UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ENHANCE THE PERFORMANCE OF CONDENSER BY USING EVAPORATIVE COOLING METHOD FOR SPLIT TYPE AIR CONDITIONER

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Engineering Technology (Refrigeration & Air-Conditioning System) with Honours

By

KARTHIGEYAN A/L RAMAKRISHNAN
B071210541
910410-08-5653

FACULTY OF ENGINEERING TECHNOLOGY
2016

DECLARATION

I hereby, declared that this report entitled “Enhance the performance of condenser by using evaporative cooling method for split type air conditioner” is the results of my own research except for quotes as cited in references.

Signature	:	…………………………………………….
Author’s Name	:	…………………………………………….
Date	:	…………………………………………….

APPROVAL

This report is submitted to the Faculty of Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfillment of the requirements for the award of Bachelor of Mechanical Engineering Technology (Refrigeration & Air-Conditioning Systems) with Honours. The member of the supervisory is as follow:

………………………………

(Mr. Azwan Bin Aziz)

ABSTRAK

Penyaman udara jenis unit terpisah adalah salah satu peralatan yang biasa digunakan di kediaman, bangunan, pejabat dan hotel. Penyaman udara jenis ini dibahagikan kepada dua bahagian iaitu unit pemeluwap dan unit gegelung kipas (unit dalam). Unit pemeluwapan terletak di luar bangunan manakala unit gegelung kipas (unit dalam) terletak di ruang penyamanan dan kedua-dua unit ini disambungkan dengan menggunakan tiub kuprum. Penyaman udara jenis unit terpisah kebanyakkannya menggunakan pemeluwap sejuk udara dan pekali prestasi sistem penyaman udara yang menggunakan pemeluwap jenis ini bergantung pada suhu persekitaran. Dalam keadaan cuaca yang panas, pekali prestasi penyaman udara akan menurun dan ia akan meningkatkan penggunaan tenaga elektrik. Pengurangan penggunaan tenaga elektrik adalah salah satu kebimbangan yang paling penting dalam keadaan cuaca panas. Penyejukan penyejatan adalah salah satu kaedah yang boleh meningkatkan pekali prestasi sistem dalam persekitaran panas. Pad penyejukan dipasang pada belakang unit pemeluwap yang sedia ada. Pam air digunakan untuk menyembur air pada pad penyejukan supaya dapat mengurangkan suhu udara persekitaran apabila melalui pad penyejukan dan seterusnya ke gegelung pemeluwap. Dengan menggunakan kaedah ini, kadar pekali prestasi sistem meningkat pada masa yang sama suhu udara persekitaran diturunkan. Keputusan kajian ini menunjukkan bahawa dengan menggunakan sistem penyejatan, kadar pekali sistem penyejukan dapat ditingkatkan 20.4% dan penggunaan tenaga elektrik dapat dikurangkan 10.2% pada suhu persekitaran 34˚C. Sistem penyejukan penyejatan ini dianggap sebagai kaedah yang mempunyai kos rendah, mesra alam dan cekap tenaga untuk meningkatkan prestasi pemeluwap sejuk udara bagi penyaman udara jenis terpisah.

ABSTRACT

Split-type air conditioner is one of the commonly used appliances in residence, building, offices and hotels. This type of air conditioners divided into two parts which is condensing unit and fan coil unit. Condensing unit normally situated at the outside of the building whereas fan coil unit fixed in the conditioned space and both units connected through copper pipes. An air-cooled condenser is normally used in this type of air conditioner and the coefficient of performance of system using air-cooled condenser is depends on the temperature of ambient air. In hot environment, the coefficient of performance of the air conditioning system decreasing thus results increasing in electrical power consumptions. Minimizing of energy consumption is a major concern especially in the hot weather conditions. An evaporative cooling method can enhance the coefficient of performance of the system in hot ambient. The conventional condensing unit of split-type air conditioner retrofitted with evaporative cooling pad at the up stream of the condenser. A water pump is used to inject the water over the cooling pad to reduce the ambient air temperature when passes over the cooling pad and then passes over the condenser coil. Application of evaporative cooling system couple with air-cooled condenser can increase the coefficient of performance of the air conditioning system and the rate of COP improvement is increased as the ambient air temperature decreased. The result shows that by using evaporative cooling method, the COP of the air conditioner improved up to 20.4% and electrical current consumption reduced up to 10.2% at 34˚C ambient temperature. This evaporative cooling system considered as low cost, environmental friendly and energy efficient method to enhance the performance of air-cooled condenser of split-type air conditioner.

DEDICATION

There are a number of people without whom this thesis might not have been written, and to whom I am greatly indebted. I owe my gratitude to all those people who have made this project possible and because of whom my graduate experience has been one that I will cherish forever. I dedicate my dissertation work to my family and many friends. A special feeling of gratitude to my loving parents, Ezhilarasi A/P Sababathy whose have been my constant source of inspiration. They have given me the drive and discipline to tackle any task with enthusiasm and determination. Without their love and support this project would not have been made possible. My deepest gratitude is to my advisor, Mr. Azwan Bin Aziz. I have been amazingly fortunate to have an advisor who gave me the freedom to explore on my own and at the same time the guidance to recover when my steps faltered. He taught me how to question thoughts and express ideas. His patience and support helped me overcome many crisis situations and finish this project. I hope that one day I would become as good an advisor to my students as he has been to me. Many friends have helped me through these difficult years. Their support and care helped me overcome setbacks and stay focused on my graduate study. I greatly value their friendship and I deeply appreciate their belief in me. Particularly, I would like to acknowledge Elvin for helping me develop my drawing skills. Besides I am also thankful to lecturers for numerous discussions on related topics that helped me improve my knowledge in the research area better. All of them have been my best cheerleaders.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to the All Mighty for His goodness and grace that sustained my performance level at the crucial times of completing this Final Year Project entitled Enhance the Performance of Condenser by Using Evaporative Cooling Method for Split Type Air Conditioner. Besides that, I would like to extend my appreciation to those who contributed time, concern and efforts to lend a helping hand thus allow me to gain valuable knowledge. On top of that, a special thanks to my supervisor, Mr. Azwan Bin Aziz for his guidance, encouraging excellence in mentoring and most of all patience throughout the entire project development. Thanks to my bachelor degree project group mates who are helping for completing the researches together. Next, I would like my academic advisor, Mr Muhammad Fairuz Bin Abu Bakar, the beginning teachers, mentor-teachers and administrators of our university faculty that assisted me with this research. Finally, I would also like to express my endless appreciation to my family members for their valuable support and motivations. It would not have been possible to complete this project without their supports.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS, SYMBOLS AND NOMENCLATURES

A	-	Ampere
ARI	-	Air-Conditioning and Refrigeration Institute
COP	-	Coefficient of Performance
CTC	-	Condenser Temperature Control
CV	-	Conventional
DBT	-	Dry Bulb Temperature
DC	-	Direct Current
DEC	-	Direct Evaporative Cooling
EC	-	Evaporative Cooling
NDDCT	-	Natural Draft Dry Cooling Tower
OD	-	Outer Diameter
PVC	-	Polyvinyl Chloride
RH	-	Relative Humidity
TWBT	-	Thermodynamic Wet Bulb Temperature
WSMCST	-	Water Spray Mist Cooling System with a Tor

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Nowadays, air conditioning is widely used during summer seasons and hot weather countries. There are many types of air conditioning systems are available in market. The most commonly used small tonnage air conditioning system at residential, offices, shops, small industries are window air conditioner and split air conditioner. But, the window air-conditioner is no more in market because of its some disadvantages such as high noise level, higher power consumption, difficulties in installation and etc. But, split type air-conditioner is currently much familiar than the window air conditioner due to some of its advantages. This split type air conditioner divided into two parts which is condensing unit normally known as outdoor unit located at the outside of the building and fan coil unit normally known as indoor unit located at the conditioned space.

The finned-tube air-cooled condenser is generally used in split type air conditioning and refrigeration application because of its ease of installation, simplicity of operation and maintenance and also the less maintenance cost as compared water-cooled condensers. In air conditioning and refrigeration system, the function of condenser is to reject heat from the refrigerant in vapour state and condense it to the liquid state by condensation. The power consumption is an importance in vapour compression cycle those using air-cooled condenser in hot weather instead of water-cooled condenser. According to Chow, Lin and Yang, (2002), the performance of air-cooled condenser based on heat transfer between the condenser coils and the airflow through the condenser coil. When the condenser temperature increases it will also causes the pressure of the system increase and consequently result in increase the power consumption because the pressure ratio becomes higher and the compressor is forced to work.

In this regard, to overcome the increase in temperature, a higher airflow rate is required by an air-cooled condenser for enhance its performance, and it sometimes causes some increase in sound level. So in general, by reducing the condenser temperature and increasing the capacity of cooling and heat rejection, COP of the system can be improved. The direct evaporative cooler is coupled with the air-cooled condenser for the purpose of reduce the ambient air temperature. The evaporative cooling pads are fixed at the upstream of the air cooled condenser and inject water on the cooling pad using water pump. The water flows down due to gravity and when the hot ambient air enter through the evaporative cooling pad, its temperature reduced before passes over the condenser coil to enhance the air cooled condenser performance of split type air conditioner, Luis Perez- Lombard, and collegues, (2008).

1.2 Problem Statements

An air-cooled condenser is mostly used in the split type air conditioner. Performance of the air cooled condenser depends on the ambient air temperature and the thermal stability fluctuates throughout the year especially in hot weather. When the ambient temperature increases thus, it will cause the pressure and temperature of the air cooled condenser increases. This will force the compressor to work under higher pressure ratio and consume more power. Sometimes the excessive pressure can cause the compressor trip. The performance can be improved by raising the air flow rate through the condenser coil but it will results in some noise problem. Luis Perez- Lombard, and colleagues, (2008), reported that 17% of the total global energy was consumed by air conditioning.

According to Chow, Lin and Yang, (2002), when the on-coil temperature of condenser increase by 1˚C, the coefficient of performance of the system will decrease by around 3%. It is because the refrigerant vapour state flowing through the condenser coil unable to fully condense because of high ambient air temperature, thus results in mixture of vapour and liquid refrigerant enters the expansion valve (capillary tube) consequently decreasing the coefficient of performance of the system. Whereas the experiment carried out by C. Chaktranond *et al*., (2010), reported that electrical power consumption increases by 4% when the condenser temperature increases every 1˚C.

1.3 Objectives of The Study

1.3.1 Main Objective:

To improve the performance of air-cooled condenser of split type air conditioner.

1.3.2 Specific Objectives:

I. To reduce the temperature of ambient air by using cellulose evaporative cooling pad before it passes over condenser coil.
II. To increase the coefficient of performance of the system by decreasing the condenser on-coil temperature using indirect evaporative cooling method.
III. To reduce the energy consumption of the system by decreasing the compressor work.
IV. To identify the relationship between ambient air temperature and COP of the air conditioning system.

1.4 Work Scope of The Study

This experimental study mainly focused on the improvement on the performance of an air cooled condenser of 1.5 horsepower split type air conditioning system. Performance of air cooled condenser will be enhanced by decreasing the ambient air temperature by placing corrugated cellulose evaporative cooling pad injected with water at the upstream of the condenser. The ambient air temperature before and after passes the cooling pad will be measured using thermocouple.

Next, comparing the coefficient of performance of the system with evaporative cooling and without evaporative cooling system by measuring the high side and low side pressure of the system using pressure gauge. The inlet and outlet temperature of the major components such as compressor, condenser, expansion valve and evaporator measured using thermocouple. Both temperature and pressure data used to plot on the Mollier Chart and calculate the COP of the air conditioning system with and without an evaporative cooling system. Also, compare the power consumption of the air conditioning system with and without an evaporative cooling system.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter will be mainly focused on the literature review regarding the enhancement of an air-cooled condenser of air conditioning and refrigeration systems. Many experiments have been done by the researchers to improve the performance of condenser by using several types of methods. There are some review related to the project were done such as the evaporative cooler coupled with air-cooled condenser, water mist system, direct evaporative cooling system, selection of evaporative cooling pad and optimization of the evaporative cooling pad thickness, effect of condenser air flow through the condenser coil, condenser fan performance and plain and finned tube performance. By review the relevant literature, it will help the author to understand the actual problem and able to conduct the experimental studies based on the literature have been done.

2.2 Performance of Air-cooled Condenser

According to Xiaoli Hao *et al.*, (2013), the air-cooled chillers have many advantages over the water-cooled chillers such as no cooling tower and condenser pump needed and also they never required any mechanical room for the chillers. Although the air-cooled chillers have advantages over water-cooled chillers, but the energy efficiency is less if compared to water-cooled chillers. Yu and Chan, (2005), reported that the air-cooled condensers are constructed to working under condensing temperature of 11-14 ˚C beyond the dry-bulb temperature of ambient air, whereas the water-cooled condenser designed to working at a condensing temperature to be near to 4-6 ˚C beyond the wet-bulb temperature of ambient air. Because of this, a greater condenser pressure is needed by an air-cooled chillers compare to water-cooled chillers, which influence to consume more power by the compressor and less refrigeration capacity.

Thermal stability of an air-cooled condenser is based on the temperature of ambient air and it is not stable throughout the year. Due to higher ambient air temperature, the refrigerant flowing in the condenser coil unable to fully condense and enters the expansion valve with the mixture of liquid and vapour thus, results in decreasing of COP of the system. Tianwei Wang, Chenguang Sheng and Agwu Nnanna, (2014). An experimental study by Chow *et al*., (2002), reported that 1˚C increased on the on-coil temperature of the condenser results in decrease of COP of the system by around 3%. To improve the COP of the system, the ambient air temperature must decrease before it passes through the condenser coil.

2.3 Application of Evaporative Cooling for Air-cooled Condenser

Hajidavalloo, (2007), carried out an experiment to investigate the effect of evaporative cooling for a window air conditioner using two methods. First, the cellulose bound cardboard is used as an evaporative cooling pad and water is injected on the cooling pad and by small water pump to provide cooling effect to the condenser by evaporation of water. This method is known as indirect evaporative cooling. Whereas, another method is direct evaporative cooling which means, water is directly injected on the condenser coil. Although this method can increase the COP of the system, there are some side effects such as mineral deposits and corrosion on the condenser coil. By using the indirect evaporative cooling method, Hajidavalloo, (2007), reported that about 16% of energy consumption decreased and at the same time, about 55% increase in COP of the system.

Based on the experimental study of Goswami, Mathur and Kulkarni, (1993), shows that the electric energy can be save up to 10% - 20% by using four evaporative cooling pad around the condenser coil of an existing 2.5 ton air conditioning system while the ambient air temperature is at 34˚C. Under local condition, an indirect evaporative cooling system applied to packaged unit air conditioner and they are able to improve the cooling load up to 75% and consume 55% less electrical energy. Delfani Shahram, (2010). Zhang *et al.,* (2000), carried out a study on the evaporative cooler permeated with corrugated holed aluminium foil and given relationship to estimate the performance, pressure drop and outlet air temperature of the cooler. They apply the relationship for estimate the enhancement of an air-cooled chiller by analyze the exit temperature of evaporative cooler with the performance curve of the chiller and conclude that the COP for chiller could be enhanced about 39%. An air-cooled chiller coupled with a direct evaporative cooler able to reduce 14.4% in power consumption and increase the refrigeration capacity about 4.6%. Yu and Chan, (2005).

Chaktranond and Doungsong, (2010), carried out an experimental study on the residential size split type air conditioner's condensing unit retrofitted with an indirect evaporative cooling system. The water injecting method on the evaporative cooling pad divided into two types which is water curtain and water spray. The evaporative cooling pad is placed in the upstream flow of air entering the condenser coil. The gap between the condenser coil and the evaporative cooling pad is 0.05m. By using this indirect evaporative cooling system, the ambient air temperature that entering the condenser coil could be reduced up to 3˚C and conclude that the ambient air temperature affects the system performances more than the relative humidity.

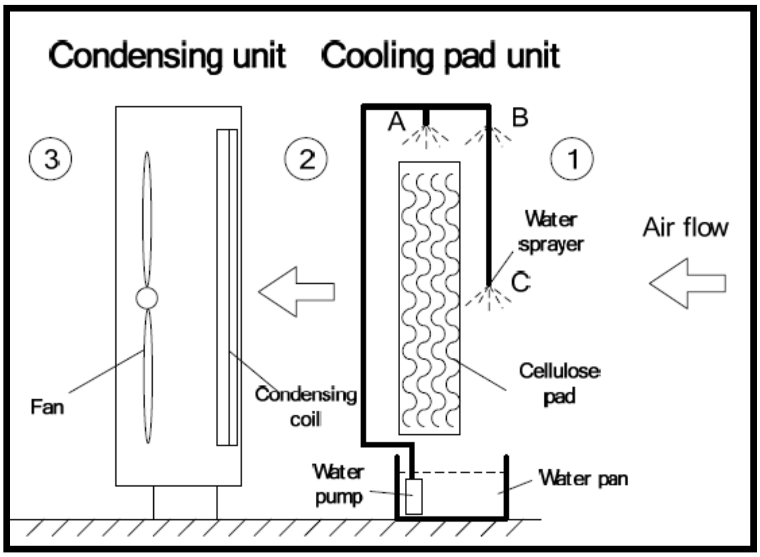

Figure 2.1: Schematic diagram of evaporative cooling system (Chaktranond and Doungsong, 2010)

2.4 Water Spray Mist Pre-Cooling System

According Hsieh and Yao, (2006), the water spray mist cooling system with a tor or mesh material (WSMCST) is not a new concept because it have been applied in various types of industries, but not common in air conditioning and refrigeration system. This condenser performance enhancement method is differing from other method due to this system monitored in real-time and electronically controlled. This WSMCST system mainly consists of three subsystems such as water treatment and control unit, high pressure pulverization unit with atomization nozzles and the third is a specially manufactured microprocessor. An experimental study by Jia Yang *et al*., (2012), shows that the high pressure pump deliver water with 70 bar pressure and forced through a micro nozzle to create a mist of 10μm droplets to produce a cloud of very small water droplets. These droplets vaporized by the ambient air before get in the condenser coil and the ambient air temperature reduced follow by the adiabatic cooling process with constant specific enthalpy.

Jia Yang *et al*., (2012), reported that, this system does not cause any flow obstructions to the air stream of the air-cooled condenser. It uses only a little amount of electric energy to run the high pressure pump to form water mist. According to Pongsakorn and Thepa, (2013), a study on the inverter air conditioning system tested under multiple water spray rates and frequencies with three different temperature scales in fixed ambient temperature. This study results in increase of COP by 35% at a lower water spray rate of 100 L/h and a higher frequency of 80-90 Hz. Yu and Chan, (2005), noticed that there is not enough research on the chillers which using multiple compressors and good water mist generation under condenser temperature control (CTC), the characteristic of dry-bulb temperature (DBT) and relative humidity (%RH) of the ambient air which get in the condenser coil is the important parameters to evaluate the thermal effectiveness of the water mist system.

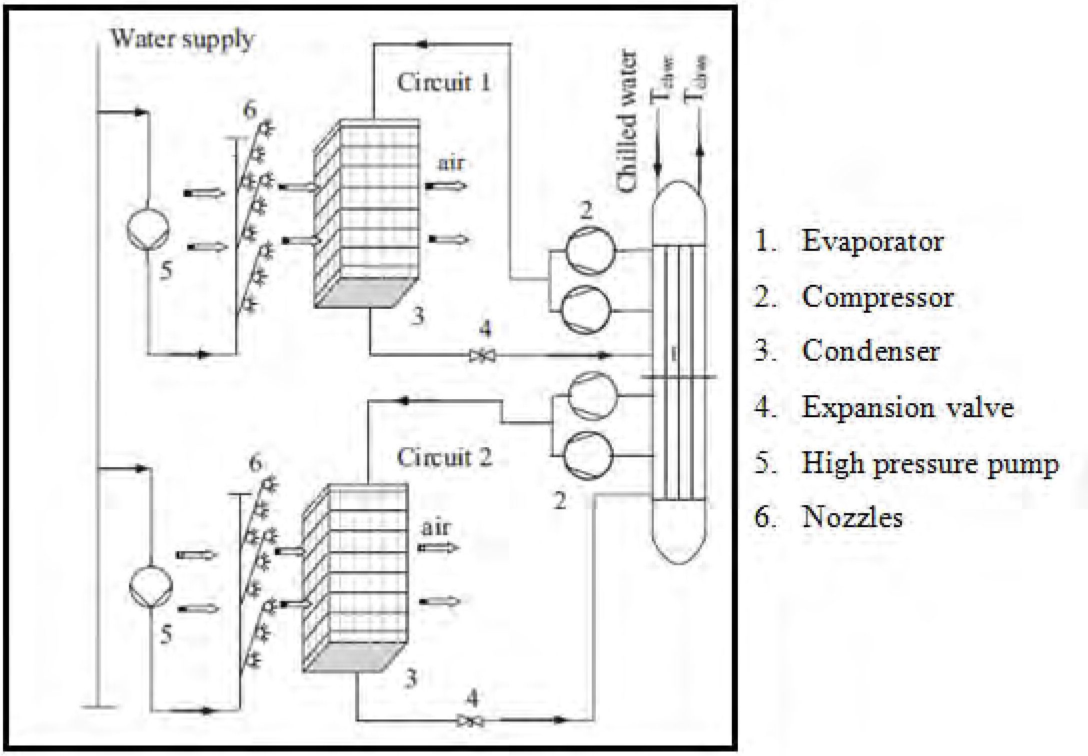

Figure 2.2: Schematic of the air-cooled chiller with water mist system (Jia Yang *et al*., 2012)

2.5 Direct Evaporative Cooling (DEC) System

Based on Camargo *et al*., (2005), induced processes of mass and heat transfer by using the water and air as working fluids is the working principal of evaporative cooling. It comprises, particularly, in evaporation of water, impelled by the transition of an air flow, thus results in lowering the temperature of the air. At the point water evaporates into the air, its temperature dropped down and consequently humidifying the air, this thermal process is called the adiabatic saturation and also known as the direct evaporative cooling (DEC). Ebinuma *et al*., (2002), study the operation principal of direct and indirect evaporative cooling systems by the development of mathematical equations of thermal exchanges, which allow finding the heat transfer convection coefficient for primary and secondary air flow. Dai and Sumathy *et al*., (2002), carried out an investigation on a cross-flow direct evaporative cooler to optimize the length of air channel in order to enhance the performance of the wet honeycomb paper constitutes packing material.