UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY ON SOLAR HEAT COLLECTOR FOR ABSORPTION REFRIGERATION

This report submitted with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Refrigeration and air-conditioning system) with Honours

By

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2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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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 degree of Bachelor of Mechanical Technology (Refrigeration & Air-Conditioning system) (Hons.). the member of the supervisory is as follow:

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ABSTRACT

Energy is the most important issue in real life application for almost activity that related to work and efficiency. Improper energy consumption may increase the cost and that situation need to be improved for better energy awareness among the community. Currently, air conditioning system can be classified as important thing for certain reasons such as comfortability, filtration, and protection for specific devices or products. This air conditioning system requires high amount of energy for the operation especially for a long duration based on certain system. Energy required for air conditioning system can be extracted from natural solar energy. Absorption air conditioning system was chosen for this solar energy extraction with certain improvement at certain parts of the system. A solar collector has been built with evacuated tube, u-tube heat pipe design and dimple heat tube to increase the efficiency of the solar collector. This solar heat collector mainly focusing on absorption system with certain criteria that can improve the efficiency. Input and output temperature from this solar heat collector were an important parameter for thermal analysis. An evacuated tube located in the solar collector was designed with different heat pipe connection with other evacuated tube to get a better performance. The heat pipe in the evacuated tube also has a unique dimple design that allowed heat transfer process to occur with higher efficiency from the normal heat pipe. Then, a temperature test was conducted to determine suitable operation temperature in absorption system based on real absorption trainer module temperature. As the result, this solar heat collector managed to obtain final temperature about 69.3°C compared to trainer absorption module which was 131°C. This situation may happen because of lack of solar heat collector, insulation loss and material loss. As conclusion, a set of solar heat collector with evacuated tube, dimple heat pipe and u-tube design were developed with better thermal efficiency by 1.4 % compared to previous research.

ABSTRAK

Tenaga merupakan perkara penting dalam kehidupan harian untuk hampir semua aktiviti yang berkaitan dengan kerja dan kecekapan. Penggunaan tenaga yang tidak cermat akan meningkatkan kos dan keadaan ini perlu dikawal agar kesedaran penggunaan tenaga dapat dipupuk dalam kalangan komuniti. Pada masa ini, penggunaan sistem penyaman udara merupakan perkara penting atas sebab tertentu seperti keselesaan, penapisan udara dan perlindungan terhadap peralatan dan produk yang dikeluarkan oleh sesebuah organisasi. Sistem penyaman udara ini memerlukan penggunaan tenaga yang tinggi terutama pada masa penggunaan yang panjang bergantung kepada jenis yang digunakan. Berdasarkan projek ini, penggunaan tenaga untuk sistem penyaman udara ini boleh dijana daripada tenaga solar. Untuk menjalankan projek ini, sistem penyerapan (absorption) penyaman udara telah dipilih dan sebahagian daripada sistem ini telah menjalani penambahbaikan untuk meningkatkan keupayaan sistem ini. Sebuah pengumpul solar (solar collector) telah dibina dengan siri-siri khas untuk meningkatkan keupayaan penyerapan haba matahari. Sistem ini lebih menekankan kepada sistem penyerapan yang mempunyai ciri-ciri yang dapat meningkatkan keupayaannya. Suhu masuk dan keluar dalam sistem ini sangat penting untuk analisa haba. Sebuah tiub pemindahan telah direka dengan reka bentuk u-tiub.Tiub haba di dalam tiub pemindahan juga mempunyai reka bentuk yang unik iaitu mempunyai lesung dalam usaha meningkatkan keupayaan pemindahan haba. Kemudian, satu ujian suhu telah dijalankan untuk mengenalpasti suhu yang sesuai untuk operasi sistem penyerapan yang sebenar berdasarkan modul pelatih sistem penyerapan. Keputusannya, sistem ini mampu untuk mengumpul suhu akhir dalam 69.3°C berbanding 131°C yang mampu dikumpul oleh modul pelatih sistem penyerapan. Konklusinya, satu set pengumpul tenaga solar dengan menggunakan tiub pindahan, tiub haba berlesung dan reka bentuk u-tiub pada tiub haba telah dibangunkan dengan kecekapan haba lebih banyak sejumlah 1.4% berbanding dengan kajian terdahulu.

DEDICATION

Here I dedicate my whole work to my family that encourage me throughout this project and support me in moral and financial in order to finish this project on time. Also, I dedicate this work to my supervisor that always remind and give advice for me to improve my work too achieve a better result. Not be forgotten, all my friends and assistant engineer that give idea and provide a good atmosphere for me to complete this project without any disturbance.

ACKNOWLEDGEMENT

First of all, I would like to thank God for giving me strength and a good thinking skill to complete my final year project without any major problem. I also would like to express a huge appreciation to my supervisor Dr Abdul Munir Hidayat Syah Lubis and my ex-supervisor Dr Safarudin Gazali Herawan for big effort of advices, reading and encouraging me during the planning and development of the project. Thank you to everyone that involved in this project directly or indirectly for their helps during my project development period. Without any of these helps, I would not have been able to complete my final year project and may this success give a little enjoyable experience work for the production and development of solar heat collector for absorption refrigeration.

TABLE OF CONTENT

CHAPTER 3: METHODOLOGY

CHAPTER 4: RESULT AND DISCUSSION

CHAPTER 5: CONCLUSION AND RECOMMENDATION

CHAPTER 1

INTRODUCTION

1.1 Background of study

Air conditioning system a most system used in any field of industry in this modern world. This situation covers many reasons on the requirement of air conditioning system. One of the reasons on the importance of air conditioning system is in commercial sector. Building with working staffs need air conditioning system to reach their thermal comfort level in order to manage their works properly without any issue. With a proper condition, staff also will become more productive and they will be less likely to be in a stress condition. Not only that, building with air conditioning system can easily control the climate inside the building and give an extra protection to the equipment inside the building especially the equipment that produce heat during the operation. The equipment failure based on moisture problem also can be solve with proper air conditioning system installed in the building. When running a shop business, the customers satisfaction and comfortability during inside the building environment is one of the important things.

Air conditioning system is important to residential sector because it is a place for human to rest after working in a day. After a tiring day, a room with an optimal temperature can reduced the tiredness of human body and the best air conditioning system is the system that does not distract the user and works silently. Air conditioning system in residential sector also manage the moisture problem related to human body. Human body will remove heat through sweat and

with air conditioning system, heat can be removed as well the sweat and maintain the temperature and moisture a appropriate level.

For public sector other than providing thermal comfort to occupant, air conditioning system mainly used for maintain and stabilize the moisture content for a historical building and treasure. The moisture control can prevent from self-disruption that happen by the excessive heat and with this system, most of historical building and those treasures can be preserved for future reference. For the most important sector is in health sector which the occupant in this sector need a proper and specific temperature for optimum body temperature to control several medical conditions. For example, for burn victims they cannot control their body temperature properly and need to be monitored. Victims body temperature needs to be kept in the warmest possible in the environment. The indoor air quality also an important factor in health sector because disease may happen because of improper air quality in medical section. For some specific section, air conditioning system need to be separated from another section area to control the area or other occupant from disease that may be spread. For example, an operation theater has a closed loop air conditioning system design to avoid bacteria come in or out from that section (Abdul, Mofarhi, Abdulwahab, & Ali, 2016).

1.2 Problem statement

Comfortability is the most significant things that must include in any sector for certain benefits. The usage of air conditioning system in this area manage to provide comfort to human specially to carry out the basic living activities. According to some research, there are several factor that affect the thermal comfort which are air temperature, air velocity, radiant

temperature, relative humidity, activity level and clothing insulation (Simion, Socaciu, & Unguresan, 2016). By using air conditioning system most of the factor can be achieved and to operate this system required a lot of energy compared to other household that use only small amount of energy consumption. The electrical energy consumption by air conditioning system is the largest which is 1,167kwh/year (Kubota, Tetsu; Jeong, Sangwoo; Toe, Doris Hooi Chyee; Ossen, 2011). Based on the research, the electrical energy consumption by household with air conditioning system is 1.4 times higher than energy consumption by household with no air conditioning system. This situation prove that air conditioning system can increase the electrical energy consumption in most of modern house in Malaysia (Kubota, Tetsu; Jeong, Sangwoo; Toe, Doris Hooi Chyee; Ossen, 2011).

This energy consumption problem leads to some research and new product to reduce the electrical energy consumption that focusing to air conditioning system. There are several researchers that have been studying about solar collector in absorption system that manage to reduce the energy consumption (Sözen & Özalp, 2005; Wang, Ge, Chen, Ma, & Xiong, 2009).So in this project, a less energy consumption solar heat collector will be developed with dimple heat pipe with u-tube piping design and using evacuated tube type. Solar heat energy manages to provide up to 20% of relatively low temperature which is less than 120°C and in a year, 17% of total thermal energy need to be used for cooling process (Phelan, Otanicar, Taylor, & Tyagi, 2013). Solar heat energy collected by solar collector can be various from simple solar collector that manage to achieve around 50°C. For glazed flat plate solar collector, temperature that can be achieve around 85°C and evacuated tube solar collector can achieve up to 120°C depending on method and material used (Phelan et al., 2013). With this situation, another source

of energy can be used to replaced electrical energy consumption for air conditioning system with retaining the process to get the optimum temperature for thermal comfort.

1.3 Objectives

This project aimed to study on solar heat collector capacity for absorption refrigeration with objectives of:

- ✓ To design and develop a set of solar heat collector with dimple heat pipe, u-tube piping design and using evacuated tube solar heat collector to increase the thermal efficiency

- ✓ To determine the output temperature of solar heat collector for heat source in absorption refrigeration

1.4 Work scope

In this research work, design and fabrication of solar heat collector for absorption refrigeration that use solar thermal source to complete the process cycle in absorption cycle refrigeration. Selecting type of solar heat collector also performed because every type of solar heat collector has different properties that will determine the efficiency and amount of heat can be collected in certain amount of time. With this method, solar energy can be utilized in the best way and reduce the electrical energy consumption especially in air conditioning system. There are many criteria in solar heat collector in current market but only certain criteria were chosen

to produce the best solar heat collector based on absorption refrigeration usage. Lastly, the testing of solar heat collector for absorption refrigeration in term of thermal input and output temperature to obtain thermal efficiency was carried out.

1.5 Significance of study

The significance of conducting this research is to study the performance of solar heat collector for absorption refrigeration. This experiment is done by using certain type method that aim to increase the efficiency of the solar heat collector. The solar heat collector developed not only can be used in refrigeration system but any system that use heat source to carry out their specific process. With this solution, solar heat energy can be utilized well and reduce the problem about high electrical energy consumption used for air conditioning and refrigeration system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The main function of literature review was to determine and clarify studies that related to the topic of the research. The utilization of solar heat energy in refrigeration system was a good topic that included in this research which can reduced the power consumption used by the system to operate well in order to achieve human thermal comfort. Not only that, there were some proper literature discussion about the solar heat collector usage and properties in absorption refrigeration system that can increase the efficiency of the solar heat collector by different types of method that related to previous research.

2.2 History

Refrigeration is the process of lowering and maintaining the temperature at certain surrounding and the purpose of this process is to remove heat for some products or space to required temperature. The most important application on refrigeration is preservation of perishable food at low temperature in order to make the bacteria inactive and extend the decaying process. Air conditioning which is part of refrigeration also being used for the thermal comfort to human. Human body will generate heat during metabolism and heat must be released to surrounding area to make the body in stable condition. When surrounding temperatures are

higher than body temperature, heat cannot be removed effectively and body may be overheating while when surrounding temperatures are too low, human body may feel too cold and it will create an uncomfortable condition (Boduch & Fincher, 2009). Air conditioning is the treatment of air to control the temperature, cleanliness, moisture content, odor and circulation that required by process, occupant or the product in the space area. The history of refrigeration has become popular especially at the development of refrigerant, prime mover, and the compressor used in the system.(M.E. Kharagpur, 2014).

2.2.1 Natural refrigeration

In the beginning of the refrigeration system operation, main function of the system achieved by using ice or by evaporative cooling and the ice was either transported from colder location, being kept in ice houses from winter for the summer usage or made by water cooling at night using radiation to stratosphere (M.E. Kharagpur, 2014). In 1800s, ice used for natural refrigeration was harvested from lakes and pristine river. The ice was kept well in large amount and being insulated with sawdust in ice houses (Briley, Life, & Ashrae, 2004). In 1806, Frederic Tudor started ice export business to various country including India by getting ice supply from Hudson River and Massachusetts ponds. Ice business in North America was developed rapidly and ice was transported to southern area in America by using train with special container that was built with 0.3m of cork insulation (M.E. Kharagpur, 2014).

Most popular natural refrigeration is known as evaporative cooling originally used by people in Near East where the condition of this location is dry and hot. In same condition refer to painting in Ancient Egypt (2500 B.C), big bowls or liquid containers were filled with water and slaves waved some equipment that can increase the air flow will make the water diffuse through the porous liquid containers. The water will evaporate to ceramic wall and keep the surface in high amount of moisture (PATIL & HIRDE, 2013). Meanwhile in India, they use this evaporative cooling method to obtain cold water by using porous pots. They kept the water inside the pots and evaporation process will occur to surrounding that make the heat being absorbed into the pots or vessel wall (M.E. Kharagpur, 2014).

Another natural refrigeration is nocturnal cooling which is a method to create ice by using a thin layer of water in tray that made of a piece of baked compressed soil. The tray usually being insulated by hay that has been compacted and the heat in the water will be removed my radiation by early in the morning the water will freeze (M.E. Kharagpur, 2014). This method is largely known and most common ways to make an ice in India when common salt dissolved in the water, the water temperature will drop and it will become cold because of the endothermic process. The word endothermic means “take heat” and in endothermic reaction, more energy needed to break the bond in the reactants to create another new product (Brainard, 2014). Most common salt such as sodium chloride (NaCl) can reduced the temperature up to -20°C and calcium chloride ($CaCl_2$) up to -50°C with good materials for the insulation to lower chances of heat being absorbed back into the brine solutions (M.E. Kharagpur, 2014). This is a method of cooling by salt solutions.

2.2.2 Artificial refrigeration

Most of the refrigeration system at this modern era are using artificial refrigeration system. Scottish professor William Cullen invented first refrigeration machine that can produce an ice but only in small quantity in the laboratory. Even it is unclear between artificial refrigeration or natural refrigeration, it is generally confirm that artificial refrigeration system started in 1755 according to William Cullen intentions (M.E. Kharagpur, 2014). By referring to system principle, there are several types of refrigeration system which are vapor compression system, vapor absorption system, and etc.

The common method in artificial refrigeration is by using vapor compression and basic aspect of modern refrigeration system is the ability of the system to absorb amount of heat as boiling or evaporation process occur. According to Professor William Cullen of University of Edinburgh, water that have been contact with some heat exchanger can be increase its evaporation rate by reducing the pressure using vacuum pump (M.E. Kharagpur, 2014). This situation correlates with two thermodynamic concept which are vapor pressure and latent heat. The pressure is related to temperature in refrigeration system that can be explained by water will boil at higher temperature in a pressure cooker (M.E. Kharagpur, 2014). For the second concept, latent heat must be removed from the water to reduce temperature of the water. The temperature will constant at certain value as long the vacuum pump provide pressure equal to saturation pressure at certain temperature needed. This condition will create vapor from vaporization process and need to be removed. In this modern world the cooling parts or the heat exchanger of the system that connected to air conditioned space is called evaporator (M.E. Kharagpur, 2014). As time goes, James Harrison is the man that take control for making proper vapor

compression system patent in 1856 using ether, alcohol, and ammonia. Then, Charles Tellier innovated vapor compression refrigeration system by using dimethyl ether that has a boiling point of -23.6°C (M.E. Kharagpur, 2014).

Other than vapor compression refrigeration, vapor absorption refrigeration also has been developed to make the cooling process in requirement. In 1810, John Leslie use sulfuric acid and water to build a system by put them in a different container and make a connection between those containers. He observed that sulfuric acid has a properties that absorb water vapor that can be used to replace compressor or pump in normal vapor compression refrigeration system and this sulfuric acid works as absorbent in this system that need to be reused or recirculated in the system by heating process of absorbed water vapor (M.E. Kharagpur, 2014). In 1860, an aqua-ammonia absorption refrigeration system was invented by Ferdinand Carre that mentioned water is a strong absorbent of ammonia. A container that filled with ammonia will respond and create strong absorption potential of water that managed to make ammonia evaporated if the ammonia reacts with another container that filled with water. This situation can reduce the power consumption because of no compressor is needed to drive the vapors (M.E. Kharagpur, 2014). Figure 2.1 shows the basic components in vapor absorption refrigeration system and figure 2.2 shows triple fluid vapor absorption refrigeration system.

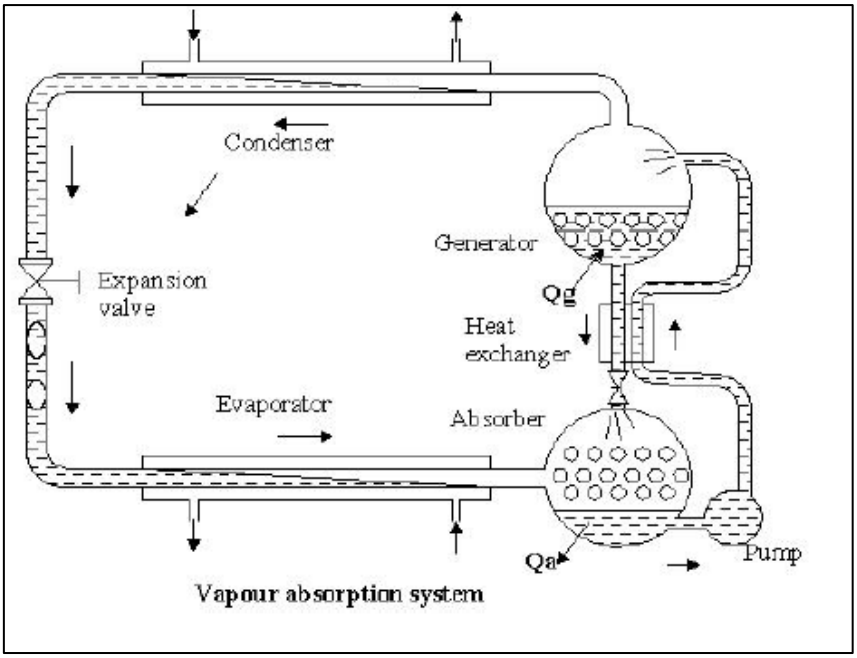

Figure 2.1 basic components of vapor absorption refrigeration system (M.E. Kharagpur, 2014)

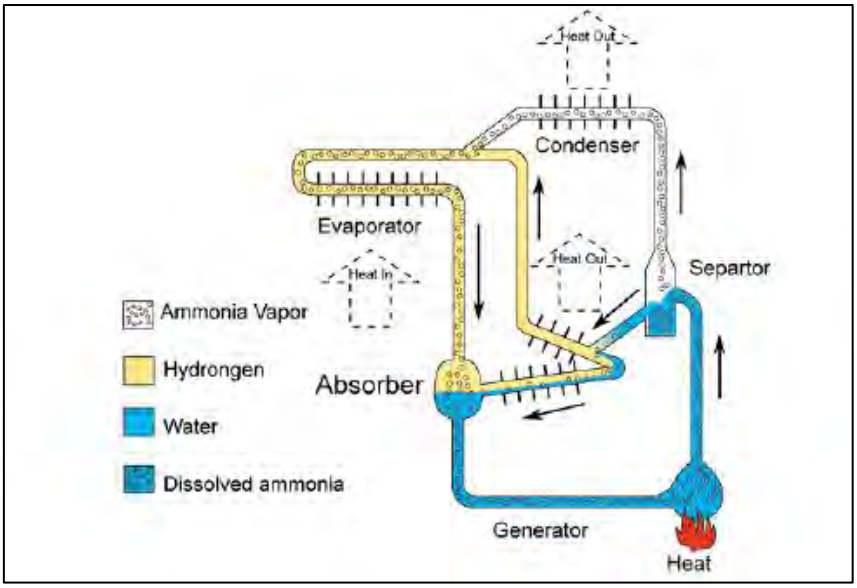

Figure 2.2 shows triple fluid vapor absorption refrigeration system (M.E. Kharagpur, 2014)

Through the year, vapor absorption refrigeration system has developed and varies in order to increase the efficiency of the system. In this version, sulfuric acid has been replaced by lithium bromide. The structure of the system also been modified with condenser and generator build in a same vessel while evaporator and absorber build in another cylindrical vessel (M.E. Kharagpur, 2014). This lithium bromide vapor absorption refrigeration system also managed to function well on low grade energy.

As time goes, energy consumption and location of the cooling process have been identified to be improved. There are several projects that used solar energy on vapor absorption refrigeration system by using concentrating and flat plate solar collectors around 1950s in certain countries. Professor G.O.G L in one of the most important people in the development of solar refrigeration using flat plate collector in early stage and in 1953, 250 kg of ice produced in each day using parabolic mirror solar collector of $10m^2$ to concentrate the solar radiation which has been carried out in Tashkent, USSR (M.E. Kharagpur, 2014). Another method was using an absorption refrigeration machine with cylindrical parabolic mirror of $20m^2$ in Montlouis, France that can make 100kg of ice in a day. Since 1965, lithium bromide has been developed for air conditioning purpose due to shortage of fossil fuel based on energy purposes. (M.E. Kharagpur, 2014). In University of Queensland, there was a solar house and first solar air conditioning system were built there to test the performance and quality of the system in 1966. Approximately, there were about 500 units of solar absorption system in United State only and almost of these units were using lithium bromide-water because of this system does not required very high heating temperature for this system to operate well.(M.E. Kharagpur, 2014). Due to successful previous project of this solar absorption system, there are several types of project that

need to be cooled at night time and the system was charged with solar energy during the day. Moreover, vapor absorption system is the most suitable system to be used at rural area because of no space limitation and environment friendly that operate based on renewable solar energy (M.E. Kharagpur, 2014).

2.3 Method of refrigeration

Refrigeration process mostly used for food storage for domestic, restaurant, and food warehouse to avoid the products spoil and maintain in a fresh condition. Refrigeration process in manufacturing activities at factory also needed to manage the gases like oxygen, nitrogen and propane in order to create those gases in liquid state. In most oil industry activities, refrigeration is needed to maintain low temperature of certain process. In other words, refrigeration process can be classified as the most important process in all field of industry and domestic. All these processes can be done by different methods of refrigeration. Different refrigeration method has different characteristic in their operational system. Methods of refrigeration involved such as non-cyclic, cyclic, thermoelectric, and magnetic.

Cyclic process in refrigeration is the most popular method and this process may recognize as the most efficient method and use the least time taken to operate this system. In this cyclic process, heat is rejected from low temperature space area to high temperature space. A change in refrigeration cycles alternately absorb and remove heat during the circulation. This system can be seen at heating, ventilating, air conditioning and refrigeration that related to indoor and automotive cooling system. By natural, heat flows from hot to cold. To cool specific

space area, work process must involve by pump heat from low temperature space area to high temperature space area. An insulation is required to reduce heat loss to surrounding during the cooling process by thermal contact or radiation from any sources. By using insulation, work and energy required to control the temperature can be reduced that is good for cost and power consumption used in the whole system. Refrigeration cycle operating system was defined by Sadi Carnot in 1824 as heat engine (Dhankhar, 2014). Cyclic refrigeration can be identified as vapor cycle and gas cycle. Vapor refrigeration cycle also can be classified as vapor compression and vapor absorption.

At early years, vapor absorption cycle was popular by using water-ammonia in the refrigeration system and commonly used by the community. However, vapor absorption system lost its advantage after vapor compression being developed. In these days, vapor absorption system was used in area which has a heat source but minimum electrical sources. Vapor absorption system also used in industry that contains huge amount of heat waste to reduce advantages exist (Dhankhar, 2014). Most of vapor absorption system is similar to vapor compression system except the ways to increase pressure of the refrigerant. In vapor absorption system, the compressor was change with absorber that dissolves the specific refrigerant and pump it to generator. At generator, the heat was added and increase the refrigerant pressure. In vapor absorption system, a suitable combination of refrigerant and absorbent was used to operate the system properly. There are several combinations of refrigerant and absorbent in this system such as ammonia-water and water-lithium bromide. During compression of the refrigerant, absorber that contains water as the absorbent will dissolve ammonia. The water-ammonia mixture then will go to pump to transport the mixture to generator with high pressure