UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECT OF VARYING CHILLED CEILING POSITION ON THERMAL COMFORT

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Refrigeration and Air Conditioning System) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Refrigeration and Air Conditioning System) (Hons.). The member of the supervisory is as follow:

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(Dr. Ahmed Salem Saeed bin Ghooth)

ABSTRAK

Siling sejuk adalah bahagian utama dalam hydronic Radiant Cooling (HRC) sistem yang menawarkan sejuk yang sesuai untuk penghuni dengan menggabungkan sinaran haba dan kesan olakan. Kesan kedudukan siling sejuk yang berbeza-beza diuji pada ketinggian 0.47m, 0.41m dan 0.35m di dalam ruang alam sekitar untuk mencapai keadaan keselesaan terma. Batasan yang dikaitkan dengan sistem penghawa dingin konvensional seperti penggunaan tenaga yang tinggi, pengudaraan lemah dan tidak mesra alam yang membuka laluan untuk mencari penyelesaian alternatif. Dua tujuan kajian ini adalah untuk menyiasat kemungkinan penerimaan sistem siling sejuk sebagai sistem alternatif kepada sistem penghawa dingin konvensional di Malaysia dengan mengguna pakai betul reka bentuk sistem HRC dan untuk menyiasat suhu bilik yang sesuai dengan mengubah ketinggian panel siling sejuk untuk mencapai suhu keselesaan terma. Reka bentuk dan fabrikasi model baru dengan pelaksanaan kerja eksperimen adalah pendekatan utama untuk mencapai objektif tersebut. Satu ruang alam sekitar dengan dimensi 0.7m (L) × 0.5m (W) × 0.5m (H) digunakan untuk menjalankan ujikaji. Parameter yang paling penting diukur adalah suhu bilik dan kelembapan relatif di dalam ruang tersebut. Ketinggian terbaik untuk panel siling sejuk boleh dioptimumkan pada 0.35m untuk menyediakan keselesaan terma yang sama dengan 2.1m di bilik sebenar dengan suhu 24.6 °C dan kelembapan relatif 56.9%. Ia dijangka bahawa sistem siling sejuk boleh digunakan di Malaysia dengan mengintegrasikan sistem untuk pengeringan udara. Oleh itu, suhu keselesaan termal boleh dicapai dengan pengurangan tenaga apabila kedudukan panel siling sejuk diubah pada kedudukan yang optimum. Projek sekarang bersedia untuk menyumbang kepada penjimatan tenaga dan alam sekitar.

Kata Kunci: Kedudukan siling sejuk, Suhu bilik, Fabrikasi dan Kelembapan

ABSTRACT

Chilled ceiling is the main part in Hydronic Radiant Cooling (HRC) system which offers appropriate cool for occupants by combining of thermal radiation and natural convection effect. The effect of varying chilled ceiling positions are tested at height 0.47m, 0.41m and 0.35m in environmental chamber for achieving thermal comfort condition.The limitations associated with conventional air-conditioning systems such as high energy consumption, poor ventilation and do not environmentally friendly are opened the door for find an alternative solution. Two purposes of this study are to investigate the possibility of accepting the chilled ceiling system as an alternative system towards the conventional air-conditioning system in Malaysia by adopting the proper HRC system design and to investigate room temperature by identifying the oppropriate height of the chilled ceiling panel for achieving thermal comfort temperature. Design and fabrication new model with implementing experimental work are the main approach to achieve standing objectives. An environmental chamber with the dimension of 0.7 m (L) × 0.5 m (W) × 0.5m (H) is used to conduct the experimental work. The most important parameters measured in this chamber are room temperature inside the chamber and relative humidity. The best height for chilled ceiling panel can be optimized at 0.35m for providing thermal comfort which is equal to 2.1m at the actual room with temperature of 24.6°C and relative humidity of 56.9%. It is expected that the chilled ceiling system can be applied in Malaysia associated with integrating independent system for dry air. Therefore, thermal comfort temperature can be achieved with energy reduction when the position of chilled ceiling panel is varied at optimum position. The current project is ready for contribution in saving energy and environment.

Keywords: chilled ceiling position, Room temperature, fabrication and humidity.

DEDICATION

I dedicate this project to my dearest parents, Che Ismail Bin Amoh and Rokiah Binti Sulaiman and also to my siblings who always love me and prayed for my success. I also dedicate all my hard work and efforts for this project to my supervisor, Dr. Ahmed Salem Saeed Bin Ghooth, for supporting me throughout this project.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

1^{st}	-	First
2^{nd}	-	Second
3^{rd}	-	Third
°C	-	Degree Celcius
%	-	Percentage
Exp.	-	Experiment
g	-	Gram
H	-	Height
HRC	-	Hydronic Radiant Cooling
kg	-	kilogram
L	-	Litre/length
m	-	meter
MRT	-	Mean Radiant Temperature
NaCl	-	Sodium Chloride
RH	-	Relative Humidity
Temp.	-	Temperature
(T_{CC})	-	Temperature of Chilled Ceiling Panel
(T_{W})	-	Temperature of Chiller
(T_{r})	-	Temperature of Environmental Chamber
W	-	Width

CHAPTER 1
INTRODUCTION

In this chapter, introduction of the most important topics that involves background, problems statement, objectives, scope of the project is provided and the thesis organization of overall chapters is provided within the chapter.

1.1 Background

Air-conditioning is the process of treating the temperature, relative humidity, cleanliness and distribution of air to the conditioned space. Thousand years ago, some ancient architectural already practiced cooling techniques for controlling building temperature to local climate condition such as high thermal wall, high room ceilings and shading. The primary modern air-conditioning system was developed in 1902 by a young electrical engineer named Willis Carrier. Today, air-conditioning system has been used in many aspects of the life over the world such as for residential, industrial and commercial. The purpose of the most system is to provide thermal comfort and improving indoor air quality (IAQ) for occupants. Significantly, the application of air-conditioning in daily live allows people to feel comfortable especially in hot climates thereby advance their lifestyle to get better. For example, air-conditioning is able to reduce the relative humidity level. Bacteria and fungi can grow rapidly under higher moist and humid condition which mean under high relative moisture level. Meanwhile, occupants might experiences eye irritation if relative humidity is too low. Besides, spreading of viral infection also may increase under low relative humidity level. Consequently, by using air-conditioning system the relative humidity level can be controlled and adapted to the environmental conditions.

Typically, there are two categories of air-conditioning system that are unitary refrigerant based systems and centralised systems. These two systems are also known as conventional air-conditioning systems. Generally, the conventional air-conditioning systems are rely on vapor compression cycle means that the refrigerant in state of a low-pressure gas is compressed to high temperature and pressure to allow heat transfer to take place. The larger the area to be cool, the more energy consume by compressor need to overcome the hot temperature from the cooling load. Furthermore, the energy that is consumed by the fans to distribute cool air through the ducts leads to increase of internal cooling peak load. As a fact electrical loads in buildings are dominant by air-conditioning system in most countries located in tropical and sub-tropical regions. In general, air-conditioning system takes for 60% of electricity consumption in such circumstance (Vangtook and Chirarattananon, 2007). In this situation, it is clearly shown that conventional air-conditioning systems have some limitations such as uneconomical and energy intensive although they have their own advantages.

In point of fact, a practical system that creates a more comfortable thermal environment than conventional all-air systems with low energy consumption would be built in the line with current modern technology. An alternative system names a Hydronic radiant cooling (HRC) system which is using water as the transport medium becomes one of the significant solutions since it is able to reduce the amount of air distribute through the buildings, as 100% ventilation is provided by outside air system without recirculating air fraction. However, this system is still not available in practice in Asian countries marketing like Malaysia. However, most people have not introduced this system due to lack of awareness with radiant cooling technology. Through this system, occupants develop cool by radiant heat transfer from their bodies to closest of the chilled ceiling panels whose temperatures are held a few degrees cooler than surrounding temperatures in the space. As the result, occupants can generate impressive saving because of water has roughly 3500 times the energy transport capacity than of the air. Therefore, by using HRC system the amount of cooling can be transfer with less than 5% of the energy required to deliver cool air by using fans (Feutsel and Stetiu, 1995). Besides, since chilled ceiling system is heat exchanger mainly rely on radiation leads to overcome noise, accordingly it shows good advantages.

Deliberately, this study intends to design and fabricate a prototype of HRC system in order to ensure the possibility of accepting the chilled ceiling system as an alternative system towards the conventional air-conditioning system in Malaysia by adopting the proper HRC system design. Moreover, the investigation of the appropriate room temperature by varying the height of the chilled ceiling panel for achieving thermal comfort temperature as well. Then, the indoor temperature is recorded and cooling capacity will be tested as well by using aluminium sheet. In order to control the humidity and dry air temperature, Silica Gel material is felt and confined in proper plastic tube at the entrance of the environmental chamber where the air inlet is supplied. The obtained result of the accepting room temperature will be the governing that chilled ceiling system either is suitable or not for use as an alternative air-conditioning system in Malaysia as hot and humid climate country.

1.2 Problem Statement

Energy consumption by conventional air-condition systems makes most Malaysian complain about the usage of air-conditioning system because they are not economic in use to provide thermal comfort especially during hot seasons. Achieving thermal comfort through obtained a standard acceptable temperature between 23°C and 26°C needs a certain amount of energy. Achieving thermal comfort condition with reducing the amount energy required is a challenge to be considered in this study.

1.3 Objectives

In this study, some targets have been set to ensure that the current study is not stray away from the original target when investigations are conducted. The most important objectives of the current study are:

a) To ensure the possibility of accepting this system as an alternative way in Malaysia by designing a Hydronic Radiant Cooling system named chilled ceiling system.

b) To investigate the appropriate room temperature by identifying the appropriate position of the chilled ceiling panel for achieving thermal comfort.

1.4 Scope

The work scope of this study focuses on two main components that are environmental chamber and mini chiller. Temperature and relative humidity will be measured inside the environmental chamber. Three positions or height of the chilled ceiling panel also will be investigated inside the chamber to achieve thermal comfort temperature based on the ASHRAE guideline recommended which is 23°C to 26°C for room temperature (TR) and 30% to 60% for relative humidity (RH). The relative humidity is kept constant for three different heights of the radiant ceiling panel by fixed the amount of silica gel use for 80g only. The silica gel is place at the air entrance inside of the environmental chamber. For the chilled ceiling panel, the copper tube is covered with Aluminium sheet during this investigation. While the temperature inside the mini chiller located outside of the environmental chamber is maintained approximately -3°C.

1.5 Organization of the Thesis

This report compromises of five chapters. Chapter 1 is the introduction of the project including the background, problem statements, objectives, and research limitations as well as work scope of the study. Chapter 2 is written to review the theories, experimental works and findings that have been done in the past research with respect to the current project. In chapter 3, the methodology used to achieve the objectives that have been set for this study will be explained clearly. Besides, all materials and equipments, procedures, and experimental work used for this study will be described. Chapter 4 presents the findings and results of currents study in form of tables and graphs. All the results of the study are discussed in detail within this chapter. Lastly, chapter 5 is the conclusion and recommendation for future work.

CHAPTER 2
LITERATURE REVIEW

Hydronic Radiant Cooling (HRC) system is an unlike system compared to the conventional air conditioning because this system does not rely on the vapor compression cycle to generate cooling effect. There are three major types of HRC system that are commonly used nowadays for cooling purpose such as chilled radiant ceiling system, chilled floor system and chilled walls system. The discussion in this chapter only focus about the chilled ceiling system and thermal comfort since this study intend to investigate the possibility of using the system in Malaysia as a hot-humid country. The theories and findings from the previous studies are reviewed and described to find the highlight knowledge associated with the current study such as radiant ceiling panel system, position of chilled ceiling panel, thermal comfort and displacement ventilation.

2.1 Conventional air-conditioning system

Recent studies by Beaty and Fink (2013) report that air-conditioning can be recognized by the methods of how they conduct cooling process in the conditioned space. Nowadays, most of air-conditioning used is conventional air-conditioning while the applications of hydronic radiant cooling system is still not to popular by publics especially in developing countries like Malaysia. Conventional air-conditioning typically relies on vapor compression. According to Feutsel and Stetiu (1995), recirculated air is important in conventional air-conditioning system in order to maintain the temperature difference between supply air and room air so that it is in comfort range. Even though this air-conditioning still providing comfort toward people but the use of refrigerant for providing cooling effect is this system have their own side-effects. For examples, global warming and ozone depletion are caused by chlorofluorocarbons (CFC) and other refrigerants type used in conventional air conditioning system (Singh et al. 2011). Therefore, conventional air-conditioning system is not practical to use nowadays even it is still able to fulfil comfort requirements for human because this system are energy intensive and not environmentally friendly.

2.2 Hydronic radiant cooling (HRC) system

Recent developments of HRC system make conventional air-conditioning system will have stiff competition. Diaz (2011) reported that as HRC system operate to provide heating or cooling for a space such as building, but this system also need to prevent two sides-effects associated with its presence in the conditioned space. The first side-effect is degradation of comfort situation due to the asymmetrical character of the radiant exchange in a room with radiant surfaces. Secondly, the side-effect is possibility of condensation in cooling process. Watson (2002) mentioned that the priority in designing HRC system is about the condensation since it is primary problem of this system while for the locations, HRC system can be set up on floor, ceiling or walls. Nevertheless, there are solutions to prevent these problems as explained in chilled ceiling system section.

Hydronic radiant cooling system becomes an alternative method to improve the conventional air-conditioning system performances in term of energy consumption because this system offers some advantages as the following:

a) Using water as the medium for heat transfer process cause HRC system able to diminish the transport energy and peak-power requirements due to building conditioning (Stetiu, 1999).
b) Since HRC system offer direct cooling to space surface, the separate ventilation and thermal conditioning is possible (Feutsel and Stetiu, 1995).

2.2.1 Chilled ceiling system

The amount to Hiu and Leung (2012), chilled ceiling system is comparatively new in hot and humid climate countries. Chilled ceiling system is a system that enables the cold water flow within piping network which is bonded to ceiling panel resulting the temperature of ceiling surface in range 16°Cto19°C which is able to remove heat loads up to 100 W/m² of floor area (S.G. Holder et al., 1998). Hiu and Leung (2012) as cite in Dieckmann and Brodrick (2004) reported that "chilled ceiling system is a water-based system which use ceiling-based radiant cooling panels coupled with chilled water pipes or coils". Condensation is the major problem when using this system. Usually, condensations easily formed on cool ceiling surface in higher humidity areas if the room humidity is not controlled. The temperature of cool ceiling must be higher than air dew-point temperature to overcome this dew condensation problem (Li Shixing, 2011). In the same time, Vangtook and Chirarattananon (2007) state in their previous studies that temperature of air in the space must be lower than 30°C to achieve thermal comfort by using this system.

2.2.1.1 Radiant ceiling panel system

The installation of chilled ceiling panel system is similar to the installation of lighting equipments but more based on the piping system which increase the level of flexibility and the connections is easily accessible for reconfiguration or modification (Timothy et al., 2006). The basic concept of using air-conditioning by thermal radiation is reducing the dependence on air as thermal transport medium as well as the indoor air quality is met and fend off the problems related to circulating high volume of air (Ardehali et al., 2004). The radiant ceiling panel utilize long-wave radiation to provide or reject heat from space and maintain proper indoor air quality as well as indoor air humidity (Diaz and Cuevas, 2010). The working principle of radiant ceiling panel system is all room loads (cooling loads) such as occupants, lighting, electrical equipments, and walls released heat to the cold surface of radiant ceiling panels. This panel is lower in temperature compared to the room temperature since there is cold water flow within the piping network attached to the panel with temperature around 14°C to 17°C. According to law of nature, heat is always flow from high temperature regions to low temperature regions. Thus, warmer heat from surrounding is flow to the radiant ceiling panel resulting temperature of nearest pipes increase by 2°C to 3°C. Then, cold water inside the pipes become warmer and is removed from the room to the outside and replace by chilled water with original temperature resulting room temperature becomes cooler (Hui and Leung, 2012). Based on the past research done by J. Miriel et al. (2002), there are two major of hydronic ceiling panels which not involved the heat transfer by ventilation system as the following:

a) The active flag made of concrete: This hydronic ceiling panel also known as ceiling cooling system. The structure of this system is made by polyethylene tubes that are implanted inside the flagstone then on the top of the tubes netting, the thermal insulator is fixed. However, this type of hydronic ceiling panel is hard to control the risk of condensation if the relative humidity inside a room increase quickly due to the high thermal inertia even the cost for this ceiling type is low.
b) The metallic ceiling water panels that are inserted into false ceilings: This hydronic ceiling panel are made by steel sor copper tubes with diffusion fins which can be attached to the tubes. For this ceiling panel, the thermal inertia is low and water capacities can be reduced since the materials used have good thermal conductivity.

In this study, the metallic ceiling water panels by using copper tube was selected due low thermal inertia. This characteristic become the first priority in this study since Malaysia is a hot humid climate country so that the risk of condensation can be reduce by selecting this type of hydronic ceiling panel. Furthermore, radiant ceiling panels offer benefit in term of setting up flexibility, control, zoning and responsiveness (Charlie et al., 2006). In addition, Bauman et al. (2012) state that radiant ceiling panels system is practical to be used because it is rapidly response in time lead to controlling this system become easier as well as radiant ceiling panels are able to adapt to fast changing loads.