UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PERFORMANCE AND ENERGY ANALYSIS FOR HYBRID EVAPORATIVE CHILLER SYSTEM CONTROLLED BY CHILLED WATER TEMPERATURE BY HEATER

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

by

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DECLARATION

I hereby, declared this report entitled "PERFORMANCE AND ENERGY ANALYSIS FOR HYBRID EVAPORATIVE CHILLER SYSTEM CONTROLLED BY CHILLED WATER TEMPERATURE BY HEATER" is the results of my own research except as cited in references.

Signature	:	………………………………………….
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APPROVAL

This report submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (HVAC) with Honours. The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRAK

Hybrid Evaporative Chiller sistem adalah teknologi yang baru untuk menggantikan sistem penyejuk konvensional yang sedia ada berdasarkan surat kejuruteraan AL-CO dan system ini adalah gabungan sistem penyejuk menggunakan udara sejuk dan sistem penyejuk yang menggunakan air sejuk. Ia mengunakan twin skru pemampat, dipatenkan "Tube-to-Plate" kondenser penyejatan dan 'dry evaporator' yang tinggi effisiensi. Analisis tentang Hybrid Evaporative Chiller sistem ini sangat kurang di industri. Suhu air sejuk (chilled water temperature) adalah salah satu faktor yang memberi kesan kepada prestasi sistem (COP) dan penggunaan kuasa sistem penyejuk konvensional. Merujuk kepada artikel Kecekapan Tenaga Pengguna, menaikkan suhu air sejuk akan memberikan penjimatan tenaga yang lebih baik dalam sistem konvensional penyejuk. Tujuan kajian ini adalah untuk menentukan pekali prestasi (COP) dan penggunaan tenaga Hybrid Evaporative Chiller Sistem dengan dikawal oleh suhu air sejuk selama empat keadaan dengan menggunakan pemanas air. Tujuan lain adalah untuk menentukan tetapan terbaik suhu air sejuk dengan COP tinggi dan penggunaan kuasa yang kurang. Empat syarat ditetapkan pada projek ini: (1) 0 pemanas; (2) 1 pemanas, 6 kW; (3) 2 pemanas, 12 kW; (4) 4 pemanas, 18 kW. Pemanas dimasukkan ke dalam 'water reservoir tank' untuk memanaskan suhu air sejuk. Penggunaan kuasa diukur dengan menggunakan 3 fasa kuasa analyzer. COP ditentukan dengan menggunakan R410A manifold gauge dan termometer digital, kemudian dikira dengan menggunakan R410A Mollier chart. Konklusinya, keadaan 3 dengan pemanas 12kW menunjukkan COP tertinggi dan penggunaan kuasa yang lebih rendah. Penentuan suhu air sejuk yang terbaik ditentukan di antara 15.6^{o}C - 16.7^{o}C.

ABSTRACT

The Hybrid Evaporative Chiller system is the new technology to replace the existing conventional chiller systems based on the AL-CO engineering letter and it is a combination of air-cooled chiller and water cooled chiller system. The Hybrid Evaporative Chiller system utilizes twin screw compressor, patented “Tube-to-Plate” evaporative condenser design and high efficiency dry evaporator. But there is lack of analysis of Hybrid Evaporative Chiller System. The chilled water temperature is one of the factor that affected the coefficient of performance and the power consumption of the conventional chiller system. By referring to the article of Energy Efficiency Manual, raising in chilled water temperature will give the better energy savings in chiller system. The purpose of this present study is to determine the coefficient of performance (COP) and energy consumption of Hybrid Evaporative Chiller System by controlled the chilled water temperature for four condition by using water heater. Another purpose is to determine the best setting of chilled water temperature with high COP and less power consumption. The 4 condition is set at this project: (1) 0 heater; (2) 1 heater, 6 kW; (3) 2 heater, 12 kW; (4) 3 heater, 18 kW. The heater is put into the buffer tank to heat the chilled water temperature. The power consumption is measured by using 3 phase power analyser. The COP is determined by using R410A manifold gauge and digital thermometer, then calculated by using R410A Mollier Chart. In conclusion, the condition 3 with 12kW of heater showed the highest COP and lower power consumption. The best setting of chilled water temperature was determined which in range of 15.6^{o}C – 16.7^{o}C.

DEDICATION

I dedicate this dissertation to my mother, my sisters, brother and my friends. People who have always been there to support me, congratulate me, and show me always the best path to follow. To my mother, I will never finish thank you for everything you do every day for my sisters, brother and me. To my friends, who has been support me and encouraging me, I will thank you for your unconditional support and encouraging.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

BS	-	Bill Savings
C	-	Cooling capacity of chiller (RT)
CO2	-	Carbon Dioxide
COP	-	Coefficient of Performance
FLA	-	Full Load Amperage
HVAC	-	Heating, Ventilating, and Air Conditioning
MCC	-	Maximum Continuous Current
PID	-	Proportional-integral- derivative
PMV	-	Pulse Motor Valve
TR	-	Tons
RLA	-	Rated Load Amperage
h	-	Enthalpy
$^{\circ}C$	-	Degree Celsius
$^{\circ}F$	-	Degree Fahrenheit

CHAPTER 1

INTRODUCTION

1.0 Introduction

HVAC is the term for Heating, Ventilation, and Air-conditioning. The HVAC is bigger field which include a range from hand-stoked stove, used for heating to the air conditioning systems, used for cooling. The HVAC systems size are varies from small unit to large unit which installed in industrial or commercial building. HVAC systems are used to provide thermal comfort, maintain good indoor air quality and climate control. The climate control referred to heating, cooling, humidity control, building pressure control, and comfort control.

The first cooling systems in the world was developed in cooling the New York Stock Exchange, in 1902. The comfort cooling system was named as the "air-conditioning". As the name implies, the air-conditioning is used for cooling. Instead of cooling, air-conditioning also provide control of the temperature, humidity, supply of outside air for ventilation, filtration of airborne particles and air movement in the occupied space.

Based on the U.S. Department of Energy, almost all of homes have their own air-conditioners and the record showed that there has only 3 out of 10 houses does not have air-conditioners in United States. The air-conditioners are one of the most electric usage in different type of electrical equipment. In United States, 6% of electricity produced are used by the air-conditioner and cost $29 billion in one year.

The air conditioner uses the same principle and components with refrigerator which transfer the heat from the conditioned space to the surrounding by using the specific components. The air conditioner comprises of compressor, condenser, thermostatic expansion valve and evaporator. The compressor is a pump which compress the low temperature and low pressure refrigerant gas. The compressor is located at outdoor unit of split type air conditioner. The condenser is a heat exchanger with hot outdoor coil which release the heat to surrounding. The high pressure and temperature refrigerant gas is undergoes condensation when going through the condenser. The high pressure and low temperature liquid refrigerant are formed. After that, the liquid refrigerant flow through the thermostatic expansion valve. The thermostatic expansion valve is used to lower the pressure of the liquid refrigerant. Then, the liquid refrigerant flow into the evaporator which is cold indoor coil to absorb heat from conditioned space. The liquid refrigerant changed to the gas again and the cycle is repeatedly.

There have a lot of type of air conditioning systems which are split unit type, window type, packaged type and central air conditioning. The hybrid evaporative chiller system in central air conditioning is the focused in this research.

1.1 Problem Statement

Based on the AL-CO engineering letter, the new technology chiller, Al-CO Hybrid Evaporative Chiller System has replaced the existing conventional chiller systems. E. Hajidavallo and H. Eghtedaril carried out that the energy consumption of the evaporative cooled air condenser can be cut down to 20% and the coefficient of performance can be progress around 50%. There are lack of the analysis in the performance and energy of Hybrid Evaporative Chiller System. The chilled water temperature is the one of the factor that affect the coefficient of performance and the energy consumption of the system. By referring to the article of Energy Efficiency Manual, raising in chilled water temperature will give the better energy savings in chiller system. According to the Sustainable Energy Authority of Ireland, the control of chilled water temperature reduced the energy consumption.

1.2 Objective

There are several objective that need to be achieved:

I. To determine the Coefficient of Performance (COP) and energy consumption of Hybrid Evaporative Chiller System by controlled the chilled water temperature by using water heater.

II. To determine the best setting of chilled water temperature with high COP and less Power Consumption.

1.3 Scope

Some of important element must be consider in order to achieve the objective of the study.

I. Hybrid Evaporative Chiller System at Renewable Energy Lab is selected which located at Faculty of Engineering Technology.

II. The cooling capacity of the Hybrid Evaporative Chiller System is 77kW.

III. The power consumption of chiller system will be recorded by using power analyzer.

IV. The duration to measure power consumption is twice in one week and keep in two month. Time duration is 9.00a.m – 1.00p.m.

V. For all conditions, the COP will be determined from R410A Mollier Chart with using HVAC formula.

VI. The capacity of the buffer tank is 450L.

VII. 3 of each 6kW of water heaters are prepared.

VIII. During the data collection, centralized air conditioning need to shut off.

1.4 Outline of Project

This report consists of five chapter which are an introduction, literature review, methodology, result and discussion, and conclusion. In the first chapter which is the introduction, it consists of project background, problem statement, and scope. For literature review in chapter 2, the studies ore researches have been done on the same or related topics will be stated clearly in this chapter. The appropriate citation of the journals, books, and articles must be put in the reference to avoid the plagiarism. Besides that, in chapter 3, a methodology will be discussed the method to collect data, analyze performance and energy of Hybrid Evaporative Chiller System. In chapter 4, result and discussion will be present which include data collection, graph analysis, and mathematical model. Last but not least, the summary of the research, achievement of the objective, limitation of the project and future work will be discussed in chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter is actually study of journals, articles, and some books before begin the performance and energy analysis for Hybrid Evaporative Chiller System controlled by chilled water temperature by heater. Literature review can help to do research in better way such as can help in identifying the relevance of studies. The study of researches can help to recommend the better methods uses for this research and help to developing my study.

2.1 Type of Air Conditioning System

2.1.1 Window Air Conditioning System

Recent research on window air conditioning system (Haresh Khemani, 2008) has shown window air conditioners are the cheapest and most popular type of air conditioner [1]. The window air conditioners can used at different types of spaces such as living room, bedroom, or study room. There are space requirement for the window type air conditioner. A place with a slot on the wall and the free space behind the wall are needed for releasing the heat and dripping water. Window air conditioners are combined all the main components which are compressor, condenser, expansion valve and evaporator in a single box. There has a shafts on both sides connected by a motor. A blower is connected to the shaft at one side which in draft the hot air from the room and blows over the cooling coil, thus sending it to the conditioned room. On the other side, the fan is connected to the shaft, which the air is blows over refrigerant gas then passing through the condenser.

2.1.2 Split Air Conditioning System

The split unit air conditioner systems are the most popular and famous type of air conditioning that used by people nowadays compare to window type which is actually replaced by split unit air conditioner. The split air conditioner is more energy efficiency and look aesthetic than window type but the window type is cheaper than split type supported by Umar Shareef (n.d.). The split air conditioners are more suitable for small rooms, halls, offices and the places where window type cannot be installed. The installation of the split air conditioner will not damage to the decoration of the room or disturb the aesthetic of room. Besides that, the split air conditioners only take some small space for installation and it provide aesthetically looks and small noise. Outdoor unit and indoor unit are the two main part of the split air conditioner. At outdoor unit, it consists of some important components which are compressor, condenser coil, and the expansion valve. The purpose to installed outdoor unit at outdoor space is to reject heat. The noise that produce by compressor can reduced when the compressor is located at outside. At the condenser part, a fan is installed to blows the air to cool the compressed refrigerant gas. Then, the refrigerant liquid is pass through the expansion valve to lower the pressure and temperature. For the indoor unit, it provide the cooling effect to a room or a space. The indoor unit consists of the evaporator coil, blower and a filter. The lower pressure of refrigerant passing through from expansion valve to the evaporator coil. Thus, the blower blows over the evaporator coil and produce the cooling air to the room. Temperature reduces and moisture losses when the air passes over the cooling coil. The cool and dry air produce and entering the room to maintain comfortable temperature around 16-25 degree Celsius.

2.1.3 Central Air Conditioning System

The large commercial buildings, hotels, hospitals, or others where require large cooling load are usually used the central air conditioning plants. This is because the central air conditioning plants can provide a large cooling capacity. The central air conditioning plants can provide large cooling effect to large building while the window or split unit only can supplied for single or small room. It is not economically to install split unit or window type air conditioning for the large buildings because the small units are not enough to cool the large buildings. There are large compressor, condenser, expansion valve and evaporator in a large plant room and have a cooling tower outside the plants room or at open area. The central systems are perform similar function with the other air conditioning. There are different type of condenser and evaporator to use in central air conditioning such as shell and tube type or tube and tube type. The thermostatic expansion valve is used in the central air conditioning system to control the pressure manually which can adjust the pressure. The water are used as medium to transfer heat at condenser and evaporator for some central systems. Thus, there has no other cooling coil or refrigeration system component at every single room. So there is no sound produced at rooms and only chilled air are passing through the ducts.

2.1.4 Packaged Air Conditioning System

The capacity of window and split type air conditioners are usually up to 5 tons while the capacity of central air conditioning system can brought to 20 tons. For the packaged unit air conditioning system, the capacity is between these two air conditioning system which are 5, 10 and 15 tons. The packaged unit usually installed at the restaurants, homes, small hall, etc. The packaged unit air conditioner same as window type which is combined all the main components in a single box. But the packaged unit air conditioner also included the cooling coil, air handling unit and the filter in a single casing and installed at factory location. The packaged air conditioners consist of two different condensers: one with water cooled condenser while another one is air cooled condenser.

2.2 Type of Central Air Conditioning System

2.2.1 Air Cooled Chiller System

Air-cooled chiller system consists of four main components such as typical refrigeration system which are compressor, condenser, thermal expansion valve and thermal expansion valve. But the only different is the condenser in the air-cooled chiller system. The condenser used in air-cooled chiller system is air-cooled type which means it using the numerous amount of fan to dissipate the heat. During condensation, the air-cooled condenser play the important role in the system where the air-cooled condensers can absorb sensible heat by using ambient air. At the same time, the latent heat energy are rejected by the refrigerant and the heat transfer is occurred. Actually a lot of air-cooled condensers are installed in rooftop or open area of large buildings because the air-cooled condensing units are bigger in size. It also less efficient compare to water-cooled condensers. The condenser airflow rate is designed in the range of 600 to 1000 cfm per ton to advance the heat rejection process and increased the efficiency. So the systems must be installed at open area in order to avoid the air flow to collide the resistance and obstruction.

This system actually installed in below 200 tons chiller plants. The noises are produced when bigger air-cooled condenser with multiple condenser fan are functioned. So the noise level will be one of the factor to be consider to design the system. In some situation such as the two air cooled condensers are placed closely, there will produce higher sound levels. In order to reduce the noise level, the fans are the main factor which the fans required low speed and large diameter fan.

The air-cooled condensers are cooled by using ambient air and it does not required water as cooling medium. So the air cooled condenser is take precedence if be pressed for water. In comparison of operating cost, the air-cooled systems are more economic than water-cooled systems since the air-cooled systems do not consist of cooling tower, condenser water pump and water treatment is not required. F.W. Yu, et al. (2017) shown that air cooled chiller is prior choice in considering the low capital cost, uncomplicated design and operation compared with water-cooled chillers which required cooling towers and water pumps. Legionella diseases can be avoided in the air-cooled system because legionella disease only growth at the places with water such as aquatic environments and cooling towers. The legionella diseases are caused by the bacteria which can brought a very serious illness to humankind. The performance of the system are determined through condensing temperature. The air-cooled systems are operated in higher condensing temperature than water-cooled systems. The higher condensing temperature decreased the performance of system or compressor in 15 to 20% lower. The bigger power compressors are recommended to decrease the condensing temperature while to increase the performance. The air-cooled condensers are not recommended to install at the salty environment because the aluminium fins will corroded. Therefore, some protection, treatment and maintenance required in order to keep the systems functioning in longer time.

2.2.2 Water-Cooled Chiller System

In the bigger industrial building, office buildings or campuses that encompass multiple buildings which larger than 200000 square feet, the water-cooled chiller systems are most commonly used because the efficiency gains of cooling load is large enough to offset with higher cost based on the Technical Primer, Water-Cooled Chiller (n.d.). The water-cooled chiller systems comprises of compressor, condenser, cooling tower, thermal expansion valve, evaporator and water pumps. Comparing to the air-cooled chillers, the water-cooled chillers use the water as a medium to absorb heat and reject it through a cooling tower. The cooling tower is the one important heat exchanger in the chiller systems because it function to released heat that absorb by water from condensers. Performance of cooling towers are the one of main components that usually investigated by researcher because the performance cooling tower will affect the COP of chiller system. The parameters that influence the performance of the cooling tower are wet-bulb temperature, entering temperature, air flow and water flow. Application of cooling tower in water-cooled chiller system is more energy efficient than air-cooled chiller system and rooftop units. In addition, the water-cooled chillers are circulated water and deliver to air handler units, where the blower can blow over the cooling coil to supply cooling air. Since the chillers circulate water, the energy is denser than air, so the water-cooled chillers are more efficient. The higher efficiency of system provide the lower power input, then the power consumption is low. Maheshwari and Mulla Ali, (2004) in their recent research found that the daily energy consumption of water-cooled chiller system is saved about 32% than the air-cooled chiller system. In the installation, the spaces requirement or water-cooled chiller systems are larger compare to other chiller systems. The spaces are installed the cooling tower, condenser water recirculation pump and additional condenser pump. Besides that, the water-cooled chiller systems are more aesthetic than air-cooled chiller systems and packaged rooftop units. The water-cooled chillers are more compact, less noisy and having longer life operating which can lower life cycle cost. The water treatment is required for cooling tower because it installed at open area which can advocate the growth of bacteria. The purpose of water treatment is to prevent the bacteria growth such a**s** Legionella and pipe corrosion.

2.2.3 Hybrid Evaporative Chiller System

The new hybrid technology applying the evaporative air-cooled design which can help to minimize the problems that faced by both conventional water-cooled and air-cooled chiller system. Hybrid Evaporative Chiller System is the combination of the air-cooled chiller and water-cooled chiller with cooling tower. The combination is called evaporative air-cooled condenser. Evaporative air-cooled condenser is the main component to minimize the power consumption and increase the performance of the hybrid chiller. The evaporative condenser is made in the type of "Tube-to-Plate" which is patented by AL-CO Company. Tube-to-Plate Evaporative Condenser Coils are made from stainless steel which increase the durability and operating lifecycle. The stainless steel condenser coils reduce the maintenance costs. The simple maintenance which is using non-chemical coil cleaning and the simple hard brush is proposed to clean tube surface. The heat transfer efficiency for the new design of evaporative air-cooled condenser is improved 10%.

After the refrigerant compress by the compressor, the hot refrigerant is flows through the "Tube-to-Plate" evaporative condenser. Meanwhile, the water is pumped upward along the pipe and spray the water to the condenser coil. When the water meets with the hot refrigerant, some of the water evaporates and causing the heat transfer. A small expansion tank is built below the condenser. After the water sprayed over the condenser coil, the water flows back to the expansion tank and recirculate again to continue spraying. The heat transfer occurred is much more efficient as the condensation temperature of water is reduced to the ambient air wet bulb temperature. The high efficiency of heat transfer in evaporative condenser means it rejects more heat, resulting in lower pressure refrigerant condensation temperature. According to The Patented AAON Evaporative-Cooled Condenser (n.d.), the lower pressure and lower condensing temperature reduced the compressor work and decreased the power consumption, resulting in 20% or 40% efficient than air-cooled condenser. Energy Design Resources (2003) stated that the efficiency and capacity of the chiller increased to 1 to 2 percent per degree as the condensing temperature depressed below 85°F.