PERFORMANCE INVESTIGATION OF VEHICLE AIR CONDITIONING SYSTEM UNDER DIFFERENT HEAT LOAD

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A report submitted

in fulfilment of the requirements for the degree of

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DECLARATION

I declare that this project report entitled "Performance investigation of Vehicle Air Conditioning System under Different Heat Load" 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 : DR. MOHAMAD FIRDAUS BIN SUKRI

Date : ……………………………………

To my beloved father and mother

ABSTRACT

This study deals with the performance investigation of vehicle air conditioning system under different heat load. The effect of different heat load on system temperature, system pressure, compressor work, cooling capacity and coefficient of performance was investigated. The heat load is simulated using electrical bulbs with the power range between 300 to 900 watt. In addition, R134a was used as refrigerant. The heat greatly affect the performance of air conditioning system. Meanwhile, the speed of compressor, speed of blower fan and ambient temperature is fixed. Measurements were taken during the 10 minutes experimental period for evaporator inlet temperature of air which 30℃. The data has been analysed in statistically and graphically by using Refprop. It seems that the result has risen up and fall regularly almost every parameter in this experiment which is not corresponding with the previous research due to some error. The result shows that the performance of the vehicle air conditioning system increase about 9.86% in 34℃ to 37℃ when the evaporator inlet temperature of air increased (heat load increase). Therefore, the best coefficient of performance of vehicle air conditioning system with different heat load is 4.57 at 37℃.

ABSTRAK

Kajian ini berkaitan dengan penyiasatan prestasi sistem penghawa dingin kenderaan di bawah beban haba yang berbeza. Kesan beban haba yang berlainan pada suhu sistem, tekanan sistem, kerja pemampat, kapasiti penyejukan dan pekali prestasi disiasat. Beban haba disimulasikan menggunakan mentol elektrik dengan jarak kuasa antara 300 hingga 900 watt. Di samping itu, R134a digunakan sebagai penyejuk. Haba sangat mempengaruhi prestasi sistem penghawa dingin. Sementara itu, kelajuan pemampat, kelajuan kipas blower dan suhu ambien tetap. Pengukuran telah diambil dalam tempoh percubaan selama 10 minit untuk penyejatan suhu masuk udara yang 30 ℃. Data telah dianalisis secara statistik dan secara grafik dengan menggunakan Refprop. Nampaknya hasilnya telah meningkat dan jatuh secara kerap hampir setiap parameter dalam eksperimen ini yang tidak sepadan dengan penyelidikan terdahulu akibat beberapa kesilapan. Hasilnya menunjukkan bahawa prestasi sistem penghawa dingin kenderaan meningkat sekitar 9.86% dalam 34 ℃ hingga 37 ℃ apabila suhu penyejat masuk udara meningkat (kenaikan beban haba). Oleh itu, pekali prestasi terbaik sistem penyaman udara kenderaan dengan beban haba yang berlainan adalah 4.57 pada 37 ℃.

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ACKNOWLEDGEMENTS

First and foremost, praises and thanks to the God, the Almighty, for His showers of blessings throughout my final year project (FYP) to complete the work successfully.

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LIST OF ABBREVIATIONS

HVAC	= Heating, ventilation and air conditioning
ASHRAE	= American Safety of Heating, Refrigerating and Air Conditioning Engineers
A/C	= Air Conditioning
AC	= Alternate Current
SOP	= Standard Operating Procedure
COP	= Coefficient of Performance

LIST OF SYMBOLS

Qe	= cooling capacity of the evaporator (kJ)
Wc	= power of the compressor (kJ)
h_1	= enthalpy on compressor (kJ/kg)
h_2	= enthalpy discharge of compressor (kJ/kg)
h_3	= enthalpy on condenser exit (kJ/kg)
h_4	= enthalpy on evaporator inlet (kJ/kg)

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Air conditioning is a part of the heating, ventilation, and air conditioning system (HVAC). Automobile air conditioning (A/C) is used to cool the air in the vehicle. In 1933, a company in New York City in the United State was the first offer of air conditioning in the cars. Then, the first air conditioning system in the world was developed by Packard Motor Car Company in 1939. Nowadays, automotive air conditioning system has competed for each other because the A/C was a very important role in human comfort and to some extent safety throughout vehicle driving in varied weather conditions. Therefore, it has become an important element for the vehicles of all categories worldwide. Based on American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), air conditioning system is used to create and maintain the temperature, humidity, motion, and cleanliness of the air. Besides that, air conditioning also controlled and provides a comfy atmosphere to the passengers and driver of a vehicle throughout summer and winter. In addition, the air conditioning also provides comfort to passengers that express satisfaction with the surrounding environment.

HVAC system known as heating, ventilation and air conditioning system is designed in an automobile to provide comfort to users. The air conditioning system transfers the heat inside the vehicle to the outside of the vehicle. There are four main components of the air conditioning system that be shown in Figure 1.1 which are condenser, evaporator, expansion valve and compressor.

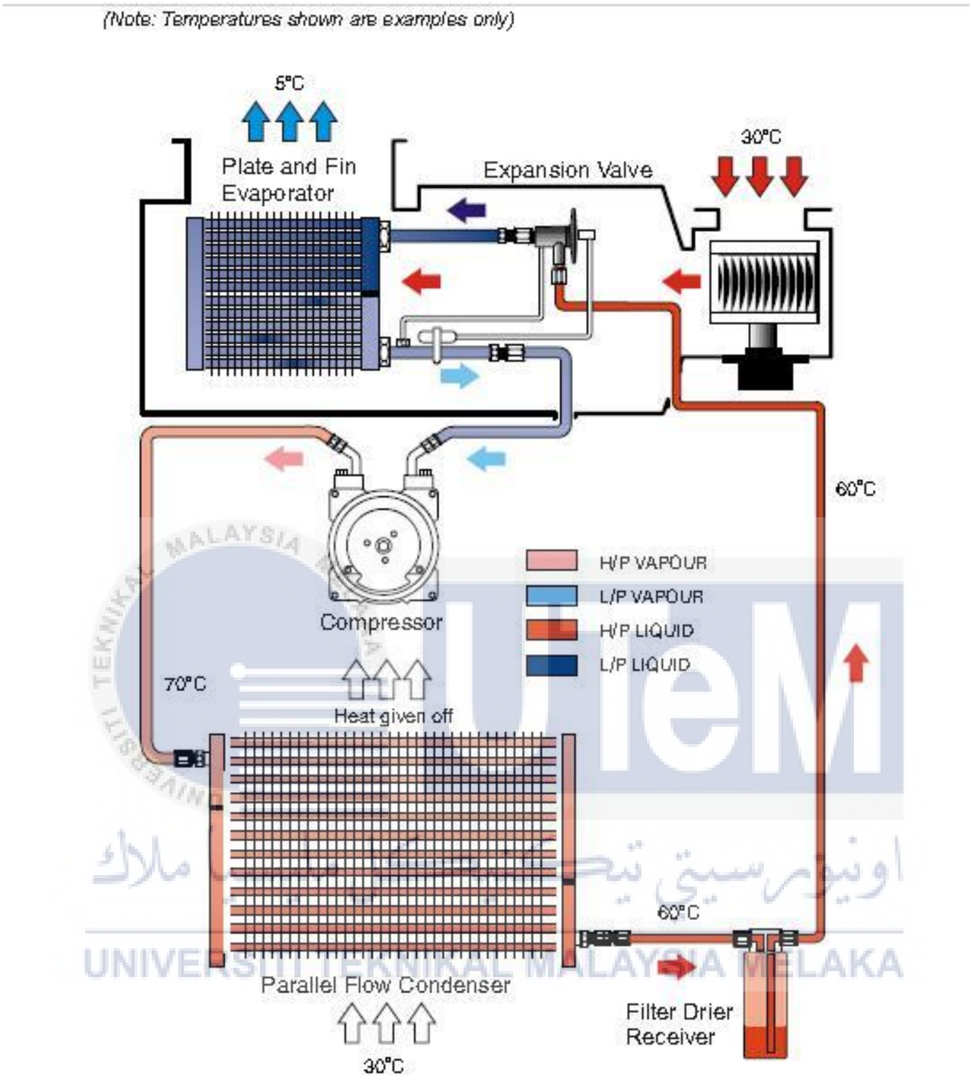


Figure 1.1: Four main components of the air conditioning system

Hence, the main of this project is to investigate the performance of vehicle air conditioning system with different heat load due to give thermal comfort for the passengers besides to reduce the fuel consumption of the vehicle.

1.2 PROBLEM STATEMENT

Due to extreme weather conditions in Asia, automotive air conditioning has played an important role in the automotive system by giving human comfort and to some extent of human safety during vehicle driving in various atmospheric conditions. It has become an essential part of the vehicles of all categories throughout the worldwide. The basic operation of the air conditioning system has resulted in the thinning of the ozone layer where the gas released by the air conditioning system such as Nitrous Oxide (NO) that can increase from time to time which are harmful to the environment. This probably due to the growing global flows and concerns that should be reinforced and secure.

There are several problems arise from the recent of air conditioning system. First of all, the problems that face by the passengers is do not feel comfortable in high temperature because of peak weather. In that time, the temperature inside the cabin of the car is high because of the heat from surrounding will enter the condenser and mixed with the heat that release by the passengers at the evaporator make the. So that, the air conditioning will used at a low temperature with high speed of the blower that make the compressor must work harder that gives effect to the fuel consumption of the vehicle.

In recent years, the fuel consumption of vehicles has received attention from the customer, the automotive industry, regulatory bodies and academia that are responsible for the operation of air conditioning. There has been much argument on the effect of air conditioning system on the fuel efficiency of a vehicle. The factors such as wind resistance, aerodynamics, engine power, and weight must be considered to find the best coefficient of performance air conditioning system. This system has a greater impact on fuel consumption which burns additional fuel to the mechanical air conditioning device and carries additional air conditioning loads throughout the vehicle all the time.

Besides, when more uses of fuel the more harmful gas such as hydrocarbons that reacts with nitrogen dioxide and sunlight to form ozone, which can affect human health such as it can cause chest pains and coughing also making it difficult to breathe. Carbon monoxide also another exhaust gas that particularly dangerous and people suffering from heart disease because it interferes with the blood's ability to transport oxygen.

1.3 OBJECTIVE

Objectives are the guidance of any project, so the objectives of this study are as follows:

a) To determine the system temperature, system pressure, cooling capacity and compressor work at different load.
b) To justify the best coefficient of performance of the air conditioning system.

1.4 SCOPE OF PROJECT

The scope of this project is to focus on the performance of the vehicle air conditioning system with different heat load based on the objective and to solve the problem faced as much as it can. The air conditioning system will be observed using analytical methods. Thus, all the data will be obtained from the experiment with different heat load that is done in the laboratory by following the procedure and safety in the lab.

In this project focus will be a focus on the coefficient of performance air conditioning system where it will be different heat load. The heat load will be manipulated the heat in watt which the values are 300 watt, 600 watt and 900 watt. Besides that, the speed of the compressor being fixed at 1500 rpm and the surrounding temperature about 28℃ to 29℃.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, reviews of the previous researches project that are related to this project will be discussed. The information will become an additional source for the project in becoming more successful. To have a brief understanding of the research related to the project, a few literature previews had been done. This chapter will describe the related literature reviews.

2.2 AIR CONDITIONING SYSTEM

Automotive air conditioning system has become the main role in a vehicle based on human comfort and some safety during driving vehicle in varied atmospheric conditions. Therefore, in this study will to investigate the performance of vehicle air conditioning system with different heat load.

2.2.1 Definition of Air Conditioning System

Air conditioning system is the system that controls the humidity, ventilation and temperature of a building or vehicle in warm conditions. Besides, air conditioning is defined in the automotive sector as a system for the maintenance of occupants of cars, buses and trucks that limited to air cooling, air heating and occasionally dehumidification.

2.3 VAPOR COMPRESSION REFRIGERATION SYSTEM AND VAPOR ABSORPTION REFRIGERATION SYSTEM

Vapour compression refrigeration system (VCRS) widely used method for automotive air conditioning system. Refrigeration is defined as lowering the temperature by remove heat from one space to be cool and reject heat elsewhere, it also as known as the air conditioner or heat pump. The basic schematic diagram is shown in Figure 2.1(a). VCRS have involve four components: compressor, condenser, expansion valve/throttle valve and evaporator. It is a compression process that aimed at increasing the refrigerant pressure because it flows from the evaporator. The high pressure of refrigerant will flows through a condenser before the initial low pressure is reached and the evaporator is returned.

Meanwhile, Vapour Absorption Refrigeration System (VARS) used ammonia, water or lithium bromide as refrigerant where the refrigerant will condense in a condenser and gets evaporated in an evaporator. At the evaporator, the refrigerant will produce the cooling effect while releasing the heat to the atmosphere through the condenser.

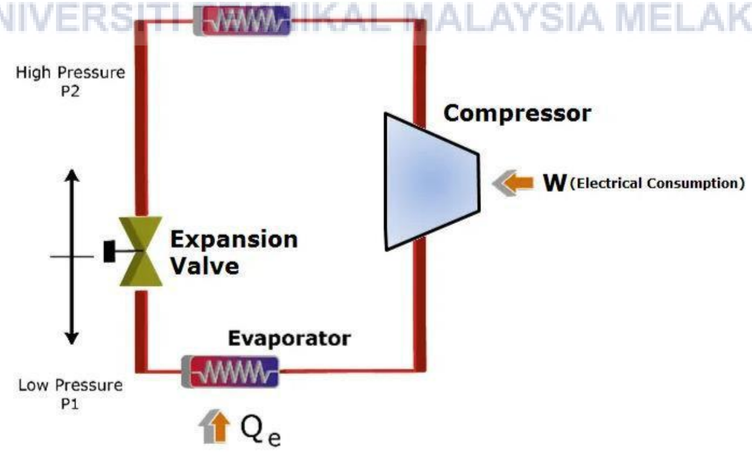


Figure 2.1 (a): Basic schematic diagram of VCRS (Araner, 2018)

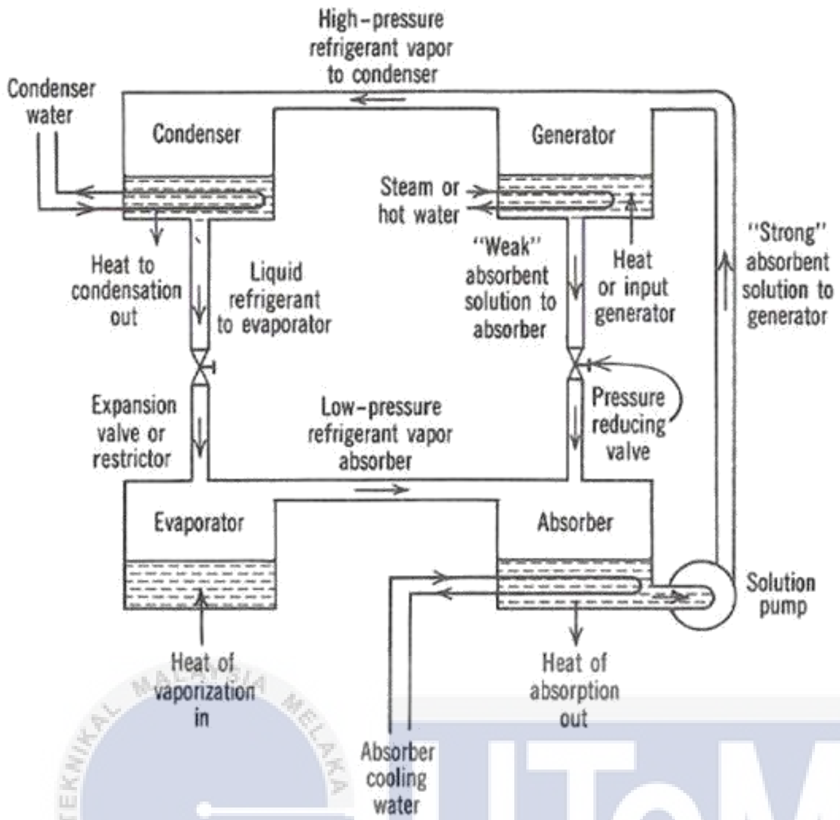


Figure 2.1 (b): Basic schematic diagram of VARS (Khemani, n.d.)

There are differences between VCRS and VARS in component part, which are VARS did not use compressor but use absorber, pump or generator in their system. The refrigeration cycle is a Rankine cycle run in reverse, a refrigerant is pushed through the system undergoes state changes from liquid to gas. The latent heat of vaporization of the refrigerant is used to transfer a lot of amount of heat energy and changes in pressure that used to control when the refrigerant absorbs heat energy.

In VCRS have four steps, the figure of the process have shown in Figure 2.1 (c) where the PV changes during each part.

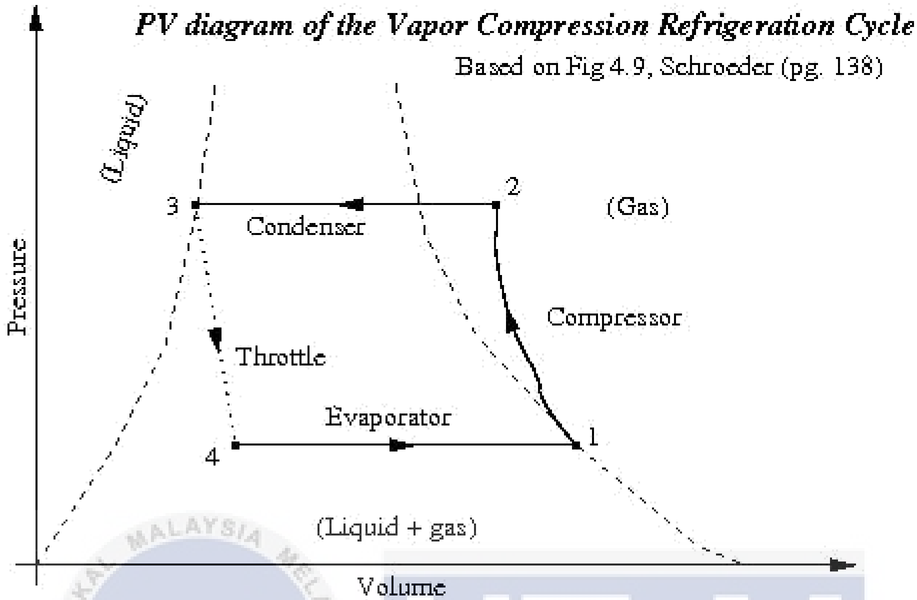


Figure 2.1 (c): PV diagram of vapor compression refrigeration cycle (S.H.Price, 2007)

At state (1- 2) occur in compression in phase of gas, in this part the refrigerant enters the compressor as a gas under low pressure also having low temperature. After that, the refrigerant will compressed adiabatically, so the fluid leaves the compressor under high pressure and with a high temperature. Then, it move to condenser at saturated mixture at state (2-3). At this state, the high pressure and high temperature make the gas releases heat energy and condenses inside the condenser of the system. The condenser is contact with the hot reservoir of the refrigeration system. After that, the refrigerant leaves as a high pressure liquid. In state (3-4) with phase of saturated liquid, the liquid of refrigerant is pushed by the throttling valve, that make it to expand so that the refrigerant change to low pressure and lower temperature in the liquid phase. For the last state (4-1), the low pressure with the low temperature of the refrigerants enters the evaporator where it is contact with the cold reservoir. When the low pressure is maintained, the refrigerant can be able to boil at low temperature. So that, the liquid will absorbs heat from the cold reservoir and evaporates. The refrigerant leaves the evaporator with low pressure of gas, low temperature and it's taken into the compressor again. The process will goes back at the beginning cycle.

2.4 EXPERIMENTAL BY PREVIOUS RESEARCH

The automotive air conditioning system is an important part of a vehicle to analyse the coefficient of performance (COP). Hisamudin et al. (2016) were studying about the effect of ambient temperature on the performance of automotive air conditioning system by experimentally where it is analysed by using different internal heat load (0, 500, 700, and 1000W) to determine the COP at different ambient temperature. The COP is a ratio of cooling provides to electrical energy uses. The COP of refrigerant that involve in VCRS cycle can be express as:

$$COP_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Cooling effect}}{\text{Work input}} = \frac{Q_L}{W_{net,in}}$$

$$COP_R = \frac{Q_L}{W_{net,in}} = \frac{Q_e}{W_c} = \frac{h_1 - h_2}{h_2 - h_1}$$

where, Qe is cooling capacity of the evaporator (kJ), Wc is power of the compressor (kJ), h_1 is enthalpy on compressor (kJ/kg), h_2 is enthalpy discharge of compressor (kJ/kg), h_3 is enthalpy on condenser exit (kJ/kg) and h_4 is enthalpy on evaporator inlet (kJ/kg)

Figure 2.2 (a) shows the schematic diagram experimental setup of the experiment. Therefore, the result shows in Figure 2.2 (b): COP against the thermal load, the performance of the automotive air conditioning system decrease when the internal heat load increased.

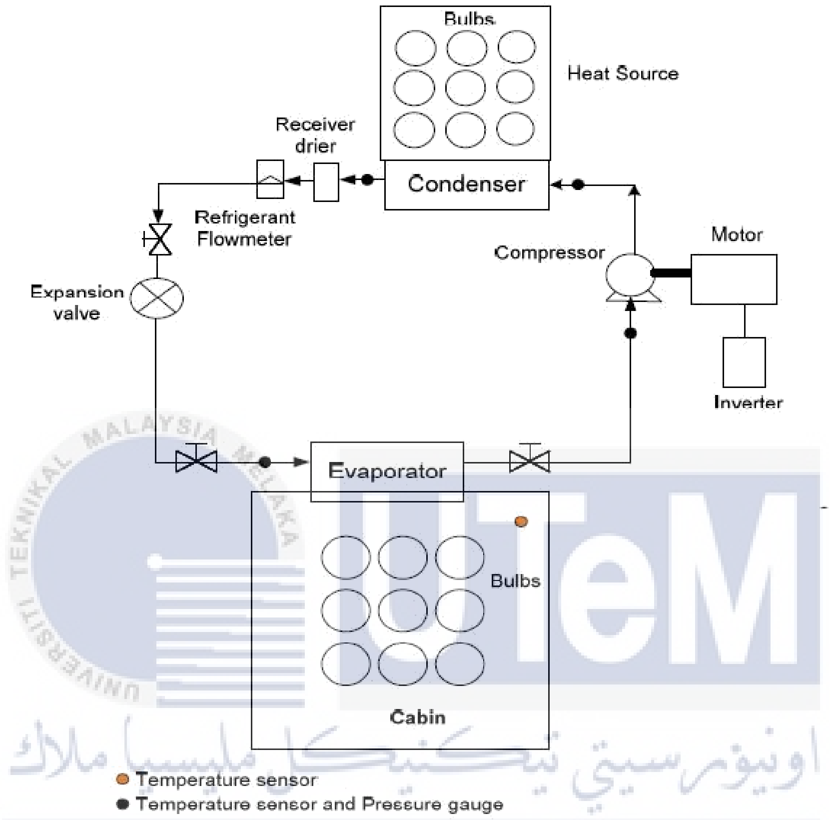


Figure 2.2(a): Schematic diagram of experimental setup (Hisamudin et al, 2016)

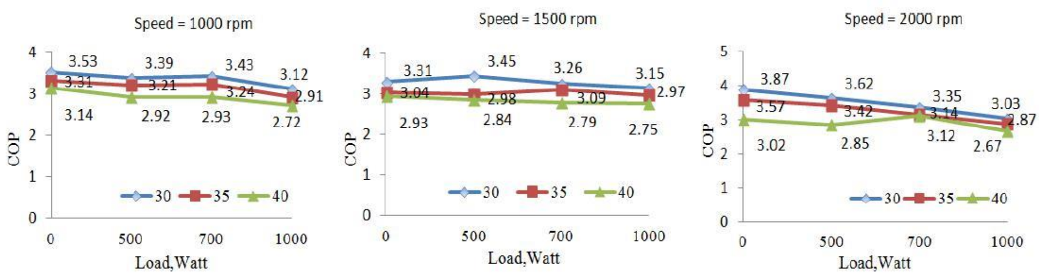


Figure 2.2(b): COP against thermal load (Hisamudin et al, 2016)

Besides that, this research is carried out by Hosoz and Direk (2006). In this project, they were studying the performance of automotive air conditioning system of an R134a that capable of operating as an air-to-air of heat pump using the ambient air as the heat source. The experimental evaluation of the performance characteristics of the integrated automotive AC and air-to-air heat pump system using R134a as the working fluid. This study operating experimentally, the results show in Figure 2.2(c) and Figure 2.2 (d) that the heating capacity increase with the increase of compressor speed and drops drastically in COP.

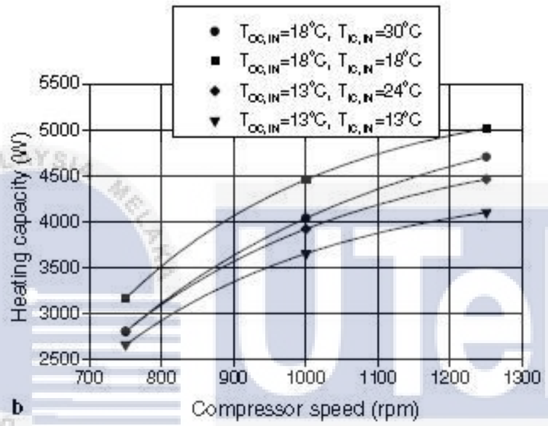


Figure 2.2 (c): Variations in heating capacity with compressor speed (Hosoz and Direk, 2006)

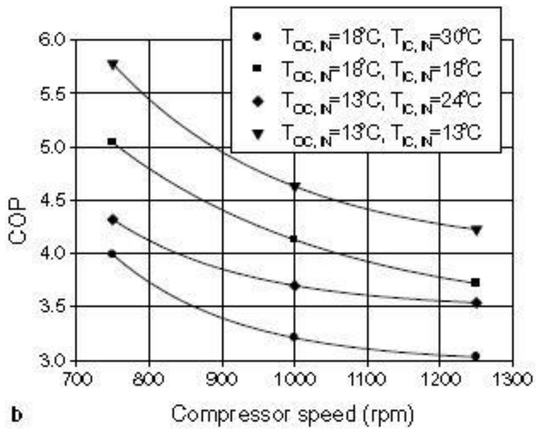


Figure 2.2 (d): Variations in COP with compressor speed for heating mode operations (Hosoz and Direk, 2006)

Meanwhile, Shete (2015) claim that factors that increasing of fuel economy is AC load on the engine include compressor of speed, a difference between ambient temperature and overall efficiency on the air conditioning system, etc. However, fuel consumption of vehicle and the thermal comfort of passengers were important in designing the automotive air conditioning system. Therefore, Afiq et al. (2014) did the research experimentally on cabin temperature and fuel consumption with a variable speed of compressor and 1000W of internal heat load. They found that the compressor power consumption rise higher than internal heat load followed by decreasing of COP. So that, the higher the thermal comfort of passengers, the lower fuel consumption and the lower carbon emission released to the environment.

In other hand, Huiming et al. (2014) has research based on ambient temperature and the operation of automotive air conditioning. The heat pump of the air conditioning system was a coupling of the battery cooling system for thermal management of electric cars. The heat can be generated from the battery is applied. A numerical simulation has been done to analyse the performance of the coupling system. The results show that the lower the heat of battery when the compressor configuration of coupling system can be kept as the same as the heat pump system.

2.5 SUMMARY

Based on the previous research that have been done by the researchers, the Hisamudin et al. (2016) that were studying about the effect of ambient temperature on the performance of automotive air conditioning system by experimentally will the suitable research that relate with the study of the performance of vehicle air conditioning system with different heat load.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will describe the methodology that will be used in this project to obtain data input to justify the best coefficient of performance of the air conditioning system with the different heat load.

This part shows the actions that need to be carried out to attain the objectives of this project.

1. Introduction

   The idea of this project will be developed based on the background of the study, problem statement, objectives and scopes.

2. Literature review

   Review the previous research that related to the project from the journals, articles, books and etc.

3. Inspection to identify the possible heat load source

   Finding and observe the suitable source for heat load based on the previous researcher.

4. Conduct the experiment

The experiment will be set up and be ruined by following SOP based on the apparatus and details of procedure that have proposed in methodology part.

5. Data collection

Data will be collected based on the experiment of the vehicle air conditioning system at different heat load.

6. Data accuracy check

Data that have been obtain have to recheck before proceed to the next step because want to ensure that either the result is relevant or not with previous research. If the accuracy of the data is relevant, it can move to the next step otherwise the experiment will conducted again by taking precaution steps and collected the new data.

7. Calculation and Statistical method

Calculation will be done with the accuracy data and will use statistical method by calculate the COP and the relationship between variables of heat load. COP and energy consumption is presented graphically.

8. Conclusion and recommendation

Summary of the experiment is conclude in this part based on the data analysis through the experimental results. The factor and effect that has relate with this experiment result will be explain roughly.

9. Report writing

A report will be written at the end of the project from the beginning of the study until the end by compiling as a report and follow the format of report.

Figure 3.1 shows the flowchart that summarized overall process of the study from start until the end of the study.

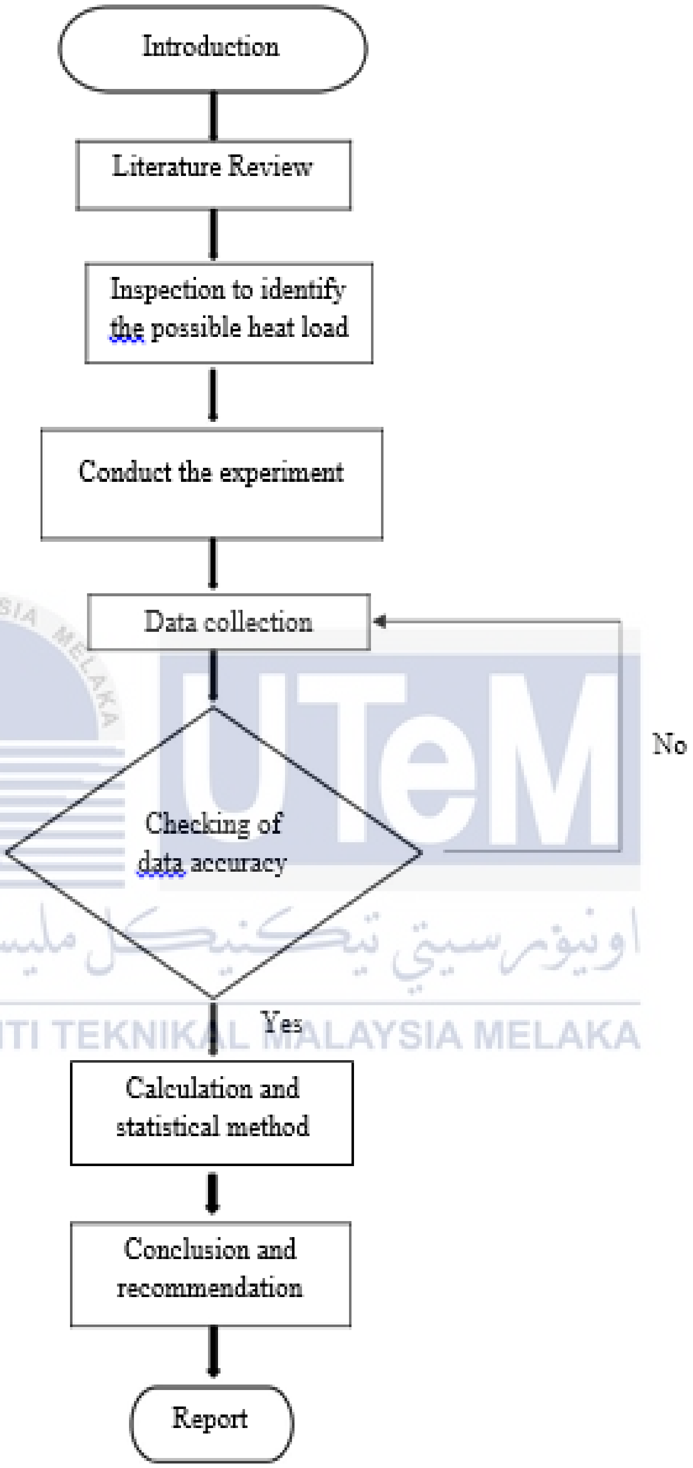


Figure 3.1: Flowchart of methodology

3.2 GENERAL EXPERIMENTAL SET UP

The schematic diagram of experimental setup for operating the performance of vehicle air conditioning system under different heat load is shown in Figure 3.2 (a). A condenser, a receiver drier, an expansion valve, an evaporator, bulb (300W, 600W and 900W), a compressor, a motor and the inverter were used to obtain data input for the experiment. While in Figure 3.2 (b) and Figure 3.2 (c) shows the real apparatus experimental setup that be used in this experiment.

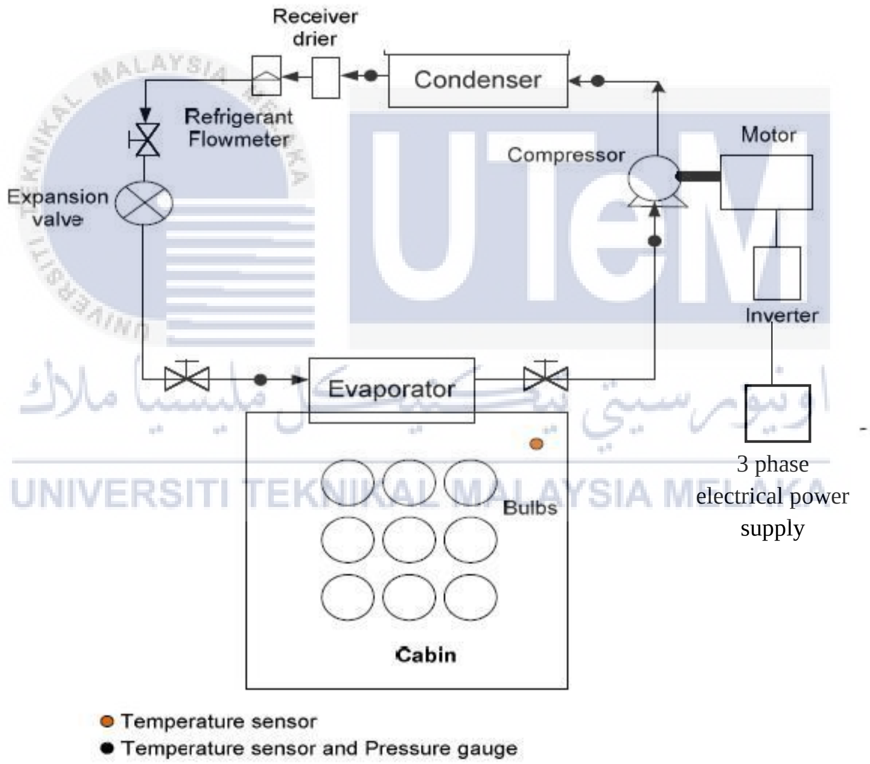
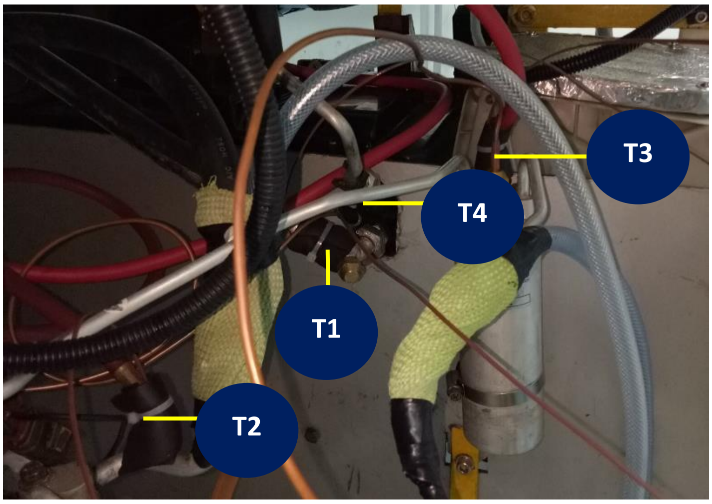


Figure 3.2 (a): Schematic diagram for heat load for the experimental setup test rig

Figure 3.2 (b): Experimental setup of test rig

1. Switch box
2. Pressure dial gauge
3. Mass flow meter
4. Condenser
5. Frequency control setting
6. Blower fan
7. Compressor
8. Motor

Position of Thermocouple at the System

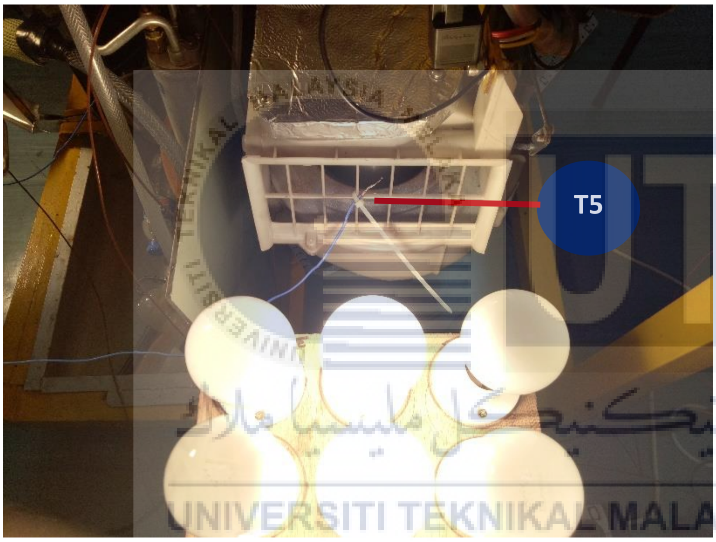


T1= Inlet compressor

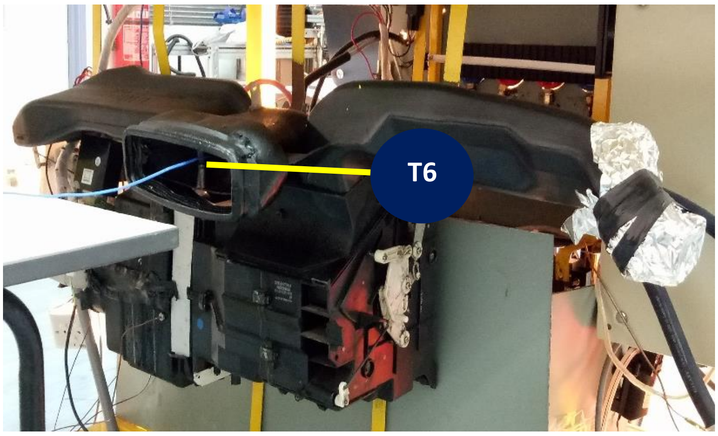
T2= Inlet condenser

T3= Inlet expansion valve

T4= Inlet evaporator of refrigerant



T5= Inlet evaporator of air



T6= Outlet evaporator of air

Figure 3.2 (c): Set up of thermocouple TC-08 Pico Data Logger at every basic part of component vehicle air conditioning system

3.3 EXPERIMENTAL PROCEDURE

The test rig has been setup as shown in Figure 3.2 (a) which is consist of basic components of vehicle air conditioning system such as compressor, condenser, evaporator and expansion device. Then, Figure 3.2 (b) shows the real picture of the component of test rig while Figure 3.2 (c) shows the thermocouple of TC-08 Pico Data Logger (USB) with tolerance ± 0.01℃ were placed at basic component of air conditioning system to collect the data of the temperature for every part of components. Next, the fabrication of heat load (bulbs) were placed at the blower fan which is located at point 6 in Figure 3.2(b) and T5 in Figure 3.2 (c) near the evaporator. After that, the AC power supply was turned ON.

Firstly, the heat load were been setup at 300watt. The speed of compressor, the speed of blower fan and the ambient temperature was fixed at 1500rpm, 3rpm and 28℃. This experiment were run about 20 minutes to make the system stable before the data been taken in 10 minutes. About 31 sample of data were collected in 10 minutes with time intervals about 20 seconds. After that, the test rig will cool down about 5 minutes to 10 minutes due to poor performance of the motor before the next value of heat load been taken. The sample of data were recorded in Table 3.1, then the sample of data been analyse in Table 3.2. Lastly, the experiment were repeated again by changing the variable of the heat load to 600Watt and 900Watt.

3.4 DATA COLLECTION

The most important part of the experiment is data collection. To ensure that the data is accurate and consistent, the data is collected and gathered in the data collection form. The measured parameter is recorded in Table 3.1 while the calculated data is record in Table 3.2. Hence, the data is well organised, reduce the mistake during collection of data and easy to analyse data.

Table 3.1: Measured Data Collection Form

Ambient Temperature (°C)							
Compressor Speed (rpm)							
Blower fan speed (rpm)							
Temperature of heat load (°C)							
Pressure low (kPa)							
Pessure high (kPa)							
No	**Time (sec)**	**Temperature (°C)**					
		T1	**T2**	**T3**	**T4**	**T5**	**T6**
Total							
Average							

Table 3.2: Calculated data collection form

Temperature (°C) / Variable			
Heat Absorbed,Qin			
Heat Rejected, Qout			
Compressor Work, W			
Coefficient of Performance, COP (%)			

CHAPTER 4

RESULT AND DICUSSION

4.1 INTRODUCTION

In this chapter, it will explain about the findings of the experiment based on the information gathered as a result of the methodology that have been applied while the purpose of discussion is to interpret and describe the significance of the findings clearly. In this experiment, there are some assumption have been made which is at point T4 (inlet of evaporator was be assume as isentropic expansion process, where h3=h4.

4.2 RAW DATA FOR THE EXPERIMENT

Raw data refers to data that has not been processed where the data has been collected from experiment such as system temperature, system pressure and mass flow rate (refer Appendix A). Besides, the raw data that have been recorded will use to gain others data by using formula or references of table to get the value such as enthalpy, cooling capacity, heat rejected, and work of compressor also coefficient of performance of vehicle air conditioning system.

4.2.1 The Effect of the Evaporator Inlet Temperature of Air on High Pressure and Low Pressure System

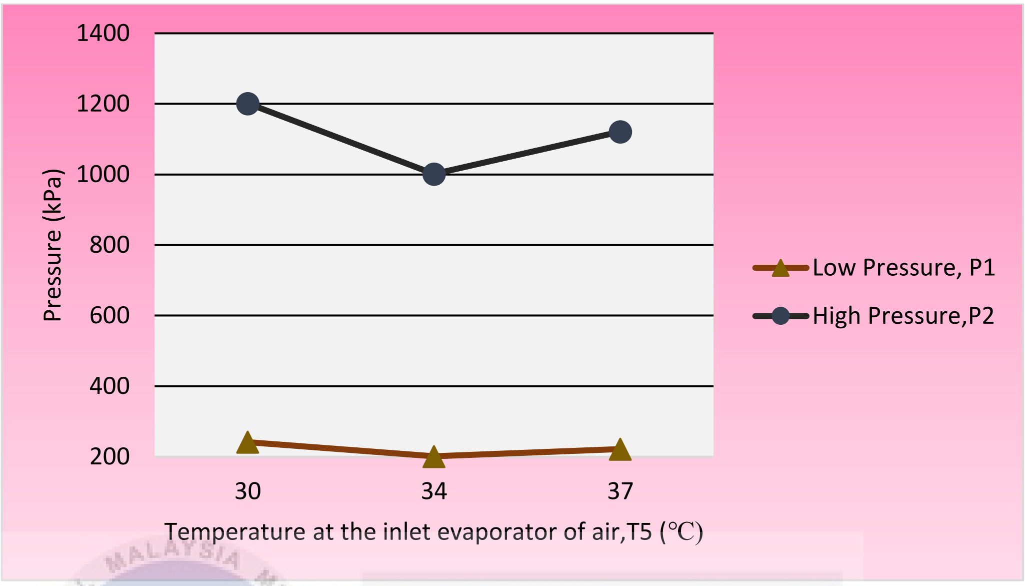


Figure 4.1: The effect of the evaporator inlet temperature of air, T5 on high and low pressure system

Figure 4.1 shows that the effect of the evaporator inlet temperature of air, T5 on the system pressure which is high pressure and low pressure. Based on the graph, the value of the pressure at high and low pressure system were rise and fall regularly. When the evaporator inlet temperature of air, T5 increase 4°C from 30°C to 34°C, the system pressure decrease about 16.57% at low pressure from 241.33kPa to 201.33kPa, however when the evaporator inlet temperature of air increase 4°C from 34°C to 37°C the system pressure rise up about 9.93% at low pressure which is from 201.33kPa to 221.33kPa.

Next, the pattern of high pressure of the system are similar with low pressure system where the pressure fall about 16.65% at the evaporator inlet temperature of air 30°C to 34°C, the value of high pressure is decrease about 1201.33kPa to 1001.33kPa. Moreover, the high pressure system slightly increase about 11.98% at

1001.33kPa to 1121.33kPa when the evaporator inlet temperature of air T5 from 34°C to 37°C.

This pattern not directly proportional due to the evaporator inlet temperature of air, T5 because of the unstable system due to leakage at the connection of piping that refrigerant of R134a flow.

4.2.2 The Effect of the Evaporator Inlet Temperature of Air on High Temperature and Low Temperature System

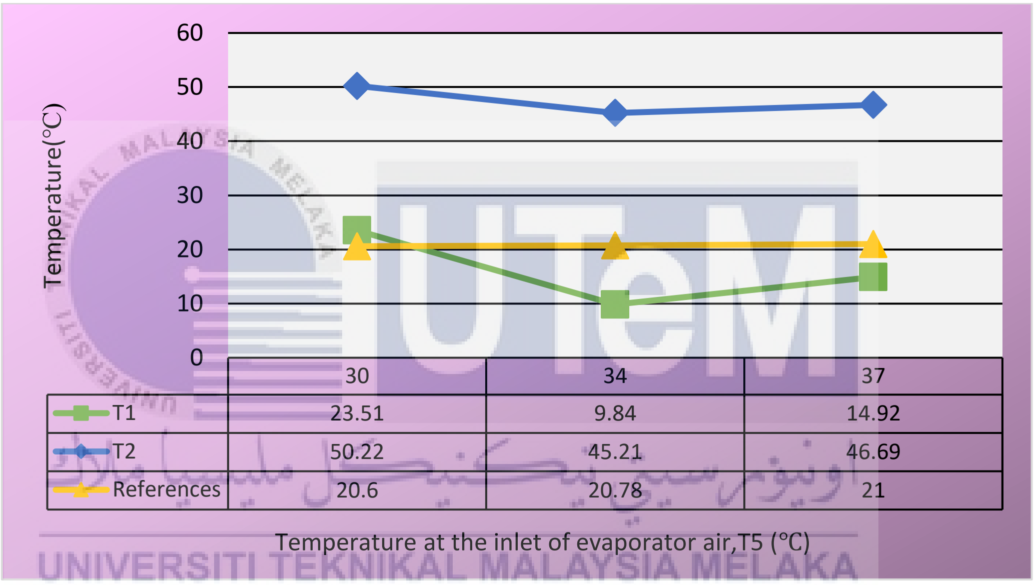


Figure 4.2: The effect of the evaporator inlet temperature of air, T5 on high and low temperature system.

Figure 4.2 shows that the effect of the evaporator inlet temperature of air, T5 on the system temperature which is determined at low (condensing temperature) and high temperature (evaporating temperature) of the system. At the evaporator inlet temperature of air, T5 from 30°C to 34°C, the condensing temperature of the system slowed down decrease about 58.11% where it is from 23.51°C to 9.84°C meanwhile at the evaporator inlet temperature of air, T5 at 34°C to 37°C, the condensing temperature of the system climb up about 51.63% from 9.84°C to 14.92°C.

In addition, the evaporating temperature system also drop about 9.98% at 50.22℃ to 45.21℃ in 30℃ to 34℃ of the evaporator inlet temperature of air while the temperature of the system increase about 3.27% from 45.21℃ to 46.69℃ at the evaporator inlet temperature of air 34℃ to 37℃. Based on Hisamudin et al, 2016 claim that the temperature of the system shows that the temperature rise up constantly with increase of the evaporator inlet temperature of air. It seems that, the temperature of the experiment have a fluctuated at 34℃ because the temperature at 34℃ is the smallest than the others.

In this case, it cause by the temperature measurement problems where the thermocouple were not insulated very well to the part of component. It just insulated around the piping of the refrigerant flow so that the temperature that been collected by TC-08 Pico Data Logger (USB) were not accurate. The thermocouple cannot be inserted into the piping because of to avoid the piping system from leakage.

4.2.3 The Effect of the Evaporator Inlet Temperature of Air on Mass Flow Rate in the System

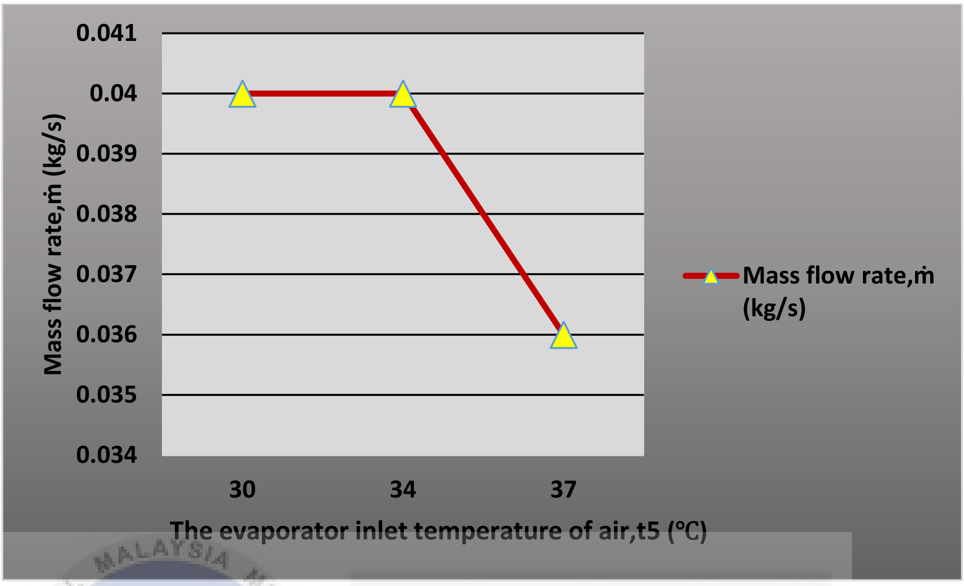


Figure 4.3: The effect of the evaporator inlet temperature of air, T5 on mass flow rate of the system.

Figure 4.3 shows that the effect of the evaporator inlet temperature of air, T5 at mass flow rate on the system. The graph show the mass flow rate remain constant at 0.04 kg/s from 30°C to 34°C of the evaporator inlet temperature of air however the mass flow rate hugely decrease about 10% from 0.04 kg/s to 0.036 kg/s at the evaporator inlet temperature of air 34°C to 37°C. Meanwhile, figure 4.3 shows that the pressure slightly constant and fall when the temperature at the evaporator inlet temperature of air increase. It is happen due to unstable mass flow rate system where it is not accurate when the measurement is taken because of it is manually take the data.

4.3 CALCULATED DATA ANALYSIS

Data for heat load 300watt (30°C)

Table 4.3 (a): Data table for heat load 300watt (30°C)

Pressure (kPa)	**Temperature (°C)**	**Mass flowrate (kg/s)**	**Enthalpy (kJ/kg)**
241.33	23.51	0.04	395.53
1201.33	50.22	0.04	426.64
1201.33	40.33	0.04	266.01
331.33	32.40	0.04	266.01

Q_H = ṁ (h_2-h_3)

= 0.04(426.64-266.01)

= 6.43kJ/s

Q_L = ṁ (h_1-h_4)

= 0.04 (395.53-266.01)

= 5.18kJ/s

W (in) = ṁ (h_2- h_1)

= 0.04 (426.64-395.53)

= 1.24kJ/s

$$COP = \frac{\dot{m}\ (h1-h4)}{\dot{m}\ (h2-h1)}$$

$$= \frac{0.04\ (395.53-266.01)}{0.04\ (426.64-395.53)}$$

= 4.18

Data for heat load 600 watt (34°C)

Table 4.3 (b): Data table for heat load 600watt (34°C)

Pressure (kPa)	**Temperature (°C)**	**Mass flowrate (kg/s)**	**Enthalpy (kJ/kg)**
201.33	9.84	0.04	392.72
1001.33	45.21	0.04	425.64
1001.33	34.45	0.04	255.57
291.33	28.41	0.04	255.57

Q_H $= \dot{m}\,(h_2 - h_3)$

$= 0.04\,(425.64 - 255.57)$

$= 6.80$kJ/s

Q_L $= \dot{m}\,(h_1 - h_4)$

$= 0.04\,(392.72 - 255.57)$

$= 5.49$kJ/s

W (in) $= \dot{m}\,(h_2 - h_1)$

$= 0.04\,(425.64 - 392.72)$

$= 1.32$kJ/s

COP $= \dot{m}\,\left(\frac{h1 - h4}{h2 - h1}\right)$

$$= \frac{0.04\,(392.72 - 255.57)}{0.04\,(425.64 - 392.72)}$$

$= 4.16$

Data for heat load 900watt (37°C)

Table 4.3(c): Data table for heat load 900watt (37°C)

Pressure (kPa)	**Temperature (°C)**	**Mass flowrate (kg/s)**	**Enthalpy (kJ/kg)**
221.33	14.92	0.036	394.18
1121.33	46.69	0.036	424.47
1121.33	37.44	0.036	261.97
291.33	30.77	0.036	261.97

Q_H $= \dot{m}\,(h_2 - h_3)$

$= 0.036\,(424.47-261.97)$

$= 5.85$kJ/s

Q_L $= \dot{m}\,(h_l - h_4)$

$= 0.036\,(394.18-261.97)$

$= 4.76$kJ/s

W (in) $= \dot{m}\,(h_2 - h_l)$

$= 0.036\,(424.47-394.18)$

$= 1.09$kJ/s

COP $= \dot{m}\,\left(\frac{h1-h4}{h2-h1}\right)$

$= \frac{392.47-283.31}{471.61-392.47}$

$= 4.37$

Table 4.3(d): Table of Data Collection Form for Heat Load (Temperature)

Variable \ Temperature (°C)	30	34	37
Heat Absorbed,Qin (kJ/s)	5.18	5.49	4.76
Heat Rejected, Qout (kJ/s)	6.43	6.80	5.85
Compressor Work, W (kJ/s)	1.24	1.32	1.09
Coefficient of Performance, COP	4.18	4.16	4.37

4.3.1 The Effect of the Evaporator Inlet Temperature of Air on Cooling Capacity

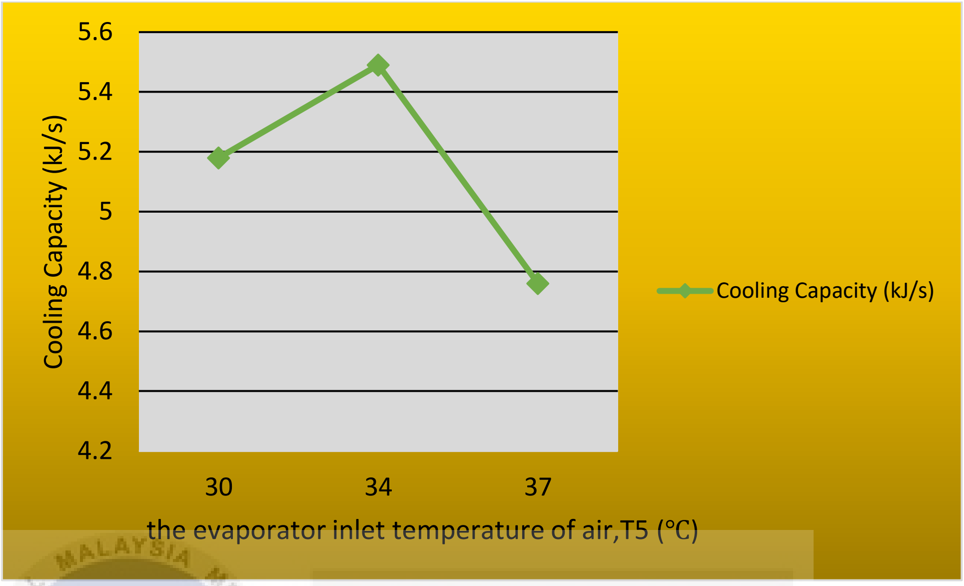


Figure 4.4: The effect of the temperature at the inlet evaporator, T5 on cooling capacity.

Figure 4.4 shows that the effect of the evaporator inlet temperature of air, T5 on cooling capacity. Based on the graph, the cooling capacity rise up about 5.98% from 5.18 kJ/s to 5.49 kJ/s at the evaporator inlet temperature of air 30°C to 34°C. However, the cooling capacity slightly drop about 13.30% from 5.49 kJ/s to 4.76 kJ/s when the evaporator inlet temperature of air reach at 34°C to 37°C. Generally, based on Hundry et al. (2016) states that the cooling capacity will decrease due to increase of the evaporator inlet temperature of air but in this experiment, there are go up and down at certain temperature. This occur due to the thermocouple which is not properly insulated to the piping of flow the refrigerant R134a so that the result of the temperature that have been recorded was been interrupted by the surrounding temperature. The thermocouple cannot be an insulated into the piping because to avoid leakage from the piping. Besides that, the performance of motor of compressor also effected the result of data because of the motor cannot be run for a long period because of overheating, so that the motor have been stop after one parameter has been done.

4.3.2 The Effect of the Evaporator Inlet Temperature of Air on Compressor Work

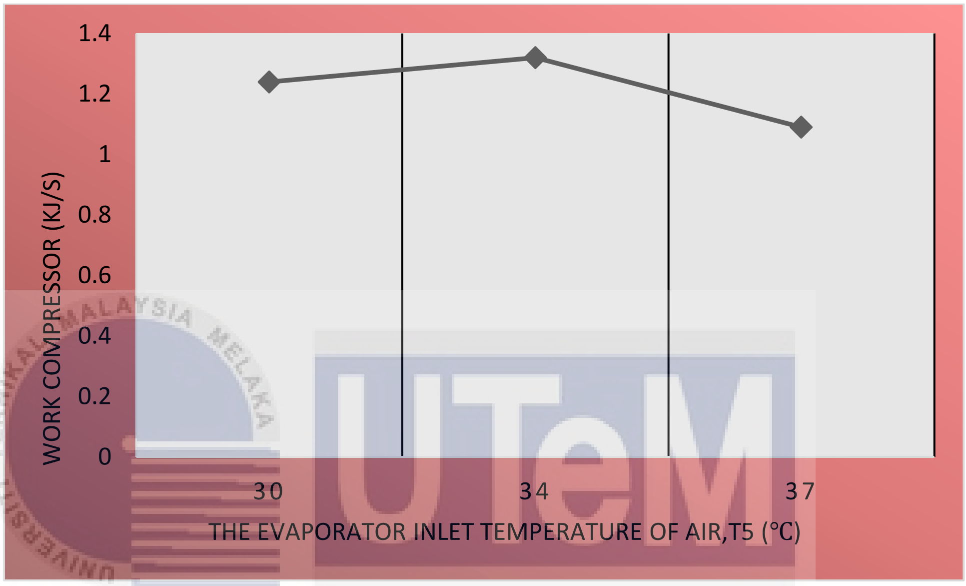


Figure 4.5: The effect of the evaporator inlet temperature of air, T5 on the work of compressor.

Figure 4.5 shows that the effect of the evaporator inlet temperature of air on work of compressor. The graph shows that the work compressor slowly increase at the evaporator inlet temperature of air 30°C to 34°C about 6.45% where the compressor work are from 1.24 kJ/s to 1.32 kJ/s. Then, the value of compressor work decrease about 17.42% from 1.32kJ/s to 1.09 kJ/s at the evaporator inlet temperature of air 34°C to 37°C. In generally, Pandiyanmech (2015) states that the work of compressor were increase when the evaporator inlet temperature increase but based on the experimental result, the work of compressor not directly proportional to the evaporator inlet temperature of air. This is due to the performance of motor which is not constant at long period when the data been recorded. It has to increase the value of frequency to make the performance of compressor be constant from slightly decrease.

4.3.3 The Effect of the Evaporator Inlet Temperature of Air on Heat Rejected, Qout

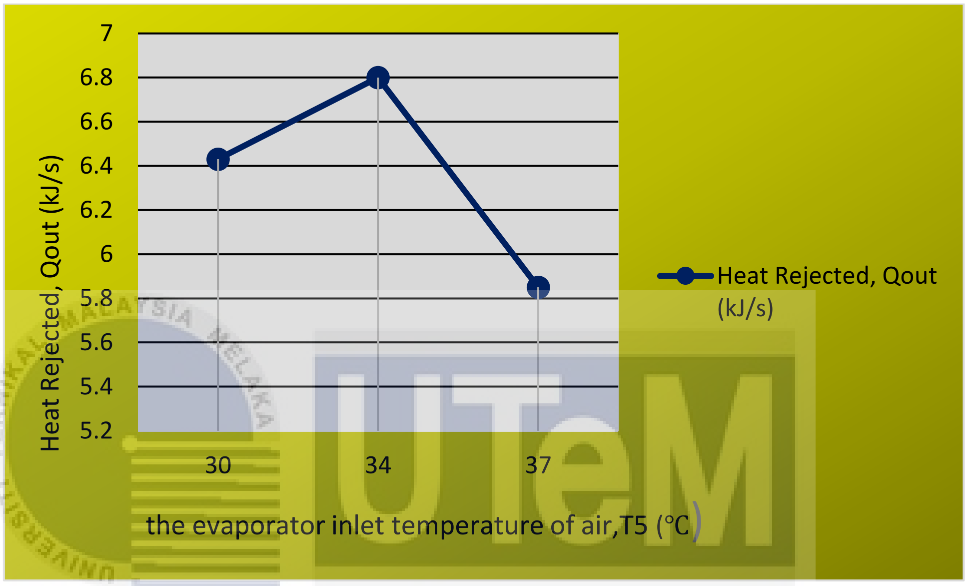


Figure 4.6: The effect of the evaporator inlet temperature of air, T5 on heat rejected, Qout.

Figure 4.6 shows that the effect of the evaporator inlet temperature of air, T5 on heat rejected. Based on the graph, the heat rejected grow about 5.75% from 6.43 kJ/s to 6.80 kJ/s at the evaporator inlet temperature of air 30°C to 34°C. Meanwhile, the evaporator inlet temperature of air 34°C to 37°C were decrease about 13.97% from 6.80 kJ/s to 5.85 kJ/s. However, the heat rejected will decrease when the evaporator inlet temperature of air increase but in the experimental the heat rejected rise up at 30°C to 34°C. This happen due to thermocouple was not insulated properly to the piping that flow the refrigerant where it has been effected the data of the temperature on the test rig that have been recorded so that the heat rejected have a rise and fall regularly pattern.

4.3.4 The Effect of the Evaporator Inlet Temperature of Air on Coefficient of Performance (COP)

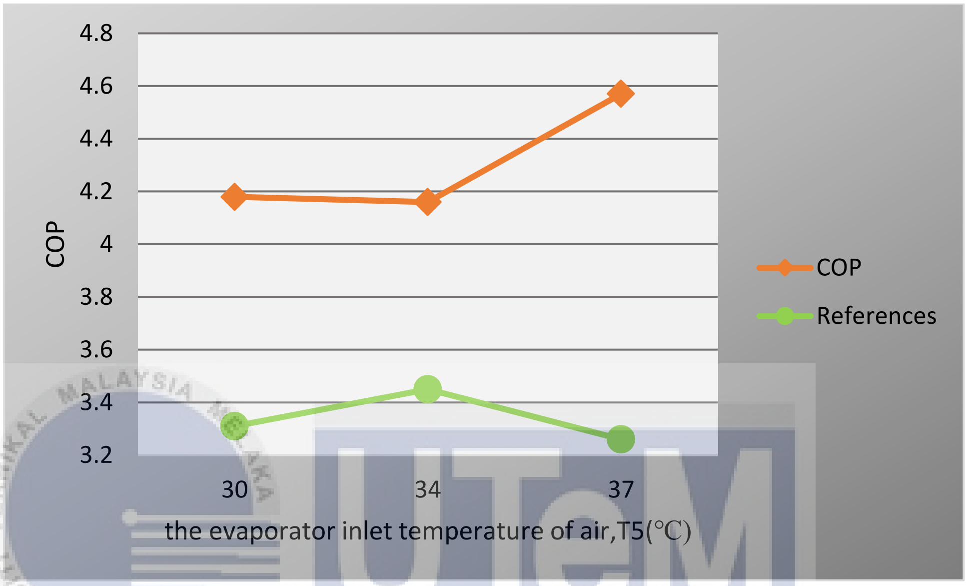


Figure 4.7: The effect of the evaporator inlet temperature of air,T5 on coefficient of performance (COP).

Figure 4.7 shows that the effect of the evaporator inlet temperature of air, T5 on the coefficient of the performance (COP). Based on the graph, the COP decrease about 0.48% from 4.18 to 4.16 at the evaporator inlet temperature of air 30°C to 34°C while the COP slightly increase about 9.86% from 4.16 to 4.37 at the evaporator inlet temperature of air 34°C to 37°C. However, based on Hisamudin et al. (2016) the COP will decrease when the evaporator inlet temperature of air increase. This due to the thermocouple that were not insulated properly to measure the temperature of the refrigerant that flow in the piping and the poor performance of the motor which is cannot be run in long period that effect the data of the evaporator inlet temperature of air.

4.4 SYSTEM P-h DIAGRAM

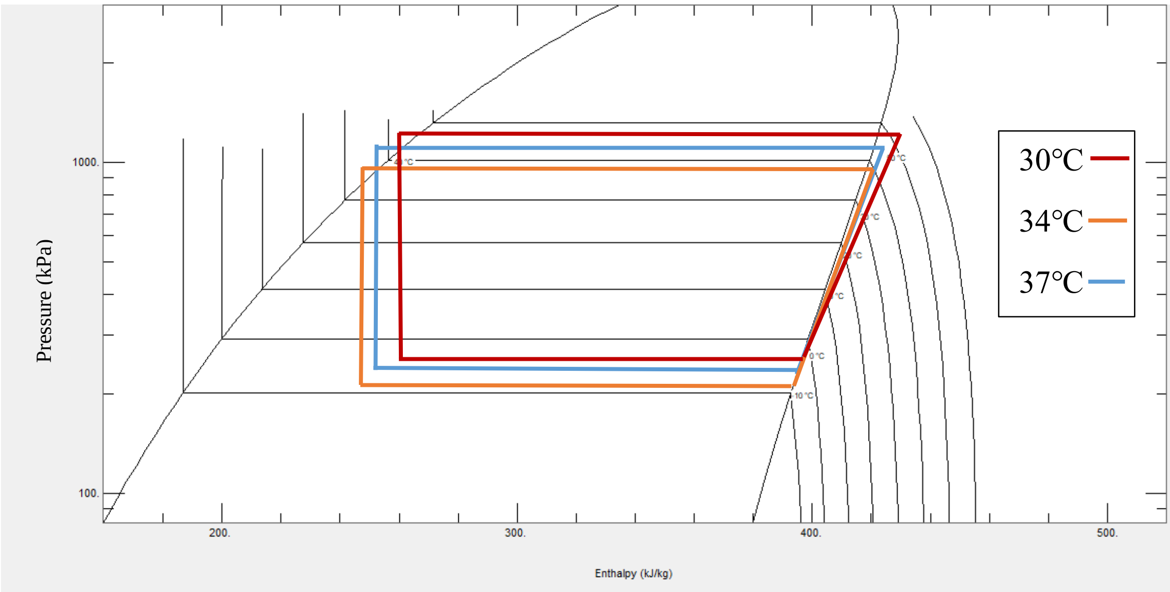


Figure 4.8: P-h diagram of system with different temperature at the inlet evaporator of air.

Figure 4.8 shows that the ideal pressure-enthalpy (P-h) diagram of three variables of the temperature inlet evaporator of air, T5. For experimental result of P-h diagram were assume as ideal state condition because of several reasons, such as the thermocouple did not attach properly to the refrigerant, it is just attach on the wall of piping that flow the refrigerant and not be insulated properly at the piping. This was affected to the temperature that has been recorded by Tc-08 Pico Data Logger through the thermocouple. The outside temperature which is ambient air at that time of the experiment were interrupt the result of the temperature. So that, we are assume that the P-h diagram was in ideal state, not actual state.

At state (1-2), the refrigerant enters the compressor with low pressure at every variables of the temperature inlet evaporator of air, T5 of three variables were being measured where T5 at 30℃ is 241.33kPa, T5 at 34℃ is 201.33kPa and T5 at 37℃ is 221.33kPa. After that, the refrigerant will compressed adiabatically, so the fluid leaves the compressor under high pressure with high temperature at every variables of the temperature inlet evaporator of air, T5. Since the gas has a higher temperature than the saturation temperature, so that every variables of T5 was a superheated region but there are differences of T5 at 34℃ and T5 at 37℃ where the enthalpy at the evaporator inlet temperature of air 30℃ the value is higher than the evaporator inlet temperature of air at 34℃ and 37℃ which is about 0.5% from 424.47kJ/kg to 426.64kJ.kg.

Then it move to the condenser at saturated mixture at state (2-3). At this state, the high pressure and high temperature and make gas release heat energy then condense inside the condenser system. The temperature at this state was lower than saturation temperature for the pressure range in every of the variables, so that there are sub-cooled region for state (2-3). Based on Figure 4.4, sub-cooled region for evaporator inlet temperature of air at 34℃ is the smallest about 0.02%. However, evaporator inlet temperature of air at 30℃ and 37℃ also have their sub-cooled region with 40.33℃ and 37.44℃.

In state (3-4) with phase of saturated liquid, the liquid of refrigerant is pushed by the throttling valve, that make it to expand so that the refrigerant change to low pressure and lower temperature in the liquid phase so that at state (3-4) were assume as isentropic expansion process which is $h_3=h_4$ in every variables where at 30℃, the isentropic expansion process were 266.01k/kg while at 34℃ and 37℃ were 255.57kJ/kg and 261.97kJ/kg. At 37℃, have the lowest isentropic expansion process than 30℃ and 34℃ this due to unstable system where there is not fix speed of compressor where the speed where slightly decrease when the system were running in long period when not increasing the frequency of inverter.

Lastly, state (4-1) the low pressure with the low temperature of the refrigerants at variables 30℃, 34℃ and 37℃ enters the evaporator where it is contact with the cold reservoir. When the low pressure is maintained about 331.33kPa, 291.33kPa and 291.33kPa at variables 30℃, 34℃ and 37℃, the refrigerant can be able to boil at low temperature about -5.22℃, -9.91℃ and -7.48℃. So that, the liquid will absorbs heat from the cold reservoir and evaporates. The refrigerant leaves the evaporator with low pressure of gas, low temperature and it’s taken into the compressor again.

CHAPTER 5

CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

5.1 CONCLUSION

This experiment aimed to determine the system pressure, system temperature, cooling capacity and compressor work at different heat load also to justify the best coefficient of performance of the air conditioning system. The parameters of the evaporator at inlet temperature was manipulated at 30°C, 34°C and 37°C while ambient temperature, compressor speed were fixed at 28°C and 1500rpm respectively.

After having carried out the experiments on the vehicle air conditioning system:

a) When the T5 is fixed at 30°C, the system pressure were at 241.33kPa at low pressure and 1201.33kPa at high pressure. Besides that for the system temperature, the condensing and evaporating temperature were 23.51°C and 50.22°C respectively. Meanwhile the cooling capacity were achieve at 5.18kJ/s and the compressor work about 1.24kJ/s.

b) When the T5 at 34°C, the system pressure slightly decrease about 16.57% at 201.33kPa at low pressure and also decrease in high pressure about 9.93% at 1001.33kPa. Meanwhile, in system temperature the condensing and evaporating temperature decrease about 58.11% and 9.98% which is 9.84°C and 45.21°C. Next, the cooling capacity were increase about 5.98% at 5.49kJ/s while the compressor work of the system also increase about 6.45% at 1.32kJ/s.

c) When the T5 at 37℃, the system pressure was rise up about 9.93% and 11.98% at low and high pressure which is at 221.33kPa and 1121.33kPa. Besides that, the system temperature were increase about 51.63% and 3.27% for condensing and evaporating temperature which is at 14.92℃ and 46.69℃. Then, the cooling capacity and the compressor work were decrease about 13.30% and 17.42% where the value at 4.76kJ/s and 1.09kJ/s.

So that, the COP of system was rise up when the evaporator inlet temperature of air increased about 9.86% because more heat supply to the evaporator inlet temperature of air. Therefore, the optimum inlet evaporator of air to achieve the best COP is 37℃ where the value of COP is 4.37.

5.2 RECOMMENDATION FOR FUTURE RESEARCH

Based on the conclusion, these are some of recommendations for the future research. Firstly, the thermocouple of TC-08 Pico Data Logger (USB) must insulated properly to the piping to avoid other interrupt from effect the data and get the accurate temperature. For the accurate data of temperature, the thermocouple must be insulated or attach into the piping to get the accurate value of temperature of refrigerant.

Figure 5.1: Thermocouple that have poor insulated

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APPENDICES

APPENDIX A

Measured Data Collection Form for 300 watt (30°C)

Ambient Temperature (°C)		28.					
Compressor Speed (rpm)		1500					
Blower fan speed (rpm)		3					
Temperature of heat load (°C)		30					
Pressure low (kPa)		241.33					
Pessure high (kPa)		1201.33					
No	**Time (sec)**	**Temperature (°C)**					
		T1	**T2**	**T3**	**T4**	**T5**	**T6**
1	0	22.55	50.15	40.59	32.05	28.96	10.33
2	20	22.61	50.30	40.53	32.04	29.62	10.29
3	40	22.70	50.58	40.46	32.04	29.03	10.30
4	60	22.80	50.82	40.45	32.05	30.39	10.36
5	80	22.89	51.00	40.37	32.06	30.86	10.34
6	100	22.98	51.18	40.37	32.11	30.38	10.35
7	120	23.07	51.33	40.36	32.14	30.45	10.43
8	140	23.18	51.42	40.36	32.22	30.37	10.42
9	160	23.26	51.48	40.39	32.28	30.97	10.54
10	180	23.35	51.43	40.39	32.33	30.96	10.63
11	200	23.43	51.36	40.37	32.37	30.82	10.64
12	220	23.49	51.36	40.42	32.41	29.90	10.75
13	240	23.55	51.31	40.41	32.40	30.30	10.88
14	260	23.59	51.13	40.37	32.39	30.86	10.95
15	280	23.64	50.79	40.37	32.40	30.38	11.10
16	300	23.70	50.38	40.37	32.44	31.23	11.24
17	320	23.77	50.00	40.37	32.48	31.37	11.38
18	340	23.82	49.92	40.36	32.49	31.77	11.51
19	360	23.86	49.88	40.30	32.47	30.77	11.61

20	380	23.90	49.89	40.29	32.47	31.27	11.78
21	400	23.93	49.96	40.29	32.49	31.26	11.85
22	420	23.95	50.08	40.27	32.51	31.20	11.93
23	440	24.00	50.22	40.26	32.56	31.54	12.03
24	460	24.06	50.27	40.25	32.63	32.08	12.12
25	480	24.11	50.02	40.27	32.68	31.45	12.19
26	500	24.12	49.44	40.23	32.67	31.67	12.27
27	520	24.13	48.78	40.15	32.64	31.57	12.34
28	540	24.15	48.34	40.05	32.62	30.01	12.48
29	560	23.84	47.86	39.76	32.51	29.71	11.93
30	580	23.24	47.88	40.16	32.65	30.16	11.42
31	600	23.17	48.17	40.55	32.74	30.21	11.70
Total		728.84	1556.73	1250.14	1004.34	951.52	348.09
Average		23.51	50.22	40.33	32.40	30.69	11.23

APPENDIX B

Measured Data Collection Form for 600 watt (34°C)

Ambient Temperature (°C)		28					
Compressor Speed (rpm)		1500					
Blower fan speed (rpm)		3					
Temperature of heat Load (°C)		34					
Pressure low (kPa)		201.33					
Pessure high (kPa)		1001.33					
No	**Time (sec)**	**Temperature (°C)**					
		T1	**T2**	**T3**	**T4**	**T5**	**T6**
1	0	11.33	44.03	33.98	27.91	33.58	14.21
2	20	11.23	43.91	33.96	27.9	33.23	14.29
3	40	11.05	43.67	33.93	27.89	32.8	14.4
4	60	10.85	43.56	33.89	27.85	33.29	14.47
5	80	10.61	43.71	33.88	27.85	33.52	14.61

6	100	10.4	43.98	33.9	27.9	33.89	14.77
7	120	10.19	44.31	33.92	27.95	33.69	14.83
8	140	10.01	44.65	33.94	28	34.54	14.98
9	160	9.89	44.94	33.94	28.02	35.23	15.15
10	180	9.79	45.17	33.97	28.06	34.67	15.31
11	200	9.74	45.35	34.07	28.16	34.8	15.4
12	220	9.65	45.48	34.16	28.26	34.8	15.51
13	240	9.54	45.57	34.25	28.33	35.03	15.6
14	260	9.48	45.62	34.32	28.36	34.65	15.69
15	280	9.47	45.65	34.42	28.41	34.15	15.79
16	300	9.44	45.66	34.52	28.5	33.88	15.83
17	320	9.46	45.68	34.6	28.58	33.89	15.94
18	340	9.47	45.71	34.67	28.61	33.92	16.01
19	360	9.51	45.75	34.71	28.62	33.71	16.04
20	380	9.53	45.77	34.74	28.65	33.96	16.13
21	400	9.55	45.78	34.78	28.67	34.09	16.27
22	420	9.53	45.75	34.82	28.68	34.09	16.38
23	440	9.53	45.71	34.88	28.74	33.95	16.45
24	460	9.55	45.68	34.93	28.79	34.31	16.55
25	480	9.54	45.67	34.95	28.82	34.31	16.63
26	500	9.54	45.72	34.93	28.83	34.14	16.7
27	520	9.55	45.8	34.94	28.86	34.33	16.72
28	540	9.54	45.86	34.93	28.89	34.88	16.82
29	560	9.41	45.88	34.93	28.91	34.35	16.9
30	580	9.32	45.83	34.95	28.92	34.3	16.91
31	600	9.3	45.77	34.99	28.92	35.09	17.01
Total		305.00	1401.62	1067.80	880.84	1059.07	488.3
Average		9.84	45.21	34.45	28.41	34.16	15.75

APPENDIX C

Measured Data Collection Form for 900 watt (37°C)

Ambient Temperature (°C)		28					
Compressor Speed (rpm)		1500					
Blower fan speed (rpm)		3					
Temperature of heat Load (°C)		37					
Pressure low (kPa)		221.33					
Pessure high (kPa)		1121.33					
No	**Time (sec)**	**Temperature (°C)**					
		T1	**T2**	**T3**	**T4**	**T5**	**T6**
1	0	15.28	42.46	35.99	29.57	36.83	15.9
2	20	15.36	42.86	36.03	29.65	37	15.95
3	40	15.35	43.53	36.1	29.76	36.93	15.99
4	60	15.26	44.16	36.16	29.89	37.97	16.06
5	80	15.28	44.76	36.27	29.98	38.29	16.18
6	100	15.25	45.31	36.41	30.08	36.92	16.18
7	120	15.15	45.74	36.48	30.12	36.09	16.23
8	140	15.12	46.13	36.57	30.15	36.14	16.32
9	160	15.07	46.49	36.71	30.22	36.66	16.43
10	180	14.98	46.85	36.87	30.34	37.66	16.56
11	200	14.99	47.13	37	30.5	36.87	16.68
12	220	15.06	47.37	37.15	30.63	39.28	16.83
13	240	15.01	47.52	37.31	30.7	37.93	16.92
14	260	14.92	47.68	37.47	30.78	38.98	16.99
15	280	14.97	47.8	37.61	30.86	36.24	17.05
16	300	14.88	47.89	37.72	30.93	38.33	17.16
17	320	14.83	47.91	37.79	31	36.75	17.22
18	340	14.91	47.94	37.87	31.09	36.72	17.33
19	360	14.86	47.86	37.93	31.14	39.77	17.51

20	380	14.89	47.77	38	31.23	36.42	17.47
21	400	14.87	47.62	38.05	31.26	37.47	17.61
22	420	14.76	47.43	38.1	31.27	38.23	17.71
23	440	14.71	47.22	38.15	31.25	39.82	17.83
24	460	14.57	47.12	38.2	31.26	38.88	17.86
25	480	14.52	47.15	38.27	31.31	36.02	17.79
26	500	14.55	47.26	38.34	31.37	38.5	17.98
27	520	14.54	47.41	38.39	31.44	39.02	18.13
28	540	14.59	47.53	38.43	31.48	37.29	18.03
29	560	14.63	47.69	38.43	31.47	38.89	18.13
30	580	14.61	47.79	38.42	31.49	37.54	18.16
31	600	14.72	47.91	38.4	31.52	38.94	18.2
Total		462.49	1447.29	1160.62	953.74	1168.38	530.39
Average		14.92	46.69	37.44	30.77	37.69	17.11