UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPLICATION OF PHASE CHANGE MATERIAL IN THERMAL ENERGY STORAGE

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

by

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FACULTY OF ENGINEERING TECHNOLOGY

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SESI PENGAJIAN: **2014/2015 Semester 2**

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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 (Mechanical) (Air Conditioning & Refrigeration System Hons.). The member of the supervisory is as follow:

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ABSTRAK

Penyimpanan tenaga haba (TES) adalah satu sistem yang boleh menyimpan tenaga haba dan tenaga yang disimpan boleh digunakan kemudian. Penyimpanan tenaga haba digunakan secara meluas dalam industri kerana ia membantu dalam mengurangkan penggunaan elektrik . Dalam kajian ini , bahan perubahan fasa yang digunakan ialah air kerana ia adalah bahan yang paling murah. Kadar aliran campuran glikol-air digunakan sebagai pembolehubah dimanipulasikan dalam kajian ini untuk menentukan pekali prestasi (COP). Satu eksperimen telah dijalankan menggunakan peralatan penyimpanan ais dalam penyejukan untuk menyempurnakan kajian ini. Data-data seperti suhu dan tekanan telah diukur dan direkodkan. Perbandingan antara tiga aliran campuran glikol-air dibuat untuk menentukan kecekapan sistem tersebut berdasarkan aliran campuran glikol-air.

ABSTRACT

Thermal energy storage (TES) is a system that can conserve thermal energy and the energy stored can be used later. Thermal energy storage is widely used in industries because it helps in reducing electricity usage. In this study, phase change material used was water because it was the cheapest substances. Flow rate of glycol-water mixture was used as manipulated variable in this study in order to determine the coefficient of performance (COP). An experiment was conducted by using ice stores in refrigeration equipment to complete this research. The data such as temperature and pressure was measured and recorded. The comparison was made between three flow rates to determine which flow rate was more efficient.

DEDICATION

I would like to dedicate this project to my beloved parents and family.

ACKNOWLEDGEMENT

I would like to express my gratitude towards my family and friends for supporting me in completing this project. Special thanks to my supervisor, Mr Aludin bin Mohd Serah for guiding me in implementation of this project. Besides, I also want to thank other lecturers that contribute their ideas for me to finish this project.

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TES	-	Thermal Energy Storage
PCM	-	Phase Change Material
COP	-	Coefficient of Performance

CHAPTER 1
INTRODUCTION

1.1 Project Background

These days, scientists around the world are looking for new and renewable sources. From the research, those scientists found that energy can be stored and they are trying to build energy storage devices. The suitable form of energy will be conserved and applied later when they are required. There are many types of energy storage method that has been recognized which is mechanical energy storage, electrical storage, thermal energy storage and thermochemical energy storage.

Thermal energy storage (TES) is a technology used nowadays for energy conservation. The energy stored will be used later for other applications such as heating, cooling and power generation. Usually, thermal energy storage will be running during off peak period to produce and store a medium that can be used later during the peak period in form of required energy. Heating and cooling is the most suitable applications for thermal energy storage system. Thermal energy storage has a lot of advantages. Some of the advantages are thermal energy storage system can help to reduce energy demand and supply on a building. This is because half of the energy stored will be used during peak period to support the energy requirement, thus reducing energy consumption and cost. Thermal energy storage can be divided into three; latent heat storage (LHS), sensible heat storage (SHS) and chemical energy storage.

Figure 1.1: Ice store in refrigeration system

There are some differences between latent heat storage (LHS) and sensible heat storage (SHS). Liquid or solid storage medium is being stored by the sensible heat storage by heating or cooling it. There are some examples of materials that can be used in sensible heat storage, such as rocks, water, molten salt and sand. In sensible heat storage, the temperature of liquid or solid storage medium will be raised so that thermal energy can be stored. Sensible heat storage is cheaper than latent heat storage because it has the cheapest storage medium which is water as an option and it has a high specific heat. In sensible heat storage, when the temperature reaches above 100°C, water cannot be used as storage medium. Therefore, other storage medium such as sand, molten salt and rocks will be used as a storage medium to replace the water.

In terms of working principle, latent heat storage is differ than sensible heat storage because the storage medium will undergo phase change from liquid to solid or solid to liquid or vice versa. Latent heat storage gain a lot of scientist's interest because it is more efficient compared to sensible heat storage. Latent heat storage store and release heat at an almost constant temperature, thus the temperature difference between storing and releasing heat is lesser in latent heat storage compared to sensible heat storage. In addition, latent heat storage has higher storage density therefore it can store more heat energy. Latent heat storage systems have lower cost because it can be produced in smaller size, thus reduce space used in a building.

Chemical energy storage is one type of TES. Chemical energy storage uses a chemical reaction named endothermic and exothermic reaction to store and release energy. Endothermic reaction is a process of absorbing heat in the surrounding and cools the surrounding. Exothermic reaction is an opposite process of an endothermic reaction. Exothermic reaction is a proces of releasing heat, to the surroundings, thus increase the temperature of the surroundings. Chemical energy can provide high energy storage density, same with latent heat storage.

Phase change materials (PCM) usually used as storage medium in latent heat thermal energy storage because of its characteristic which is changing the phase as temperature changes. Phase change materials should have the certain properties to be the most efficient storage medium. The latent heat of the material must be large to ensure high energy density. The thermal conductivity also must be high, hence, reduce the temperature gradient between absorbing and releasing thermal energy storage. Besides, they must be cheap, non-toxic, non-corrosive and stable in term of chemical. The applications of phase change materials can be classified according to melting point of the materials. Phase change materials which melt below 15°C frequently used to keep the coolness in air conditioning. Furthermore, in absorption refrigeration, the materials must have melting point above 90°C. Materials that have melting points between 15°C and 90°C can be used in solar heating applications and others.

There are three categories of phase change materials, which are organic phase change materials, inorganic phase change materials and eutectics. A large amount of latent heat can be absorbed and released by organic phase change materials over a certain temperature range during phase change process. Organic phase change materials can be classified into paraffin and non-paraffin. Paraffin wax can release a large amount of latent heat because it contains straight chain *n*-alkanes CH_3-(CH_2)-CH_3 mixture. The length of *n*-alkanes will affect melting point and latent heat. Melting point and latent heat will increase as well as the length of chain increase. In this industry, pure paraffin waxes cannot be used because it is very expensive. The only paraffin that can be used due to its price is technical grade paraffin. Paraffin was mostly used because it is non-corrosive, safe and chemically inert but it has low thermal conductivity which causes in low charging and discharging. In order to overcome this problem, a metal matrix was inserted into paraffin wax and it is encased in spherical capsules or microcapsules to prevent leakage during solid-liquid phase change. Non-paraffin can be classified as a fatty acid. Fatty acid was unsafe because it is flammable thus, it cannot be exposed to high temperature, oxidizing agent and flames. In addition, fatty acid also has low thermal conductivity, high heat of fusion and unstable at high temperature. Fatty acid consists of reproducible melting and freezing behaviour and it can be frozen without super cooling. However, fatty acid cannot be used because it is more expensive than technical grade paraffin.

Inorganic phase change material can be classified into salt hydrates and metallic. Salt hydrates undergo processes of hydration and dehydration as well as it transforms from liquid to solid. There is one problem with salt hydrates that is it melting inconsistently because the water in the salt hydrates is not enough to dissolve all the solid phase. This problem can be overcome by mechanical stirring because the material will dissolve faster. Besides, encapsulating of phase change material also can be used to reduce separation. Salt hydrates have a high latent heat of fusion per unit volume, high thermal conductivity and small volume changes on melting. Furthermore, metallic can be categorized as low melting metals. Metals are not widely used as phase change material yet in the industry. However, it has high thermal conductivity which is one of the most important characteristics that every phase change material should have. Metallic also has a low specific heat, low vapor pressure and high heat of fusion per unit volume.

The other types of phase change material are eutectics. Eutectics are a material that consists of two or more components. This material has very low melting composition. During the freezing process, crystallization will be formed. Thus, there is no separation in the material during melting and freezing process, hence the components cannot separate.

1.2 Problem Statement

Nowadays, the demand of electricity during the day is more than night. The energy consumption in a building will increase rapidly during day time. In order to reduce the cost, scientists all over the world are looking for a solution to this problem. Then, they come up with a thermal energy storage system that can conserve energy. This energy can be applied later in our daily life to reduce energy consumption, reduce energy demand and supply on a building and reduce cost. However, they want to enhance the efficiency of the system. In order to gain required efficiency, some modification must be made.

1.3 Objectives

The objective that needs to be achieved to complete this project is to determine the coefficient of performance (COP) for the ice. Coefficient of performance (COP) was important to compare which flow rate of glycol/water mixture working more efficiently.

1.4 Scope

This study will only focus on sensible heat thermal energy storage. This is because the principle of latent heat storage which undergo phase change from solid to liquid or liquid to solid or vice versa by increasing temperature of the substances. Hence, the focus of this study will only go to latent heat thermal energy storage. This experiment mainly focuses on how flow rate of glycol-water mixture affects efficiency for charging process.

1.5 Summary

In chapter 1, there is project background, problem statement, objective and scope. Project background is about the background and theory of the project while problem statement is the problem that we want to fix. Then, the objective explained about the purpose of project and scope of project is a focus area and limitation of the project. In this project, there will be five chapters. Chapter one is an introduction of the project. Chapter two will explain about literature review of the project is a review of previous research. Then, chapter three is a methodology which describes on how this project is being conducted. Moreover, chapter four consists of results and discussion of the project. Finally, chapter five is a conclusion and recommendation. This chapter will review explanation of the significance and reason of findings. Besides, this chapter will also recommend the project for future studies.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this literature review, there are a lot of sources that relates to thermal energy storage and phase change material. There are researchers that wrote a journal related to thermal energy storage and phase change material such as Farid et. al (2004), Solomon (2013), Trane (n.d.), Sharma et al. (2009), Agyenim et al. (2010), Zhang and Fang (2006), Colvin et. al (1989), IRENA (2013) and Ng and Zainal (2011).

2.2 Thermal Energy Storage

Nowadays, people around the world use electricity in almost every need of this life. The demand for electricity is relatively high, especially during the day compared to night time. Besides, the electricity demand also high during weekdays rather than weekend because people go to work and lots of equipment uses electricity at the office. In order to fulfill the demand of energy, researchers and scientists all over the world struggle to search new and renewable energy source. Solar energy is one of