THE EFFECT OF THE CONDENSATE WATER TEMPERATURE ON THE PERFORMANCE OF THE VEHICLE AIR CONDITIONING SYSTEM

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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 "The Effect of The Condensate Water Temperature on The Performance of The Vehicle Air Conditioning System" is the result of my own work except as cited in the references.

Signature	:	....
Name	:	Muhammad Aiman bin Wahid
Date	:	16th July 2021

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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	:	19th July 2021

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DEDICATION

To my beloved Umi and Ayah.

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ABSTRACT

This study experimentally investigates the effect of condensate water temperature on the performance of automotive air conditioning (AAC) systems. The experimental test rig consists of the actual components of the AAC system from the Proton Wira passenger car. The experimental test rig has been modified by adding a spraying compartment to manipulate the temperature of the condenser. In the experimental work, the temperature of the condensed water was manipulated at 8 ±3°C and 27 ±3°C. The results were compared with the baseline conditions of the condenser with no condensate water sprayed. The other parameters such as the speed of compressor, volume flow rate of condenser, and the air inlet evaporator temperature were fixed at 1550 rpm, 450 ml/min and 30 ±3°C, respectively. The study showed that the coefficient of performance (COP) of the AAC system increases at lower temperature of condensate water sprayed. It was due to a significant decrease in compressor work from both conditions as compared to the baseline state, and an increase in cooling capacity. In addition, the highest COP is at 4.81, increase 16.6% as compared to baseline condition, and this increment occurred at condensate water sprayed at 8.01°C. This is followed by condensate water sprayed at 27.2°C (15.5%), as compared to baseline condition.

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ABSTRAK

Kajian ini meneliti secara eksperimental pengaruh suhu air tersejat terhadap prestasi sistem penyaman udara automotif (AAC). Rig ujian bagi tujuan eksperimen terdiri daripada komponen sebenar sistem AAC kereta penumpang Proton Wira. Sistem ini telahpun diubahsuai dengan penambahan peralatan penyembur air bagi memanipulasi suhu kondenser. Dalam kajian eksperimental ini, suhu air yang tersejat telah dimanipulasi pada kadar 8.01 dan 27.2℃. Manakala keputusan kajian telah dibandingkan dengan keadaan biasa kondenser tanpa sebarang penyemburan air tersejat dilakukan. Parameter lain seperti kelajuan awal pusingan pemampat penyejuk, kadar aliran isipadu kondenser dan suhu udara masuk penyejat telah ditetapkan pada 1550 ppm, 450 ml / min dan 30 ± 3°C. Kajian telah menunjukkan bahawa pekali prestasi (COP) bagi sistem AAC meningkat apabila air tersejat disembur pada suhu yang menurun. Hal ini disebabkan oleh kadar kerja pemampat yang menunjukkan penurunan yang signifikan jika dibandingkan dengan keadaan dasar kondenser, dan kenaikan kadar penyejukan. Tambahan pula, COP tertinggi telah direkodkan pada 4.81 meningkat sebayak 16.61% jika dibandingkan dengan keadaan dasar, dan peningkatan ini berlaku ketika air penyemburan di suhu 8.01°C. Peratusan peningkatan COP ini juga diikuti oleh air tersejat yang disembur pada suhu 27.2°C (15.5%) dan situasi ini juga dibandingkan dengan keadaan dasar kondenser.

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful

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Lastly, my deepest gratitude goes to my parents and housemates for their moral support, patience, and encouragement in realization of this project especially during this pandemic COVID-19 period.

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LIST OF ABBEREVETIONS

AAC	Automotive Air Conditioning
VCRC	Vapor Compression Refrigeration System
COP	Coefficient of Performance
CO_2	Carbon Dioxide
R12	Dichlorofluoromethane
A/C	Air-conditioning
CFC	Chlorofluorocarbon
HVAC	Heating, Ventilating and Air Conditioning
TXV-RD	Receiver drier and Thermostatic expansion valve
OT-AD	Accumulator-drier and Orifice tube
TXV	Thermal expansion valve
RD	Receiver drier
OT	Orifice tube
AD	Accumulator drier
Q_H	Rate of heat removal (kW)
Q_L	Rate of heat rejection (kW)
Q_e	Cooling capacity (kW)

LIST OF ABBEREVETIONS

W_{in}	Work of compressor (kW)
p	Absolute pressure (kPa)
P	Gauge pressure (bar)
$\dot{m}$	Mass flow rate of refrigerants (kg/s)
h_1	Compressor refrigerant enthalpy (kJ/kg)
h_2	Evaporator refrigerant enthalpy (kJ/kg)
T_1	Temperature refrigerant at inlet compressor (°C)
T_2	Temperature refrigerant at inlet condenser (°C)
T_3	Temperature refrigerant at inlet expansion valve (°C)
T_4	Temperature refrigerant at inlet evaporator (°C)
T_5	Temperature air inlet evaporator (°C)
T_6	Temperature air outlet evaporator (°C)
T_7	Temperature water storage (°C)
T_8	Ambient temperature (°C)

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LIST OF ABBEREVETIONS

P_1	Pressure of refrigerant at inlet compressor (Bar)
P_2	Pressure of refrigerant at inlet condenser (Bar)
P_3	Pressure of refrigerant at inlet expansion valve (Bar)
P_4	Pressure of refrigerant at inlet evaporator (Bar)

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CHAPTER 1

INTRODUCTION

1.1 Background

The improvement of living society demanding for the comfortable environment of the car interior including the performance of the automotive air conditioning (AAC) system. Furthermore, driver fatigue reduces as road safety and pleasant environment improve accordingly to the driver contentment (Sukri et al., 2020). Usage of the air conditioning system is considerably relates to some factors such as weather, time of day, season, type of vehicle, automotive paint, parking lot, driver apparel, active intensity of the driver, distance to destination, vehicle overtaking, and personal preference (Farrington & Rugh, 2000). Thus, it is necessary to improve the performance of the AAC system as the usage is reportedly higher in Malaysia climates.

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AAC system normally manufactured based on the Vapor Compression Refrigeration System (VCRC) which refers to the air treatment that results in temperature control, humidity, purity, scent, and flow, as needed by the users in a circumstance (Sukri et al., 2020). Due to the operation of AAC system, condensate water is formed through the air condensation on the evaporator surface. The temperature of the condensate water formed is slightly higher than the evaporator temperature which approximately at 5-7°C (Sumeru et al., 2019).

Numerous of studies have proven that the improvement of air conditioning performance can be made by the wasted condensate water. The result of the experimental investigation showed that 6.1% of power consumption of compressor was reduced, while refrigeration capacity and coefficient of performance (COP) showed an increment by 20.5% and 21.4% respectively (Ibrahim et al., 2017). Apparently, the temperature difference between the cooling medium and the product relates to the cooling rate (Thompson, 1992). It is believed that differences happen on temperature of wasted condensate water produced to assist the sub-cooling process, and the effect is yet to be investigated.

1.2 Problem Statement

The contribution of the road transportation sector to emissions of air pollutants and greenhouse gases is a growing concern in developing countries (Thambiran & Diab, 2010) such as Malaysia. The increasing unit of car usage as a part of road transportation have resulting in a significant of air pollution and greenhouse effect. As shown in Figure 1, the emissivity of carbon dioxide (CO_2) by transportation ranked second after the power generation, as the CO_2 emission contributor in Malaysia. The annual growth increases by 6.4%, 4.4%, 3.6% and 13.9% in the respective sectors, power generation, transport, manufacturing, and other industries contributed 46%, 22%, 19% and 13% of total CO_2 emissions in 2013 (IEA,2014). These effects have resulted in the increment in the atmospheric concentrations of greenhouse gases which produces hot weather.

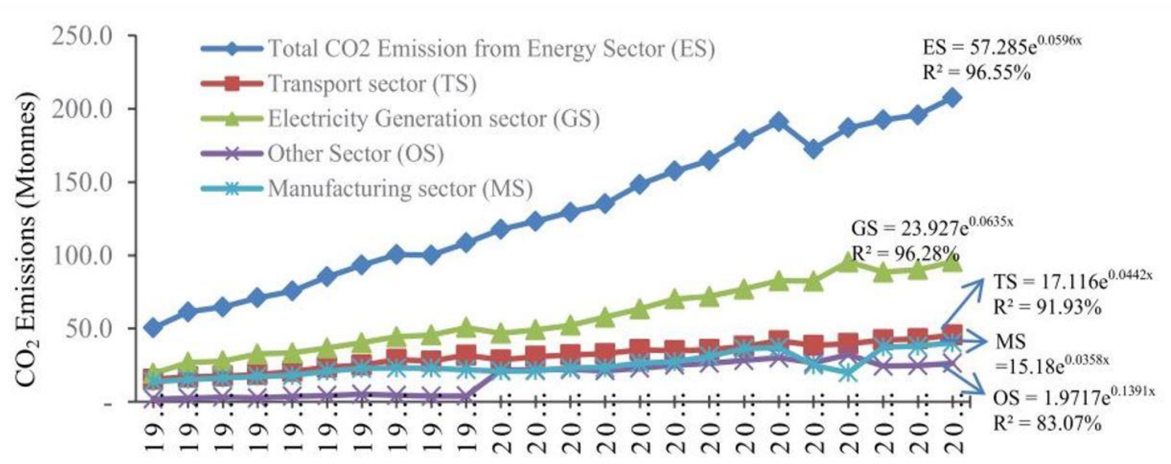

Figure 1.1: CO_2 emissions patterns from energy sub-sectors in Malaysia (1990-2013) (IEA,2014)

Hot and humid climates in certain countries have led to an innovation to improve the efficiency of AAC system especially to a private transportation such as car. AAC system is found to be improved in performance due to the decrement of compressor discharged temperature. The used of unwanted condensate water discharged sprayed to the condenser has increased the cooling capacity of AAC system. In addition, the effect of water-injection of condensate water temperature also influenced the power consumption of the condenser. The COP of the AAC system will be compared in this study, as the manipulation of unwanted condensate temperature is made.

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1.3 Objective

The objectives of this project are as follows:

1. To investigate the system pressure and temperature of the proposed system as compared to conventional system.
2. To determine the COP of AAC system assisted by different condensate water temperature.

1.4 Scope of Project

The scopes of the project will be covered in three dimensions, which are method of the project of the project, variables covered and validity of results. The scopes are prepared as shown below:

1. Only the result involving the experimental method are presented in this report.
2. Condensate water temperature are varied at 8 ±3°C and 27 ±3°C in comparison to conventional system as baseline condition, but compressor speed and condensate water speed are maintained. Other than that, humidity of air, air velocity and wet temperature are to be ignored during the experimental studies.
3. Validity of the result is determined by the highest COP produced in the limitation of the compressor speed and condenser water speed are fixed at 1550 rpm and 450 ml/min, respectively.

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CHAPTER 2

LITERATURE REVIEW

2.1 History of AAC system and refrigerants

2.1.1 AAC system

The development of AAC system was began in the end of 1920s by General Motors (GM) researchers with the development of dichlorofluoromethane (R12) or Freon 12, a type of refrigerants that had been utilized in the refrigeration cycle in the early days. The research on the AAC system had reached its climax with the development of prototype self- contained unit mounted in the trunk of a 1939 Cadillac by the following years. In 1939, a complete air-conditioning (A/C) system for summer conditioning and winter warming was offered at $274 by Packard Motor Car Company.

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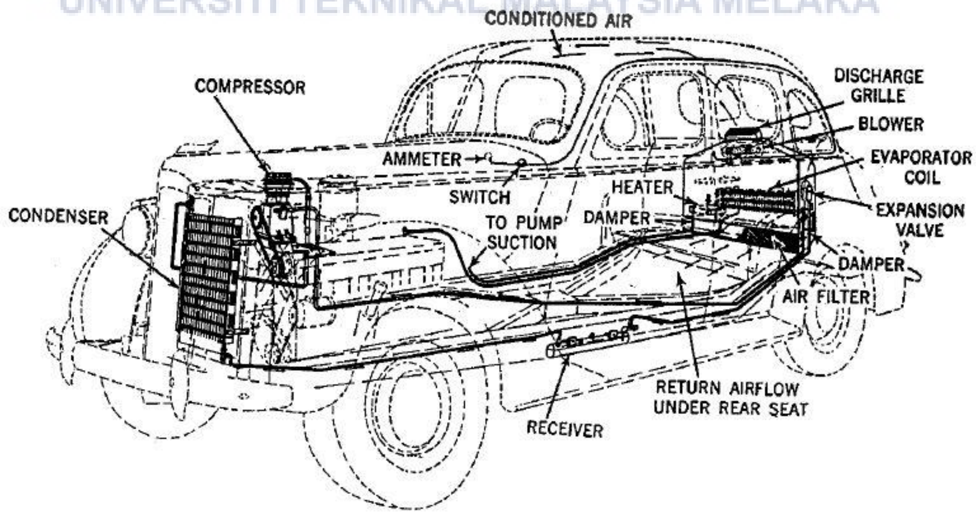

Figure 2.1: Complete system by Packard Motor Car company (Bhatti, 1999)

The initial studies were conducted in 1934 by a collaboration of Houde Engineering of Buffalo, N.Y. and Carrier Engineering of Newark, N.J. to create first bus accommodated with A/C system by implementation of the ideas on a Ford V8 five – passenger car. The system implemented to the car was compact, with the condenser was installed on the roof and least power equipped by the bus engine. Starting 1940s, A/C system were made available on the closed body models luxury cars. However, numerous problems were complained by the consumers during the earliest designs of the A/C system as well as World War II had stuttering the progress of the innovation.

It was until 1953 model launched, automotive air conditioning had made a revival and thrived to be an actual demand for more common cars owner. This was associated with measures taken by General Motor, Chrysler, and Packard introduced a practical A/C system, in which resolving previous major problems. The revolutionary air – conditioner model could be spaced in the under hood in the engine section was introduced by Harrison Radiator Division of General Motors in 1953. Throughout 1950s until 1960s, the utilization of air conditioning units became the feature element mounted by all the car makers including Ford, which had set A/C unit price at $232, almost half of the average price due to its popularity.

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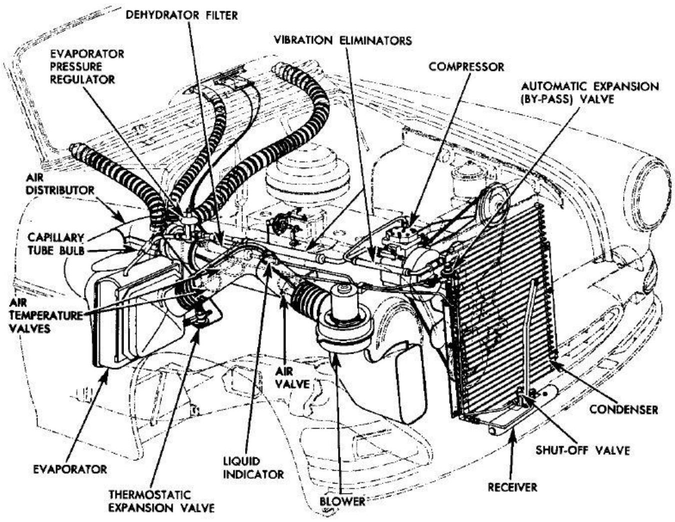

Figure 2.2: A/C system disposition in the under hood by Harrison Radiator Division of General Motors in 1953 (Bhatti, 1999)

2.1.2 Refrigerants

In 1974, Molina and Rowland the winner of 1995 Nobel Prize in Chemistry, revealed that the extensive use of the Chlorofluorocarbon (CFC) has depleted the ozone layer in stratosphere. CFC was widely use in the Heating, Ventilating and Air Conditioning (HVAC) instrument, as a food processing substance, foam blowing agent, sterile gas diluent, and aerosol oxidizer (Brown, 2012). R12 is considered as CFC as its molecular structure consists of chlorine and fluorine.

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In 1976, Harrison Radiator did the chlorine elimination to produce R134a as the substitute for R12. Although the sustainability of R134a was proven by Harrison through wind tunnel test on a car model, the production of A/C system with R134a was halted due to the lack of R134a production. The commercial used of the R134a began by having chlorine replacement with fluorine in the refrigerant composition, and the production initially started by Du Pont De Nemours and Company (Dupont) and Imperial Chemical Industries (ICI) in 1990. The conversion to R134a as A/C system refrigerant took place in USA, Japan, and European country during 1991 to 1994, followed by the rest of the world during late1990s and beginning of 2000s.

2.2 Present-day conventional AAC systems

There are two types of conventional A/C system are installed in the car: system with receiver drier and thermostatic expansion valve (TXV-RD) and system with accumulator-drier and orifice tube (OT-AD). The arrangement of both TXV-RD and OT-AD are shown in Figure 2.3 and Figure 2.4, respectively. Both systems are lining up almost the same essential components such as compressor, condenser, and evaporator.

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The basic operation of both systems start with the compressor compresses the cool gaseous state of the refrigerant from evaporator and pressurizes it in high pressure and temperature to the condenser. In the condenser, the refrigerant is then liquidized into lower temperature small pressure droplets after the refrigerant experiencing cooling phases, as cool air flow is provided by the condenser fan. The subcooled liquid refrigerant will then flow into receiver drier (RD) in TXV-RD system. In OT-AD system, the liquid will direct into fixed diameter orifice tube (OT).