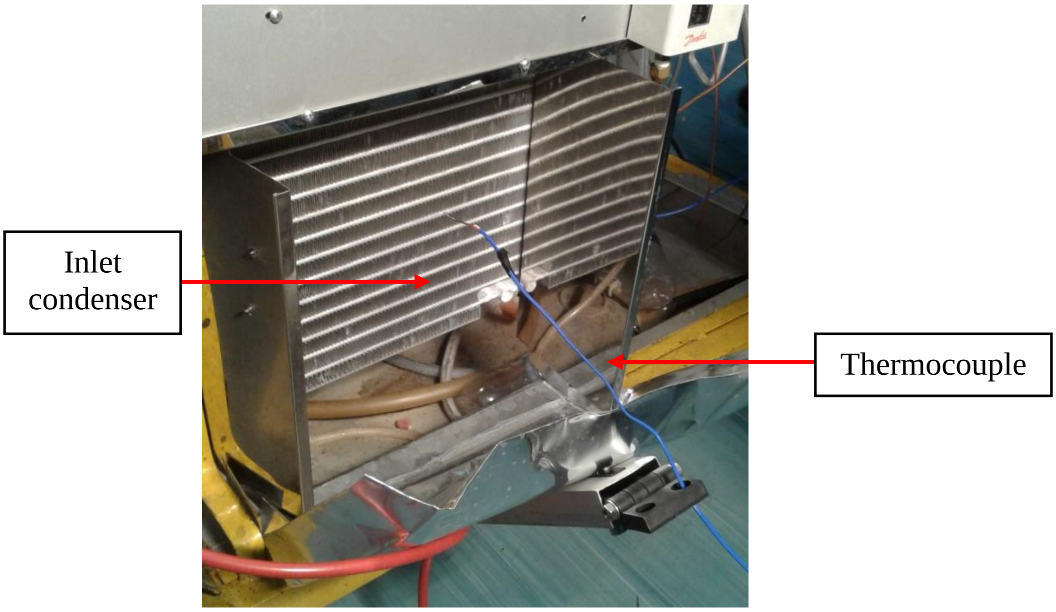

Figure 3.6: The thermocouple was placed at the inlet of the condenser.

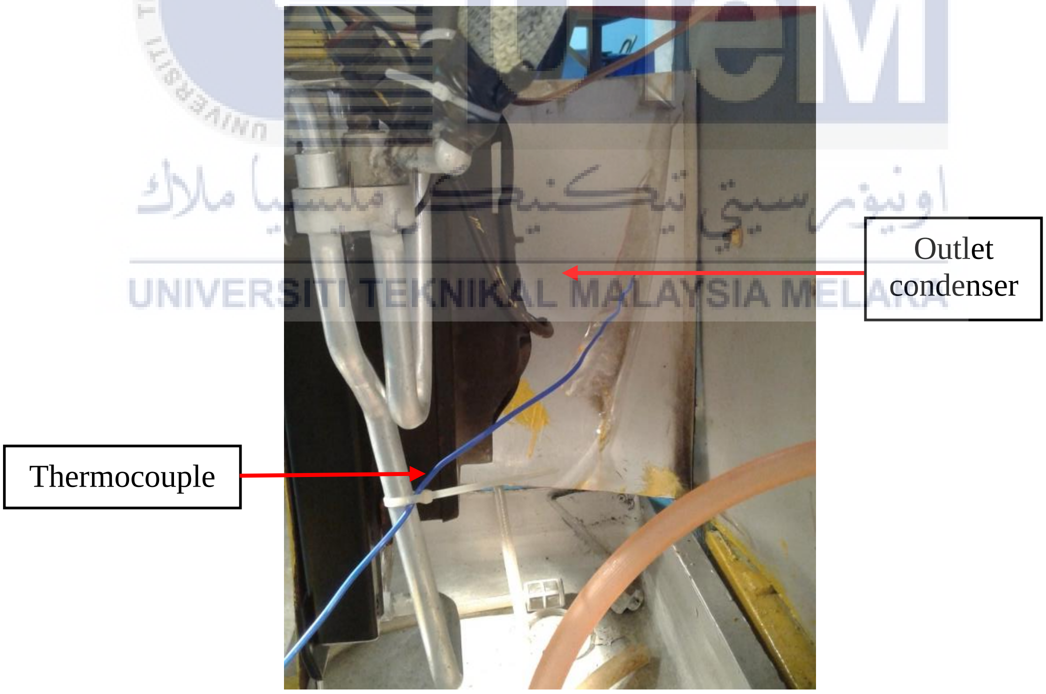

Figure 3.7: The thermocouple was placed at the outlet of the condenser.

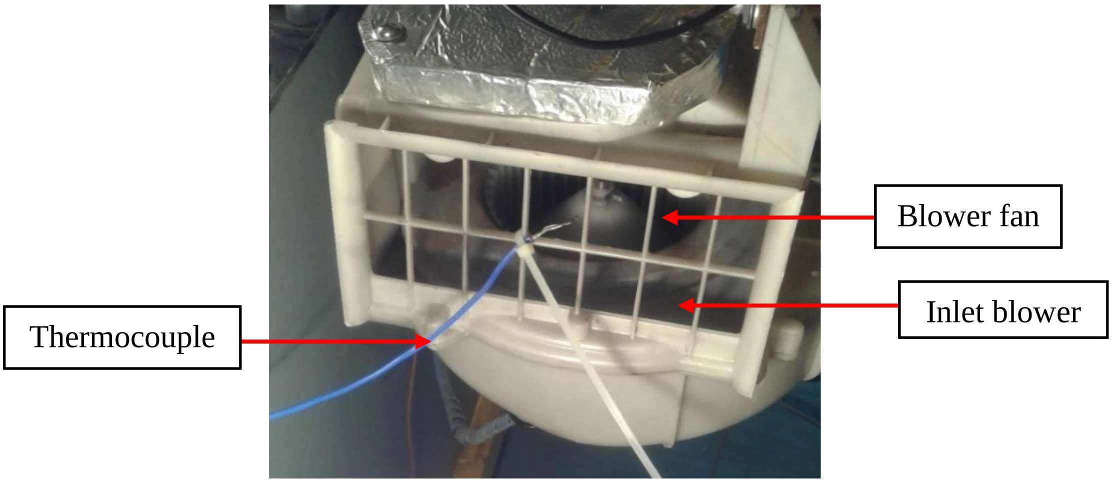

Figure 3.8: The thermocouple was placed at the inlet of the blower.

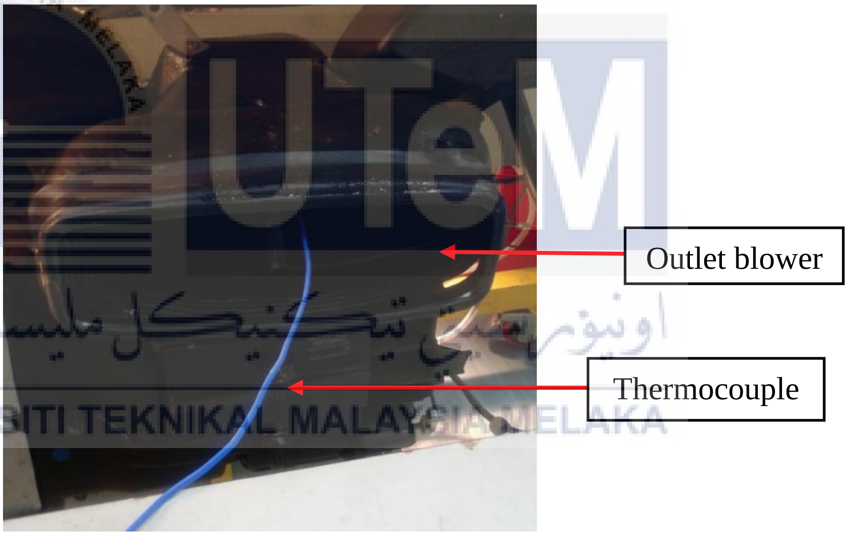

Figure 3.9: The thermocouple was placed at the outlet of the blower.

Once the setup of the instrument and the test rig is ready, switch on the power supply and push the ON button. After that, push the air conditioning button and adjust the inverter to get the desired rpm of the motor compressor and let the test rig to be stabilized for 10 minutes. After 10 minutes, the data being collected and recorded for 10 minutes and the frequency, Hz of the inverter (Figure 3.10) is being adjusted and controlled so that the rpm of the compressor will get 1500 rpm. The fan is placing at the motor compressor so that the motor will not overheat based on Figure 3.11.

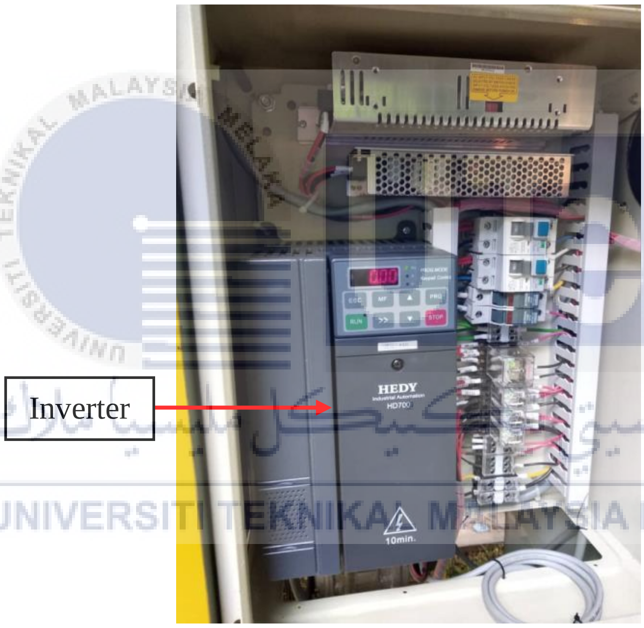

Figure 3.10: Inverter.

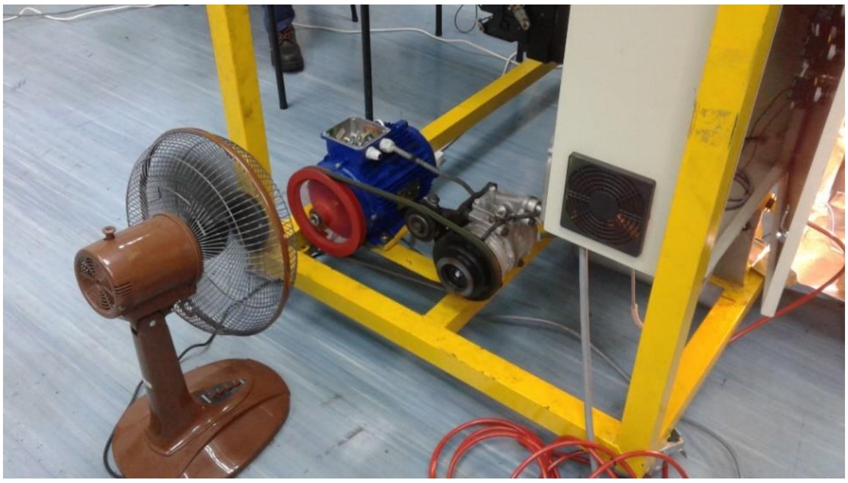

Figure 3.11: Fan is placing at the motor.

The temperature at the inlet condenser is controlled by using the spotlight that consist the energy of 1000 Watt (Figure 3.12) to get the temperature of 28^{o}C and then for the higher temperature which are 33^{o}C and 38^{o}C, the bulb that consist of the 100 Watt for each of the bulb is used based on Figure 3.13. At the same time, the temperature at the inlet blower is also must be controlled to get the fixed temperature which is 30^{o}C and controlling by using the bulb or the spotlight according to the condition of the temperature in the lab.

Figure 3.12: Spotlight.

Figure 3.13: Bulb.

The reading of the pressure gauge (Figure 3.14) and mass flow rate as in Figure 3.15 is being recorded manually during the experiment. The experiment will be repeat again at the same action but at different ambient temperature required that is depends on the place that the test rig is placed. Figure 3.16 shows the location of the thermocouple for T_1, T_2, T_3 and T_4 that is located at the test rig. Table 3.1 shows the data collection form that collect and record all the data needed.

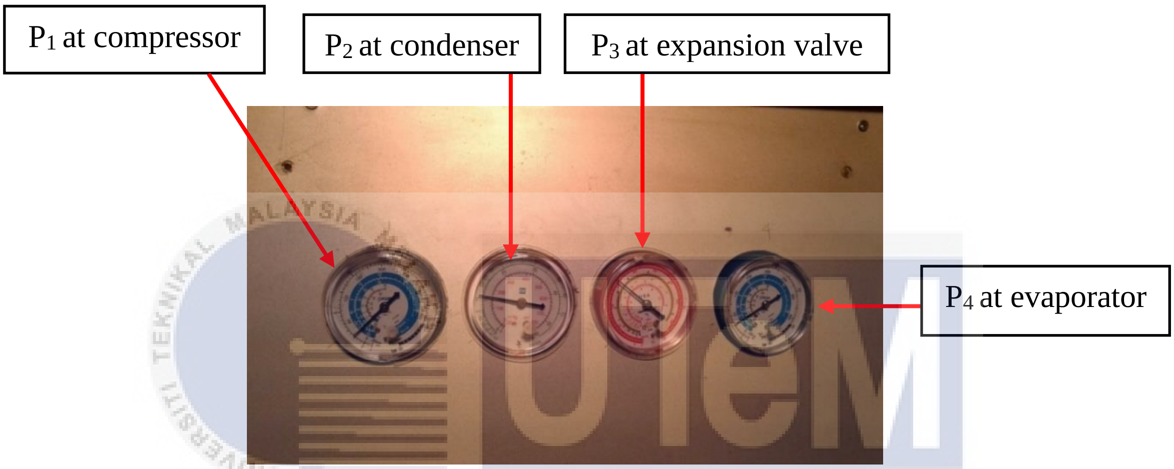

Figure 3.14: Pressure gauge.

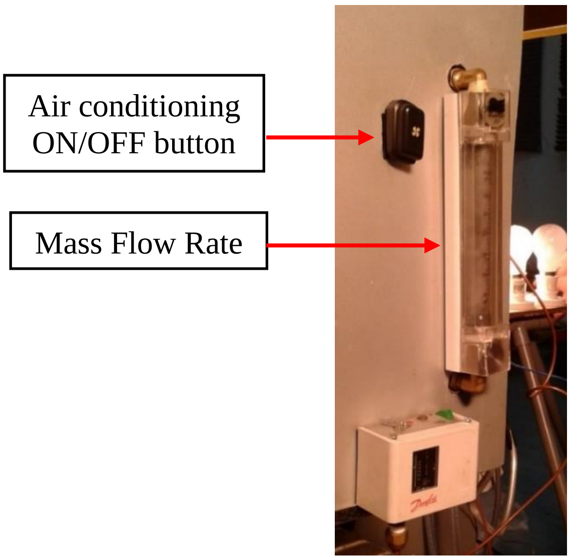

Figure 3.15: Mass Flow Rate.

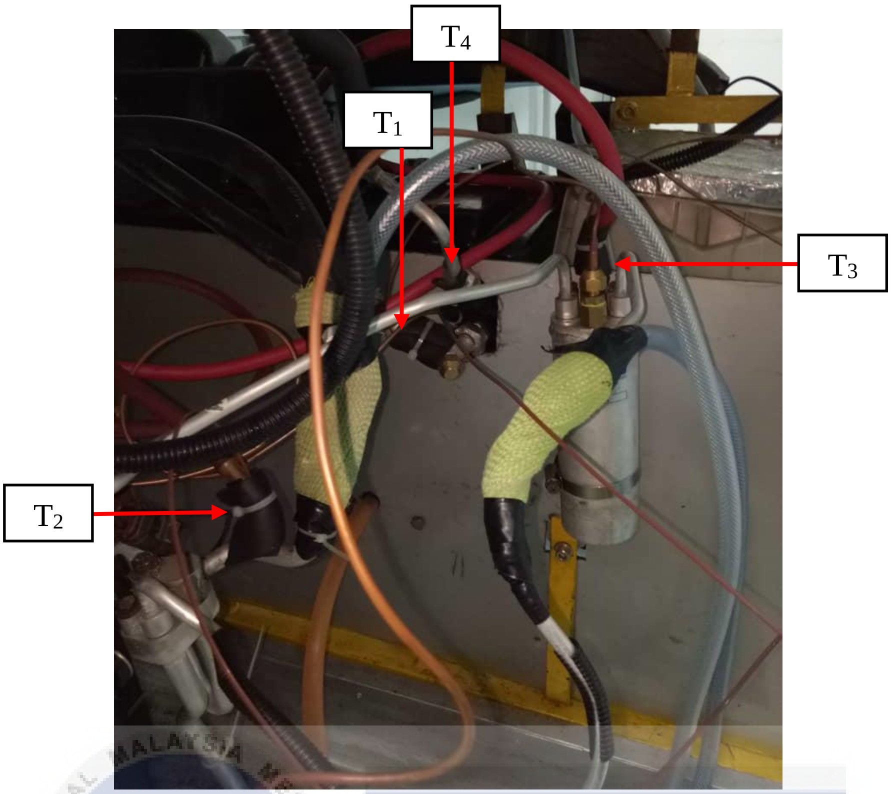

Figure 3.16: Location of T_1, T_2, T_3 and T_4 at the test rig.

Table 3.1: Data Collection Form.

Compressor Speed (rpm)		1500														
Inlet Blower Temperature (°C)		30°C														
Heat Load (W)		300 and 1000														
Ambient Temperature		28°C					33°C					38°C				
Num.	Time (sec)	Mass Flow Rate (kg/s)	P_1 (bar)	P_2 (bar)	P_3 (bar)	P_4 (bar)	Mass Flow Rate (kg/s)	P_1 (bar)	P_2 (bar)	P_3 (bar)	P_4 (bar)	Mass Flow Rate (kg/s)	P_1 (bar)	P_2 (bar)	P_3 (bar)	P_4 (bar)
1.																
2.																
3.																
4.																
5.																
6.																
7.																
8.																
9.																
10.																

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter explains the results and discussions that have been done during the experiment. The experiment is done inside the air-conditioning laboratory with time around 9.05 am until 9.15 am for an ambient temperature of 28^{o}C while another two ambient temperature which are 33^{o}C and 38^{o}C is done around 1.00 pm until 1.10 pm and 1.32 pm until 1.42 pm. The data is being recorded for every 20 second for 10 minutes and consist of total 31 sample of the data but only an average have been taken as a result. An ambient temperature of 28^{o}C, compressor speed of 1500 rpm and temperature at the inlet blower of 30^{o}C are taken as the baseline of the experiment. In this experiment, the mass flow rate, $\dot{m}$ is constant which is 0.04 kg/s. Besides that, this chapter also discuss the result of the pressure, temperature, compressor work, condenser heat rejection, evaporator heat absorption and the COP of the system according to the three different ambient temperature.

4.2 Calculated Data

4.2.1 Pressure

Table 4.1: Data for the pressure at different ambient temperature.

Ambient Temperature (^oC)	P_1 (bar)	P_2 (bar)	P_3 (bar)	P_4 (bar)
28	2.4	12	12	3.3
33	2.3	11.2	11	3
38	2.5	12.5	12.3	3.2

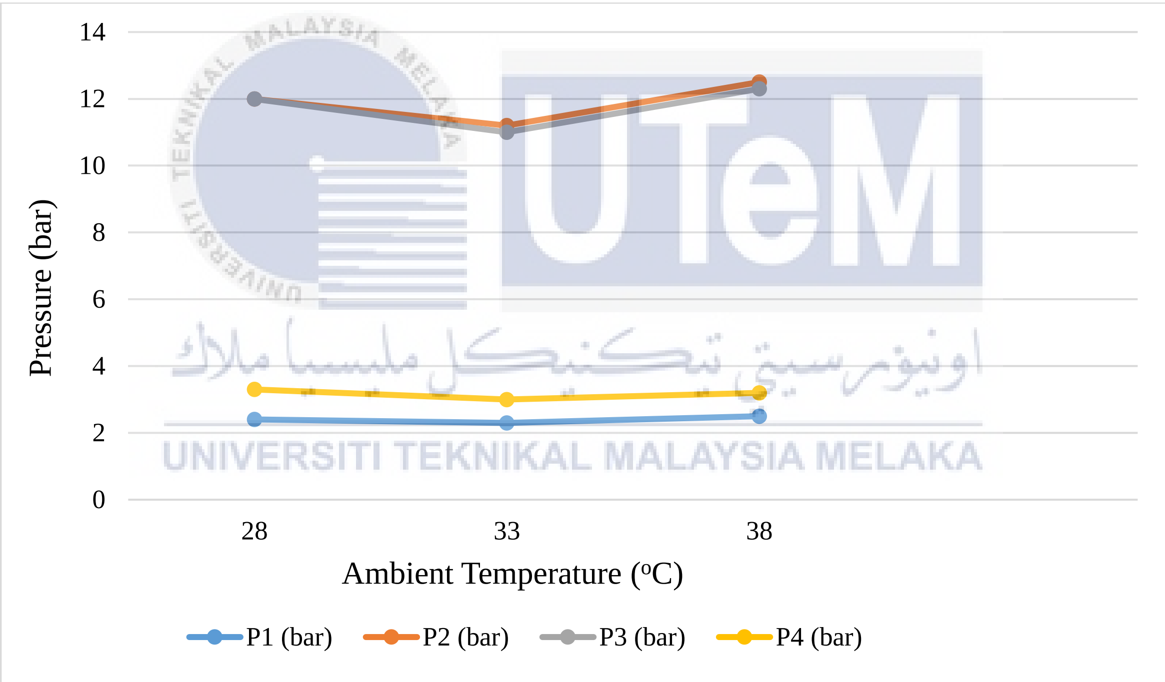

Figure 4.1: Pressure vs Ambient Temperature.

Based on the Figure 4.1, it can be seen that among the four pressure at various ambient temperature, P_1 that located at the compressor is the lower while P_2 that located at the condenser is the higher. This is because P_1 is in gas condition with low temperature while P_2 is in gas condition with high pressure. The P_3 and P_4 are actually same value with P_2 and P_1 that is in high pressure and low temperature but different condition where P_3 that located at the expansion valve is in gas to liquid condition while P_4 that is located at the evaporator is in liquid to gas condition.

4.2.2 Temperature

Table 4.2: Data for the temperature at different ambient temperature.

Ambient Temperature (ºC)	T_1 (ºC)	T_2 (ºC)	T_3 (ºC)	T_4 (ºC)
28	23.51	50.22	40.33	32.4
33	14.17	43.96	37.06	29.14
38	18.12	48.59	42.23	34.39

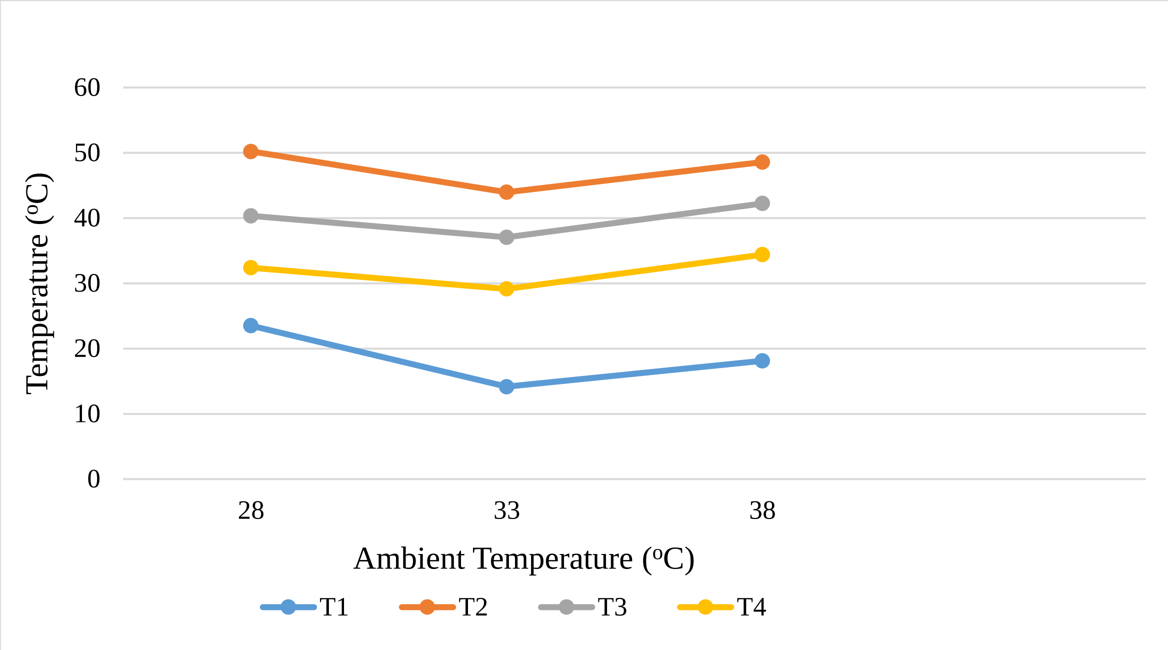

Figure 4.2: Temperature vs Ambient Temperature.

Figure 4.2 shows that T_2 is in the high temperature because T_2 is located at the outlet of the compressor. The temperature for T_2 at 28°C is highest followed by the 38°C and 33°C. This is because during the experiment, the temperature of 28°C use the spotlight to control an ambient temperature by turning off an air conditioning and opening both laboratory door while for 33°C, the air conditioning re-opened and the door close but method used to control an ambient temperature have been exchanged using bulbs.

Next, T_1 measure the temperature at the outlet evaporator that is in cool gas condition while T_3 measure the outlet of condenser where T_3 is in low temperature but high pressure and it can be seen that the temperature of T_3 is lower than T_2. The T_4 measure the outlet of the expansion valve and it in cool liquid gas condition so the temperature is lower than T_3. An overall, it can be seen that the ambient temperature for 28°C is highest while temperature of 33°C is the lowest for the T_1, T_2, T_3 and T_4 due to the method of controlling an ambient temperature.

4.3 The Effect of an Ambient Temperature on System Performance

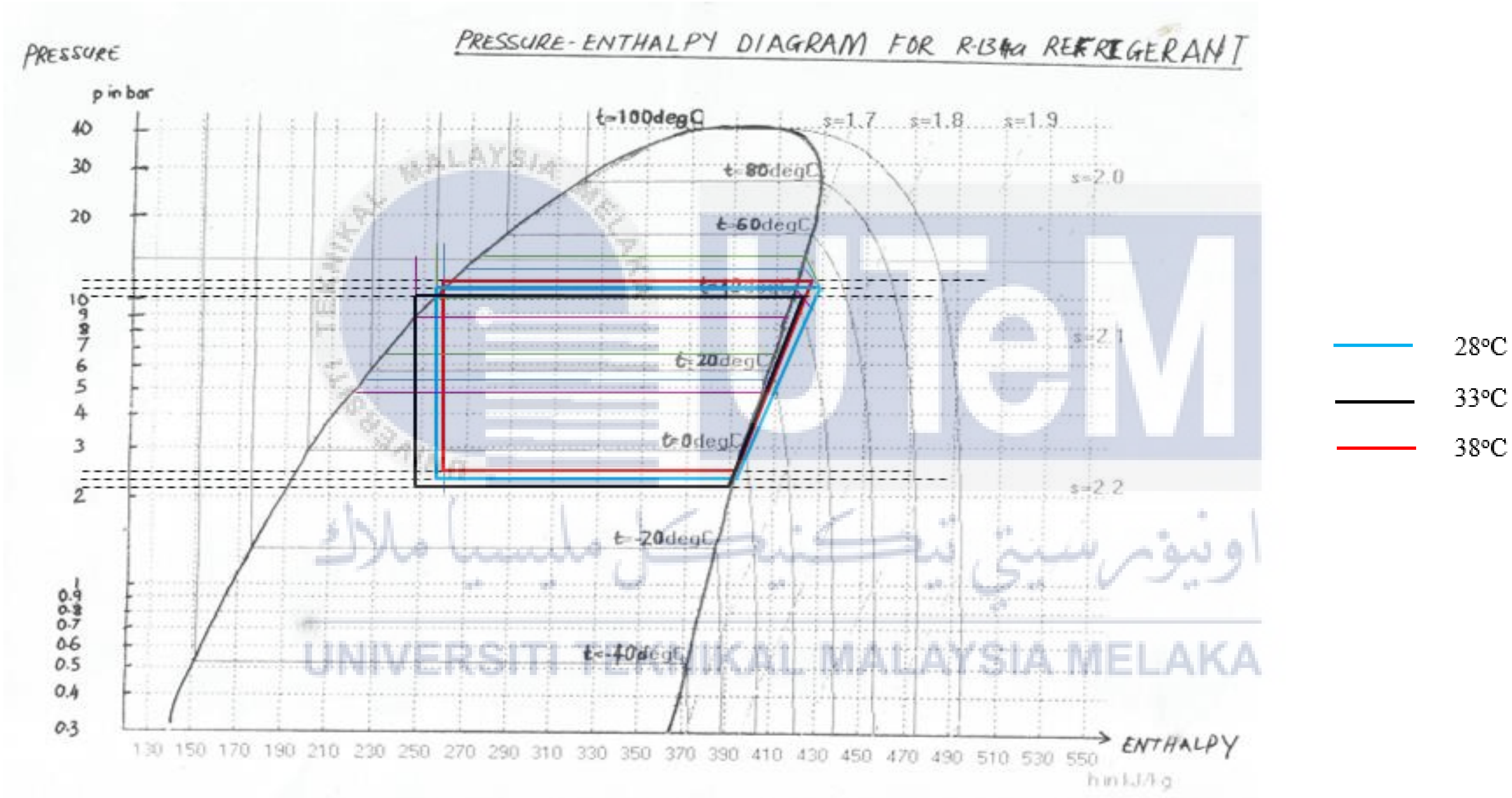

Figure 4.3: Pressure-enthalpy diagram for three different ambient temperature.

The pressure-enthalpy diagram based on R-134a refrigerant as in Figure 4.3 is used to determine the enthalpy by entering the pressure and temperature values obtained from the experiment. Based on the diagram, out of all four pressure taken, only P_1 and P_2 is chosen as data that is because refrigerant is in gas condition same goes to P_1 and P_2. State 1 in the diagram assume as dry saturated at inlet compressor (ideal condition) because the difference between T_{sat} for P_1 and T_1 for all three condition is far different. Besides that, the thermocouple located at T_1 is not measure the temperature of the refrigerant but measure the ambient temperature and the value obtained is not due to heat from the refrigerant but influenced by the high external temperature.

State 2 is the superheated process because at this condition, the gas out of the compressor in high pressure and low pressure while state 3 is the sub-cooling process where the gas out of the condenser in cool liquid condition. The actual state 2 is actually greater than the state 2 obtained from the experiment but due to the losses causing the temperature to decrease. State 4 assume as perfect throttling process where there is no change in enthalpy because of the changes from cool liquid to become a vapor that in cold condition with low pressure and low temperature. The difference in state 1, 2, 3 and 4 of the three ambient temperatures is due to the difference in temperature and pressure. The enthalpy data for the three different ambient temperatures of 28°C, 33°C and 38°C are stated in Table 4.3.

Table 4.3: Data for the enthalpy at different ambient temperature.

Ambient Temperature (°C)	Enthalpy on inlet compressor, h_1 (kJ/kg)	Enthalpy on outlet compressor, h_2 (kJ/kg)	Enthalpy on condenser exit, h_3 (kJ/kg)	Enthalpy on evaporator inlet, h_4 (kJ/kg)
28	394	428	257	257
33	392	421	248	248
38	395	422	262	262

4.3.1 Result of Qe, Qc, Wc and COP

Table 4.4: Data for the Qe and qe at different ambient temperature.

Ambient Temperature (°C)	Cooling capacity, Q_e (kJ/s)	Cooling capacity per unit mass of refrigerant, q_e (kJ/kg)
28	5.48	137
33	5.76	144
38	5.32	133

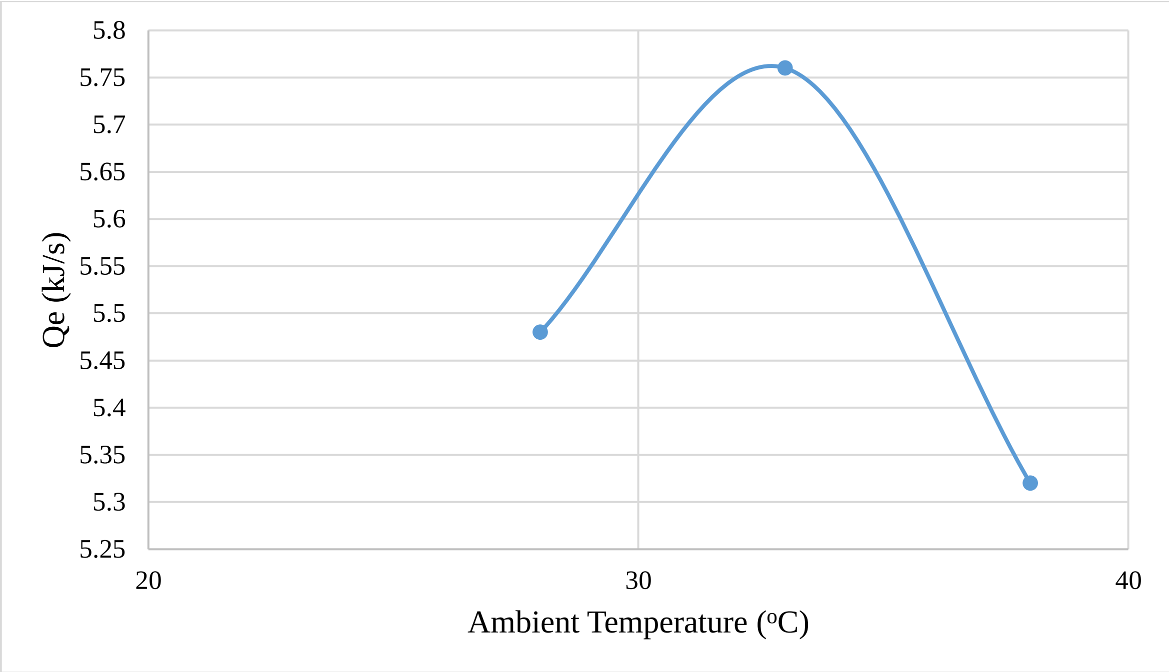

Figure 4.4: Q_e vs Ambient Temperature.

Figure 4.4 indicates that the Q_e from the temperature of 28°C ascending at 33°C and then decreased again at temperature of 38°C. This is due to the cooling coil that function to absorb heat so that the temperature will reduce. Higher ambient temperature cause the ability of cooling coil to absorb more heat and lower ambient temperature cause the ability of cooling coil to absorb less heat but for an ambient temperature of 33°C, the Q_e is higher than ambient temperature of 28°C probably because of the air-conditioning in the laboratory is opened and helps in reducing the heat.

Table 4.5: Data for the Q_c, q_c and condenser out at different ambient temperature.

Ambient Temperature (°C)	Condenser Heat Rejection, Q_c (kJ/s)	Condenser Heat Rejection per unit mass of refrigerant, q_c (kJ/kg)	Condenser out (°C)
28	6.84	171	37.46
33	6.92	173	36.12
38	6.40	160	38.73

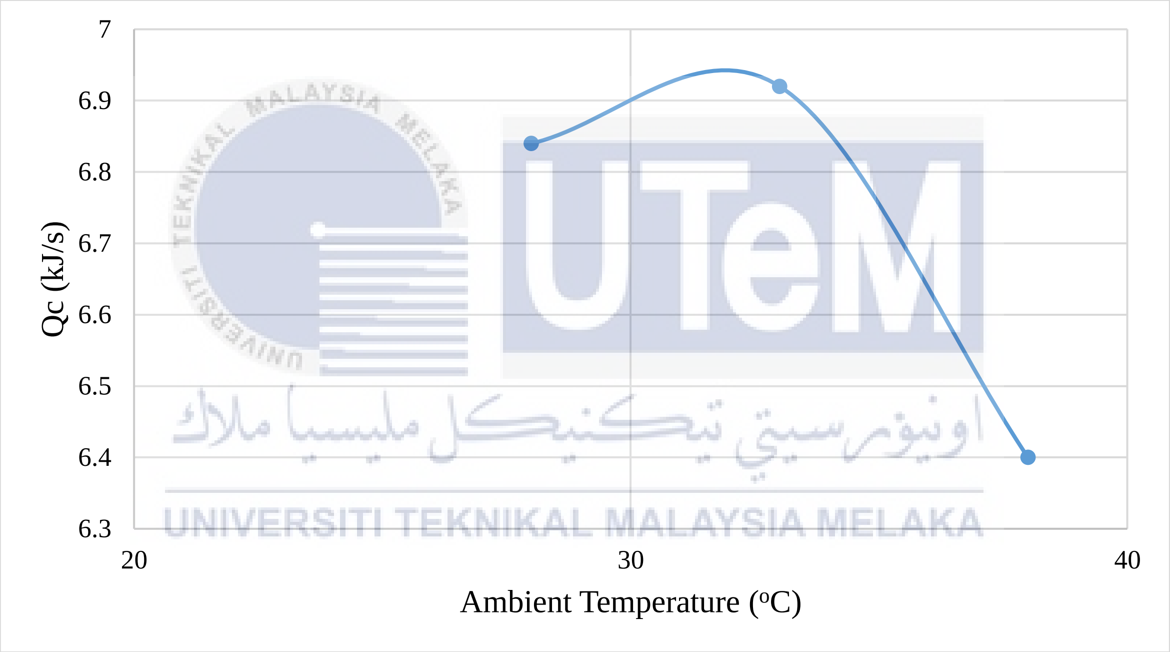

Figure 4.5: Q_c vs Ambient Temperature.

At an ambient temperature of 28°C in Figure 4.5, the Q_c is at 6.84 kJ/s, then rising up to 6.92 kJ/s at an ambient temperature of 33°C and drop to 6.40 kJ/s when an ambient temperature reach 38°C. This condition happen because, in the condenser, the heat rejected by the condenser, Q_c must be equal to the heat absorb by the air, Q_a. In general, heat received by the ambient air is defined as $\dot{m}C_p\Delta T$. When ΔT reduce, Q_a will reduce, therefore the Q_c will also reduce due to the energy balance that is $Q_a = Q_c$. When ambient temperature already at high temperature which is 38°C, so the temperature difference will be lower as the condenser out recorded at the temperature of 38.73°C.

Table 4.6: Data for the W_c, w_c and blower out at different ambient temperature.

Ambient Temperature (°C)	Compressor Work, W_c (kJ/s)	Compressor Work per unit mass of refrigerant, w_c (kJ/kg)	Blower out (°C)
28	1.36	34	11.23
33	1.16	29	15.16
38	1.08	27	16.09

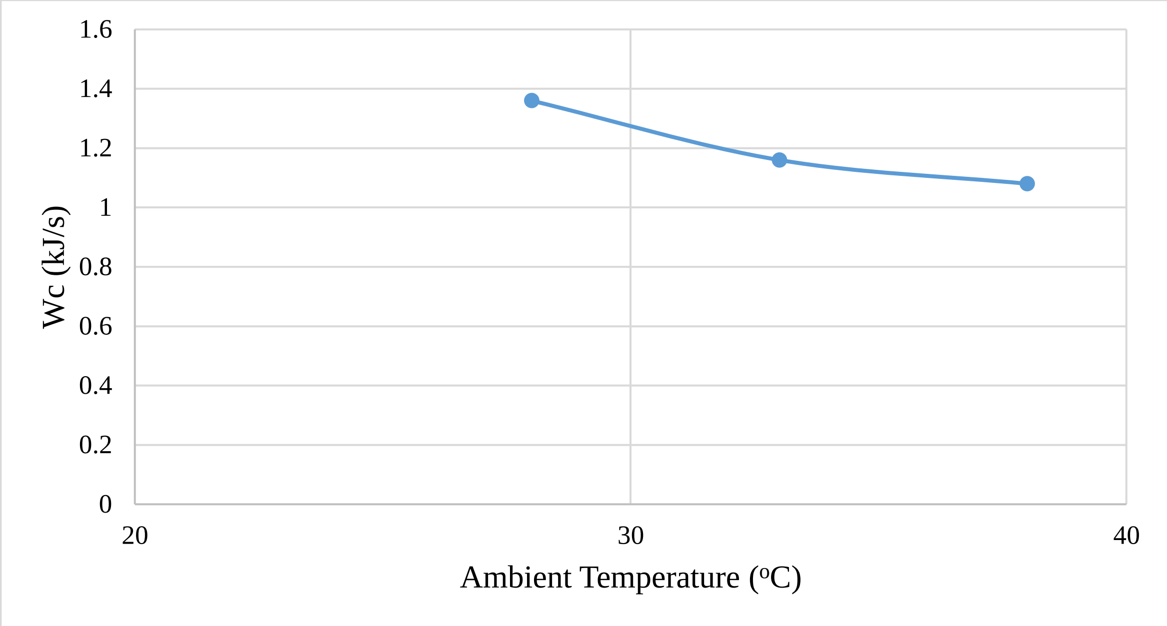

Figure 4.6: W_c vs Ambient Temperature.

Figure 4.6 shows that the ambient temperature at 28ºC on W_c is the highest and then drop after reach the ambient temperature of 33ºC and then drop again when at ambient temperature of 38ºC. This is because an ambient temperature at 28ºC need more energy to get the temperature at the blower out which is 11.23ºC while for the ambient temperature at 38ºC, the energy need by the compressor to compress the gas is lower. Therefore, the temperature at the outlet of blower for an ambient temperature of 38ºC is 16.09ºC. Besides that, the compressor is only able to supply a temperature of 16.09 at the outlet of blower and cause a low compressor work. Moreover, for the system to get equilibrium, it can only give this value even the system is controlled by itself without being influenced by other causes.

Table 4.7: Data for the COP at different ambient temperature.

Ambient Temperature (ºC)	Coefficient of Performance, COP
28	4.03
33	4.97
38	4.93

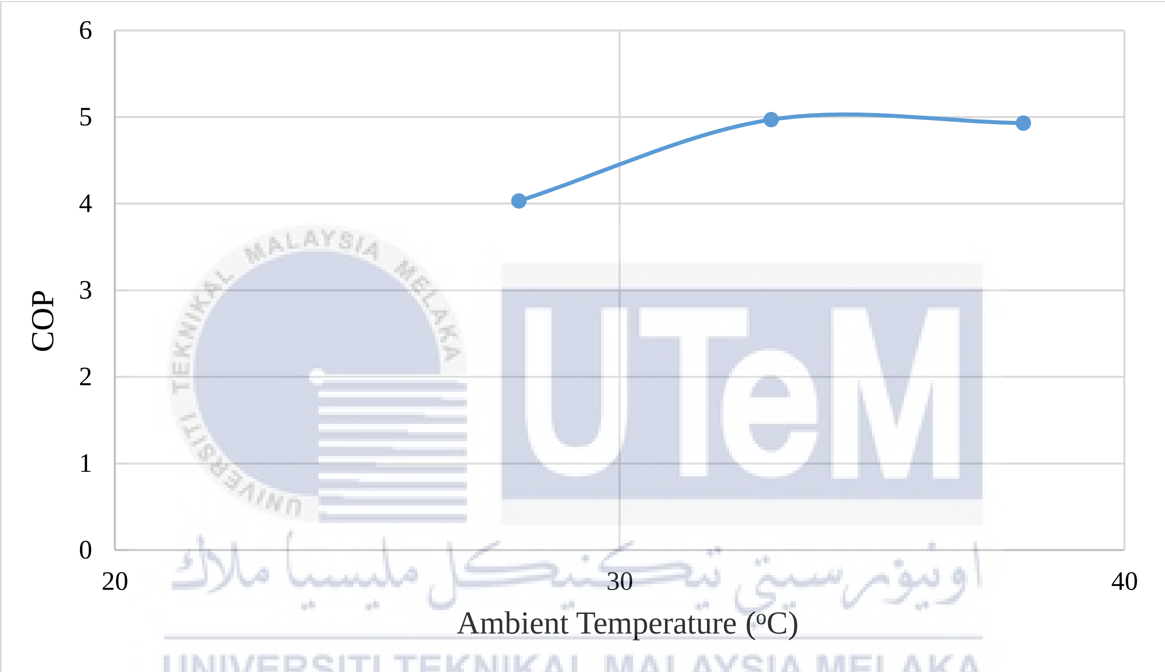

Figure 4.7: COP vs Ambient Temperature.

The value of the COP for an ambient temperature of 28^{o}C is 4.03 as in Figure 4.7. After that the COP increase to 4.97 for an ambient temperature of 33^{o}C and then decrease to 4.93 for an ambient temperature of 38^{o}C. An ambient temperature of 33^{o}C is higher on COP than 28^{o}C and 38^{o}C because the value of the COP is related to the equation of the cooling capacity over compressor work where increase in cooling capacity is dominant as compared to the compressor work. The optimum value of COP is at ambient temperature of 33^{o}C and the minimum value is at 38^{o}C followed by 28^{o}C.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this report, all the introduction, literature review, methodology and the result from the experiment on the performance investigation of vehicle air conditioning system under different ambient condition has been presented. The objective for this experiment has been achieved because the best coefficient of performance of the air conditioning system is known even other parameters such as system temperature, system pressure, cooling capacity and different work at different ambient condition can also be determined.

The COP at an ambient temperature of 28^{o}C is 4.03 and then rose by 18.80% for an ambient temperature of 33^{o}C while at an ambient temperature of 38^{o}C, the percentage decrease by 0.80%. The ambient temperature at the 28^{o}C is the lowest and the difference between an ambient temperature of 38^{o}C is about 9.0%. Increase in COP will decrease the power consumption that related to the energy consumption which will decrease the compressor work and heat load. Besides that, the condition of the experiment being run also can affect the COP. The best operating is at ambient temperature of 33^{o}C which give the COP of 4.97.

5.2 Recommendations

Various challenges and problems that need to be taken while conducting the experiments using the test rig to obtain the data that capable of delivering satisfactory results and some recommendation are needed to fix the existing weaknesses. For the future, the test rig requires a change in terms of the motor where the compressor motor must be able to bear the load and not easily heat when the test rig is carried out continuously.

Besides that, the thermocouple at inlet compressor, T_1 requires proper insulated so that the temperature measure is not from the outside temperature but from the refrigerant temperature and due to this condition, the data taken did not get the required result. In addition, wiring and installation of each component should be done neatly and properly to make it easier to identify the source of each thermocouple in the rig test.

Lastly, to get an efficient data, the system used should be changed to an actual vehicle system because actual system of vehicle can be run continuously even in the long period but it is necessary to follow the temperature and the environment condition to get the desired ambient temperature because an ambient temperature is subjective and cannot be control unless using certain method as done for experiments on test rig.

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APPENDICES

Time (s)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	Blower in (°C)	Blower out (°C)	T in (°C)	T out (°C)
20	22.55	50.15	40.59	32.05	0.05	28.96	10.33	27.79	36.94
40	22.61	50.3	40.53	32.04	0.01	29.62	10.29	27.68	36.96
60	22.7	50.58	40.46	32.04	-0.25	29.03	10.3	27.98	37.15
80	22.8	50.82	40.45	32.05	-0.34	30.39	10.36	27.86	37.05
100	22.89	51	40.37	32.06	-0.48	30.86	10.34	28.06	37.13
120	22.98	51.18	40.37	32.11	-0.71	30.38	10.35	28.07	37.19
140	23.07	51.33	40.36	32.14	-0.76	30.45	10.43	28.06	37.15
160	23.18	51.42	40.36	32.22	-0.85	30.37	10.42	28.23	37.3
180	23.26	51.48	40.39	32.28	-1.02	30.97	10.54	28.5	37.35
200	23.35	51.43	40.39	32.33	-1.16	30.96	10.63	28.45	37.31
220	23.43	51.36	40.37	32.37	-1.44	30.82	10.64	28.49	37.45
240	23.49	51.36	40.42	32.41	-1.81	29.9	10.75	28.5	37.47
260	23.55	51.31	40.41	32.4	-2.12	30.3	10.88	28.72	37.41
280	23.59	51.13	40.37	32.39	-2.51	30.86	10.95	28.92	37.44

300	23.64	50.79	40.37	32.4	-2.81	30.38	11.1	29	37.5
320	23.7	50.38	40.37	32.44	-3.11	31.23	11.24	28.87	37.48
340	23.77	50	40.37	32.48	-3.32	31.37	11.38	29.23	37.5
360	23.82	49.92	40.36	32.49	-3.46	31.77	11.51	29.1	37.54
380	23.86	49.88	40.3	32.47	-3.58	30.77	11.61	29.26	37.56
400	23.9	49.89	40.29	32.47	-3.67	31.27	11.78	29.28	37.6
420	23.93	49.96	40.29	32.49	-3.7	31.26	11.85	29.36	37.66
440	23.95	50.08	40.27	32.51	-3.73	31.2	11.93	29.69	37.71
460	24	50.22	40.26	32.56	-3.78	31.54	12.03	30.53	37.78
480	24.06	50.27	40.25	32.63	-3.75	32.08	12.12	30.97	37.86
500	24.11	50.02	40.27	32.68	-3.62	31.45	12.19	29.99	37.79
520	24.12	49.44	40.23	32.67	-3.52	31.67	12.27	29.87	37.68
540	24.13	48.78	40.15	32.64	-3.34	31.57	12.34	29.84	37.58
560	24.15	48.34	40.05	32.62	-3.01	30.01	12.48	29.64	37.43
580	23.84	47.86	39.76	32.51	-1.71	29.71	11.93	29.75	37.1
600	23.24	47.88	40.16	32.65	-1.06	30.16	11.42	29.58	38.25

An ambient temperature at 28°C.

Time (s)	T_1 (ºC)	T_2 (ºC)	T_3 (ºC)	T_4 (ºC)	T_5 (ºC)	Blower in (ºC)	Blower out (ºC)	T in (ºC)	T out (ºC)
20	16.38	38.08	37.02	29.37	9.23	31.82	16.87	33.76	36.24
40	16.4	38.61	37.32	29.56	8.97	31.64	16.68	33.78	36.13
60	16.43	39.59	37.66	29.8	8.55	31.84	16.37	33.55	36.23
80	16.35	40.48	37.85	29.9	8.3	31.85	16.07	33.6	36.29
100	16.06	41.26	37.91	29.95	8.23	31.65	15.79	33.57	36.45
120	15.92	41.98	37.89	29.93	8.08	31.69	15.61	33.26	36.33
140	15.62	42.61	37.82	29.83	7.97	31.71	15.4	33.36	36.16
160	15.34	43.13	37.7	29.72	8.03	31.65	15.28	33.38	36.16
180	15.14	43.58	37.59	29.61	8.02	31.65	15.12	33.37	36.13
200	14.82	44.01	37.5	29.51	8.02	31.62	15.01	33.32	36.18
220	14.62	44.4	37.45	29.46	7.88	31.63	15	33.32	36.31
240	14.38	44.76	37.39	29.41	7.9	31.45	14.95	33.51	36.17
260	14.17	45.06	37.26	29.3	7.93	31.17	14.88	33.28	36.1
280	14.03	45.28	37.18	29.22	7.87	31.21	14.86	33.28	36.1
300	13.86	45.46	37.11	29.15	7.58	31.31	14.86	33.13	36.16
320	13.73	45.65	37.06	29.1	7.57	31.07	14.84	32.78	36.11
340	13.64	45.76	36.93	29	7.44	31.03	14.79	33.08	36.06
360	13.53	45.81	36.85	28.92	7.36	31	14.75	33.11	36.09

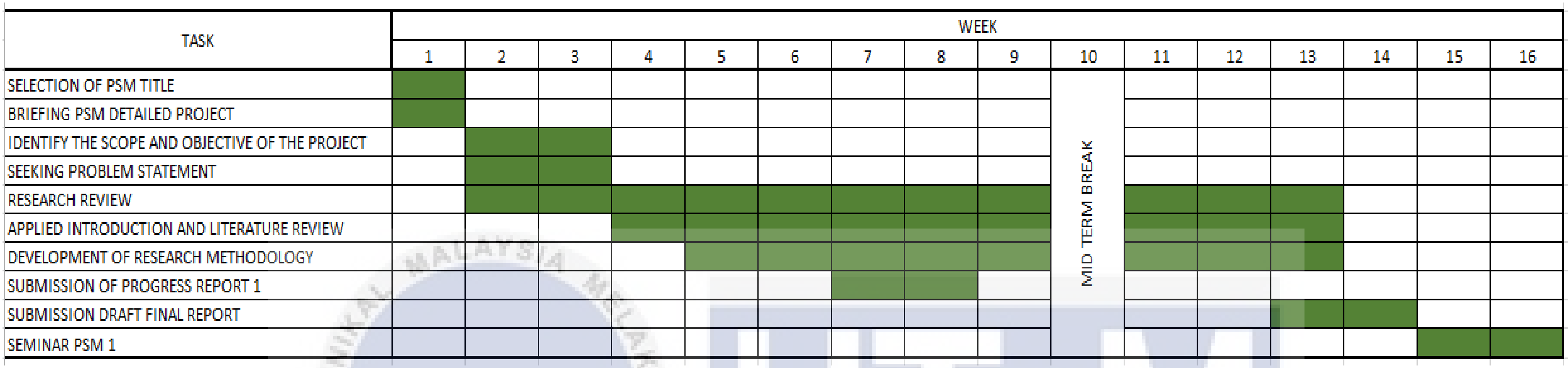
380	13.44	45.87	36.83	28.91	7.4	30.91	14.77	32.63	36.12
400	13.34	45.82	36.79	28.9	7.46	31.08	14.77	32.43	35.98
420	13.25	45.66	36.71	28.86	7.57	30.84	14.76	32.52	35.96
440	13.24	45.51	36.6	28.78	7.91	30.64	14.74	32.52	35.9
460	13.16	45.35	36.55	28.72	7.97	30.63	14.76	32.52	35.93
480	13.01	45.16	36.5	28.64	8.04	30.47	14.77	33.07	35.94
500	12.97	45.04	36.53	28.61	8.19	30.53	14.82	32.21	36.02
520	12.86	44.9	36.54	28.57	8.22	30.36	14.8	32.05	36.01
540	12.78	44.78	36.5	28.51	8.37	30.51	14.83	32.21	35.9
560	12.7	44.72	36.44	28.46	8.52	30.39	14.87	32.38	35.85
580	12.69	44.75	36.44	28.53	8.61	30.37	14.95	33.69	36.19
600	12.73	44.83	36.45	28.59	8.61	30.38	14.99	34.12	36.22

An ambient temperature at 33ºC.

Time (s)	T_1 (ºC)	T_2 (ºC)	T_3 (ºC)	T_4 (ºC)	T_5 (ºC)	Blower in (ºC)	Blower out (ºC)	T in (ºC)	T out (ºC)
20	18.14	41.1	40.97	32.88	8.06	29.38	16.43	37.61	37.28
40	18.21	41.58	41.08	33.03	8.19	29.24	16.34	36.72	37.2
60	18.28	42.42	41.16	33.25	8.34	29.29	16.18	38.45	37.41
80	18.3	43.2	41.25	33.38	8.39	29.43	16.05	37.36	37.58
100	18.14	43.98	41.4	33.53	8.47	29.03	15.9	37.64	37.77
120	17.99	44.75	41.52	33.68	8.8	29.69	15.83	36.57	38.05
140	17.9	45.42	41.67	33.78	9.1	29.45	15.74	37.24	38.22
160	17.72	46.12	41.84	33.9	9.31	29.47	15.66	38.48	38.48
180	17.67	46.92	42.02	34.06	9.53	29.39	15.68	38.52	38.71
200	17.66	47.74	42.18	34.16	9.81	29.62	15.73	39.56	38.81
220	17.64	48.52	42.26	34.24	10.11	29.93	15.75	38.61	38.84
240	17.72	49.14	42.38	34.35	10.26	29.81	15.8	38.24	38.93
260	17.78	49.62	42.47	34.44	10.43	29.65	15.83	38.39	38.89
280	17.84	49.86	42.49	34.48	10.64	29.65	15.87	38.21	38.95
300	17.92	49.99	42.51	34.55	10.61	29.81	15.92	38.17	38.93
320	17.96	49.97	42.52	34.61	11.05	29.82	15.95	38.1	39
340	18.02	49.97	42.55	34.67	11.66	29.72	15.98	38.36	39.08
360	18.01	50.01	42.58	34.72	12.05	30.2	15.98	38.13	39.04

380	18.02	50.06	42.57	34.7	12.38	30.44	16.04	38.3	39.04
400	18.1	50.26	42.58	34.74	12.69	29.74	16.04	38.99	39.03
420	18.14	50.51	42.56	34.75	12.84	29.86	16.09	38.6	39.04
440	18.2	50.77	42.55	34.75	12.87	29.98	16.14	38.06	39.12
460	18.23	50.99	42.6	34.8	12.88	30.13	16.2	37.5	39.11
480	18.29	51.17	42.63	34.86	12.73	29.95	16.29	37.8	39.12
500	18.37	51.34	42.68	34.96	12.43	30.35	16.37	37.21	39.19
520	18.46	51.54	42.68	35.05	12.32	29.52	16.38	37.4	39.2
540	18.52	51.63	42.68	35.05	12.29	29.79	16.43	37.41	39.15
560	18.55	51.67	42.71	35.05	12.4	30.35	16.48	37.97	39.22
580	18.63	51.85	42.78	35.16	12.57	29.84	16.55	39.12	39.36
600	18.68	51.99	42.86	35.22	12.63	29.81	16.58	38.8	39.42

An ambient temperature at 38°C.



Gantt Chart Final Year Project 1.

TASK	WEEK															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CONDUCT THE EXPERIMENT																
DATA COLLECTED																
DATA ANALYSIS																
RESULT AND DISCUSSION																
DEVELOP CONCLUSION																
SUBMISSION OF DRAFT REPORT																
EDIT REPORT																
SUBMISSION FINAL REPORT																

Gantt Chart Final Year Project 2.