EVALUATION OF LIQUID DESICCANT REGENERATOR FOR EVAPORATIVE COOLING

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DECLARATION

I hereby declare that this thesis, submitted to University Malaysia Sabah as a partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering, has not been submitted to any other university for a degree. I also certify that the work described herein is entirely my own, except for quotations and summaries of sources which have been duly acknowledged.

28th June 2022

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ABSTRACT

Liquid desiccant air conditioning evaporative cooling system is an alternative to traditional dehumidification in hot and humid areas due to their advantages in being environmentally friendly, removing pollutants from the process air, and reducing electrical energy. The purpose of this project is to investigate the performance of the regenerator using an internally-heated regenerator to improve its performance. To increase the performance of the regenerator the effect of desiccant temperature, air temperature and humidity on the performance of the modified regenerator have to studied. To run generate the liquid desiccant, low-grade heat of desiccant regeneration needed a temperature to start of between 40-50 °C which is sufficient for regeneration which is easily achieved.

ABSTRAK

PENILAIAN PENJANA SEMULA BAHAN PENGERING CECAIR UNTUK PENYEJUK SEJAT

Sistem penyejatan penyejatan penyaman udara bahan pengering cecair adalah alternatif kepada penyahlembapan tradisional di kawasan panas dan lembap kerana kelebihannya dalam menjadi mesra alam, menyingkirkan bahan pencemar daripada udara proses, dan mengurangkan tenaga elektrik. Tujuan projek ini adalah untuk menyiasat prestasi penjana semula menggunakan penjana semula yang dipanaskan dalaman untuk meningkatkan prestasinya. Untuk meningkatkan prestasi penjana semula kesan suhu bahan pengering, suhu udara dan kelembapan ke atas prestasi penjana semula yang diubah suai perlu dikaji. Untuk menjalankan menjana bahan pengering cecair, haba gred rendah penjanaan semula bahan pengering memerlukan suhu untuk bermula antara 40-50 °C yang mencukupi untuk penjanaan semula yang mudah dicapai.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Liquid desiccant air conditioning evaporative cooling system were proposed as an alternative to traditional dehumidification in hot and humid areas due to their advantages in being environmentally friendly, removing pollutants from the process air, and reducing electrical energy (Abdulrahman Th. et al., 2013). The issue of hot and humid area can be solved by applying desiccants to remove the moisture and evaporative cooling to lower the temperature. While both solid and liquid desiccants can be applied, liquid desiccants offer several benefits over solid desiccants, including the ability to hold more moisture than solid desiccants (Longo et. all, 2005).

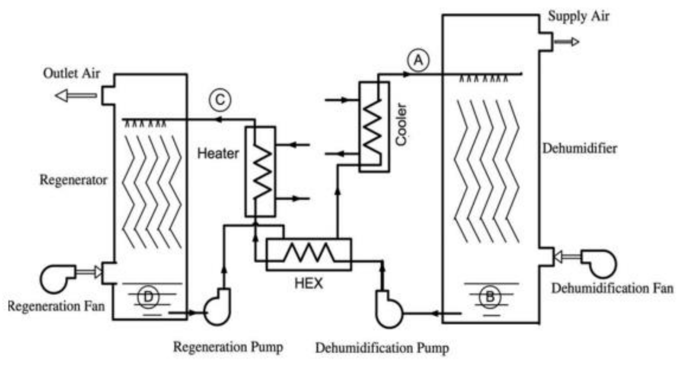

Figure 1.1: Schematic diagram of liquid desiccant cooling system.

(Source: Xinli Wang et. al., 2013)

A simple liquid desiccant system consists regenerator and absorber as shown in Figure 1.1. The liquid desiccant in the dehumidifier unit absorbs the water vapour in the process air (Xinli Wang et. al., 2013). Adsorption dehumidification and evaporative cooling are the principles behind desiccant cooling systems. In this system usually consist an absorber for dehumidifying the air, a regenerator for regenerating the solution, and a set of heat exchangers, heaters or solar panels, and evaporative coolers for sensible cooling and heating of the air and solution (T.S. Ge et al., 2016). Liquid-based desiccant systems improve air quality and increase indoor air quality, according to studies. Water–lithium chloride (LiCl–H_2O) and water–calcium chloride ($CaCl_2$–H2O) solutions are used in these liquid desiccant cooling systems for sorption. Liquid desiccant cooling systems have a better rate of air dehumidification at the same range of output temperatures than solid desiccant cooling systems, and they have a better energy storage capacity when used in concentrated solutions (G. G. Maidment et al., 2012). rate.

Because the refrigerant (water) supplies its cooling effect directly and functions in an open cycle rather than a closed cycle, evaporative cooling is a viable low-energy alternative to vapour compression cooling systems. Evaporative cooling may cut energy usage by up to 70% under the proper climatic conditions. A liquid desiccant air-conditioning system (LDAS) can combine liquid desiccant dehumidification and evaporative cooling. Because the LDAS cycle is largely heat-driven, as opposed to the work-driven vapour compression cycle, it offers substantial energy-saving potential. Desiccant dehumidification allows for effective evaporative cooling in humid areas, and it increases the capacity of evaporative cooling alone. In a basic liquid desiccant cooling circuit with storage, LiCl, $CaCl_2$, LiBr, and KCOOH are investigated as desiccant options for an LDAC system. By pre-dehumidifying with $CaCl_2$, this method lowers exergy loss in heat recovery and the irreversibility of the process (Ross A. Bonner et al., 2020).

Malaysia is an equatorial country with tropical climate, located at 3°08'20.4"N latitude and 101°41'12.8"E longitude. The average midday temperature of dry bulb, temperature of wet bulb, and relative humidity in a tropical climate nation are 32°C, 25°C, and 62 %, respectively. The decreased relative humidity throughout the day shows that evaporative cooling devices might be used to reduce indoor temperatures. The effectiveness of the cooler is indicated by temperature. The greater the temperature, the better the effectiveness of the cooler (Ir Julian Saw et al., 2018).

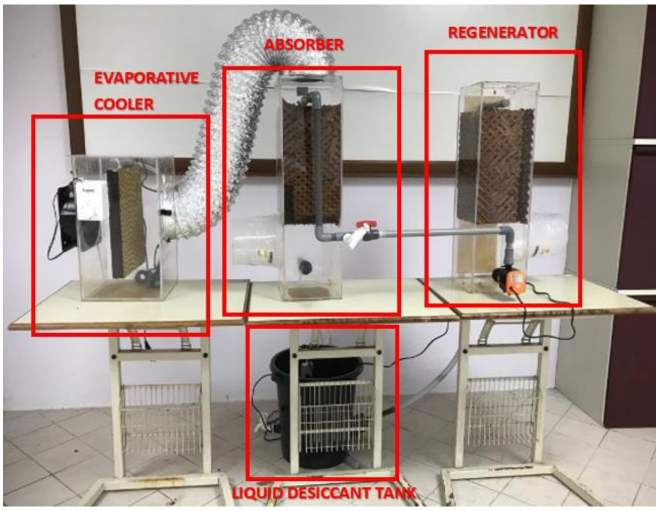

Figure 1.2: Existing Liquid Desiccant Air Conditioning System.

(Source: Continuous project by Mr. Zulkarnain)

This project is about to evaluation of liquid desiccant regenerator for evaporative cooling. It was a continuous project to improve the performance of the system which is developed by a master student MK191107T Zulkarnain bin Hassan under supervision supervision of Dr. Mohd Suffian bin Misaran @ Misran and Nancy Julius Siambun. This work will focus on assisting Mr. Zulkarnain's study of liquid desiccant air cooling system, primarily in terms of regenerator performance, under the same author's supervision of Dr. Mohd Suffian bin Misaran @ Misran. Some modifications had been made for the regenerator to increase its performance of the project. Before that, testing and experiment must be done to observe the effect of inlet parameter on outlet parameters.

1.2 PROBLEM STATEMENT

Traditional air conditioners use a lot of energy and power to perform, and they produce more pollution than evaporative coolers. Evaporative coolers emit far fewer pollutants than air conditioners. They also produce far less noise than typical air conditioners (Preferred Climate Solution, 2021). In hot weather, traditional air conditioning equipment used a lot of electricity and created a lot of electricity tension. Furthermore, germs were easily spread and grew since the air handled in air conditioning systems was wet due to the dehumidification process in hot weather. Furthermore, the air humidity in most central air conditioning systems is rarely regulated, making people feel uncomfortable in these spaces (Yonggao Yin et al., 2006).

In this project, the system of the liquid desiccant regenerator for evaporative cooling that will be used is a continuous project to improve its performance. The current system used a packed regenerator which is an adiabatic regenerator. Heat and mass transfer occur exclusively between the air and the desiccant in a packed regenerator. Since there's no extra heat supplied into the regenerator, which is an adiabatic regenerator, the desiccant temperature would decrease as regeneration progressed in the regenerator. It is very likely that the liquid desiccant regeneration would weaken fast (Y. Yin et al, 2010). Internally heated regeneration could be a solution to this problem by changing an adiabatic method to an internally heated method because this method has a higher regenerative rate.

To regenerate the desiccant, a source of heat is needed. Low-grade heat of desiccant regeneration needed a temperature to start of between 40-50 °C which is sufficient for regeneration which is easily achieved (Longo et. all, 2005). So, in this project, heaters are used to investigate designs that can function at the lowest heat temperatures.

1.3 RESEARCH OBJECTIVE

The main objective of this project is to investigate the performance of the regenerator using an internally-heated pipe coil and fins to improve its performance. The sub-objectives of this project were to study the effect of desiccant temperature, air temperature, and humidity on the performance of the modified regenerator.

1.4 SCOPE OF WORKS

The scope of works for this project are as follow:

i. The literature of current and previous research on the liquid desiccant for evaporator cooling systems has been reviewed from multiple sources including journals, books, and articles.
ii. The working principle and the cycle process of the continuous system used in this project have been understood.
iii. Several types of heat sources are used that can run the liquid desiccant for evaporator cooling at low-grade heat.
iv. Run the liquid desiccant for evaporator cooling to take the reading.
v. Experiments to study the effect of inlet parameters on the outlet parameter of the regenerator have been carried out.
vi. The modified regenerator has been made to increase the regenerator's performance.
vii. The system has been run to measure the performance before and after modification.
viii. The documentation of the project progress and data have been carried out.

1.5 RESEARCH METHODOLOGY

This project is based on research from both local and international writers about liquid desiccant regenerator for evaporative cooling. Several researchers were made related to this topic as guideline for completing this project. Testing and experimental will be made to show how the project works and carry out data analysis of the project. Then documentation will be made, including a complete report and presentation to give a clear understanding of the project for the examiner. The proposal and project progress report drafts are sent to the supervisor for comments and recommendations during the project.

1.5.1 PROBLEM STATEMENT

A problem statement is a useful communication tool that ensures that other people understand the problem of the project that must to solve and why the project is important. Several technologies, including multiple-effect boilers and vapour compression distillation, must be used to increase the performance of the regenerator. Also, since traditional air conditioners use a lot of energy, power and produce pollution, so liquid desiccant regenerator for evaporative cooler is one of the ways to avoid such problems.

1.5.2 LITERATURE REVIEW

Regarding to the previous researcher related to this topic are studied for obtain a better knowledge and understanding for this project. Materials, equipment, parameters, and techniques for conducting this research are determined based on previous studies.

1.5.3 DESIGN MODELLING

The liquid desiccant regenerator of evaporative cooling will be set up at indoor to get optimum reading. This system consist regenerator, absorber, evaporative cooler, water tank, heat source, pipe and pump.

1.5.4 EXPERIMENTAL AND ANALYSIS

A liquid desiccant regenerator of evaporative cooling is set up. The weak desiccant solution will pass through the regenerator then absorber before it is heated. To regenerate the desiccant, low-grade heat of desiccant regeneration needed a temperature to start of between 40-50 °C which is sufficient for regeneration which is easily achieved (Longo et. all, 2005). for regeneration by using suitable heat source. The inlet and outlet parameters will be measured and recorded for data analysis. To increase the performance of the system, modification will be made on regenerator.

1.5.5 DOCUMENTATION

The research process as well as the information and data collected will be documented. The problem statement, objectives, literature review, experimental set-up and methodology, data obtained, related calculations, figures, diagrams, and graphs, discussion of results, and conclusions made based on the experiment's results will all be included in the documentation.

1.6 MATERIALS AND EQUIPMENT

The materials and equipment needed to carry out the experiment such as acrylic liquid desiccant, PVC Pipe, honeycomb cooling pad, fan, pump, pipe coil, fins and equipment to measure the highlight parameters for this experiment.

1.7 RESEARCH EXPECTED OUTCOMES

It is expected that the liquid desiccant regenerator for evaporative cooling system would perform effectively when heated using the suitable heat source. The regenerator's performance increases as the temperature of the liquid desiccant rises. Low-grade heat of desiccant regeneration needed a temperature to start of between 40-50 °C which is sufficient for regeneration which is easily achieved (Longo et. all, 2005). Based on the experimental study, it is able to explain the impact of inlet parameters on outlet parameters in regenerators, such as air temperature, humidity, and liquid desiccant temperature.

1.8 RESEARCH CONTRIBUTIONS

This project will be able to introduce a new form of liquid desiccant regenerator for evaporative cooling system which are emit far fewer pollutants, low in energy consumption and high in performance. It is stated that increasing the performance is important for keeping and productive indoor environment in buildings while saving energy consumption. Due to the general lower relative humidity throughout the day, evaporative cooling systems should be more efficient in decreasing indoor temperatures. Temperature increases the performance of the cooler. The system's performance improves as the temperature increases (Ir Julian Saw et al., 2018).

1.9 RESEARCH COMMERCIALISATION

Because the weather in Malaysia is hot and humid all year, there's a good chance in need a device that's intermediate between a fan and an air conditioner which is liquid desiccant evaporative cooling. This liquid desiccant of evaporative cooling system which is emit far fewer pollutants are suitable for indoor and outdoor to the lower temperature and humidity to create a comfortable environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, all the current knowledge, information and theories that related to this project will be discussed. It will present a review of relevant research of liquid desiccant regenerator for evaporative system and past research of adiabatic and internally-heated regenerator. Furthermore, all finding on Heating, Ventilation and Air Conditioning (HVAC), desiccant cooling, Liquid Desiccant Cooling System (LDCS) and desiccant will be stated. In order to evaluate and improve the performance of liquid desiccant regenerator for evaporative cooling, basic information about previous and current system must be studied.

2.2 Heating, Ventilation and Air Conditioning

Due of fast population increase and rising living standards, power consumption in the heating, ventilation, and air conditioning (HVAC) sector, as well as the related HVAC equipment demand, has reached most uptrend. This increase in energy usage for HVAC leads in increased fossil fuel use, an increase in peak electric demand, and a strain on the power system at peak hours. Thorough the evaluated in the design of HVAC systems, the amount of moisture present in the ventilation air as it might be responsible for structural difficulties with the structure as well as comfort and health issues for the inhabitants (Giampieri, A. et al., 2018).

Heating, ventilation, and air conditioning (HVAC) systems are the primary energy users in public buildings, accounting for 30–40% of total energy usage (Tong Z et al, nd). The construction sector has overtaken agriculture as the world's greatest energy user (Fan et al. , 2017). It accounts for more than one-third of worldwide ultimate energy use (Hong et al, nd). In reality, however, HVAC systems are typically inefficient in terms of energy use. About 15% to 30% of the energy consumed in HVAC systems is lost due to sensor problems, device faults, performance degradations, ineffective control techniques, and so on (Zhang, C et al, 2019).

2.2.1 Conventional Vapor Compression Refrigeration System

Vapor compression systems (VCSs) currently dominate the air conditioning market due to their high performances stability, low cost and long life. However, vapor compression systems employ toxic refrigerants such as R-22, R-410A, and R-134A, which have a high global warming potential, and demand considerable amounts of electrical energy to run the compressor (Elmer et al, 2017).

In refrigeration cycle, heat flows from high-temperature regions to low-temperature areas in the form of thermal energy. The transfer of heat from a low-temperature to a high-temperature environment needs the use of a refrigerator or a heat pump. Refrigerators and heat pumps are same device, they differ only in their purpose (M. Bahrami et al., 2011). The problem of the old method is its poor efficiency, since the impact of heating or cooling is only 2-3 times greater than the use of electrical energy (F. S. et al., 2005).

The conventional vapor compression systems have a weak control capability, unable to deal with variations in sensible and latent loads efficiently. Conventional vapor-compression systems have become less effective when dealing with latent loads existing in buildings, resulting in system oversizing when dealing with high moisture content. An oversized system raises the capital cost of the ducting installation system as well as the operational cost for fans. Furthermore, an unintended consequence of traditional air-conditioning systems is the re-evaporation of moisture condensed in the building when the coil is turned off, causing in dehumidification ineffectiveness when the system is switched on or off (Giampieri et al., 2018). Different from the few systems above, Mohan et al proposed a hybrid system by combining vapor compression system with liquid desiccant dehumidifier as shown in Figure2.1 below. They proposed a hybrid system where the liquid desiccant was used for the dehumidification of the supply air. From the Figure2.1, liquid desiccant was circulated from the evaporator to the condenser with very low flow rate to further satisfy low humidity requirement (Mohan et al, 2008).

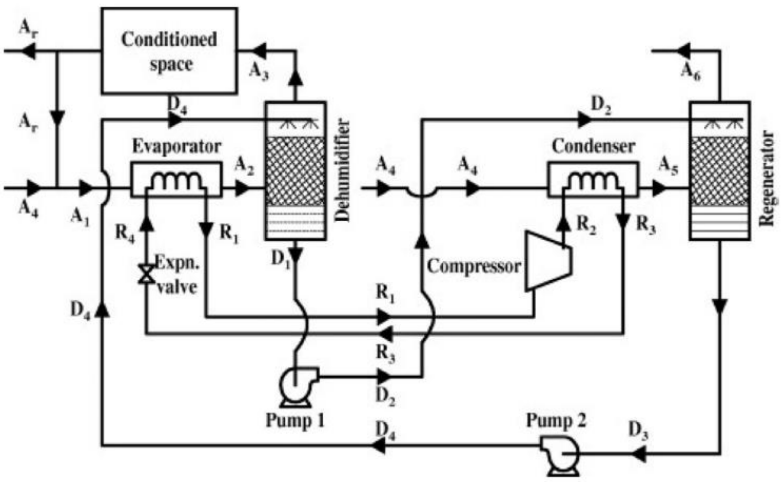

Figure 2.1: Schematic diagram of vapor compression system combined with liquid desiccant dehumidifier.

Source: (Mohan et al, 2008)

2.2.2 Liquid Desiccant Air Conditioning (LDAC)

A liquid desiccant air-conditioning system uses a liquid desiccant substance to remove moisture and latent temperatures from process air which consist regenerator and dehumidifier as shown in Figure 2.2 below. Liquid desiccant air conditioning minimizes the need for electrical energy while increasing the need for thermal energy to replenish the desiccant solution. This thermal energy is obtained from waste (process), solar, internal combustion engine, gas or oil-fired, waste heat, or fuel cell heat. (Elmer et al., 2017)

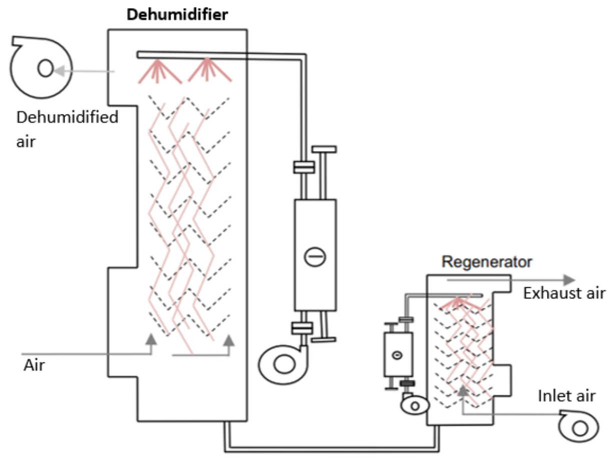

Figure 2.2: Liquid desiccant system.

(Source: R. Narayanan et al., 2017)

To limit the amount of external heating and cooling necessary, designs often incorporate a counterblow heat exchanger between the absorber and the regenerator. The majority of the liquid desiccant air-conditioning market is made up of industrial units for thorough drying and applications needing precise humidity control. Commercial air-conditioning systems are becoming accessible, but have a relatively modest market share at the moment. As shown in Figure 2.2, the system is an open cycle absorption system that uses water as a refrigerant. Because of the direct contact with air, the absorbent must be nontoxic and environmentally friendly. Lithium chloride and calcium chloride are two regularly used liquid desiccants. To dehumidify the process air, it is routed via a desiccant spray in the conditioner module. To renew the desiccant, outside air is routed and through a heated desiccant spray in the regenerator module. (R. Narayanan et al., 2017)

2.2.3 Liquid Desiccant Evaporative Cooler

To provide cooling effect, an evaporative cooling system can be paired with a liquid desiccant cooling system. Cui et al. presented a compact heat and mass exchanger that could dehumidify and cool at the same time. The entering air was first dehumidified to achieve a lower relative humidity and also a larger cooling potential. After that, it was pre-cooled in the evaporative cooling channel. The effect of the working-to-intake air flow rate ratio, liquid desiccant film length, and inlet conditions