ANALYSIS PERFORMANCE OF WAJA CAR AIR-CONDITIONING SYSTEM

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Thesis submitted in fulfilment of the requirements
for the award of the degree of
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SUPERVISOR'S DECLARATION

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

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

Air-conditioning system is important in nowadays life style due to it is capable to maintain the level of life in comfort level. Due to its functions, which are to maintain the temperature in the room, also to control the cleanness in room, air-conditioner is among the popular device that been use around the world. It's having been use widely in houses, office rooms, supermarkets and cars. This thesis represents the analysis of air-conditioning system in Waja car, which is common car use by Malaysian. The objective of this thesis is to analysis the relationship of performance of air-conditioning system and speed of compressor with period of time. The thesis describes the fundamental of air-conditioning system, the way the system works and briefly explanation of each component involved in air-conditioning system. The experiment procedures are explained to obtain the important parameters and data. Finally, manual calculation is used to calculate the coefficient of performance of the system. The acquired results indicate the performance is decrease due to higher speed of compressor and the longer the system running. The obtained results show the performance decrease slightly in low speed of compressor compared than in high sped of compressor. The results concluded that the system at the unsteady state in low speed of compressor and it is become steady state at high speed of compressor. However the experiment is done with no velocity of winds outside the system. The results maybe change if the car is moving in high speed because the winds can help in heat transfer in condenser. The results can significantly reduce the cost of fuel when the car in standstill state.

ABSTRAK

Sistem penyaman udara adalah sangat penting di dalam kehidupan sekarang kerana keupayaannya untuk mengekalkan tahap keselesaan sekeliling. Fungsinya ialah untik mengekalkan tahap suhu di dalam sesebuah bilik, juga untuk mengawal kebersihan telah menjadi terkenal diseluruh dunia. Ia digunakan secara meluas, di dalam rumah, bilik pejabat, pusat membeli-belah dan kereta. Tesis ini menerangkan analisis terhadap sistem penyaman udara kereta Waja yang biasa digunakan oleh penduduk Malaysia. Objektif tesis ini ialah untuk menganalisis hubungan prestasi sistem terhadap kelajuan kompresor dalam tempoh tertentu. Tesis in menerangkan serba sedikit tentang sistem penyaman udara, cara sistem in berfungsi dan penerangan ringan tentang komponen-komponen yang terlibat di dalam sistem penyaman udara. Aturan eksperimen diterangkan untuk mencari parameter dan data yang penting. Akhir sekali, pengiraan manual digunakan untuk mencari prestasi sistem tersebut. Keputusan didapati bahawa prestasi merudum dengan peningkatan kelajuan pemampat and semakin lama sistem in berfungsi. Keputusan yang diperolehi menunjukkan prestasi menurun secara perlahan ketika kelajuan pemampat rendah berbanding kelajuan pemampat tinggi. Keputusan dapat diringkaskan bahwa sistem berada di dalam kedaan tidak serata ketika kelajuan pemampat rendah dan berubah menjadi keadaan serata ketika kelajuan pemampat tiggi. Tetapi, eksperiment dijalankan tanpa kelajuan angin di luar sistem. Keputusan akan berubah sekiranya kereta bergerak dengan kelajuan tinggi kerana pergerakan angin akan membantu di dalam perpindahan haba di condenser. Keputusan juga berupaya untuk mengurangkan penggunaan minyak kereta ketika kereta berada di dalam keadaan tidak bergerak.

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LIST OF SYMBOLS

h	Enthalpy
s	Entropy
P	Pressure
T	Temperature
Q	Heat transfer
W	Work
COP	Coefficient of performance
COP_R	Coefficient of performance for refrigerator
η_C	Efficiency of compressor

CHAPTER 1

INTRODUCTION

1.1. PROJECT BACKGROUND

Analysis performance of car air-conditioning system involved the experiment on the system with measuring the coefficient of performance. The experiment will be done by taking the reading of temperature and pressure of certain place in air-conditioning system inside the engine. The data taken are used in manual calculation to calculate the system's performance. The coefficient of performance, heat absorbs within evaporator and work done by compressor are measured and analyzed with the variation of compressor speed and period of time.

The principal of air-conditioner are studied, which involve the fundamental of the air-conditioning system and review briefly about the components of the car air-conditioner. The review of the principal will help to understand the system's cycle.

Focuses on the project that was held at Mechanical Engineering Lab in University Malaysia Pahang (UMP), the analysis for Waja car air-conditioning system will be studied. Generally, the functions of air-conditioner are:

i. Temperature control

   Air-conditioner control the temperature inside passenger compartment by adjusting the measurement device, according to passenger needs.

ii. Air circulation control

Air-conditioner will absorb air inside passenger compartment, filter it and blow back inside passenger compartment.

iii. Humidity control

Air-conditioner control the humidity inside passenger compartment to make sure humidity level is in comfort state.

iv. Air purification

Air-conditioner filter air, form dust and bacteria, either from passenger compartment or outside car before it is blow back inside passenger compartment.

1.2. PROBLEM STATEMENT

Performance of the air-conditioning system can be described as to define the efficiency of the system. High efficiency of the system acquired low in power consumption but high in its performance. For air-conditioner, high performance can be achieved when compressor consumes a low power but evaporator can absorb more heat from passenger compartment.

Important data to measure the system's performance are temperature, pressure, total flow rate and humidity for every component. All of this data are used to completes the calculation to determined the system's performance, either in manual calculation or computerize calculation.

1.3. OBJECTIVES OF PROJECT

The objective of the project is to analyze the relationship between performance of air-conditioning system and speed of compressor by manipulates the variable of compressor speed trough time.

1.4. SCOPE OF PROJECT

The scopes of this project are:

i. Study the fundamental of air-conditioning system
ii. Review the important device that related to the experiment
iii. To analyze heat transfer, Q, work done, W, and Coefficient of performance, COP of air-conditioner

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Nowadays, air-conditioner is used widely around the world for multipurpose use either for cooling function or for controlling humidity and hygiene of the environment. There are three main principles of air-conditioner, which are:

i. Cooling load
ii. Compression heating
iii. Expansion cooling

2.1.1 Cooling load

Cooling load describes the removal heat, which is the purpose of air-conditioners and evaporative coolers. Heat must be move to a cooler location in order to handle cooling load. Mechanical refrigeration or air-conditioner uses the gas to absorb and move heat from evaporator to the condenser and sends the liquid back to evaporator to boil again and absorb more heat. It requires energy to drive the compressor for this process to occur.

2.1.2 Compression heating

When gas is been compress into higher pressure, it also increase the temperature of the gas. Raising the pressure increase the gas temperature to a point above the ambient temperature. Air-conditioner use compressor to raise the pressure of the refrigerant that has boiled in the evaporator. Raising the temperature of the refrigerant allows the required heat flow from the refrigerant to ambient air, this removal of heat causes the change of state to liquid. Condenser has removed all of the heat that was absorbed on the evaporator, and recycles the gas back into liquid.

2.1.3 Expansion cooling

Expanding a volume of gas spreads out the heat energy over a larger area and lowers its temperature. Refrigerant enters expansion valve as a gas, and the gas expand thus the temperature and pressure are decrease. The cooler refrigerants absorbed heat from the passenger compartment as it expanded.

2.2 FUNDAMENTAL OF AIR-CONDITIONING SYSTEM

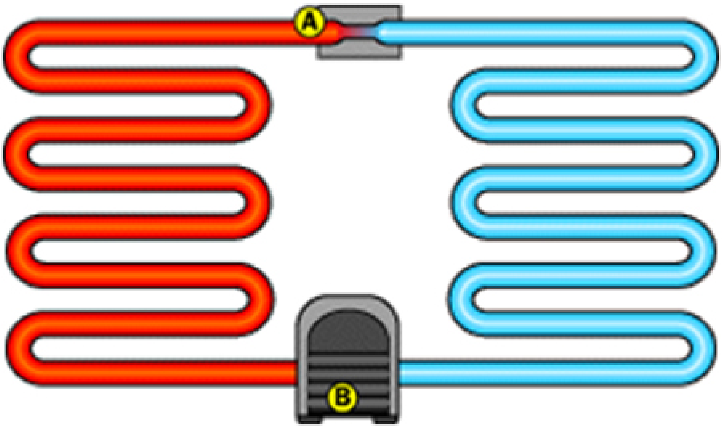
Basically, air-conditioner is a type of refrigerator without the insulted box**.** Figure 2.1 show the basic of air-conditioner. There are four main components to complete the air-conditioning system, which are:

i. Compressor
ii. Condenser
iii. Expansion valve
iv. Evaporator

Function of compressor is to increase the temperature and pressure of refrigerant before it enters the condenser. Condenser removes heat from refrigerant to outside air. Expansion valve expand the refrigerant to decrease it temperature and pressure. Evaporator absorbs heat from passenger compartment. All this components are working together with R-134a as a liquid refrigerant. The detail of the component will be discussed on **Section 2.4**.

The system's cycle begin when the refrigerant enters the compressor. At this stage refrigerant is in gas form. In the compressor, refrigerant will be compressed causing it to become hot and high in pressure. The hot gas then runs through a set of coils, the red part as shown in figure 2.1. The fans help the hot gas to release its heat and the hot gas condense into liquid.

The liquid refrigerant then enters the expansion valve. Inside the expansion valve, refrigerant will be expand, thus the temperature and pressure will be drop suddenly. The low temperature, low pressure liquid refrigerant will flow through the evaporator. As shown by the blue part as shown in figure 2.1, and absorb heat and cool down the air inside the cool space. At this time, the refrigerant slowly become gas, and flow back to the compressor.



A – Expansion Valve
B – Compressor

Figure 2.1: Basic air-conditioner

2.2.1 Refrigeration cycle

Air-conditioning system is typically similar to refrigeration system. Simple refrigeration system consists of four main components, which are compressor, condenser, expansion valve and evaporator as shown in figure 2.2.

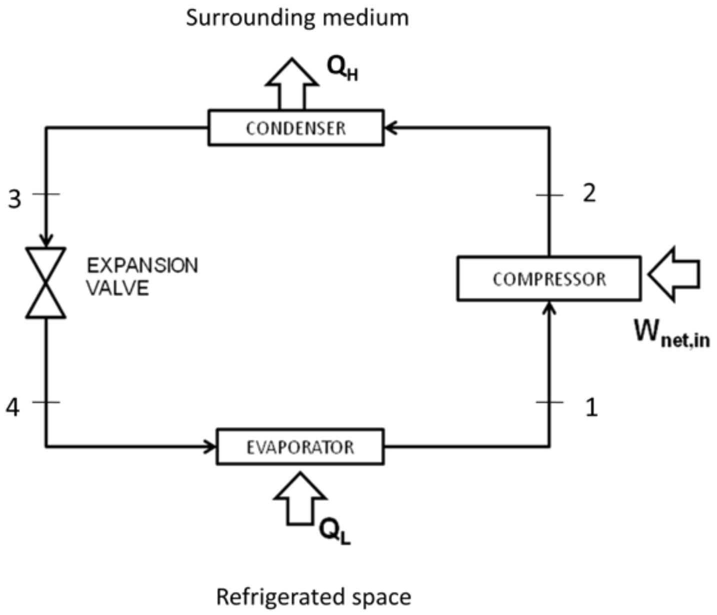


Figure 2.2: Basic components of a refrigeration system

Based on Figure 2.2, Q_L is the magnitude of the heat rejected from the refrigerated space at temperature T_L, Q_H is the magnitude of the heat rejected to the warm environment at temperature T_H and $W_{net.in}$ is the net work input to the refrigerator. Q_L and Q_H represent magnitudes and thus are positive quantities.

The efficiency of a refrigerator is expressed in terms of the coefficient of performance (COP), denoted by COP_R. The objective of a refrigerator is to remove heat (Q_L) from refrigerated space. The COP_R can be expressed as

$$COP_R = \frac{Desired\ Output}{Required\ Input} = \frac{Q_L}{W_{net.in}} \tag{2.1}$$

The conservation of energy principal for a cyclic device requires that

$$W_{net.in} = Q_H - Q_L \tag{2.2}$$

Then the COP relation becomes

$$COP_R = \frac{Q_L}{Q_H - Q_L} = \frac{1}{Q_H/Q_L - 1} \tag{2.3}$$

The value of COP_R can be greater than unity, which is the amount of heat removed from the refrigerated space can be greater than the amount of work input. A reason for expressing the efficiency of a refrigerator by another term is the desire to avoid the oddity of having efficiencies greater than unity.

The vapor-compression refrigeration cycle is the most widely use cycle for refrigerators and air-conditioning systems. Based on figure 2.2, we can say it consist of four processes:

1-2 Isentropic compression in compressor
2-3 Constant-pressure heat rejection in a condenser
3-4 Throttling in an expansion device
4-1 Constant-pressure heat absorption in an evaporator

Figure 2.3 shows the T-s diagram for the ideal vapor-compression refrigeration cycle. The refrigerant enters the compressor at sate 1 as saturated vapor and is compressed isentropically to the condenser pressure. The temperature of the refrigerant increase during the isentropic compression process to well above the temperature of the surrounding medium.

The refrigerant then enters the condenser as superheated vapor at state 2 and leaves as saturated liquid at state 3, as result of heat rejection to the surrounding. The temperature of the refrigerant at this state is still above the temperature of the surroundings.

The saturated liquid refrigerant at state 3 is throttled to the evaporator pressure by passing it through an expansion valve. The temperature of the refrigerant drops below the temperature of the refrigerated space during this process. The refrigerant enters the evaporator at state 4 as a low-quality saturated mixture, and it completely evaporates by absorbing heat from the refrigerated space. The refrigerant leaves the evaporator as saturated vapor and reenters the compressor, completing the cycle.

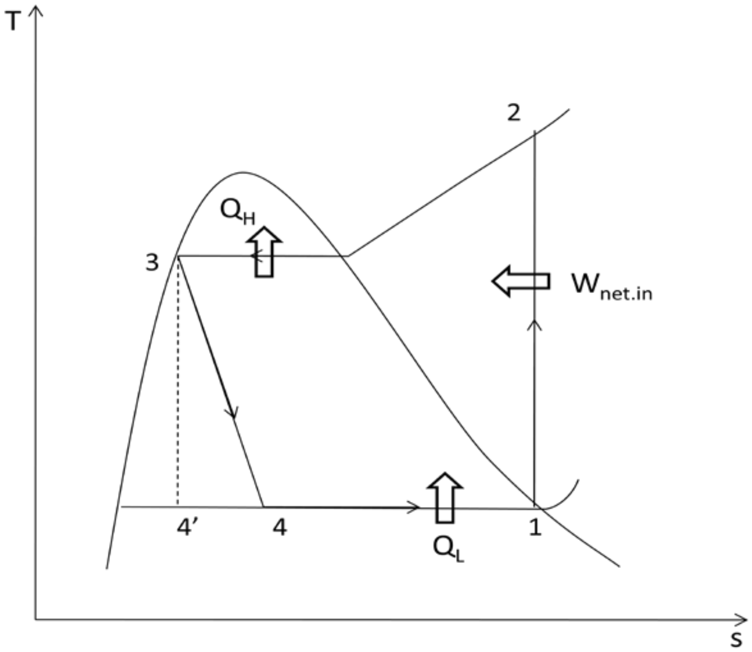


Figure 2.3: T-s diagram fir the ideal vapor-compression refrigeration cycle

2.3 CAR AIR-CONDITIONING SYSTEM

Car air-conditioner consists of five main components. All of this components located inside the engine, except for the evaporator which located under dashboard, boot or duel installation. Five main components are:

i. Compressor
ii. Condenser
iii. Receiver drier
iv. Expansion valve
v. Evaporator

The air-conditioning and ventilation system can be classification by zone. A zone is an area of the internal space of the vehicle that can be cooled to a specific temperature. A driver and passenger can controls to adjust their temperature and ventilation rate at their personal space. Systems that have more than one zone are generally electronic controlled.

i. Dash air-conditioning system

Installed under the dashboard with one single zone which is the interior space, as shown in figure 2.4. The dashboard type has the benefit of forcing cold air to the occupants enabling cooling effect to be felt to a much greater degree that the system's capacity to cool the entire space.

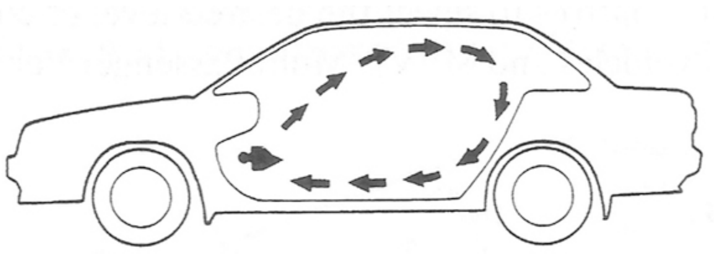


Figure 2.4: Dashboard installed air-conditioning system

ii. Boot air-conditioning system

Installed in the boot which has a large space available for the cooling units, as shown in figure 2.5. The outlets are positioned at the back of the rear seat. Negative aspects of this design include loss of boot space and cool air streams flowing from rear of the vehicle.

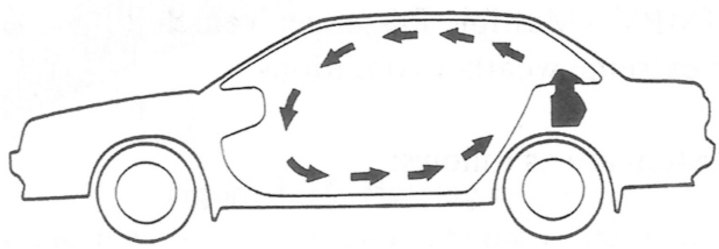


Figure 2.5: Boot installed single zone air-conditioning system

iii. Dual air-conditioning system

Generally installed at the front of the vehicle under the dashboard and extend to the rear, as shown in figure 2.6. Dual systems can include up to three zones, driver, front passenger and the rear passengers. All zones have set of air-conditioning controls to select the desired level of comfort. This system is common on high specification vehicles and MPVs (Multi Purpose Vehicles) – vehicles with high capacity.

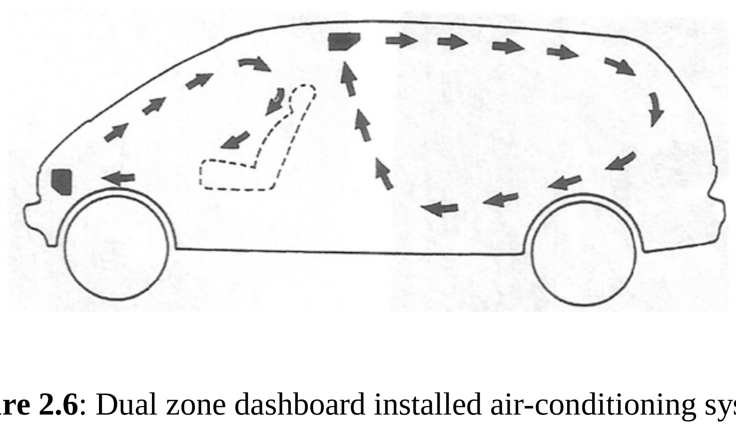
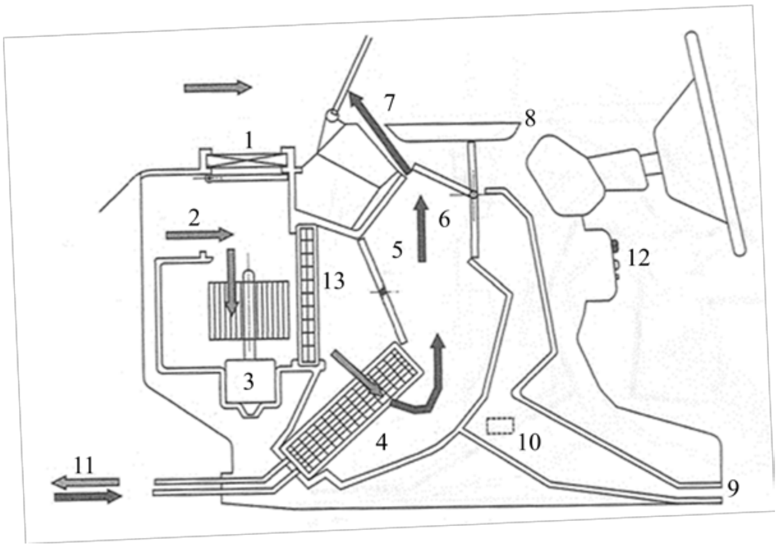


Figure 2.6: Dual zone dashboard installed air-conditioning system

The air distribution unit is generally located under the instrument panel of the vehicle. The air distribution unit controls the air circulation inside the car. Figure 2.7 shows the air circulation for dashboard installed air-conditioning system. Inside the air distribution unit is a system of ducts and mixing/directing doors. In addition the unit houses the blower motor and evaporator. The filtered incoming air from the intake panel grille is induced by the blower motor and id forced through the air distribution unit. The air coming from the blower is directed to the different air ducts via the moving doors in the air distribution unit. The air is the directed to different air outlets/air nozzles and panel vents. All air passes through the evaporator irrespective of whether the system is operating. When the air-conditioning system is running, the evaporator temperature is approximately 2-6^{o}C. This causes the temperature of the air to reduce and moisture in the air to condense producing water droplets on the evaporator's surface. This reduces the moisture content (dehumidifying) of the air and also helps remove dirt particle (purifying) suspended in the air stream, the water covers the surface of the evaporator trapping dirt particles and eventually dripping off the surface on to a drain tray which directs the water to the outside of the vehicle.



1. Air filtration
2. Air recirculation door
3. Blower motor and centrifugal fan
4. Heat exchanger
5. Temperature blend door
6. Air distribution door
7. Panel vent (not adjustable)
8. Face/head vent (adjustable)
9. Panel vent – rear passenger foot well
10. Ducting to passenger foot well
11. Flow of coolant
12. Control panel
13. Evaporator

Figure 2.7: Air circulation for dashboard installed air-conditioning system

There are basically two ways for the ventilation system to take in air: fresh air from the outside and recirculated air from the interior. Therefore the air distribution unit has two air inlets which are alternately closed by a door. Operating in recirculation mode allows it to keep away unpleasant outside smells from the inside and it also improves the cooling output of the air-conditioning system. When circulation mode is switched on for longer period of time, the humidity level inside the vehicle will increase because of the moisture content of the breath of the passengers. This can lead to fogging on the windows. Switching to fresh air mode with the air-conditioning system reduces the humidity of the inside of the vehicles.

While the air is recirculating there is a danger that the water vapor will condense on the inside of the vehicle’s windscreen. This affected by the following:

i. External air temperature
ii. Interior temperature
iii. Number of occupants
iv. Relative humidity of the air inside the vehicle

Automotive air-conditioning system are either orifice tube (OT) systems or thermal expansion valve (TXV) systems, depending on which type of flow control or expansion device is used. In this thesis, thermal expansion valve systems will be discussed, since the system used TXV system.

Car air-conditioning system can be easily divided into two parts of region, the low side, with its low temperature and pressure, and the high side, with its high temperature and pressure, as shown in figure 2.8 which the red side is high side and the blue side is low side. The low side begins at the expansion valve device and ends at the compressor; the high side begins at the compressor and ends at the expansion valve. Refrigerant boils or evaporates in the low side and it condenses in the high side.

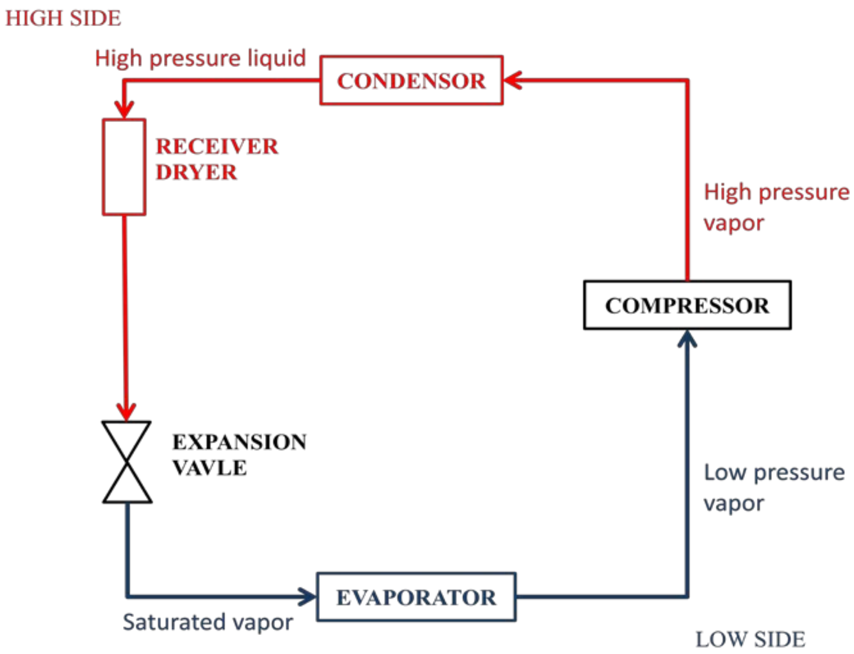


Figure 2.8: The section of low and high side

2.4 CAR AIR-CONDITIONER COMPONENTS

There are five main components inside the system of a car air-conditioner that complete the system, which are:

i. Compressor
ii. Condenser
iii. Receiver drier
iv. Expansion valve
v. Evaporator

Each component is located at different places and works for the different purpose. Basically compressor is used to compress the refrigerant. Condenser rejects heat from refrigerant to outside air. Receiver drier acts as a filter to remove dirt and moisture. Expansion valve control the level of refrigerant before it enters evaporator. Evaporator absorbs heat from passenger compartment.

2.4.1 Compressor

The function of the compressor is to compress and circulate superheated refrigerant vapor around the system (any liquid or dirt will damage the compressor). Compressors vary in design, size, weight, rotational speed and direction and displacement. Also compressors can be mechanically or electrically driven. Some compressors are variable displacement and some are fixed. The compressor uses 80% of the energy required to operate an air-conditioning system. This means that the type of compressor used in system will determine the overall efficiency of the system. This is particularly important for fuel economy and pollution which is monitored through government regulation.

The compressor is driven by an engine driven pulley system. At the front of the compressor is a magnetic clutch which when given power engages the compressor. The compressor draws in refrigerant vapor from the suction side which is the outlet of the evaporator. Because the refrigerant that left the evaporator is a vapor it can no longer absorb heat energy and act as a cooler. The compressor can only compress refrigerant vapor. Any liquid or dirt allowed to enter the compressor will cause damage. There are three main categories of compressor:

i. Reciprocating – crank and axial piston (swash plate)
ii. Rotary – vane
iii. Oscillating – scroll type

Crank type compressors are not generally used in the automotive industry any more. They may have up to two cylinders including ‘V’ shape configuration. They are driven by the engine pulley system which rotates a crankshaft inside the pump. The crankshaft is connected to a piston via connecting rod which travels up and down the bore. Above the piston there is a valve assembly to direct the flow of refrigerant.

Basically, Vane type rotary compressor is a compact machine in it design and has low frictional loses. The vane type compressor normally has few rotating parts and smooth operation. Generally, there are two types of vane of vane type compressor which are sliding vane rotary compressor and rolling piston rotary compressor.

It is important to note that the vane type compressor has three compression spaces. When the refrigerant is discharged, a space is available on the suction side of the compressor and is filled with refrigerant. At the same time the compression space of the will have refrigerant being pressurized. This means that suction, compression and discharge are continually occurring during every full rotation.

Pumping operation start when refrigerant enters the suction of compressor. Refrigerant under low pressure enters the suction port on figure 2.9(a), and fills the space between the two vanes. This space forms the chamber. The suction complete when the rotor moves and the space pass the suction port as shown in figure 2.9(b). No more refrigerant can enter the space at this time. At the beginning of compression, the rotor moves and the compression space start to reduce, as shown in figure 2.9(c). A reduction in compression volume will cause an increase in pressure and temperature of the refrigerant. The pumping cycle end when the compression space approaches the discharge port, as shown in figure 2.9(d). The refrigerant exits in a high pressure and temperature state (superheated vapor).

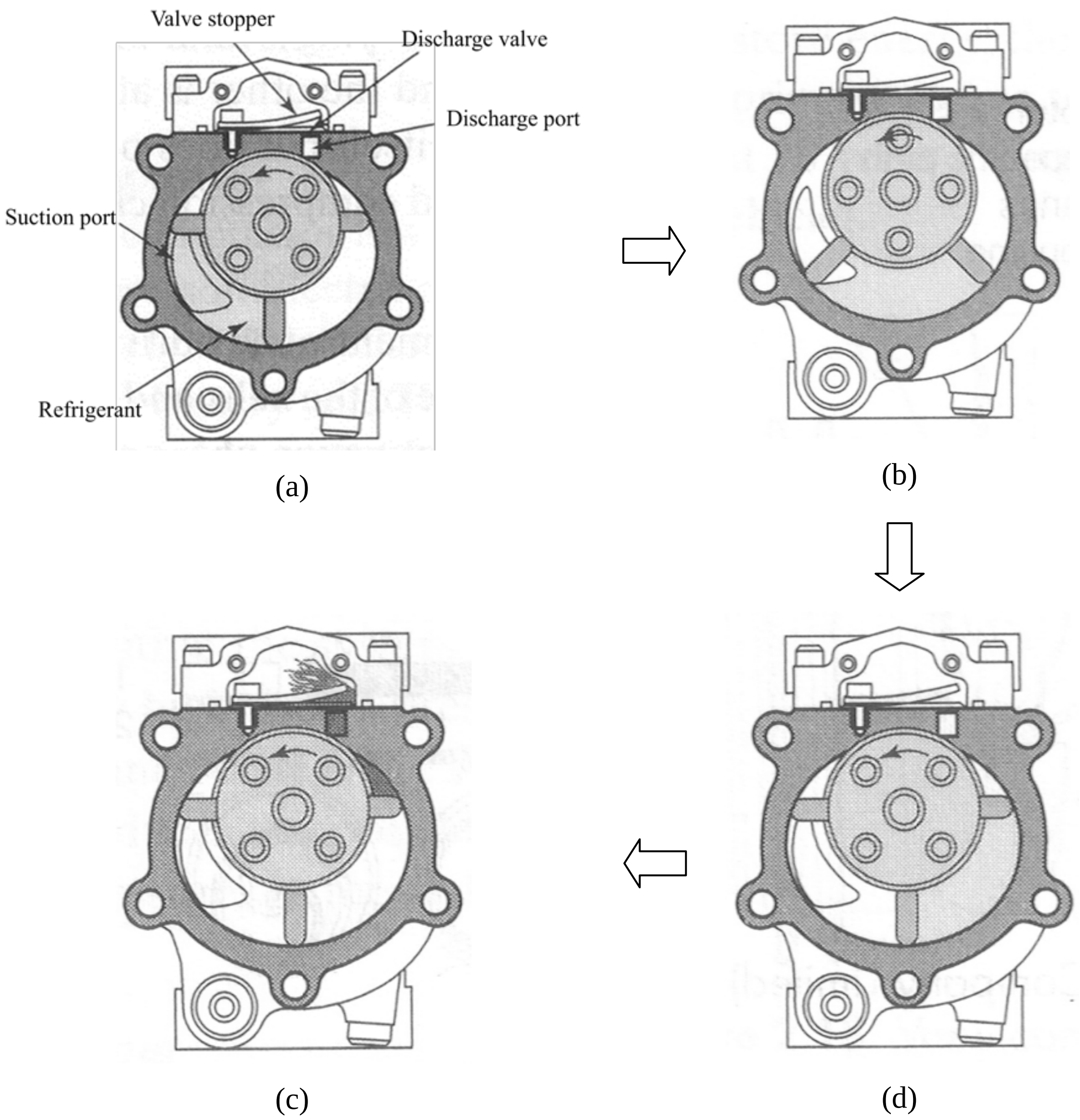


Figure 2.9: Pumping operation of a sliding vane rotary compressor

2.4.2 Condenser

The function of the condenser is to act as a heat exchanger to dispel the heat energy contained in the refrigerant. Superheated vapor enters the condenser at the top and subcooled liquid leaves the condenser at the bottom. The condenser must be highly efficient but as compact as possible. The pressure and temperature has been raised by the compressor. There is a need lower the temperature of the heat laden refrigerant to change it back into liquid enabling it to act as a cooler again later in the system. to do this the refrigerant flows into the condenser as a vapor and gives off heat to surrounding area and most of the refrigerant (depending on system load) condense back into liquid which the flows into receiver drier.

The condenser is located at the front of the vehicle where strong air flow through its core can be achieved when the vehicle is in motion. To aid the removal of heat when the vehicle is stationary or at low speed the condenser is fitted with a single or double fan system. Shrouds are often used to direct the air flow over the surface of the condenser.

The ideal condenser should have no pressure drop between the inlet and the outlet. Condensers are generally made from aluminium to prevent any chemical reaction between the metal and refrigerant/oil mixture. They are generally constructed with tubes and fins. Tubes carry the refrigerant and fins to increase the surface area in contact with the outside air. Their shapes vary and include:

i. Serpentine fin type
ii. Tube and plate type
iii. Parallel flow type (a flat tube condenser)

The condenser is the point within the air-conditioning system which s used to remove the unwanted heat. This makes it very important in the overall efficiency of the system. As the latent heat of condensation is transferred to the air stream, the refrigerant vapor makes the necessary change into liquid.

The flow is either serpentine, as shown in figure 2.10 or parallel flow, as shown in figure 2.11. Serpentine flows through the tubes evenly eventually condensing while following the same path. Parallel flow allows the path of the refrigerant to go vertically as well as horizontally across the condenser. Parallel flow is considered to be the more efficient layout. The key to the design is the header tanks/manifolds fitted to the sides of the core allowing the flow to break up small streams.

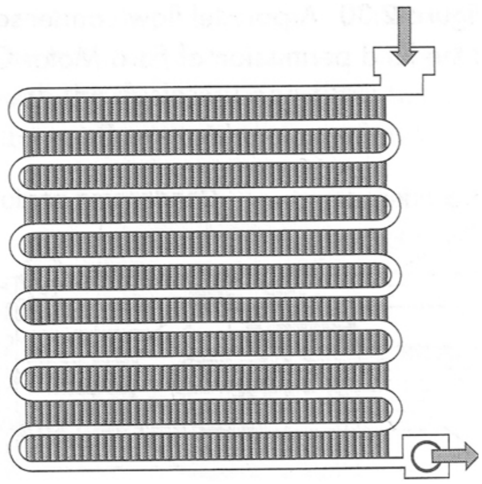
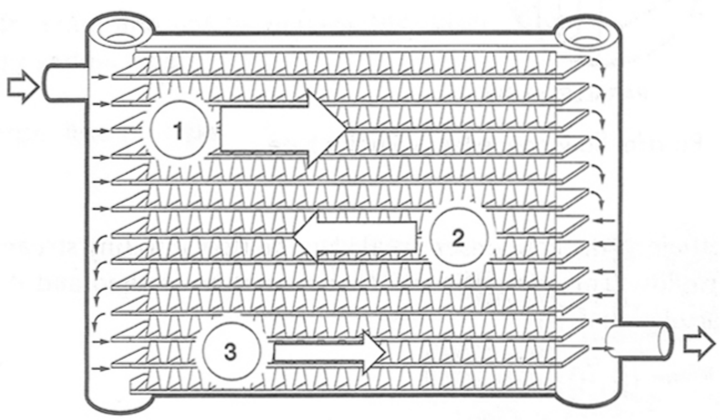


Figure 2.10: Serpentine flow from top to bottom



1. High pressure hot vapor
2. High pressure hot liquid
3. High pressure warm liquid

Figure 2.11: A parallel flow condenser

2.4.3 Receiver drier

A receiver drier is used when a thermostatic expansion valve metering device is used and is positioned between the condenser and the thermostatic expansion valve. The functions of the receiver drier are as follows:

i. To ensure the system is free from dirt preventing any excessive wear or premature failure of component
ii. To remove moisture from the refrigerant ensuring no ice form on any components within the system which may cause blockage and to ensure no internal corrosion can form
iii. To act as temporary reservoir to supply the system under varying load conditions
iv. To allow only liquid refrigerant to flow to the expansion valve.
v. To act as a point for diagnostics (sight glass sometimes fitted).

The design of the receiver drier is shown in figure 2.12. Refrigerant entering the receiver drier in an ideal system will be in liquid state, if the system is under heavy load the condenser may have not been efficient enough to completely condense the refrigerant. This means a small vapor may be present. Liquid and vapor can enter the receiver through the inlet where it will separate. Liquid will fall to the bottom of the receiver while vapor will rise to top. The outlet is connected to a receiver tube internally which has pickup point at the bottom to the receiver where the filter is positioned. The refrigerant flows through the desiccant and filter to get to the outlet pickup tube. This ensures only liquid refrigerant flows to the expansion valve.

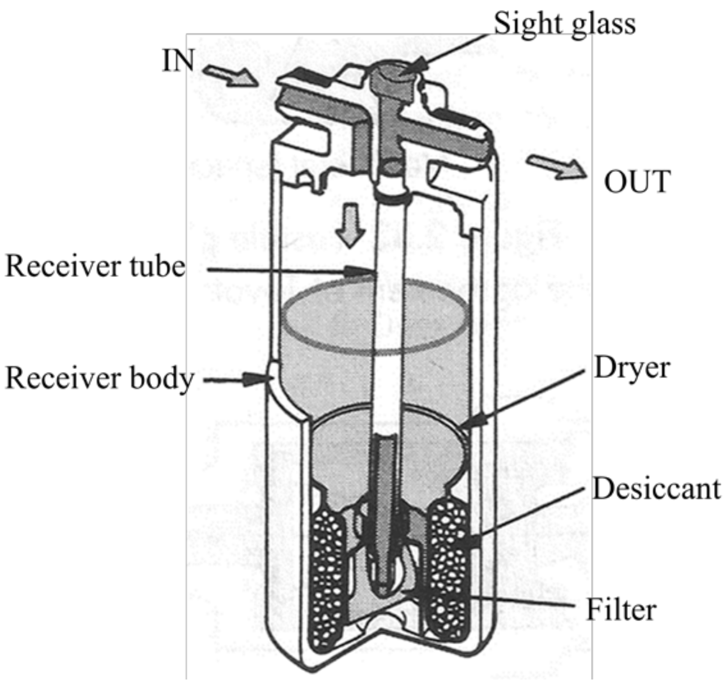


Figure 2.12: Receiver drier

2.4.4 Expansion valve

To control the amount of refrigerant volume flowing through the evaporator a metering device must be used. The functions of the metering device are:

i. To separate the high pressure and low pressure side of the system
ii. To meter the volume of refrigerant and hence the cooling capacity of the evaporator
iii. To ensure that there is superheated refrigerant exiting the evaporator.

Currently there are two main categories of metering device used, a Thermostatic Expansion Valve (TXV or TEV) and a Fixed Orifice Valve (FOV). The pressure drop across the evaporator is used to determine which type of valve is the most appropriate. Simple air-conditioning system will generally use only one of these metering devices. Dual air-conditioning system may use both TXV and an FOV within the system.

Liquid refrigerant enters the block valve housing. The orifice is very small and there is a large pressure drop on the other side of the ball valve. The liquid and small amount of vapor refrigerant enters the evaporator. The liquid/vapor will boil due to the drop in pressure and the vapor will become saturated. The saturated vapor will continue to flow expansion valve. The valve position is controlled by the temperature and pressure of the superheated vapor entering it form the evaporator.

If the temperature of the refrigerant is high due to high cooling demand then this additional heat will be transferred to sensing element and diaphragm head. The liquid will expand and apply pressure downwards on the ball valve and superheated spring enlarging the orifice and allowing an increased volume of refrigerant to flow through evaporator. The increased volume of refrigerant will provide additional cooling capacity and the refrigerant temperature entering the valve inlet from evaporator should reduce.

When this occur the sensing element will transfer the reduce temperature to the diaphragm head which will the contract and reduce the pressure applied to the ball valve and superheated spring. The pressure of the superheated vapor is directly under the diaphragm head via internal drillings. If the pressure is high then the diaphragm head flexes upward reducing the pressure applied to the ball valve and superheated spring. This cause the orifice to reduce in size thus reducing the volume and pressure of the refrigerant flowing to the evaporator. If the pressure applied to the diaphragm is low then the diaphragm will flex downward and apply additional pressure to the ball valve and superheated spring. This will increase the size of the orifice and allow a larger volume of refrigerant at a higher pressure to flow through the evaporator.

2.4.5 Evaporator

The function of an evaporator is to provide a large surface area to allow the warm often humid air to flow through it releasing its heat energy to the refrigerant. The refrigerant by this time will have just had a large pressure and temperature drop coming through the expansion valve causing it to want to boil and just requiring the heat to do so. The evaporator absorbs the heat energy from the air flowing over its surface. The energy transferred and the refrigerant reaches saturation point. At this point the refrigerant can still absorb a small amount of heat energy. The refrigerant will do so and become superheated. The superheated refrigerants will the flow to the compressor.

The evaporator is extremely cold at this stage and any moisture in the air flowing through the evaporator will adhere to the evaporator's surface. The water droplets on the surface help clean the incoming air by trapping dirt and foreign particles. The humidity content is also reduced so leaner drier air is delivered to the interior of the vehicle. This improves the comfort level especially in high humid conditions and allows perspiration to evaporate more quickly. The moisture drips off the evaporator's surface into a drain which directs it to the outside of the vehicle via a duct.

Dehumidified air is very effective for window defogging due to a large number of passengers in a vehicle and/or humid conditions. The design of an evaporator is based on the size, shape, number of tubes, and fins and the number of rows. This is to maximize the flow rate and surface area. The evaporator is tested for the maximum amount of heat and moisture which can be removed by the evaporator within given period.

2.4.6 Anti-frosting devices

2.4.6.1. Evaporator pressure regulator (EPR)

The evaporator pressure regulator, shown in figure 2.13, is mounted between the outlet of the evaporator and the compressor inlet (suction side). The valve regulates the pressure inside the evaporator to prevent icing. If the pressure drops below a certain threshold then the valve closes to restrict the flow of refrigerant and increase the pressure inside the evaporator. This is to stop the evaporator temperature from reaching 0^{o}C due to the relationship between temperature and pressure.

When the cooling load is high the vapor pressure of the refrigerant in the evaporator is high. The valve fully opens and the refrigerant flows unobstructed to the compressor. The valve operation is based on a spring bellows which expands and contracts with changes in refrigerant pressure. The device virtually eliminates the need for the compressor to cycle on and off to regulate the temperature of the evaporator.

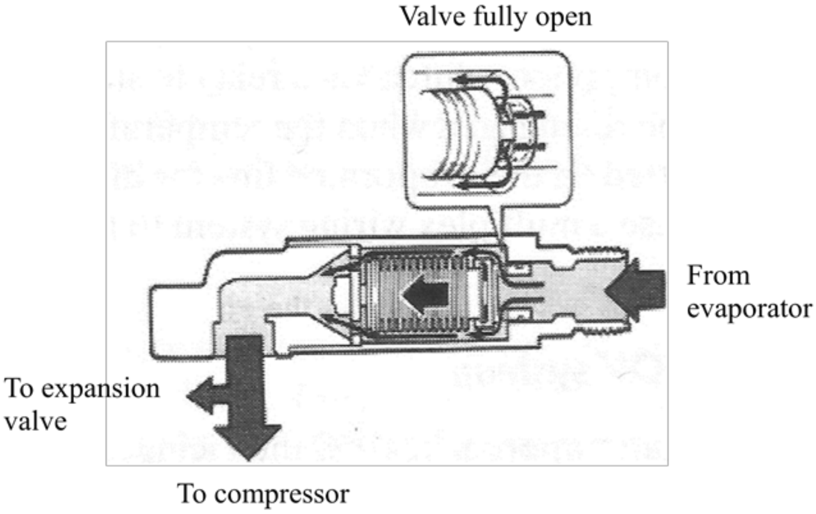


Figure 2.13: EPR valve detail

2.4.6.2. De-ice switch

A de-ice switch is a temperature sensor and relay built as one unit. The temperature sensor is fitted to the evaporator's fins and measures the temperature of the evaporator surface using NTC type temperature sensitive resistor. This sensor sends the information to relay in the form of the voltage drop when approaching the freezing point of water (0^oC) the current to the compressor clutch is interrupted to increase the pressure in the evaporator and avoid the surface water freezing. With a system threshold of 1oC at the surface, the relay will turn the compressor off. Once the surface increase to 2.5^oC, the compressor, via the relay, will be switched on again.

2.4.7 Refrigerants

Refrigerants are the working fluids of the air-conditioning system. An ideal refrigerant would have the following properties:

i. Zero ozone depleting potential and zero global warming potential
ii. Low boiling point
iii. High critical pressure and temperature point
iv. Miscible with oil and remain chemically stable
v. Non-toxic, non-flammable
vi. Non-corrosive to metal, rubber, plastics
vii. Cheap to produce, use and dispose

Generally, there are two types of refrigerant used in automotive application which are R12 and R134a. R12 is a CFC (Chloro Fluoro Carbon). It was used for many years from the early development of air-conditioning systems up to mid-1990s when it was progressively phased out leading to a total ban on 1 January 2001 due to its properties which deplete the ozone and contribute to global warming. A benefit of R12, when it was originally designed, was its ability to withstand high pressures and temperatures (critical temperature and pressure point) without deteriorating compared to other refrigerants that were around at that time.

The R12 properties are:

i. It is miscible with mineral oils
ii. It does not attack rubber or metals
iii. It is not explosive
iv. It is odourless (in concentration of less than 20%)
v. It is not toxic (except in contact with naked flames or hot surfaces)
vi. It readily absorbs moisture
vii. It is an environmentally harmful CFC gas (containing chlorine which destroys the atmospheric ozone layer
viii. It is heavier than air when gaseous, hence the danger of suffocation

Meanwhile, R134a is known as substitute for R12, because the refrigerant has no chlorine that it does not deplete the ozone. R134a is non-toxic, non-corrosive and does not contribute to global warming. It is not miscible with mineral oil so synthetic oil, called PAG (Poly Alkaline Glycol), was developed. PAG oil is hygroscopic and absorbs moisture rapidly. Properties of R134a are:

i. It is only miscible with PAG lubricants, not with mineral oil
ii. It does not attack metals
iii. It attacks certain plastics, so only use seals suitable for R134a
iv. It is explosive
v. It is odourless
vi. It is not toxic in low concentrations
vii. It is readily absorb moisture
viii. It is inflammable
ix. It is heavier than air when gaseous, hence the danger of suffocation near the ground

2.5 EXPERIMENT ON AUTOMOTIVE AIR-CONDITIONING SYSTEM

There a lot of experiments have been done to the automotive air-conditioning system, from experiment to identify the performance of the system to the experiment of exchange the refrigerant from R-134a to CO_2. All those experiment is to find the alternative of refrigerant and to improve the performance of the system.

Joudi et al. experiment the automotive air-conditioning system using alternative refrigerant. Alternative refrigerants are R12, R-134a, R-290, R-600a and the mixture of propane and isobutene R290/R600a (62/38 molar percentage). The objective is to find the most suitable alternative refrigerant for R-12. The basic task is to find the enthalpy value of refrigerant at four indicated points of the refrigerant system and the enthalpy values of the air entering and leaving the evaporator and condenser for different operating condition. The parameters are evaporator temperature, condensing temperature and compressor speed. The result show that R290/R600a exhibits superiority as a substitute for R-12 in terms on performance. R290/R600 can be regarded as an optimum substitute for R-12. The time required to reach passenger comfort conditions are with R290/R600a is less than R-12 for all experiment conditions. The power consumption of the mixture is slightly higher than R-12 system.

Liu et al. investigate the CO2 as a refrigerant to automotive air-conditioner. The objectives are to make the comprehensive investigation experimentally on the CO2 prototype and explore the system performance and further improvements. The parameters are different lubricants, CO2 charge level, evaporator outlet pressure, compressor discharge pressure, compressor speed, air inlet temperature and flow rate of gas cooler, and the air flow rate of evaporator. The results show that lubricants affect the system performance greatly. Lower air flow rate of the heat exchangers (evaporator and gas cooler) and fixed displacement compressor at higher speed will result in deterioration of the system performance. To make system efficient, larger air flow rate of the evaporator and gas cooler can be selected, taking into account such problem as air resistance and noise.

Wang et al. investigate the vapor quality and performance of an automotive air-conditioning system. The parameters are outside temperature at the evaporator and condenser, speed of the compressor, refrigerant charge and oil charge. It measure coefficient of performance, COP, evaporator cooling capacity, compressor power consumption, total mass flow rate, vapor mass flow rate, liquid mass flow rate, oil in circulation and pressure and temperature at every component, inlet and outlet. The result show that quality (refrigerant and Poly Alkaline Glycol (PAG) at inlet evaporator is directly related to COP and cooling load. Vapor quality is necessary to analyzing automotive air-conditioning precisely. Total mass flow rate increase with increase of refrigerant charge, evaporator air inlet temperature, condenser water temperature and compressor speed.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discuss on the steps of the analysis performance of Waja car air-conditioning system. There are four steps that had been listed out in a form of flowcharts to understand of analysis of the air-conditioning system.

Flow of methodology is shown in figure 3.1 where by the project is started from the literature review that described about the fundamental of air-conditioning system and end with conclusion and recommendations.

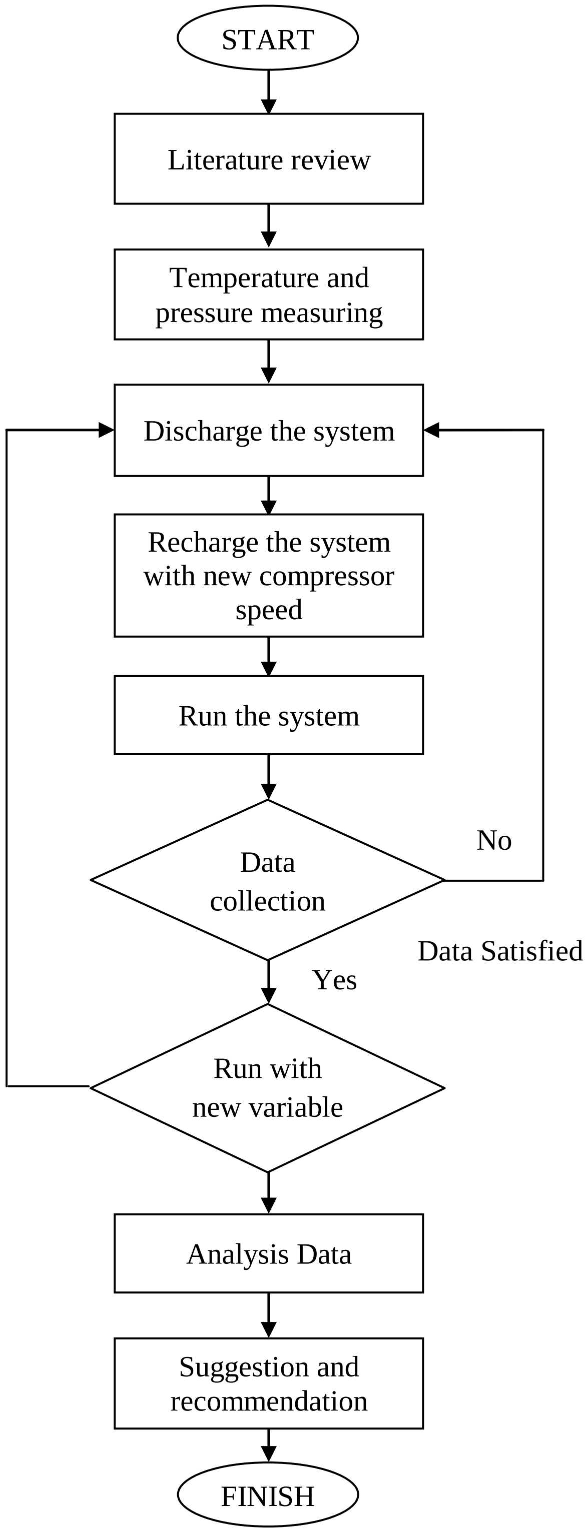


Figure 3.1: Methodology Chart

3.2 DETAILS OF WAJA AIR-CONDITIONER

The basic system of car air-conditioner and its components are discussed in **section 2.4**. However, in this chapter it is specifically discussed on standard Waja car air-conditioning system. The standard layout of the Waja car air-conditioning systems is shown in Figure 3.2.

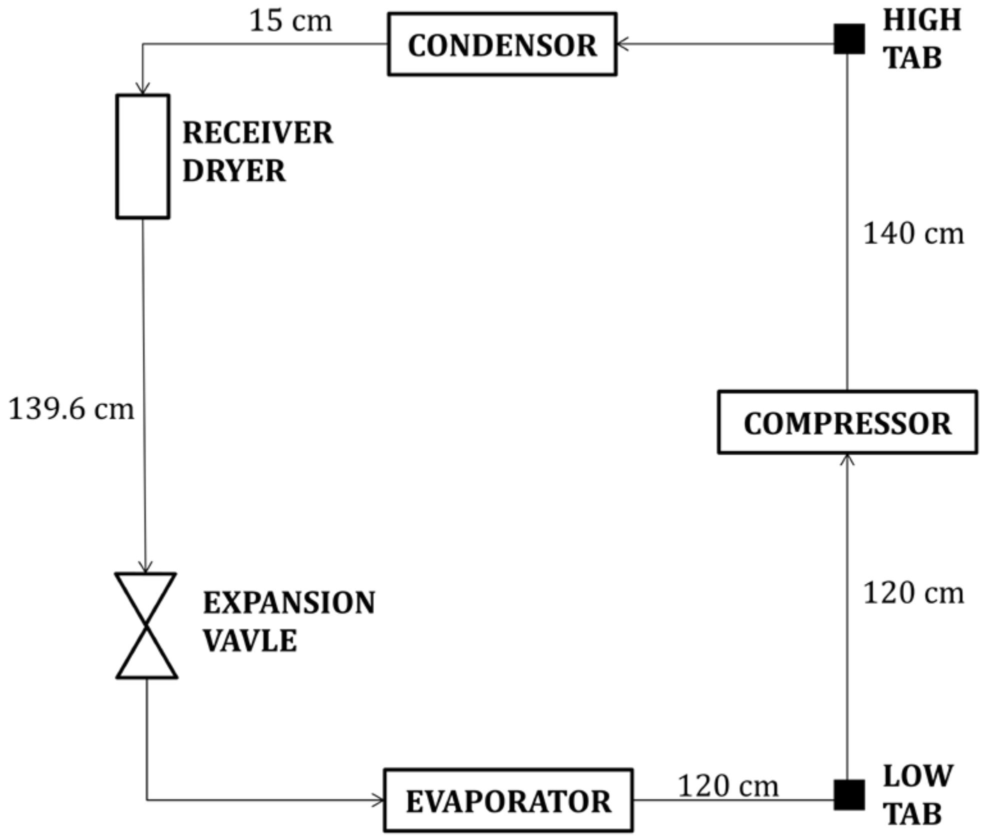


Figure 3.2: Waja Car Air-Conditioner Layout

Waja car use Thermostatic Expansion Valve (TXV) system since it is use expansion valve as a metering device.

3.3 SYSTEM OPERATION AND PREPARATION

Performance of air-conditioner is based on its COP_R. To get COP_R we must get the temperature at outlet and inlet of compressor and expansion valve. Those data will be used to calculate enthalpy (h), magnitude of heat rejected (Q_H) and absorbed (Q_L), and coefficient of performance (COP_R).

3.3.1. Method for Temperature Measurement

Thermocouples are placed at four points, inlet (T_1) and outlet (T_2) compressor and inlet (T_3) and outlet (T_4) expansion valve as shown in figure 3.3. Those temperatures at those points will help to get enthalpy, h at every point. The enthalpy is used to calculate Q_L and Q_H, thus calculated COP_R.

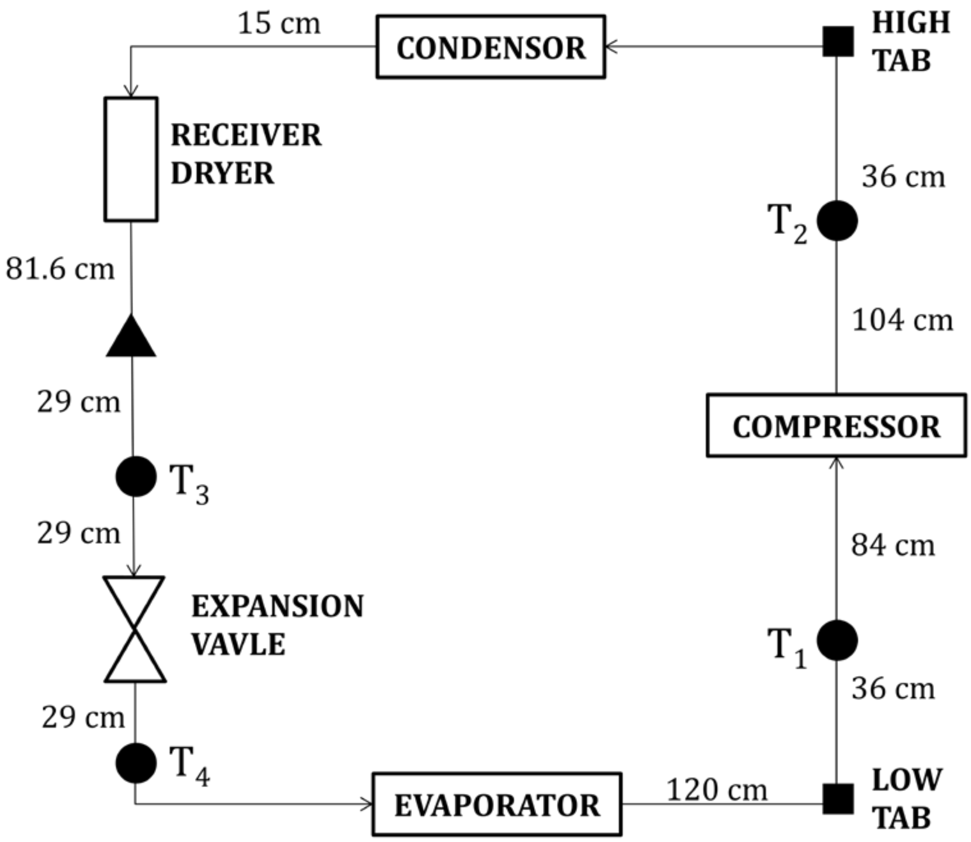


Figure 3.3: Waja Car Air-Conditioner Layout with thermocouple.

3.3.2. Method for Pressure Measurement

To get the value of pressure, two Bourdon pressure gauges will be use. Those two Bourdon pressure gauges will be located at Low tab (P_1) and High tab (P_2) (refer to Figure 3.3). At this point, the value of pressure inlet and outlet of compressor can be measure. It was assume that value of pressure in condenser and evaporator are same as the value of pressure of discharge and suction of compressor. Use measurement scale of 0-100 kg/cm^2 at the high tab and measurement scale of 0-30 kg/cm^2 at low tab.

3.3.3. Manipulating the parameter

The speed of compressor will be as an independent variable, which the main variable to determine the result of the analysis. Every experiment will be reconstructed with new speed of compressor, only when the previous experiment's results are accepted.

3.3.4. Charging process

The main instrument about charging and discharging process is manifold gauge set. Manifold gauge set consist with two gauges, which are:

- Low-pressure gauge.
- High-pressure gauge.

Low-pressure gauge is located at left side of manifold gauge. It is use as a measurement instrument to measured both pressure and vacuum. High-pressure gauge located at right side of manifold gauge. Manifold gauge have three set of hoses, which are low-side hose, center hose and high-side hose. Those hoses can be control using low-side hand valve and high-side hand valve.

3.3.4.1. Evacuate Process

Before starting charging process, air inside the gauge set must be blow out. This process can be done by following steps.

1. Put on safety glasses and wear gloves.
2. Turn off the engine. Connect low pressure hose to low-pressure charging valve and high pressure hose to high-pressure charging valve. Connect the center hose to center valve on manifold gauge set. Tighten the hose’s nut using hands.
3. Closed both low-side hand valve and high-side hand valve on the manifold gauge set. This can be done by turning the valve clockwise until the valves are fully seated.
4. Connect center hose to vacuum pump inlet.
5. Open both low-side hand valve and high-side hand valve by turning counterclockwise, and start vacuuming process.
6. If high-pressure gauge show the pressure reading is below vacuum level after low-side hand valve open, it is means there is no blockage occur in system.
7. After 10 minute, check low-pressure gauge indicator. It must be on 600 mmHg (23.62 in.Hg, 80.0 kPa) vacuum.
8. If the reading is not exceeding 600 mmHg, both valves must be closed and the process must stop. Check if leaking happen within the system.
9. Continue the process until low-pressure gauge indicate 750 mmHg (29.53 in.Hg, 99.98 kPa).
10. Closed both valves and stop vacuum pump. Let the system rest about five minute and check if reading on both gauge changes.

3.3.4.2. Refrigerant Charging Process

1. Turn off the engine. Connect low pressure hose to low-pressure charging valve and high pressure hose to high-pressure charging valve. Connect the center hose to center valve on manifold gauge set. Tighten the hose's nut using hands.
2. Closed both low-side hand valve and high-side hand valve on the manifold gauge set. This can be done by turning the valve clockwise until the valves are fully seated.
3. Connect low-pressure hose to suction line (low side) and high-pressure hose to discharge line (high side) at compressor. Connect center hose to refrigerant supply tank (refer to sub-topic 3.3.4.3 to further information).
4. Open high-pressure hand valve.
5. Start the engine and maintain the speed up to 1500 rpm. For safety, do the process with car's door open and not under direct sunlight. Also set the blower to maximum speed and thermostat to maximum level.
6. Continue charging until reading on low-pressure gauge show about 30 to 40 psi and high-pressure gauge show 200 to 250 psi.
7. The amount of refrigerant is sufficient when low-pressure gauge show 30 to 40 psi and high-pressure gauge show 200 to 250 psi. The process can be stop at this time.
8. Disconnect all three hoses. Be careful with high-pressure side to avoid hot refrigerant gas.

3.3.4.3. Connect center hose with refrigerant supply tank

1. Turn handle counterclockwise until valve needle open completely.
2. Turn disc counterclockwise until it reach maximum level.
3. Screw the valve downward on refrigerant supply tank.
4. Fully turn disc clockwise.
5. Connect center hose with valve fitting.
6. Fully turn handle clockwise to fill center hose with gas.
7. Push Schrader valve at low-side valve to free out gases inside center hose.

3.3.5. Analysis Data

After getting a result, manual calculation can be done using data from experiment to get COP_R for the system. The temperature and pressure at each point in figure 3.4 is use as a reference to data from a result.

Inlet compressor temperature (^oC)	= T_1
Outlet compressor temperature (^oC)	= T_2
Inlet expansion valve temperature (^oC)	= T_3
Inlet compressor pressure (kPa)	= P_1
Outlet compressor pressure (kPa)	= P_2

Using saturated refrigent-134a – temperature table, saturated refrigerant-134a – pressure table and superheated refrigerant 134a table, value of specific volume (υ), enthalpy (h) and entropy (s) can be determine.

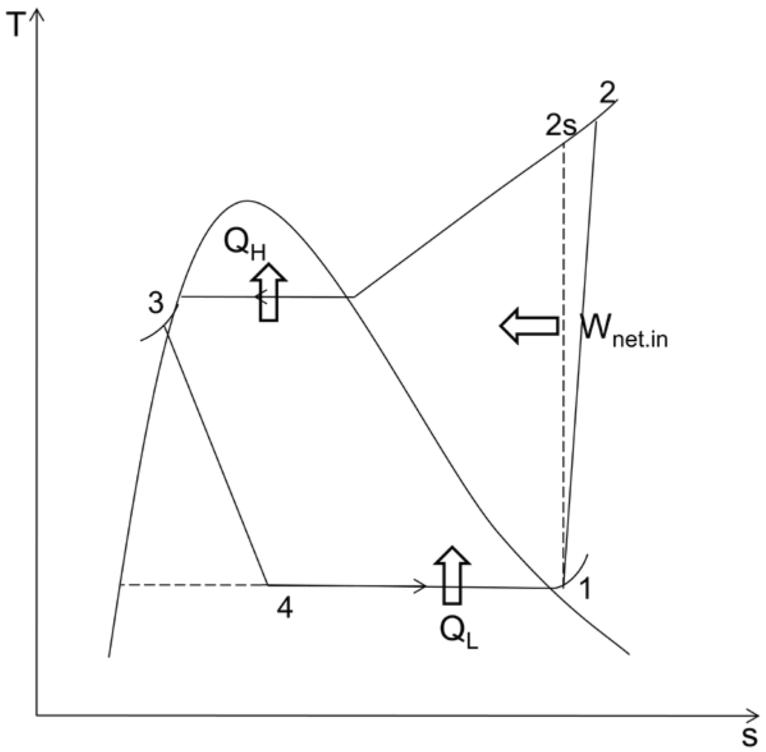


Figure 3.4: T-s diagram for the actual vapor-compression refrigerant cycle

$$\left.\begin{matrix} P_1 \\ T_1 \end{matrix}\right\} \ h_1$$ - Get from superheated refrigerant-134a table

$$\left.\begin{matrix} P_2 \\ T_2 \end{matrix}\right\} \ h_2$$ - Get from superheated refrigerant-134a table

$$\left.\begin{matrix} P_3 = P_2 \\ T_3 \end{matrix}\right\} \ h_3 \cong h_{f@T_3}$$ - Get from saturated refrigerant-134a – temperature table

$h_4 \cong h_3 \longrightarrow$ (Throttling)

$$\left.\begin{matrix} P_{2s} \\ s_{2s} = s_1 \end{matrix}\right\} \ h_{2s}$$ - Get from superheated refrigeramt-134a table

Using interpolation method to determined the value of h_{2s},

$$\frac{h_{2s}-h_a}{h_b-h_a} = \frac{s_{2s}-s_a}{s_b-s_a} \tag{3.1}$$

$$h_{2s} = h_a + (h_b - h_a)\left(\frac{s_{s2}-s_a}{s_b-s_a}\right)(\text{kJ/kg}) \tag{3.2}$$

After getting the value of enthalpy (h) for each point, efficiency of compressor can be determine.

$$\eta_C \cong \frac{h_{2s}-h_1}{h_2-h_1} \tag{3.3}$$

Heat removal from the refrigerated space, Q_L

$$Q_L = (h_1 - h_4)(\text{kJ}) \tag{3.4}$$

Power input to the compressor, W_L

$$W_{in} = (h_2 - h_1)(\text{kJ}) \tag{3.5}$$

Coefficient of performance of refrigerator, COP_R

$$COP_R = \frac{Q_L}{W_{in}} \tag{3.6}$$

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss about the results for the analysis of performance on air-conditioning system of car. The results are consisting of the value of parameter taken and the parameter that affect the value of COP_R. The data are used to find the value of enthalpy, h for each point. Then the value of heat absorbed at evaporator and work done by compressor can be calculated using the value of enthalpy. The value of CPO_R can be calculated manually by using the value of heat transfer and work done by compressor.

4.2 RESULT OBTAINED BY EXPERIMENT

The results for four different speeds of compressor are shows in Appendix A. The experiment using four different speeds of compressor, which are 1500 rpm, 2000 rpm, 2500 rpm, and 3000 rpm, and the time taken is 30 minutes with 5 minutes interval for taken the data. The data consist of temperature at inlet compressor, T_1, temperature at outlet compressor, T_2, temperature at inlet expansion valve, T_3, pressure at inlet compressor, P_1, and pressure at outlet compressor, P_2.

Temperature at outlet evaporator is slightly decreased at increasing of time and compressor speed, as shown in figure 4.1. It's happen when the compressor speed are increase. The flow rate of refrigerants is increase, so the heat absorbed in evaporator decreases slightly. It is happen because rate of heat transfer of refrigerant become slow due to the increasing of flow rate. This can be adjusted by increasing the speed of blower fan.

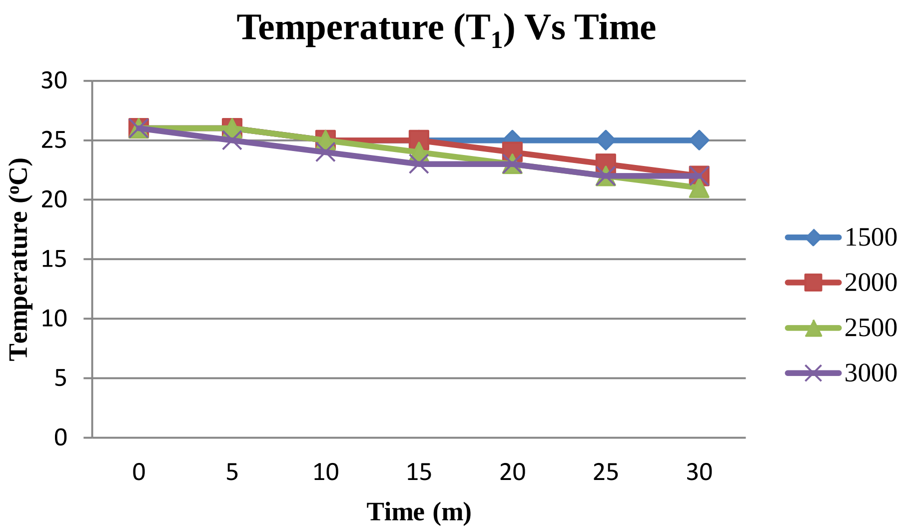


Figure 4.1: Graph temperature (T_1) Vs Time for different compressor speed

Temperatures at outlet compressor are increase constantly for every five minutes as shown in figure 4.2. Temperatures increase due to increasing of compressor speed. Higher compressor speed means higher pressure on refrigerant, thus increase its temperature. High temperature will evaporate refrigerant and will help the refrigerant to condense much faster inside the condenser.

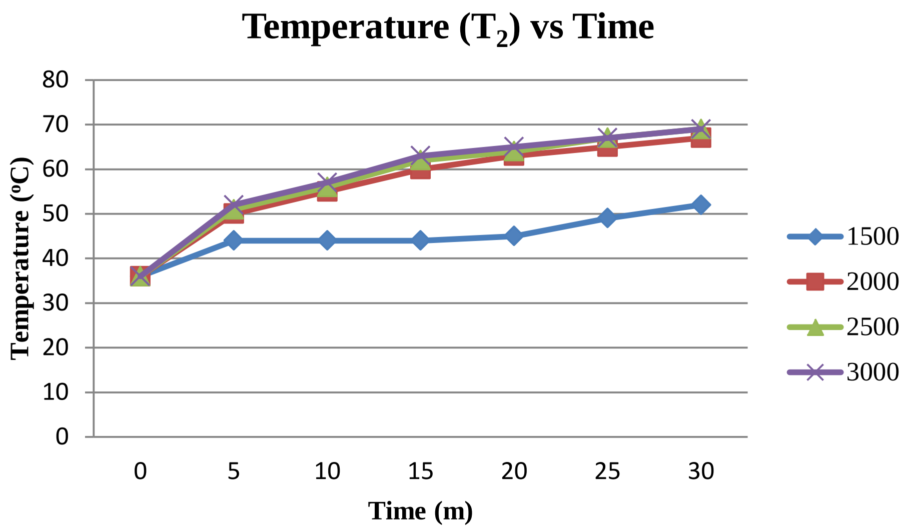


Figure 4.2: Graph temperature (T_2) Vs Time for different compressor speed

Figure 4.3 show that the temperature T_3 increase slightly. Temperature T_3 is temperature at inlet expansion valve can also be related to temperature at outlet condenser. Higher T_3 means the condenser cannot remove heat from refrigeration efficiently. T_3 should be in lower level so that the heat inside car can be absorbed well within evaporator.

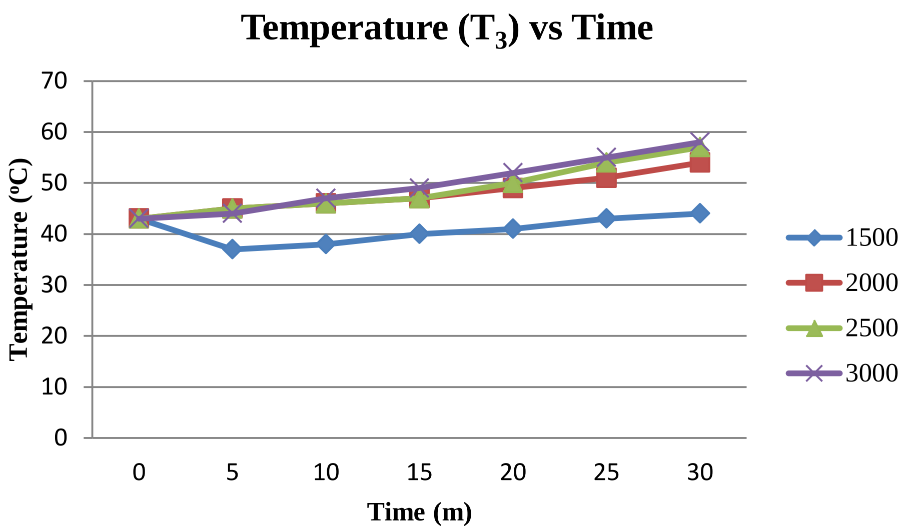


Figure 4.3: Graph temperature (T_3) Vs Time for different compressor speed

4.3 CALCULATION FOR Q, W, AND COP_R

After getting a result, heat transfer at evaporator, Q, work done by compressor, W and coefficient of performance, COP_R can be calculated using manual method. The formulae are discussed in section 3.3.5. The results of calculation for Q, W and COP_R are shown in table 4.1, 4.2, 4.3 and 4.4.

The value of heat transfer at evaporator, Q and COP_R can explain the condition of system. Higher value of Q means the evaporator absorbs more heat from inside of the car. Higher value of COP_R means the system is efficient, which is compressor do not used over energy to evaporator to absorb heat.

Table 4.1: Result for Q, W, and COP_R for 1500 rpm compressor speed

Time (m)	Q (kJ)	W (kJ)	COP
5	170.403	1.632	104.423
10	167.943	2.587	64.930
15	164.902	2.617	63.015
20	163.363	3.233	50.527
25	160.397	5.322	30.136
30	158.954	7.892	20.142

Table 4.2: Result for Q, W, and COP_R for 2000 rpm compressor speed

Time (m)	Q (kJ)	W (kJ)	COP
5	158.809	3.779	42.028
10	156.203	11.354	13.758
15	154.514	14.765	10.465
20	150.622	19.130	7.874
25	146.717	22.316	6.574
30	141.220	25.433	5.553

Table 4.3: Result for Q, W, and COP_R for 2500 rpm compressor speed

Time (m)	Q (kJ)	W (kJ)	COP
5	159.198	4.609	34.538
10	156.645	11.739	13.344
15	149.701	16.049	9.328
20	147.980	19.657	7.528
25	140.765	23.513	5.987
30	135.901	25.194	5.394

Table 4.4: Result for Q, W, and COP_R for 3000 rpm compressor speed

Time (m)	Q (kJ)	W (kJ)	COP
5	160.220	11.701	13.693
10	154.568	13.135	11.768
15	150.770	16.705	9.025
20	144.525	18.490	7.816
25	140.484	20.770	6.764
30	135.665	22.520	6.024

4.4 EFFECT OF TIME TO Q AND COP_R

Efficiency of heat transfer and coefficient of performance can be depending on period of time. There are huge different on result between moving car and standstill car. So the obtained results have big differed between those four compressor speeds due to heat transfer that occur within the system.

The longer the system running, efficiency within condenser is decrease slightly. This happen because every time the refrigerant complete one cycle, temperature of refrigerant increase slowly. But rate of heat transfer in condenser are constant due to no external parameters, such as no winds involved.

Temperature inside cabin can be control by adjusting the quantity of refrigerant that enter the evaporator. Temperature at outlet evaporator, which is temperature at inlet of compressor also influence the performance of the system. Higher temperature at this point show the system is well performed, because evaporator has absorbed more heat from passenger compartment. Usually the longer the system is running, temperature at this point becomes lower instead when car is moving.

4.4.1. Effect of time to heat transfer within evaporator, Q

The effect of time to heat transfer within evaporator is show in Figure 4.4. During the experiment, blower speed and refrigerant mass are constant. The slopes for this graph show that the temperature is slightly decreased. This happen because the longer the system running, heat transfer that occur within system become weaker.

Rate of heat transfer depend on temperature different between inlet evaporator, same as outlet condenser and outlet evaporator. To increase the efficiency of evaporator, temperature of refrigerant at outlet evaporator should be higher. This can be happen when heat absorb within evaporator are being increase, either increasing the speed of blower or decrease the temperature at outlet of condenser.

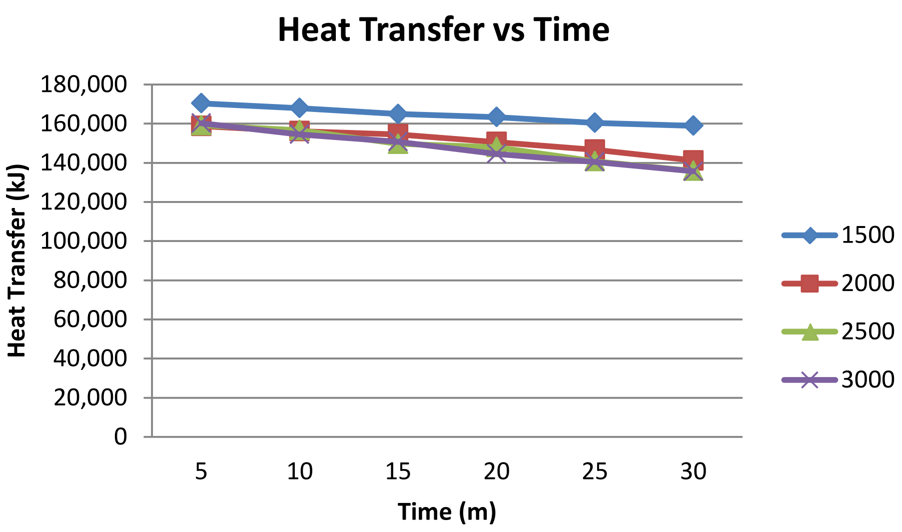


Figure 4.4: Graph Heat Transfer (Q) Vs Time for different compressor speed

4.4.2. Effect of time to coefficient of performance, COP_R

The effect of time to coefficient of performance is show on Figure 4.5. During the experiment, speed of blower and refrigerant mass are constant. COP_R are decrease to increasing of time. The value of COP_R is big influence by heat transfer that occurs within evaporator and condenser and also the volumetric efficiency of compressor.

Temperature at evaporator and condenser, pressure at inlet and outlet give big influence to the value of COP_R. To get higher value of COP_R, volumetric efficiency of compressor should be higher. Temperature at outlet condenser should be more lower that temperature at inlet condenser. This can be obtained by increasing the heat rejected inside condenser. Temperature at outlet evaporator should be higher than it inlet. This show that the evaporator working well because heat transfer within it occur in high rate.

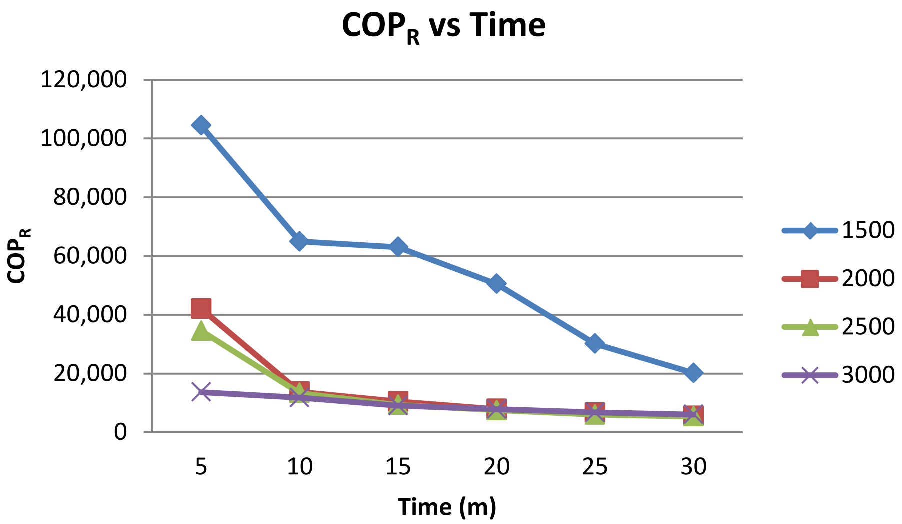


Figure 4.5: Graph Coefficient of Performance (COP_R) Vs Time for different compressor speed

4.5 EFFECT OF COMPRESSOR SPEED TO Q AND COP_R

Another parameter that has big effect to the performance of system is compressor speed. Compressor speed can affect the pressure at suction and discharge of compressor. This pressure hugely influences the temperature before the refrigerant enters the condenser, and it is effect the heat transfer within it.

Compressor speed has control the flow rate of refrigerant within the system; beside the expansion valve which controls the amount of refrigerant before enter the evaporator. Flow rate of refrigerant has big influence in rate of heat transfer within the evaporator and condenser.

Manual calculation can prove the efficiency of compressor by taken the value of compressor suction and discharge temperature and pressure, also the efficiency of evaporator. By refer to superheated refrigerant-134a table, higher value of pressure and temperature, the value of enthalpy, h will be increase slightly. To get higher efficiency at evaporator, temperature at outlet evaporator must be much higher than at inlet.

4.5.1. Effect of compressor speed to heat transfer at evaporator, Q

The effect of compressor speed to heat absorbed at evaporator is shown in Figure 4.6. Slopes of the graph show that the heat transfers within the evaporator decrease at increasing of compressor speed. During the experiment, blower speed and mass of refrigerant are constant.

Total mass flow rate (mass flow rate of refrigerant and PAG oil) are increasing with increasing of compressor speed, but the quality is decreased. Thus it decreases the efficiency of rate heat transfer at evaporator. By increasing the total flow rate, time taken by evaporator to transfer heat from refrigerated space is lowed, thus heat cannot be transfer well.

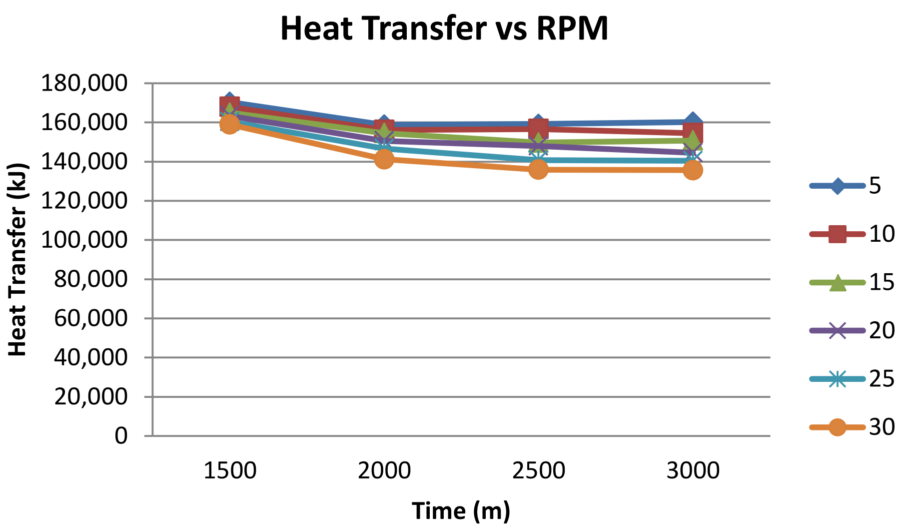


Figure 4.6: Graph Heat Transfer (Q) Vs Compressor Speed

4.5.2. Effect of compressor speed to coefficient of performance, COP_R

The effects of compressor speed are shown in Figure 4.5. Slope of the graph show that the values COP_R are decrease with increasing of compressor speed. During the experiment, blower speed and mass of refrigerant are constant.

They are few parameters that affect the value of COP_R. Compressor discharge pressures are increase and suction pressure increase slightly with increasing compressor speed, which result decrease of the volumetric efficiency of compressor. Pressure at those points effect the value of enthalpy, h which is important data to determine COP_R.

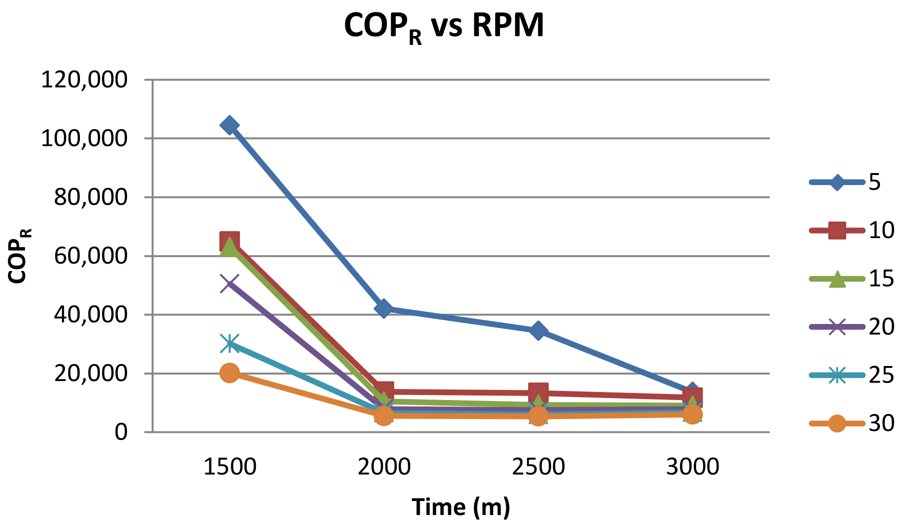


Figure 4.7: Graph Coefficient of Performance (COP_R) Vs Compressor Speed

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Analysis performance of car air-conditioning system can be determined by calculate the coefficient of performance, COP_R of the system. COP_R can be obtained by calculating heat transfer at evaporator and work done by compressor. Heat transfer at evaporator can be determined by taking the temperature at outlet and inlet evaporator. Work done by compressor can be calculated by taking the temperature and pressure at suction and discharge compressor.

The first analysis was to determine the effect of time to coefficient of performance of the system and heat transfer at evaporator. The system is running for 30 minutes, and data was taken for every 5 minutes. Temperature and pressure at suction and discharge compressor are taken. Temperature at outlet condenser was taken, which the value at this point is the same as temperature at inlet evaporator. These parameters were used to determine the value of enthalpy, and thus coefficient of performance can be determined. The results showed that heat transfer at evaporator and coefficient of performance was decreased at increasing of time the system running.

The second analysis was to determine the effect of compressor speed to coefficient of performance of the system and heat transfer at evaporator. The system is running for 30 minutes with different compressor speed, 1500 rpm, 2000 rpm, 2500 rpm and 3000 rpm, and data was taken for every 5 minutes. Temperature and pressure at suction and discharge compressor are taken. Temperature at outlet condenser was taken.

The result showed that heat transfer at evaporator and coefficient of performance was decreased at increasing of time the system running.

In this project, the result show that performance of the system are decrease when high compressor speed are used and the system running for long time. However, the result maybe different when the car is moving at high speed due to the wind can affect the rate of heat transfer.

5.2 RECOMMENDATION FOR FUTURE WORK

Several future works are expected to be done, to increasing the performance of the automotive air-conditioning system, in term of efficiency and environmental friendly. The heat directly from the sun, heat from the engine and heat from road has increase the temperature inside car, and the system should working well to make sure inside the car can keep the temperature at comfort level. If the car is in static, compressor should be running in constant low speed, in order to reduce the cost of fuel consumption and will ensure the system run in stable condition.

REFERENCES

Birch T.W. 2006. *Automotive Heating and Air-Conditioning 4th ed.* Ohio: Pearson Prentice Hall.

Boyce H.D. 2001. *Automotive Air-Conditioning 8th ed.*

Chek C. 2004. *Automotive Heating, Ventilation, Air-Conditioning System*

Steven D. 2006. *Automotive Air-Conditioning and Ultimate Control.* New York: Butterwort-Heinemann

Steve D. 2006. *Automotive Air-Conditioning System Techbook*

Wang S., Gu J., Dickson T., Dexter J. and McGregor I. 2004. Vapor Quality and Performance of Automotive Air Conditioning System. *Experimental Thermal and Fluid Science.* **30**(2005): 59-66.

Joudi K. A., Mohammed A. S. and Aljanabi M. 2002. Experimental and Computer Performance Study of an Automotive Air Conditioning System with Alternative Refrigerants. *Energy Conversion and Management* **44**(2003): 2956-2976

Liu H., Chen J. and Chen Z. 2005. Experimental Investigation of an CO_2 Automotive Air Conditioner. *International Journal of Refrigerant* **28**(2005): 1293-1301

APPENDIX A

Table A-1: Result of different temperature and pressure point at 1500 rpm compressor speed

Time (m)	T_1 (oC)	T_2 (oC)	T_3 (oC)	P_1 (kPa)	P_2 (kPa)
0	26	36	43	0	0
5	26	44	37	261.72	1112.58
10	25	44	38	266.53	1123.08
15	25	44	40	270.11	1139.67
20	25	45	41	272.05	1150.44
25	25	49	43	269.84	1165.36
30	25	52	44	266.49	1173.12

Table A-2: Result of different temperature and pressure point at 2000 rpm compressor speed

Time (m)	T_1 (^oC)	T_2 (^oC)	T_3 (^oC)	P_1 (kPa)	P_2 (kPa)
0	26	36	43	0	0
5	26	50	45	241.57	1194.73
10	25	55	46	250.06	1252.29
15	25	60	47	259.90	1272.43
20	24	63	49	255.83	1262.40
25	23	65	51	251.98	1254.81
30	22	67	54	247.28	1249.37

Table A-3: Result of different temperature and pressure point at 2500 rpm compressor speed

Time (m)	T_1 (^oC)	T_2 (^oC)	T_3 (^oC)	P_1 (kPa)	P_2 (kPa)
0	26	36	43	0	0
5	26	51	45	220.85	1204.18
10	25	56	46	222.19	1261.99
15	24	62	47	224.87	1310.41
20	23	64	50	226.06	1348.53
25	22	67	54	229.44	1377.50
30	21	69	57	231.17	1416.20

Table 4-4: Result of different temperature and pressure point at 3000 rpm compressor speed

Time (m)	T_1 (^oC)	T_2 (^oC)	T_3 (^oC)	P_1 (kPa)	P_2 (kPa)
0	26	36	43	0	0
5	25	52	44	201.06	1337.52
10	24	57	47	211.85	1340.61
15	23	63	49	218.88	1377.03
20	23	65	52	222.74	1404.62
25	22	67	55	225.70	1449.75
30	22	69	58	229.19	1482.03