



**INVESTIGATION OF TEMPERATURE
VARIATION ON THERMAL ICE STORAGE BY
USING PROPYLENE-GLYCOL AND 100%
WATER**

**RAJA MUHAMMAD ASYRAF BIN RAJA
ADNAN B091810063**

**BACHELOR OF MECHANICAL ENGINEERING
TECHNOLOGY
(Refrigeration and Air Conditioning System) WITH
HONOURS**

2022



**Faculty of Mechanical and Manufacturing Engineering
Technology**



**INVESTIGATION OF TEMPERATURE VARIATION ON THERMAL
ICE STORAGE BY USING PROPYLENE-GLYCOL AND 100%
WATER**

RAJA MUHAMMAD ASYRAF BIN RAJA ADNAN

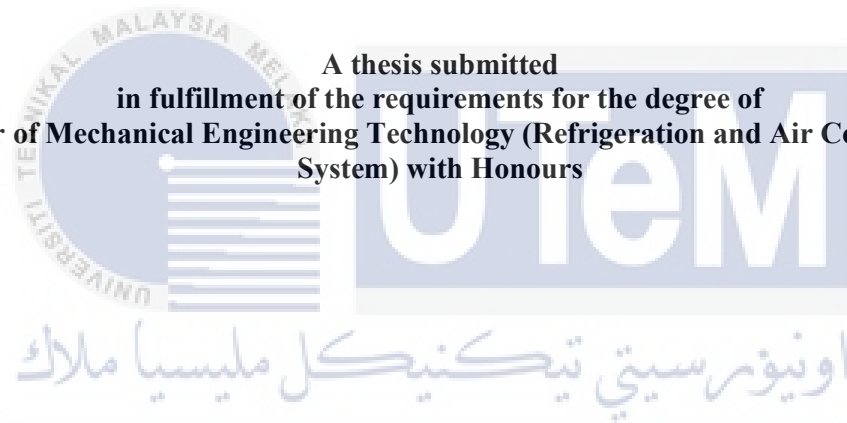
**Bachelor's Degree in Mechanical Engineering Technology (Refrigeration and Air
Conditioning System) with Honours**

2022

**INVESTIGATION OF TEMPERATURE VARIATION ON THERMAL ICE
STORAGE BY USING PROPYLENE-GLYCOL AND 100% WATER**

RAJA MUHAMMAD ASYRAF BIN RAJA ADNAN

**A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Refrigeration and Air Conditioning
System) with Honours**



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this Choose an item. entitled “Investigation of Temperature Variation On Thermal Ice Storage by using Propylene-Glycol and 100% Water” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature

:



Name

: RAJA MUHAMMAD ASYRAF BIN RAJA ADNAN

Date


: 25/01/2022

اونيورسيتي تیکنیکل ماليسيا ملاک

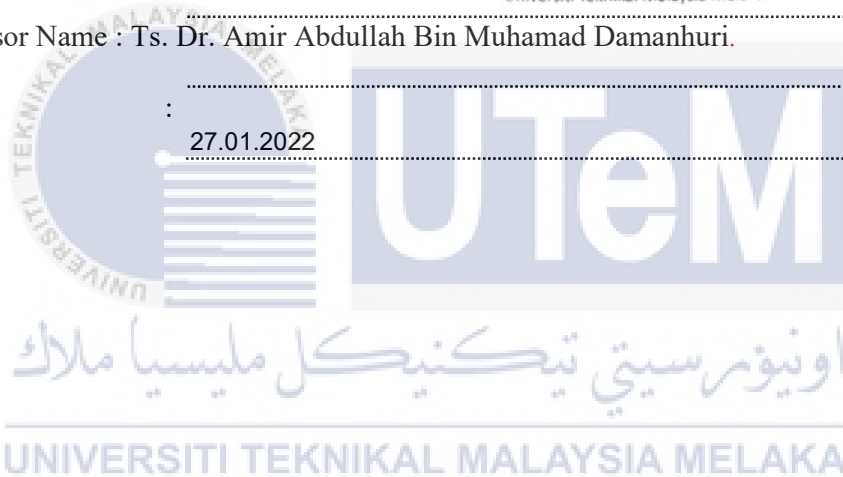
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Of Mechanical Engineering Technology (Refrigeration and Air Conditioning System) with Honours.

Signature :  :
Supervisor Name : Ts. Dr. Amir Abdullah Bin Muhamad Damanhuri.
Date : 27.01.2022

TS. DR. AMIR ABDULLAH BIN MUHAMAD DAMANHURI
Pensyarah
Jabatan Teknologi Kejuruteraan Mekanikal
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

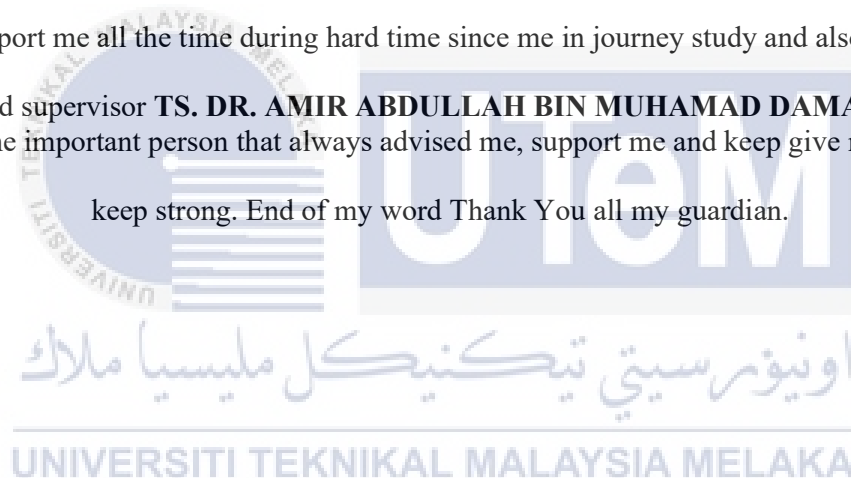


DEDICATION

Every challenging during all the work needs stronger self effort as well as guidance of elders especially those who were very close to our heart. My humble effort I dedicate to my sweet and loving parent

RAJA ADNAN BIN RAJA ABDULLAH and RAKIAH BINTI ANANG

That support me all the time during hard time since me in journey study and also my respected supervisor **TS. DR. AMIR ABDULLAH BIN MUHAMAD DAMANHURI**, one of the important person that always advised me, support me and keep give me spirit to keep strong. End of my word Thank You all my guardian.



ABSTRACT

Thermal energy storage systems (TES) can store heat or cold for later use, under different variables such as temperature, location or power. Sensitive heat, latent heat and thermochemical systems are classified into three different categories of TES systems. For each TES system and identifies the requirements for each technology and application. TES systems may successfully meet energy redistribution requirements for cooling or heating. By using the stored thermal energy from TES units, peak load demand may be moved to off-peak hours. As a result, compare the variation of temperature on compressor, evaporator and water temperature in between 100% water and propylene-glycol mixture water. This research is focus to thermal ice energy storage that using 100% water for system or propylene glycol mixture water in system to determine the cop and range temperature for both medium. System will be running for 16 hours in other to collect the data. In this project, refrigeration R134a will use as main refrigeration in system. The lowest temperature in water achieved is 2.3°C. For this project, the COP for 100% water and propylene-glycol is different which is system use propylene-glycol mixture water has better result of COP with 3.61, meanwhile COP for 100% water is 3.38 lower than propylene- glycol.

ABSTRAK

Sistem penyimpanan tenaga termal (TES) dapat menyimpan panas atau sejuk untuk kegunaan kemudian, di bawah pemboleh ubah yang berbeza seperti suhu, lokasi atau kuasa. Haba sensitif, haba pendam dan sistem termokimia dikelaskan kepada tiga kategori sistem TES yang berbeza. Terdapat gambaran keseluruhan jenis sistem dan penerangan mengenai aplikasi khusus dan baru. Sistem TES berjaya memenuhi keperluan pengagihan semula tenaga untuk penyejukan atau pemanasan. Dengan menggunakan tenaga haba yang tersimpan dari unit TES, pemindahan haba yang tinggi dapat dipindahkan ke waktu malam hingga keesokan pagi. Perbandingan variasi suhu pada pemampat, penyejat dan suhu air di antara 100% air dan air campuran propylene-glycol. Penyelidikan ini tertumpu kepada penyimpanan tenaga ais terma yang menggunakan air 100% untuk sistem atau air campuran propilena glikol dalam sistem untuk menentukan suhu cop dan jarak bagi kedua-dua medium. Penyelidikan ini difokuskan kepada penyimpanan tenaga termal yang menggunakan 100% air semula jadi didalam sistem penyimpanan tenaga termal atau cecair propylene glycol yang dicampur dengan air ke dalam sistem untuk menentukan kecekapan sistem dan perbezaan suhu untuk kedua-dua medium. Sistem ini akan beroperasi selama 16 jam bagi mengumpul data yang diperlukan. Dalam projek ini, bahan pendingin R134a akan digunakan sebagai bahan pendingin utama. Suhu terendah yang dicapai melalui eksperimen ialah 2.3°C. Dalam penyelidikan ini, COP sistem telah diperolehi dimana COP untuk sistem yang menggunakan propylene glycol bercampur air mempunyai COP yang lebih baik iaitu 3.61 jika dibandingkan dengan COP 100% water yang sedikit rendah iaitu 3.38

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the University Technical Malaysia Melaka (UTeM) for providing the research platform. Thank you also to the Malaysian Ministry of Higher Education (MOHE) for the financial assistance.

My utmost appreciation goes to my main supervisor, Ts. Dr Amir Abdullah Bin Muhamad Damanhuri, faculty of mechanical and manufacturing engineering, University Technical Malaysia Melaka (UTeM) for all his support and adviser. His constant and patient for guiding and providing knowledge and good information will forever be remembered.

Lastly, I would thank you for all person that involve directly or indirectly during my thesis especially my beloved parent that always support and give spirit to go through all this.

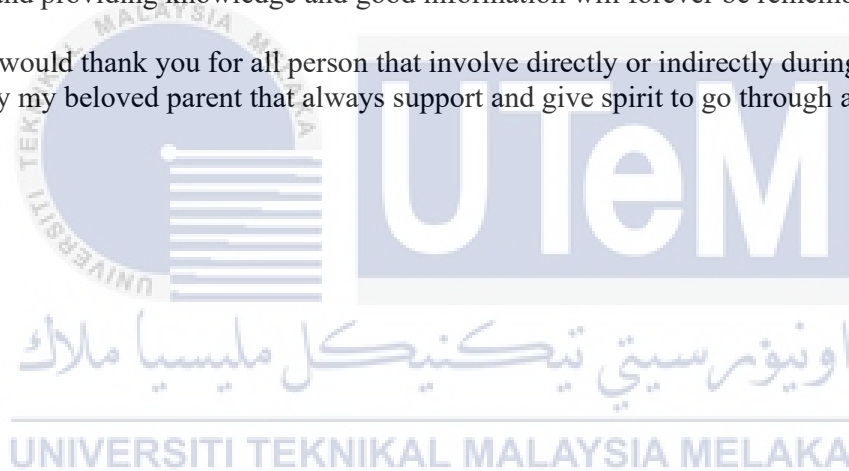


TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF SYMBOLS AND ABBREVIATIONS	x
LIST OF APPENDICES	xi
CHAPTER 1 INTRODUCTION	12
1.1 Background	12
1.2 Problem Statement	13
1.3 Research Objective	13
1.4 Scope of Research	14
CHAPTER 2 LITERATURE REVIEW	15
2.1 Introduction of Thermal Storage	15
2.2 The Classified of Thermal Storage System	15
2.3 Sensible Heat Storage System (SHS)	16
2.4 Latent Heat Storage System (LHS)	17
2.5 Thermo Chemical Storage System	17
2.6 Ice-Cold Storage System	18
2.7 The Charging and Discharging Process (ITES)	19
2.8 External-melt Ice Thermal Storage	19
2.9 Internal-melt Ice Thermal Storage	21
2.10 System Operating mode	22
2.11 Internal Melt System Diagram	22
2.11.1 Ice Build Mode	23
2.11.2 Chiller and Ice Storage mode	23
2.11.3 Ice Build With Cooling	24
2.12 External Melt System Diagram	24
2.12.1 Ice Build Mode	25

2.12.2	Chiller and Ice Storage Mode	25
2.13	Operating Cool Thermal Storage	26
2.13.1	Operation at Full Storage	26
2.13.2	Operation at Partial Storage System	27
2.14	Storage Tank	28
2.14.1	Steel Tank	28
2.14.2	Concrete tank	28
2.14.3	Plastic tank	29
2.15	Heat Transfer by Thermal Storage	29
2.15.1	Equation Heat Transfer Sensible Heat	30
2.15.2	Equation Heat Transfer Latent Heat	31
2.15.3	Extended Heat Transfer Surface	33
2.15.4	Low Pressure Drop	33
2.15.5	No possibility of over-charging when making ice	33
2.16	System Operation Cryogel Ice Ball	34
2.16.1	Charge – Ice Building	34
2.16.2	Discharge- Ice Melting	35
2.16.3	Standby Mode	36
2.17	Glycol	37
2.17.1	Propylene Glycol	37
2.17.2	Ethylene Glycol	38
2.17.3	Table Freezing point and Bursting point for both glycol	38
CHAPTER 3 METHODOLOGY		40
3.1	Introduction	40
3.2	Parameter Design	42
3.3	Experimental Design	42
3.4	Equipment and Tool	48
3.5	Specification Ice Thermal System and Component	51
3.6	Coolpack Software	52
3.6.1	Coolpack P-h Diagram Chart	52
3.7	Pilot Study for Data Ice Thermal Storage System	55
3.8	Coefficient of Performance System (COP)	56
3.9	Summary	57
CHAPTER 4 RESULT AND DISCUSSION		58
4.1	Introduction	58
4.2	Experimental Data	58
4.2.1	Result of The Experiment For 100% Water	58
4.2.2	Result of The Experiment for Glycol Mixture Water	61
4.2.3	P-h Chart Diagram of 100% Water in Ice Thermal Storage	63
4.2.4	P-h Chart Diagram of Glycol Mixture Water in Ice Thermal Storage	64
4.3	Graph Comparison Temperature of Water and Propylene- Glycol	65
4.4	Graph Comparison Outlet Compressor Temperature	67
4.5	Graph Comparison Outlet Evaporator Temperature	68
4.6	Comparison the Coefficient of Performance (COP)	69
CHAPTER 5 CONCLUSION AND RECOMMENDATIONS		71

5.1	Introduction	71
5.2	Achievement of Project Objective	71
5.3	Recommendation	72
5.4	Future Work	72
REFERENCES		73



LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1	Freezing point and Bursting point	39
Table 3.1	Legend ice thermal storage circuit	43
Table 3.2	Legend of temperature	45
Table 3.3	Equipment and tool	48
Table 3.4	Specification ice thermal storage	51
Table 3.5	Specification component	51
Table 3.6	Reading Temperature System	56
Table 4.1	Data temperature system 30 minutes	59
Table 4.2	Data system after 16 hours (100% Water)	60
Table 4.3	Data temperature system 30 minutes	61
Table 4.4	Data system after 16 hours (Propylene Glycol)	62
Table 4.5	Data calculated 100% Water	64
Table 4.6	Data Calculated Propylene-Glycol	65
Table 4.7	Data Enthalpy 100% water	69
Table 4.8	Data Enthalpy Propylene-Glycol	69

LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 2.1	Ice thermal energy storage (Lago et al, 2019)	18
Figure 2.2	Charging and discharging in ice ball (Lago et al., 2019)	19
Figure 2.3	External melt (Lago et al., 2019)	20
Figure 2.4	Charging and discharging of an internal ice on coil storage (Lago et al., 2019)	21
Figure 2.5	Basic system internal melt (Alvarez et al., 2003)	22
Figure 2.6	Basic external melt system (Yi & Dong, 2015)	24
Figure 2.7	Full storage operation (Bayomie et al., 2018)	26
Figure 2.8	Load leveling and demand limiting (Bayomie et al.,2018)	27
Figure 2.9	The diagram of phase change material (Regin et al., 2008)	29
Figure 2.10	Volumetric heat capacity of selected liquid and solid (Bauer et al, 2012)	31
Figure 2.11	Cryogel ice ball (Ott & Diego, 2011)	34
Figure 2.12	Charging cryogel (Source: https://www.google.com/search?q=charge+ice+building)	35
Figure 2.13	Discharge ice melting (Ott & Diego, 2011)	36
Figure 2.14	Stanby mode (Source: http://cryogel.com/operation)	36
Figure 3.1	Research flowchart	41
Figure 3.2	Ice thermal circuit	43
Figure 3.3	Display temperature screen	44
Figure 3.4	Propylene-Glycol mixture with water	46
Figure 3.5	Mini Data Logger	47

Figure 3.6 Refrigeration utilities	53
Figure 3.7 P-h diagram chart cycle	53
Figure 3.8 Refrigerant R134a	53
Figure 3.9 Diagram P-h Chart	54
Figure 3.10 Cycle chart	54
Figure 3.11 Input Data	55
Figure 3.12 Data cycle P-h Diagram	55
Figure 4.1 P-h chart diagram	63
Figure 4.2 P-h chart diagram propylene glycol	65
Figure 4.3 Graph comparison water temperature	66
Figure 4.4 Graph temperature compressor	67
Figure 4.5 Graph temperature evaporator	68

LIST OF SYMBOLS AND ABBREVIATIONS

TES	-	Thermal Energy Storage
SHS	-	Sensible Heat Storage
LHS	-	Latent Heat Storage
HTM	-	High Temperature Material
PCM	-	Phase Change Material
ITES	-	Ice Thermal Energy Storage
HDPE	-	High Density Polyethylene
°C	-	Celsius
°F	-	Fahrenheit



LIST OF APPENDICES

APPENDIX	TITLE	PAGE
APPENDIX A	GANTT CHART PSM 1	76
APPENDIX B	GANTT CHART PSM 2	78
APPENDIX C	TURNITIN REPORT	80



CHAPTER 1

INTRODUCTION

1.1 Background

Thermal energy storage system (TES) one of the method for storing energy dependent on a temperature change. The hot water or cold water thermal energy system can be conventional energy. Thermal energy storage systems, such as temperature, location or power, can store and use heat or cold later (Cabeza et al., 2015). Generally, the energy is converted from natural sources of energy to a difference temperature in the water used during times of heavy energy demand. The energy of TES systems is provided to a subsequent storage system that has three step charge, storage and discharge, providing a full storage cycle.

Thermal energy storage for construction and process cooling is used in two main sensitive and latent forms. Each shape has its pros and drawbacks. Water is now the most common storage medium used for cooling, using solid or liquid phase alteration for latent storage, and cooled liquid water for sensible storage (Fe- & Corps, 2014).

Usually, this medium use in system that have storage to store it. For example, central type air-conditioner use for a large cooled area and suitable to use glycol as a refrigeration medium. Furthermore, for thermal storage has three (3) type which is sensible heat storage, latent heat storage and thermo chemical storage (Diaz, 2016).

1.2 Problem Statement

In the developed world, the majority of countries that are already seeing fast urbanization and population growth today. In the past few decades, electricity demand in these countries has increased dramatically. For example, Malaysia's national demand for energy in the last two decades has grown fivefold, while over the last 30 years, the overall population has doubled from 10.4 million in 1970 to 22.2 million for 2000. In several countries, especially in the developing world has been studied intensively for reduce the power consumption during using a HVAC system in term to maintain the temperature. In additional, propylene-glycol has the lowest freezing point than the water in HVAC system. Nowadays, many building use system chiller or thermal energy storage in order to reduce the consumption of power electric. The energy usage will have the greatest influence on the overall performance of the HVAC system. However, A high level of loss efficiency might reduce the amount of time required to cool the area around the location. As theoretical, It is possible to use the certain fluid as a refrigerant. The air that is utilized in an air cycle refrigeration system can be considered a refrigerant as well.

1.3 Research Objective

The main aim of this research is to determined either propylene-glycol mixture with water or 100% water has more efficiency with comparison of coefficient of performance (COP) system.

- i. To compare the different temperature variation with 100% water and propylene-glycol mixture with water at thermal ice storage trainer unit.
- ii. To compare coefficient of performance (COP) for 100% water and propylene-glycol mixture with water to the thermal ice storage.

1.4 Scope of Research

The scope of this research are as follows:

- i) Ice thermal storage system with capacities 45 liters water.
- ii) Charging mode process for thermal storage with 150 liter ice store.
- iii) Mixture propylene glycol and water in storage system with ratio 2:1 water glycol (propylene glycol 33%).
- iv) Size of the system that using thermal energy storage based on needed cooling capacity.
- v) Storage material (steel, concrete and plastic).
- vi) Circulation pump type UPS 25-80 with pump capacity 140 L/min.
- vii) Electric motor with 0.37 kW and 50Hz with 2800 rpm.
- viii) Refrigerant use in thermal ice storage system is R134a.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Thermal Storage

In today's modern society, energy efficiency is very making some building have a higher power consumption. So, for reduce the power consumption some of the building use storage system to keep and hold the temperature during a night. Thermal energy storage is a system that stores or keep thermal energy by heating or refreshing a storage medium in order to use it for heating, cooling, and power generating applications at a later time. Thermal Energy Storage systems are generally use in a big buildings and industrial processes (Monde et al., 2018).

In additional, the most important for design the Thermal Energy Storage must high another word for energy density in a storage medium is storage capacity. Besides that, it also must be suitable and compatibility of the storage medium with the container medium such as glycol (Cabeza et al., 2015).

2.2 The Classified of Thermal Storage System

For Thermal Energy Storage it has are three type of TES systems which is a form of sensible heat storage that relies on heating or chilling a liquid or solid storage medium to store thermal energy (Diaz, 2016). Secondly is latent heat storage that based on phase change materials or PCM and last is thermo-chemical storage (TCS) using chemical reactions to store and release thermal energy. Sensible heat storage system is based on storing thermal energy by heating or cooling a solid or a liquid storage medium. The increases of

refrigeration medium or removal of heat can cause a temperature variation. For Sensible heat storage system, the cheapest refrigeration to use as a cooling medium is water.

Meanwhile, for latent heat storage it dependent on phase change (PCMs). The intensity here is on the consumed or emissions of energy when a phase shift occurs. Temperature fluctuations are ignored in a latent heat storage system. Conversion from the solid to the liquid state is an example of phase transition. Chemical- energy storage based on chemical reaction to store and release the thermal energy (Diaz, 2016).

2.3 Sensible Heat Storage System (SHS)

According to article written by (Diaz, 2016) which is the principal theme of a method of sensible heat storage (SHS) is thermal energy storage, which occurs by a increasing of the temperature of a solid or liquid substance. This approach makes advantage of the heat potential of the material throughout the loading and unloading operation, as well as the temperature change during the process. The difference of temperature, the special thermal content and storage materials have a significant impact on the amount of heat that is retained. The store material used plays a major role in constructing an efficient store (Diaz, 2016). The main requirements of a store material can be summarized as follows

- i. Ability to bear charging/discharging cycle without change in structure, reduction in storage capacity and loss in performance
- ii. Ease of accessibility, ease of handling and capability of storage in simple container
- iii. Less expensive.

2.4 Latent Heat Storage System (LHS)

The center of latent heat storage systems is the changing of material (PCM). The chemical bond in the PCMs collapses and the substance undergoes transformation in stage where the source temperature increases (Diaz, 2016). In solid-liquid PCMs this transformation is from solid to liquid. This step is an endothermic mechanism as heat is required. In the process, the PCM absorbs heat. When the changing process is completed, the heat is trapped in the storage tank, and the material begins to melt. Until the melting process is completed, the temperature remains constant. (Diaz, 2016). Latent heat can be described as the heat which is stored during the change of phase process, in this situation the melting process is happen. Advantage from this system are

- i. It has a high storage density.
- ii. Small temperature changes can result in storing large amount of heat
- iii. Ability to apply at a precise operating temperature, since they may work with high storage density in isothermal setting.

2.5 Thermo Chemical Storage System

Thermal energy storage seen as a technique that supports a wide range of applications. This covers the creation and disposal of energy waste, as well as the utilization of solar heat. Thermal storage materials provide high storage capacity per mass or volume compare to SHS and LHS. Thermochemical energy conservation is divided between chemical reactions and the mechanism of sorption (absorption and adsorption considered as a single process). High energy storage density and reversibility of materials is needed for chemical reactions (Diaz, 2016).

2.6 Ice-Cold Storage System

Ice-cool TES has been designed and make use of many years now, generally called an Ice -Thermal Energy Storage (ITES) system. In order to efficiently comply with the need for cooling load and energy redistribution in buildings, ITES depends on the operating mode either full or partial storage, storage type and charge-and-discharge properties (Lago et al., 2019). One of the most important components of this system is a primary chiller facility that use for maintain cold water in a storage tank while reducing the temperature of the latent heat, causing the cooled water to change to the ice. During the water-to-ice transition, cold thermal energy is stored (charged) and the same was released (discharged) when the solid ice is converted into water (Lago et al., 2019). Figure 2.1 shows the of ice thermal energy storage.

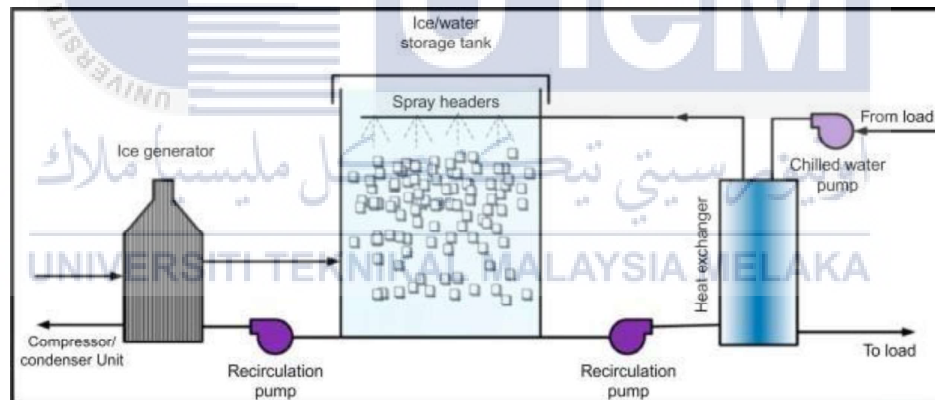


Figure 2.1 Ice thermal energy storage (Lago et al, 2019)