DESIGN & CONSTRUCTION OF AN EVAPORATIVE COOLING SYSTEM

A thesis

by

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JUNE 2024

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Submitted to the
DEPARTMENT OF MECHANICAL ENGINEERING
SONARGAON UNIVERSITY (SU)
In partial fulfillment of the requirements for the award of the degree
of
Bachelor of Science in Mechanical Engineering

JUNE 2024

Acknowledgement

Evaporative cooling works on the principle that converting water to a gas requires energy. This energy is taken from the air as heat and the process thereby cools the air as it extracts heat. This is called enthalpy which is the measurement of energy in a thermodynamic system

Abstract

This paper reported a review based study into the Indirect Evaporative Cooling (IEC) technology, which was undertaken from a variety of aspects including background, history, current status, concept, standardisation, system configuration, operational mode, research and industrialisation, market prospect and barriers, as well as the future focuses on R&D and commercialisation. This review work indicated that the IEC technology has potential to be an alternative to conventional mechanical vapour compression refrigeration systems to take up the air conditioning duty for buildings. Owing to the continuous progress in technology innovation, particularly the M-cycle development and associated heat and mass transfer and material optimisation, the IEC systems have obtained significantly enhanced cooling performance over those the decade ago, with the wet-bulb effectiveness of greater than 90% and energy efficiency ratio (EER) up to 80. Structure of the IEC heat and mass exchanger varied from flat-plate-stack, tube, heat pipe and potentially wave-form. Materials used for making the exchanger elements (plate/tube) included fibre sheet with the single side water proofing, aluminium plate/tube with single side wicked setting (grooved, meshed, toughed etc), and ceramic plate/tube with single side water proofing. Counter-current water flow relevant to the primary air is considered the favourite choice; good distribution of the water stream across the wet surface of the exchanger plate (tube) and adequate (matching up the evaporation) control of the water flow rate are critical to achieving the expected system performance.

Chapter 1

Introduction

1.1 General

This research is based on the evaporative cooling where hot dry air can be passed through evaporative pad, get cooled and then be blown to a building space as illustrate. Simple evaporative cooling process provides cooling effect by adiabatic evaporation of water. The process can be demonstrated. In this example air at 30oC dry-bulb temperature and 20% RH passed through an evaporative cooling media making its state to change to a dry-bulb temperature of 18oC and 79% RH. That is lowering the temperature but increasing the relative humidity (RH).

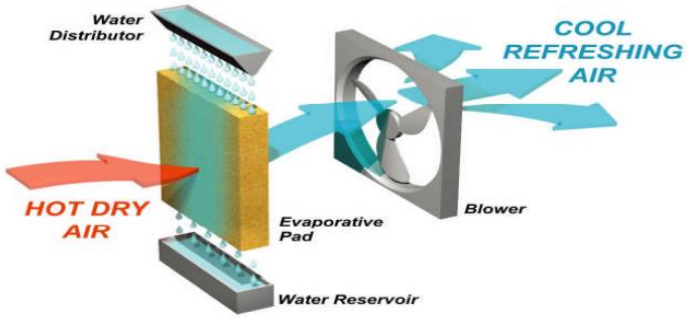


Figure 1.1: Basic evaporative cooling processes

In this research several novel evaporative cooling devices suitable for building cooling have been identified. These consist of direct evaporative cooling using porous ceramics; porous ceramics integrated with thermoelectric cooler and also indirect cellulose fibre (paper) tubes novel evaporative cooling systems. This chapter briefly outlines these novel evaporative cooling systems, the reasons for undertaking the research and the relevance to potential users.

1.2 Background Study

World energy consumption pattern showed that fossil fuels including oil, coal and gas are being consumed significantly higher than the environmentally friendly renewable energy sources as shown in Figure 1-1. This will result in increased CO2 emission to the environment and subsequent climate change. Similarly the historical and projected share of primary world energy consumption represented in Figure 1-2(a) indicated continuous dominance on oil, gas and coal (International Energy Outlook, 2000). However, renewable energies which represent very small amount of the world energy consumption are receiving attention because of the falling trend in their costs as shown in Figure 1.2b and are also friendlier to the environment (TCS, 2007). Therefore in 1992 at the Environment and Development (UNCED, 1992) conference in Rio de Janeiro the European Union committed itself to stabilising and then reducing carbon dioxide (CO2) and CFCs emissions into the environment. Chapter 1: Introduction - 2 - Majority of the energy consumption in building for cooling or heating is derived from fossil fuels. It is therefore very vital to provide a less energy intensive system for space cooling which will replace or minimise dependency on the conventional vapour compression air conditioning systems. Usually buildings in hot climates are continuously heated by the sun and dry winds during the day time as shown in Figure 1.3. Therefore the wall mass acts as a heat storage medium emitting heat to the interior making the entire space warm and uncomfortable up to late evening periods. Evaporative cooling is one method of simulating natural cooling effects commonly experienced at or near seas and lakes during warm periods of the day (Figure 1.4) and the same technique have long been realised to be used for the cooling of buildings. The evaporative cooling system can be integrated with a heat transfer unit such as thermo electrics or heat pipes to make the application of the system more flexible for either cooling with humidification or cooling without humidification. It can also be used as a heat sink to other cooling devices such as thermoelectric system. This research will deal with several novel evaporative cooling methods and their applications to provide comfortable cooling for building space. It will involve mathematical modelling and experimental investigation of the above mentioned evaporative cooling methods. These are novel evaporative cooling systems using porous ceramics and the porous ceramics-cum-thermoelectric cooling system. Then paper fibre horizontal tubes evaporative cooling system was developed. The proposed systems can be interchanged to be suitable for cooling with humidification or cooling without humidification.

1.3 Problem Statment

Traditional air conditioning systems consume significant energy and contribute to environmental issues due to their reliance on refrigerants. Evaporative cooling offers an eco-friendly alternative by utilizing the natural process of water evaporation to reduce air temperature. This system will use a DC fan to draw warm air through an evaporative pad moistened with water from a tank, resulting in cooler air being circulated in the desired space.
Water Management: Ensuring a continuous and sufficient water supply to keep the evaporative pad wet.
Energy Efficiency: Optimizing the system to minimize power consumption while maximizing cooling effectiveness.
System Durability: Designing components to withstand prolonged exposure to water and environmental conditions.
Temperature Control: Achieving consistent and controllable cooling based on environmental variables.

The system will be developed for small to medium-sized indoor or outdoor spaces. The solution should be scalable, with the potential to integrate additional sensors for monitoring temperature and humidity, as well as IoT capabilities for remote control and monitoring. The project aims to deliver a functional evaporative cooling system that reduces air temperature efficiently, operates on low power, and offers an environmentally friendly cooling solution for residential, commercial, or industrial applications.

1.4 Objectives

1- To design an evaporative cooling system.
2- To construct and test the performance of the evaporative cooling system.

1.5 Project Organization

The report has been organized into five chapters.

Chapter 1: Discusses introduction, Background and objectives.

Chapter 2 : Description about theoretical issues.

Chapter 3 : Description of circuit elements, such as Circuit diagram, Block Diagram, Working Procedure etc.

Chapter 4: Description of result, Advantages, Limitations, Applications & Discussion.

Chapter 5: Finally, we discussed here the Conclusion and future works.

Chapter 2

Theory Of The Project

2.1

This chapter includes the total over view of the device. In this chapter we have followed-up the theory of Cooling Pad, Water Pump, Water Tank, Pipe, Metal Angle, Sun Board, 12V DC Fan, SMPS, Node MCU, LCD Display, DHT11, DS18B20, Vero board, and other components. Here we can know that the total system overview of the projects. And we will also know that how the equipment are working with each other.

2.2.1 Cooling Pad

A metal cooling pad is a type of heat exchanger used in evaporative cooling systems. It is designed to facilitate the evaporation of water to cool down air passing through it. Unlike traditional cooling pads made from materials like cellulose or synthetic fibers, metal cooling pads are constructed from metals such as aluminum, stainless steel, or galvanized steel. These metal pads have several unique properties and advantages that make them suitable for specific applications.



Figure 2.1: Cooling Pad

2.2.2 Water Pump

12 Volt water pump is a dc electric water pump motor that powered by a 12V direct current power supply. It use centrifugal force that generated by high speed rotated impeller to booster, transfer, lift or circulate liquids like water, oil, coolant for sprayers, car, fountain, shower, garden etc.



Figure 2.2: Water Pump

2.2.3 Water Tank

A water tank is a container for storing water, for many applications, drinking water, irrigation, fire suppression, farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other uses. Water tank parameters include the general design of the tank, and choice of construction materials, linings. Various materials are used for making a water tank: plastics (polyethylene, polypropylene), fiberglass, concrete, stone, steel (welded or bolted,[citation needed] carbon, or stainless). Earthen pots, such as matki used in South Asia, can also be used for water storage. Water tanks are an efficient way to help developing countries to store clean water.



Figure 2.3: Water Tank

2.2.4 Plastic Pipe

A plastic hose pipe for a water pump is a flexible, cylindrical conduit used to transport water from one location to another. These hoses are commonly used in conjunction with water pumps to direct the flow of water for various purposes, including irrigation, drainage, cooling systems, and household water supply. They are made from various types of plastic materials and come in a range of sizes, strengths, and configurations to suit different applications.



Figure 2.4: Pipe

2.2.5 Iron Angle

Steel angle (also known as angle iron) is one of the world's most-used steel structural shapes due to its 90° L-shape and functional mechanical properties. Angle iron can be manufactured in steel and metal alloys in smaller bar and larger L-shape sizes.



Figure 2.5: Iron Angle

2.2.6 Sun Bard

PVC Sunboards are Rigid PVC Sheets manufactured using foaming agent to foam the PVC Sheets. "Sunboard" is our brand. This brand's popularity has made people remember the product has SunBoard Sheets. These sheets are extruded from Virgin grade PVC granules using Italian machines.

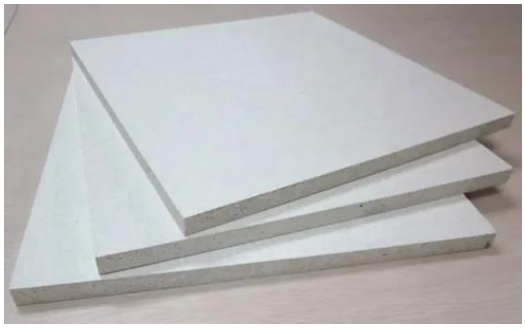


Figure 2.6: Sun Board

2.2.7 12V DC Motor with Fan

12 volt DC motor is a rotary motor which can convert the direct current into mechanical energy or convert mechanical energy into DC power. It means that the 12 volt DC motor can interconvert electric energy and mechanical energy. When it is operated as a DC motor, electric energy is converted into mechanical energy.



Figure 2.7: DC Motor With Fan

2.2.8 Node MCU

NodeMCU is an open-source firmware, hardware, and software development environment project developed initially for the Node MCU ESP8266 Wi-fi SoC chip based on LUA. The most spectacular features are: It is a low-cost, small, and powerful board.



Fig: 2.8 Node MCU

2.2.9 SMPS

Switched-mode power supplies (SMPS), sometimes referred to as switch mode power supplies, have become the workhorse of efficient power conversion, taking a mains voltage AC input and converting it down to a low voltage DC output.



Fig: 2.9 SMPS

2.2.10 LCD Display

The I2C LCD component is used in applications that require a visual or textual display. This component is also used where a character display is needed but seven consecutive GPIOs on a single GPIO port are not possible. In cases where the project already includes an I2C master, no additional GPIO pins are required.



Fig: 2.10: LCD Display

2.2.11 DHT11 – Temperature Sensor

The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin (no analog input pins needed).

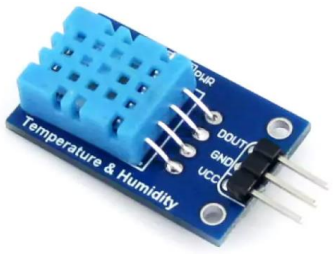


Figure 2.11: Temperature Sensor

2.2.12 DS18B20 – Temperature Sensor

DS18B20 - Programmable Resolution 1-Wire Digital Thermometer. Page 1. General Description. The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points.



Figure 2.12: DS18B20 – Temperature Sensor

Chapter 3

Methology

3.1 Block Diagram

In this Part of disscusion we will descrive about the block diagram of our system. Here you see that, we use here a Node MCU as a microcontroller to control this total system. Here We provide AC 220V power to 12v SMPS, it will provide 12V DC and then it will be converted to 5V DC voltage using a Buck Converter.

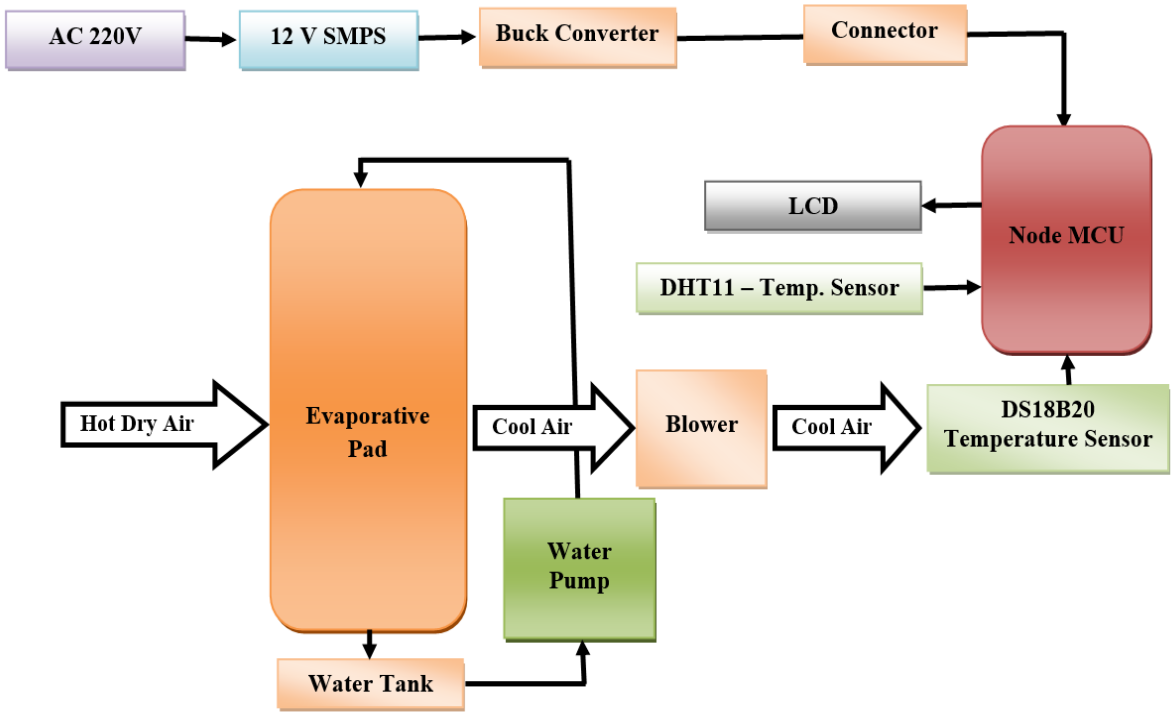


Fig: 3.1: Block diagram of Proposed System

This 5V DC power will be distributed to all components to run this system. we use here a 12V DC Water Pump to recycling water from water Tank to upper side of Evaporative Pad again and again . One 12V DC motor is used here to Blowing air from Evaporative Pad side to room side. To Read the temperature of this cool water we use here a water Proof Temperature sensor Named DS18B20. This Temperature will be read by using a node MCU and it will show in our LCD Display. LCD is used here to show all the operation output for manually monitoring. Here One another temperature sensor also used here to read the Natural Temperature of air. By seeing this both Temperature we can define that how much temperature are reduced by using our proposed system.

3.2 Circuit Diagram

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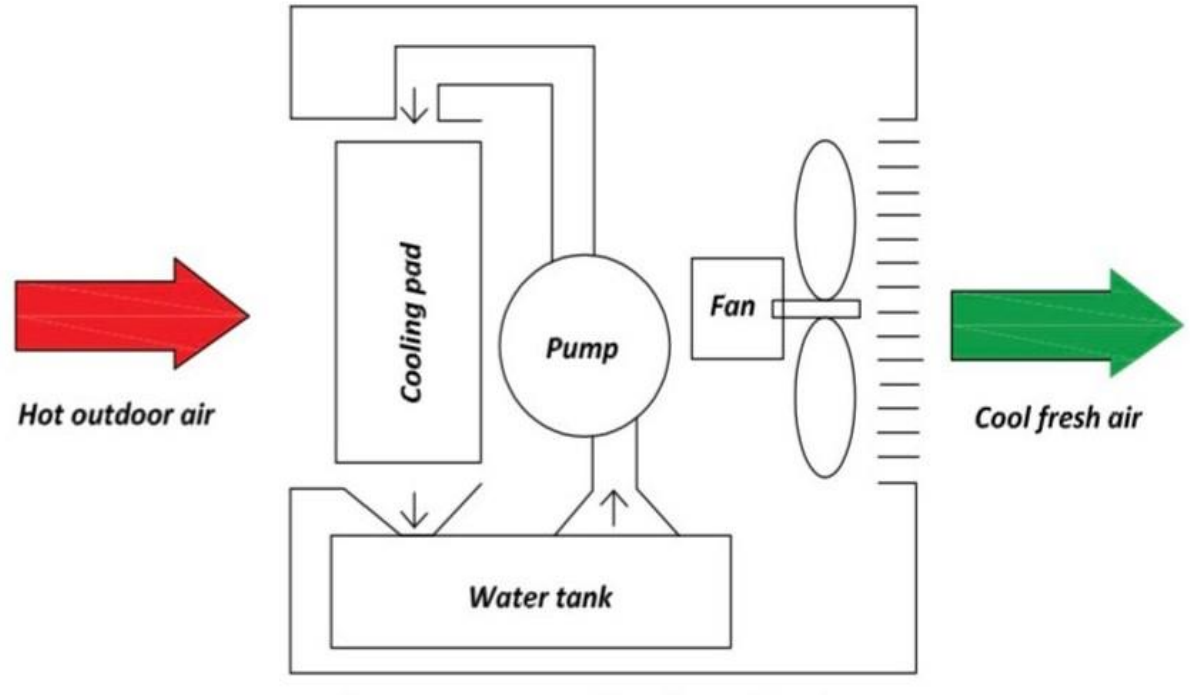


Fig: 3.2: Circuit diagram of Proposed System

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3.3 Project Overview

This is the full over view of our project. First of all we design here a metal frame then we set our all components and after that we covered total frame by using Sun Board. we use here a Node MCU as a microcontroller to control this total system. Here We provide AC 220V power to 12v SMPS, it will provide 12V DC and then it will be converted to 5V DC voltage using a Buck Converter.

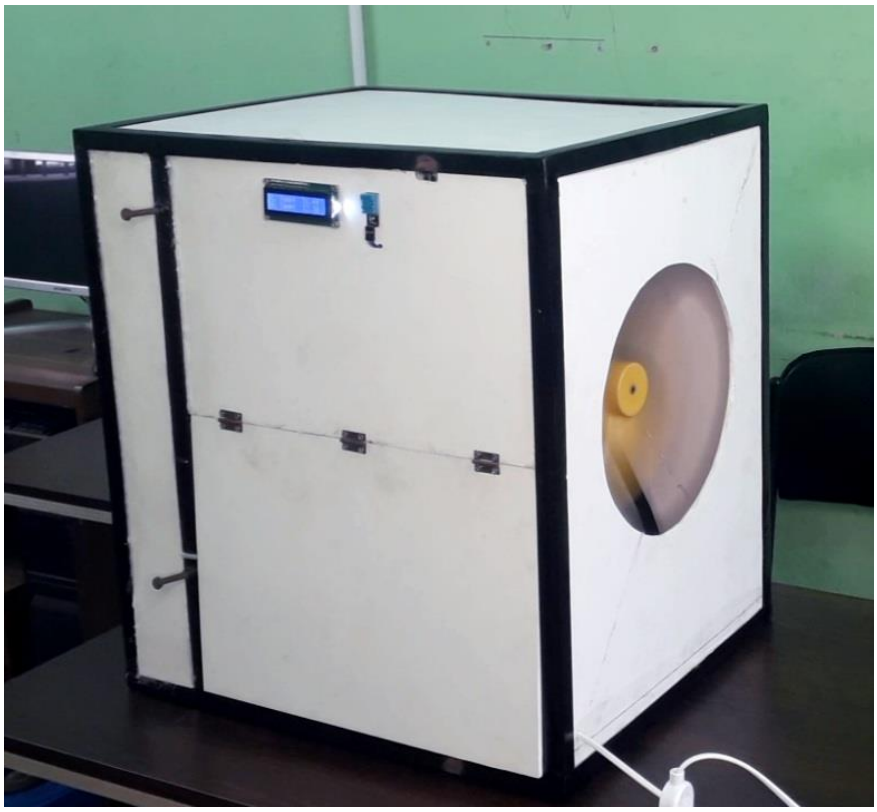


Fig: 3.3: Overview of Proposed System

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3.4 Working Principle

We provide here the total working procedure of our proposed system. Here you see that, we use here a Node MCU as a microcontroller to control this total system. Here We provide AC 220V power to 12v SMPS, it will provide 12V DC and then it will be converted to 5V DC voltage using a Buck Converter. This 5V DC power will be distributed to all components to run this system. we use here a 12V DC Water Pump to recycling water from water Tank to upper side of Evaporative Pad again and again . One 12V DC motor is used here to Blowing air from Evaporative Pad side to room side. To Read the temperature of this cool water we use here a water Proof Temperature sensor Named DS18B20. This Temperature will be read by using a node MCU and it will show in our LCD Display. LCD is used here to show all the operation output for manually monitoring. Here One another temperature sensor also used here to read the Natural Temperature of air. By seeing this both Temperature we can define that how much temperature are reduced by using our proposed system.

Chapter 4

Result & Discussion

4.1 Result

Here we will try to show the results of our project.

Data Table													
Minute	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Temp. Input	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**	**32.21**
Temp. Output	**32.21**	**30.83**	**29.51**	**28.49**	**28.01**	**27.29**	**27.02**	**26.83**	**26.58**	**26.30**	**26.30**	**26.30**	**26.30**

4.2 COP

$COP\ for\ 5\ min,\ \frac{T2}{T1-T2}\ ,\ = \frac{30.83}{32.21-30.83}\ ,\ = 22.34$

$COP\ for\ 10\ min,\ \frac{T2}{T1-T2}\ ,\ = \frac{29.51}{32.21-29.51}\ ,\ = 10.92$

$COP\ for\ 15\ min,\ \frac{T2}{T1-T2}\ ,\ = \frac{28.49}{32.21-28.49}\ ,\ = 7.65$

$COP\ for\ 20\ min,\ \frac{T2}{T1-T2}\ ,\ = \frac{28.01}{32.21-28.01}\ ,\ = 6.97$

$COP\ for\ 25\ min,\ \frac{T2}{T1-T2}\ ,\ = \frac{27.29}{32.21-27.29}\ ,\ = 5.55$

$COP\ for\ 30\ min,\ \frac{T2}{T1-T2}\ ,\ = \frac{27.02}{32.21-27.02}\ ,\ = 5.20$

$COP\ for\ 35\ min,\ \frac{T2}{T1-T2}\ ,\ = \frac{26.83}{32.21-26.83}\ ,\ = 4.99$

$COP\ for\ 40\ min,\ \frac{T2}{T1-T2}\ ,\ = \frac{26.58}{32.21-26.58}\ ,\ = 4.77$

$COP\ for\ 45\ \text{min},\ \frac{T2}{T1-T2}\ ,\ = \frac{26.30}{32.21-26.30}\ ,\ = 4.45$

$COP\ for\ 50\ \text{min},\ \frac{T2}{T1-T2}\ ,\ = \frac{26.30}{32.21-26.30}\ ,\ = 4.45$

$COP\ for\ 55\ \text{min},\ \frac{T2}{T1-T2}\ ,\ = \frac{26.30}{32.21-26.30}\ ,\ = 4.45$

$COP\ for\ 55\ \text{min},\ \frac{T2}{T1-T2}\ ,\ = \frac{26.30}{32.21-26.30}\ ,\ = 4.45$

4.2 Advantags

Evaporator cooling systems, particularly those using the principles of evaporative cooling, offer several distinct advantages over traditional refrigeration and air conditioning systems. These advantages make them especially suitable for certain climates and applications. Here's a detailed look at the key benefits:

Energy Efficiency:

- Low Power Consumption: Evaporator cooling systems consume significantly less electricity compared to traditional air conditioning systems. They primarily use power for running fans and water pumps, which are much less energy-intensive than compressors in air conditioners.
- Cost-Effective Operation: Due to their lower energy requirements, they reduce operational costs, making them an economical choice for continuous cooling needs.

Environmental Benefits:

- No Refrigerants: Evaporator cooling systems do not use refrigerants, which are often greenhouse gases with high global warming potential (GWP). This makes them more environmentally friendly.
- Low Carbon Footprint: The reduced energy consumption leads to lower greenhouse gas emissions, contributing to a smaller carbon footprint.

Low Installation and Maintenance Costs:

- Affordable Installation: The initial installation cost is often lower than that of traditional air conditioning systems, especially for large-scale applications.
- Easy Maintenance: Maintenance is straightforward, often involving routine cleaning and occasional replacement of parts like cooling pads. This simplicity reduces maintenance costs and downtime.

Air Quality Improvement:

- Filtration and Fresh Air: Many evaporative coolers draw in fresh outdoor air, which passes through water-saturated pads that act as filters, trapping dust, pollen, and other particulates. This can improve indoor air quality compared to recirculating systems that might accumulate and redistribute contaminants.

- Cooling with Fresh Air: They continuously supply fresh, cooled air instead of recirculating indoor air, reducing the buildup of indoor pollutants.

Comfort and Health Benefits:

- Reduced Air Dryness: Unlike conventional air conditioners that often dry out the air, evaporative coolers increase humidity levels, which can alleviate discomfort caused by dry air, such as dry skin and respiratory issues.
- Evaporative Cooling Effect: The natural process of evaporative cooling provides a gentle, moist breeze, often perceived as more comfortable and refreshing compared to the dry, cold air from traditional air conditioning.

Silent Operation:

- Low Noise Levels: Many evaporator cooling systems operate quietly, especially when compared to the noise generated by compressors in traditional air conditioners. This makes them suitable for use in residential areas, offices, and other noise-sensitive environments.

4.3 Disadvantages

While evaporative cooling systems offer numerous advantages, they also have some limitations and drawbacks that should be considered. Here are the key disadvantages of evaporative cooling systems:

Limited Cooling Capacity in High Humidity:

- Temperature Constraints: They are less capable of achieving the low temperatures possible with traditional air conditioning systems, especially when humidity levels are high.

Limited Applicability:

- Not Suitable for All Climates: Their performance is optimal in hot, dry climates. In regions with high humidity or where precise and significant cooling is required, traditional air conditioning systems may be more suitable.
- Inappropriate for Enclosed Spaces: Evaporative coolers are often less effective in tightly enclosed spaces without adequate ventilation because they can raise humidity levels excessively and recycle the same air.

Seasonal Use and Limitations:

- Less Effective in Winter: These systems are primarily designed for cooling and are not effective for heating or use during cold weather. In climates with significant seasonal temperature variations, a separate heating system would be necessary.
- Dependency on External Conditions: Their performance is directly tied to outdoor temperature and humidity, which can limit their effectiveness during varying weather conditions.

4.4 Applications

Smart Evaporative cooling systems are efficient and environmentally friendly solutions that utilize the natural process of evaporation to cool air. Unlike traditional air conditioning systems, which use refrigerants and consume significant amounts of electricity, evaporative coolers are simpler and can be more cost-effective in suitable environments. Here are various applications of evaporative cooling systems across different sectors:

1. Residential Cooling
   - Homes and Apartments: Evaporative coolers are popular in homes, especially in regions with hot and dry climates. They provide a cost-effective way to maintain comfortable indoor temperatures.
   - Outdoor Spaces: They can also be used to cool patios, decks, and other outdoor areas, making them more comfortable during the summer.

2. Commercial and Industrial Cooling
   - Warehouses and Factories: These environments often generate a lot of heat from machinery and processes. Evaporative coolers can help maintain a safe and comfortable working environment.
   - Greenhouses: By maintaining lower temperatures and higher humidity, evaporative cooling systems help in providing a suitable environment for plants.

3. Agricultural Applications
   - Livestock Shelters: Cooling systems help keep livestock comfortable, reducing heat stress and improving productivity.
   - Crop Storage: Proper cooling in storage facilities can prolong the shelf life of agricultural produce by maintaining appropriate temperatures and humidity levels.

4. Automotive and Transportation
   - Vehicle Cabins: Some vehicles, especially in hot climates, use evaporative cooling to maintain comfortable cabin temperatures.
   - Transport Refrigeration: It can be used in refrigerated trucks to keep perishable goods cool during transport.

5. Climate Control in Remote and Off-Grid Areas

- Remote Buildings: In areas without reliable electricity, evaporative coolers offer an effective solution for temperature control.
- Disaster Relief Camps: They are used in temporary shelters and relief camps where quick and cost-effective cooling is needed.

Chapter 5

Conclusion

5.1 Conclusion

This In conclusion, Research and development in evaporative cooling have been going on for decades but still investigations are continuing for improvements. The technology is environmentally friendly and has the potential of minimising the dependency on hydro chlorofluorocarbons (HCFCs) and chlorofluorocarbons (CFCs) based conventional air conditioning systems. Interest in new methods and materials to find solutions to the problems associated with evaporative cooling is receiving the attention of researchers in order to make the technology more attractive. In the light of the above this research was embarked upon and investigated novel evaporative cooling systems based on direct and indirect evaporative cooling methods. The research initially carried out a review on evaporative cooling processes comprising of direct, indirect, combined direct and indirect and also desiccant based types. The review covered status and developments in evaporative cooling using porous ceramics. Theoretical studies covering the heat and mass transfer as well as psychrometric associated with evaporative cooling were presented because of their relevance in the modelling and performance evaluation of the novel evaporative cooling systems investigated. The research then focussed on the following novel evaporative cooling systems.

5.2 Future Work

The current/past R&D works and commercial activities have created significant technical advance and market development in IEC technology. These, however, also help identification of the problems, difficulties and barriers that are still in existence, which in turn stimulate the development of the forthcoming research and industrial activities.

In line with the above review-based study, future research and development activities related to the IEC may be (1) heat exchanger structure and material.

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