A Mini Project-1 Project report on

Modelling & Analysis of an Air Cooler with Dehumidification

Submitted to

Velagapudi Ramakrishna Siddhartha Engineering College, Vijayawada

In Partial fulfilment for the award of the degree of

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MECHANICAL ENGINEERING

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Acknowledgement

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DECLARATION

We are the Project associates of the entitled with "**Modelling & Analysis of an Air Cooler with Dehumidification**" here by declared that the matter embodied in this project is a genuine work, done by us and has not been submitted to any other university of the requirement of any course of study.

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Abstract

Dehumidification is a highly energy intensive process, especially in humidity conditions we felt some lack of comfort, health issues, Allergies, corrosion of components etc., To reduce this we use Dehumidifiers (Air conditioner ‘s), these gives more comfort than Humidifiers (Air Coolers) but consume more power to run and emission of CFC are highly when compared to Air Coolers.

In general, the Air Coolers give humid air it feels less comfort to human because the humid content in air absorbs latent heat from human body and human body becomes dry it feels irritation when we spend more time on Air Cooler.

We are working just overcome this humid content in air adding heat exchanger (dehumidifier) to the Air Cooler than passing of de humid air is possible.Here we Sub-cooling of air to condense out moisture using chilled water or refrigerant is the most common method for dehumidifying and designing the Air Cooler as dehumidifier and study its properties to prepare the best and economic Air Cooler which works as dehumidifier to achieve the dehumidifiers properties and comfort.

Keywords:

Humidity, Dehumidification, Latent heat, Sub-cooling, Dry bulb temperature, Relative Humudity.

Table of Contents

Introduction

An Air Cooler with a dehumidifier is a versatile appliance that provides not only cooling but also helps in reducing humidity in the air. This combination is particularly useful in areas with high humidity levels, as it helps create a more comfortable environment.

Dehumidifiers are essential appliances that play a crucial role in maintaining a comfortable and healthy indoor environment. They serve the purpose of reducing excess humidity levels in homes, offices, and various indoor spaces.

A dehumidifier is an electrical appliance designed to remove excess moisture from the air. It works by drawing in humid air, passing it over coils that cool and condense the moisture, and then releasing drier air back into the room. The collected moisture is typically stored in a container that needs periodic emptying or can be drained through a hose.

In regions having especially hot and humid climates, air-conditioning systems are essential for maintaining required human comfort. The challenge for air-conditioning systems in especially excess humid weather is to control indoor air quality (IAQ) while meeting the user's thermal comfort.

Countries with climates having high humid ambient can experience extreme temperature and humidity levels which make the correct design of air- conditioning systems vital to lower power required to produce necessary cooling.

Literature survey

G B Heimrich proposed Ice design and operation and describes the complete data and calculations on home air conditioning by the use of Ice. Gives cost, sun effect, calculated load, arrangements and type of equipment and other data in Ice design, Installation and operation of home cooling job in 1932.

R T Brizzolara proposed control methods for ice melting and describes the various methods to control the rate and uniformity of ice melting by using a tall, narrow ice chamber of size 26” x 32” x 10” using broken ice and also described about the spray system gives greater coefficient of heat transfer in Control methods for ice melting in 1932

E. C. Soares describes the best for short time loads or rapidly fluctuating loads. Utility sales to ice manufacturers offers splendid load. Suggestions as to energy required.

If cheap ice used in air conditioning, made for less than 50 KW-HR; melted with about 5 KW-HR. First cost of ice 25- 30% of mechanical system in Ice for air conditioning in 1932.

RC Stubbs describes the complete detailed description of an ice system installed in a room.it contains designing the ice tank like location, material used, say concrete tank cheaper than welded stell tank properly insulated. Duct works same as for other systems. Duct’s needed be insulated. Depends on length of time unit in operation. Blanket insulation usually cheaper than corkboard. Ice melt age reduced by exhausting spray water to the sewer at 55-degree Fahrenheit instead of 32-degree Fahrenheit and use economizer. He also described about the construction and operation air conditioning system using Ice in 1941.

Terry Mitchell describes about how the ice is used for space cooling and explains various methods of cooling air with ice i.e., water piped through coils or fins type cooler, Ice sits on top of plates and water runs down then plate, spray washer. Also describes about various ice installations in 1932.

I. J. Rocklin proposed the Portable air conditioning unit using Ice and Discusses the increasing use of portable ice coolers. Best method of air conditioning a building where no duct work present. Much cheaper than equivalent mechanical unit coolers. Illustrated diagram of a cool-clean portable air conditioning unit. Example of costs: initial and operating costs approximately one-half of mechanical costs in June, 1938.

P. R. R. Uses Ice for Cooling Passenger Trains. Lce and Refrigeration: Vol. 87, No 3, Sept. 1934, pp. 99-100. Illustrated description of ice activated type air conditioning systems installed on passenger cars of P. R. R. Describes important features of the system giving capacities of the various components.

"Air Conditioning with Ice," by **A. J. Authenreith**. Ice and Refrigeration: Vol. 83, No. 5, Nov., 1932, pp. 200-202. · Notes two types of air conditioning systems (unit and central) and methods of obtaining cool water: wells. Refrigerating machinery, ice, etc. Amount of ice required to produce a given refrigeration capacity varies with the design of the air conditioning system in which the ice is melted. Experience has shown that ice air conditioning systems use less ice than hasty calculations based on refrigeration capacity indicate. Two types of ice tanks: spray type and submerged type. Usually designed to hold one day’s supply of ice. Contrasts operating costs of ice and mechanical air conditioning installations. In the case of ice, the factors to be considered are initial cost of ice melting tank with pumps and control, fixed charges, cost of ice supplied, pump power, maintenance, and depreciation. Discusses factors in mechanical systems, and factors to be considered in determining suitability of one system over another.

“Ice Melting and Freezing Rates,” by **A. H. Willis, B. E. Short, and W. R. Woolrich**. Refrigerating Engineering: Vol. 39, No. 5, May, 1940, pp. 307-310. Apparatus and procedure of tests described; findings of tests are summarized in chart which constitutes complete statement of heat transfer situation and chief factors affecting it for conditions stated, i.e., for natural convection and block ice. Following conclusions obtained:

1. Rate of melting proportional to the heat transfer from the air to the ice, rather than the heat content of the air.
2. Rate of melting increases rapidly with increase in relative humidity.
3. Rate of melting increases rapidly with increase in air velocity. Used still air. Curves, tables, diagrams

“The Outlook for Ice in Comfort Cooling,” by **H. L. Lincoln**. Refrigerating Engineering: Vol. 33, No. 5, May, 1938, pp. 308-309. Divides ice equipment as follows:

1. Room coolers-200-300# ice ; 400-1,000 cfm fan.
2. Comfort coolers.
3. Air conditioners.

Type of year-round conditioning system using evaporative cooling in combination with ice.

“Comfort Cooling in the Research Residence at the University of Illinois,” by **A. P. Kratz and H. J. McIntire**. Refrigerating Engineering: Vol. 33, No. 1, Jan., 1937, pp. 29-39. Results of the investigation on cooling of residence by various methods. Contains results of tests on the use of ice and night air. It was found that:

1. Awnings decreased the cooling load by 32%.
2. 25% of usual cooling requirements due to condensation of the water vapor.
3. 100° F. outside temperature 72° F. inside temperature required 2 tons ice per day of 24 hours.
4. Actual load lagged behind the calculated load by 4 hours.

Contains charts, curves, diagrams of systems as installed. List of references.

Methodology

Cooling-based Dehumidification Most people are familiar with the principle of condensation. When air is chilled below its dewpoint temperature, moisture condenses on the nearest surface. The air has been dehumidified by the process of cooling and condensation. The amount of moisture removed depends on how cold the air can be chilled — the lower the temperature, the drier the air.

If the outside air is dry and cool, then circulating it without spraying water and letting out the return air can reduce humidity quickly. However, if the outside is more humid, then we need to remove the moisture from the air, which is let inside the department.

Drying the air with cooling is required when outside air is hot and humid. The air is passed over a set of cooling coils, where the moisture from the air gets condensed on the cooling coils. The cooled and dehumidified air can then be let into the working area. Some air conditioning units dry the air without cooling air. They work like normal air conditioning units except that they contain a heat exchanger which is placed between the intake and exhaust.

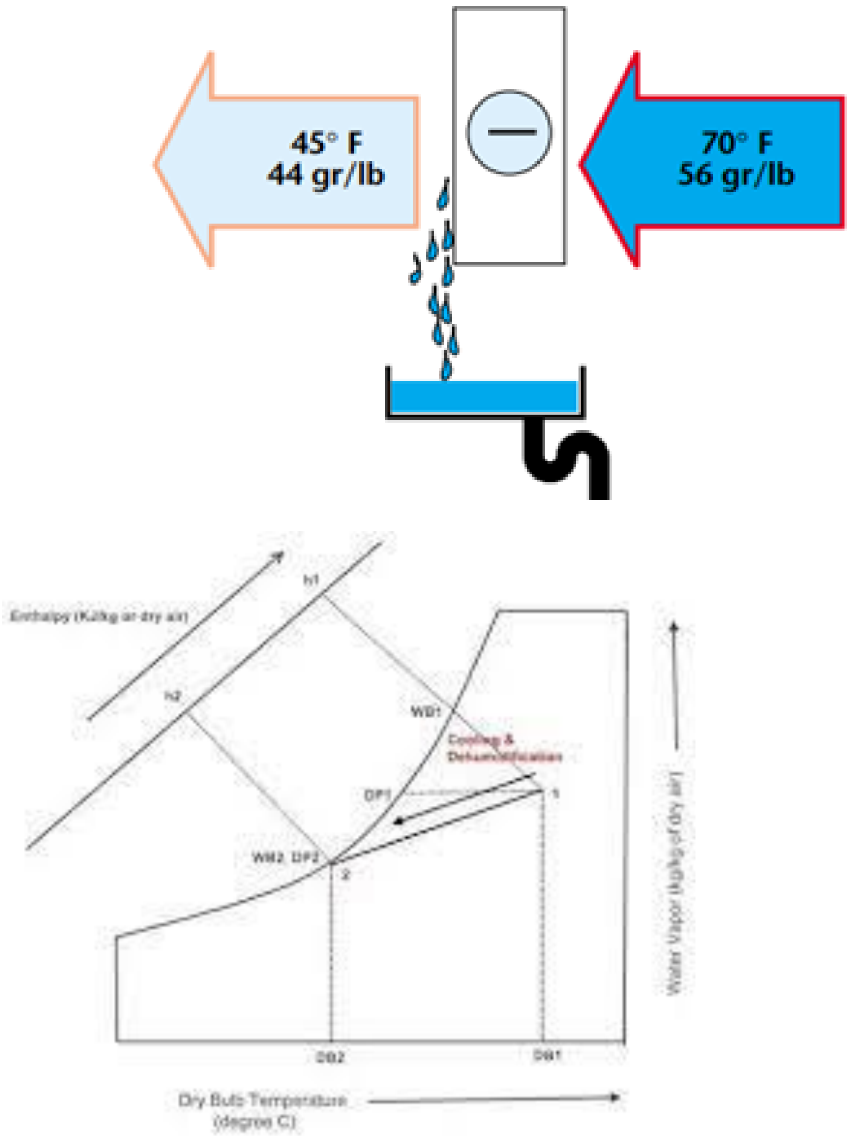


Fig -1 Cooling based Dehumidification

Extract moisture out of the air:

Fan in the moist air in the house, run it over a cold coil (Evaporator) which condenses moisture out of that air and collects the water via a drip tray into a water tank. We end up with cold but dry air.

Equipment setup:

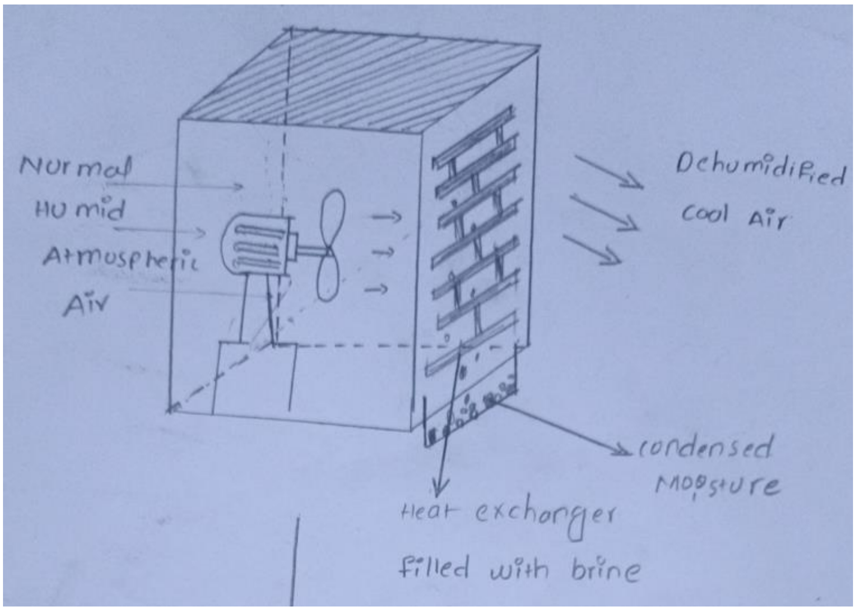
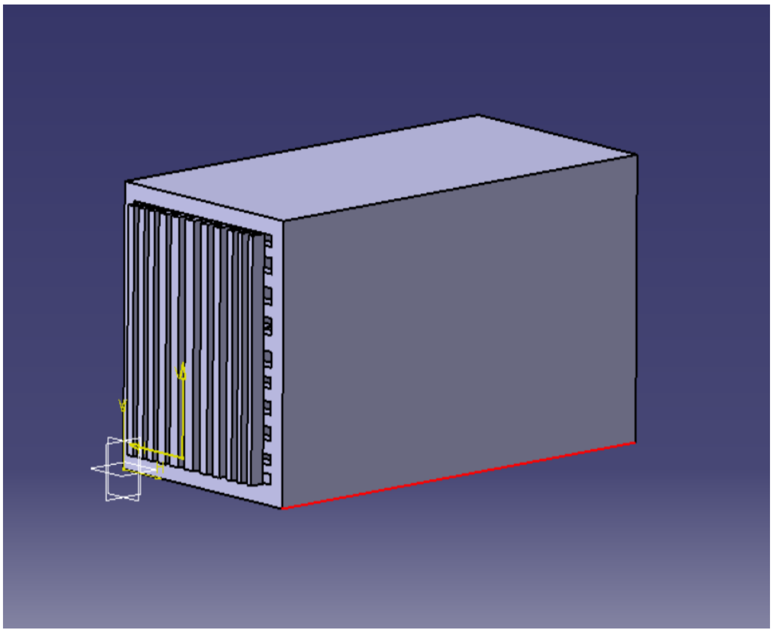


Fig-2 Equipment setup



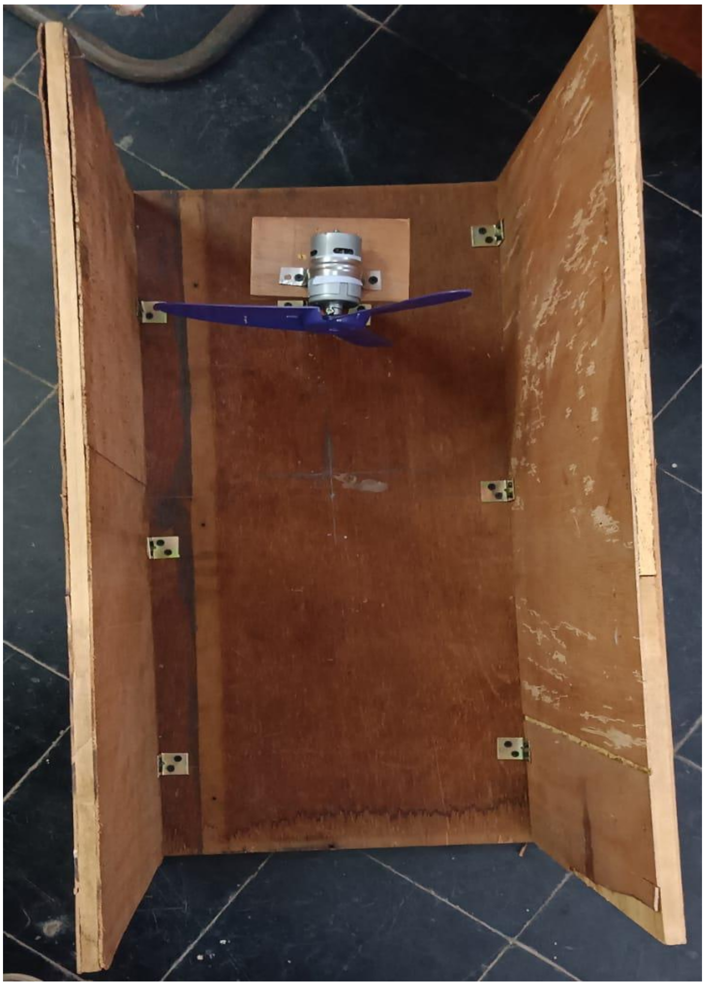


Fig-3 Fabricated model

Modification

The Air Coolers give humid air it feels less comfort to human because the humid content in air absorbs latent heat from human body and human body becomes dry it feels irritation when we spend more time on Air Cooler

By regulating voltage supply to motor to get desired velocity of air speed i.e. in between 1m/s to 10m/s .Allowing that air on to the heat exchanger i.e. Ice block or brine solution. We are working just overcome this humid content in air adding heat exchanger(dehumidifier)to the Air Cooler than passing of dehumidified air is possible.

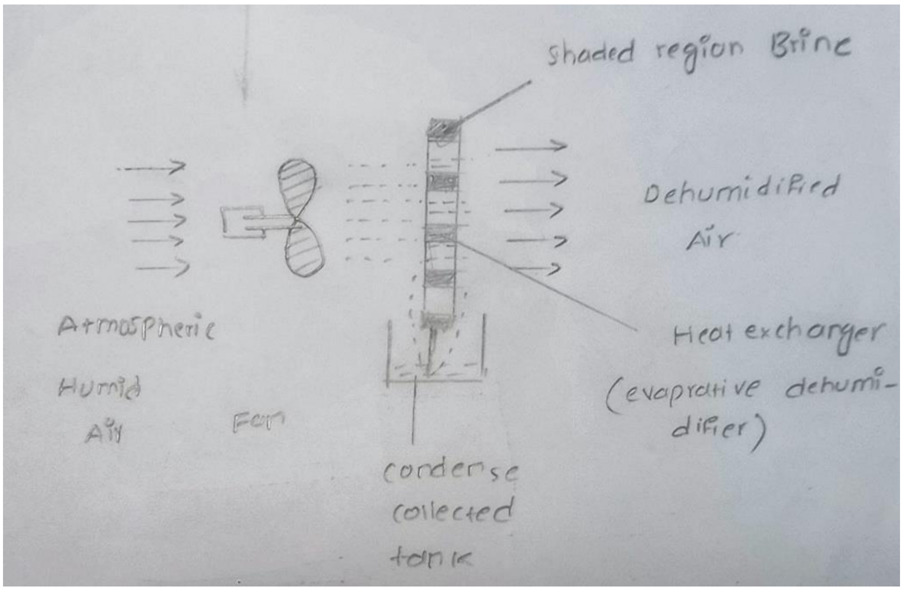


Fig 4 – Modified working operation

By modifying this equipment, we regulate the speed of motor using regulator to get desired variation in velocity of air from fan and allowing the air to pass through heat exchanger and study the thermal properties.

Components and its Working

Some major components to build this Air Cooler to achieve the dehumidifier objectives are:

a) Motor with fan
b) Voltage Regulator
c) Heat Exchanger unit
d) Thermocouples K type to measure the temperature.
e) Hygrometer

Motor with fan -

To produce the air extracting from outside environment. The specifications of motor we used here are:

Phase = Single phase

Voltage = 220V

Power = 50W

Speed = 1200rpm

Winding material = Copper

Fig -5 Motor with fan blade (internet)

Thermocouples –

Used to measure the temperature. Here we use K type thermocouple to measure the temperature. K type thermocouples are nickel-based, and therefore also have good resistance to corrosion. This makes them suitable foe use in oxidising atmosphere.

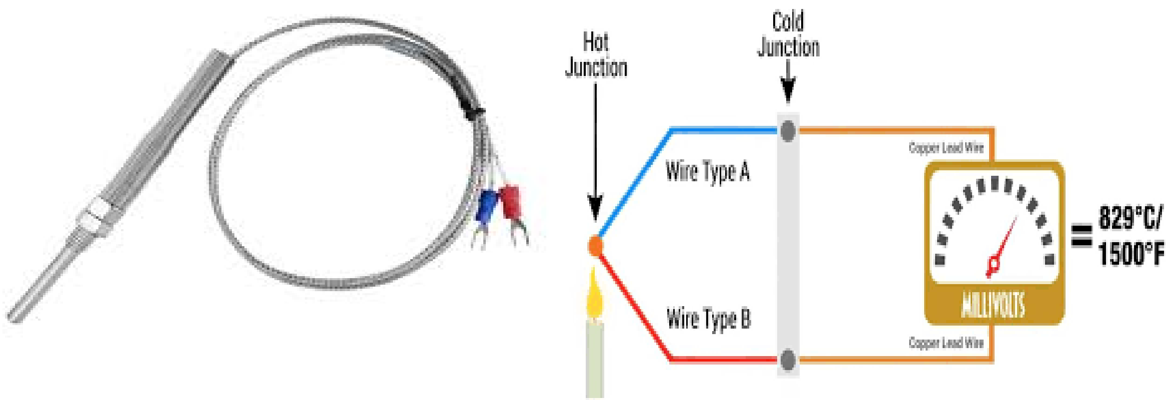


Fig-6Thermocouples K type (Internet)

Voltage regulator –

To regulate the input voltage of motor to run at desired speed to get required velocity of air. Here we use Pulse width modulation (PWM) which is a voltage regulator circuit that creates and maintains a fixed output voltage, irrespective of changes to the input voltage or load conditions.

If we switch the power on and off quickly enough, the motor will run at some speed part way between zero and full speed. This is exactly what a PWM controller does: It switches the motor on in a series of pulses. To

Control the motor speed it varies the width of the pulses. Hence Pulse Width Modulation

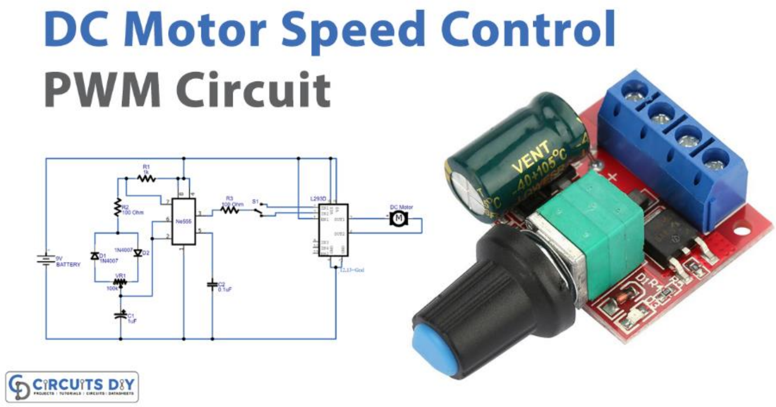


Fig – 7   PWM voltage regulator circuit diagram

Heat Exchangers —

A heat exchanger is a system used to transfer heat between a source and working fluid. Here we designed a heat exchanger, and we use the Ice blocks or jelly packs as heat exchanger to transfer the heat.

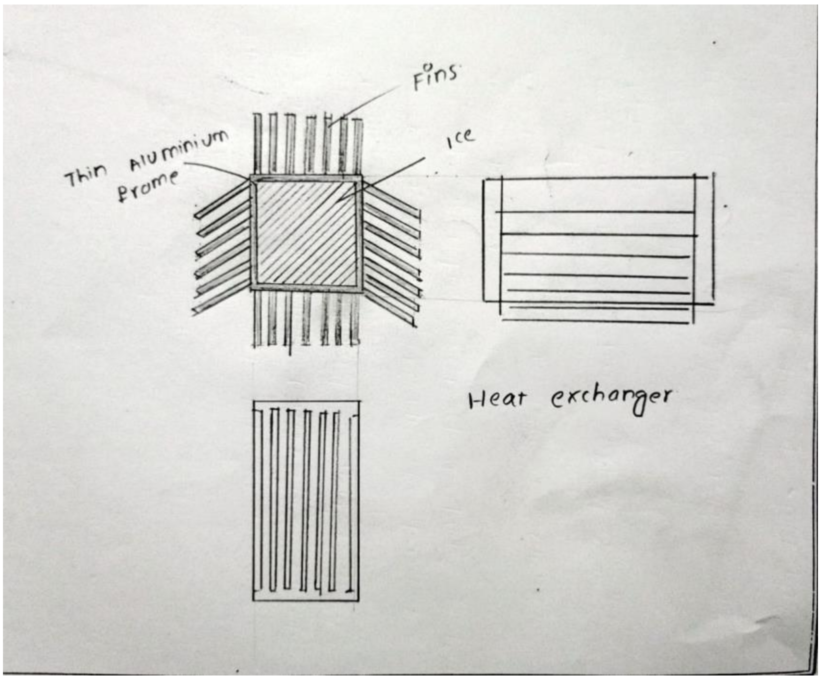


Fig – 8 Heat Exchanger (Designed)

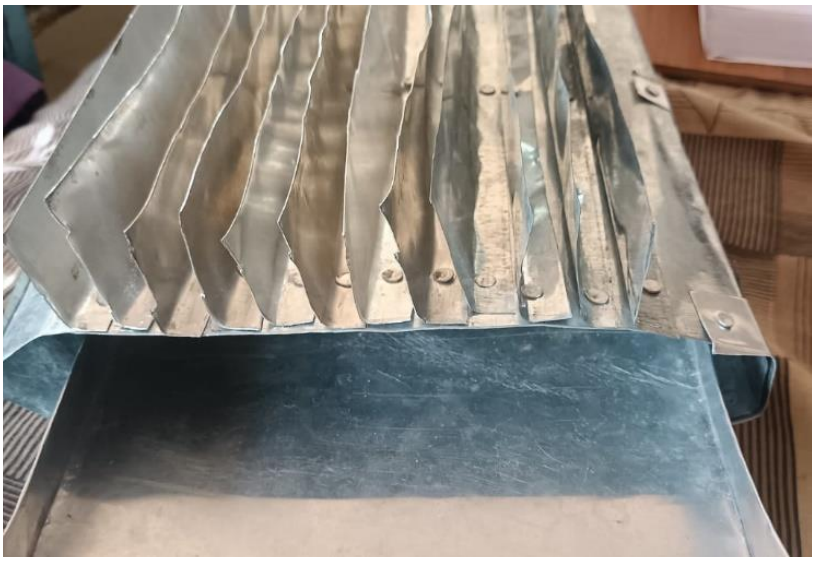


Fig – 9 Heat Exchanger (Designed) (Front view)

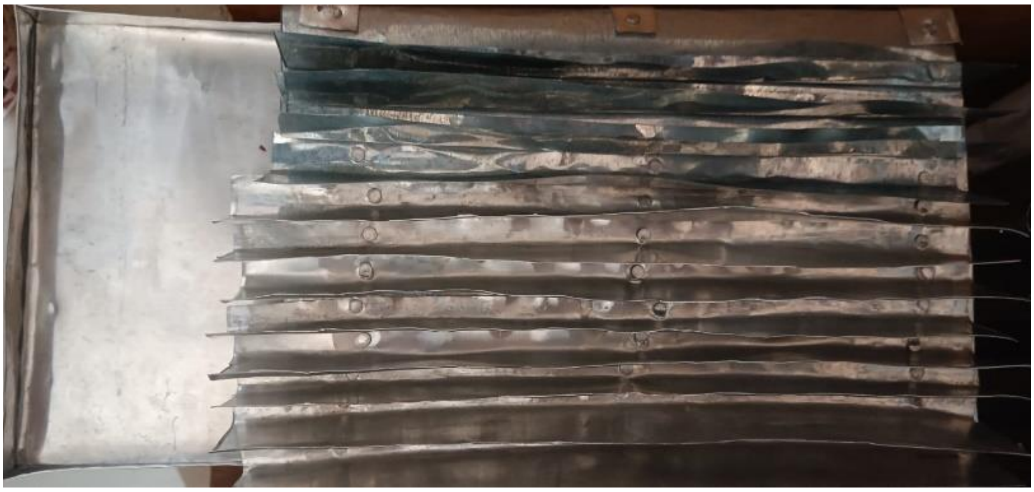


Fig – 10 Heat Exchanger (Designed) (Top View)

Hygrometer —

This device is used to measure the humidity and temperature in the workspace of the air cooler.

Fig – 11 Hygrometer

Dehumidification Load Calculation Procedure

Determining the part-load cooling moisture removal requirements involves three main steps:

1. Calculate the Dry bulb and wet bulb temperatures at inlet and outlet conditions at various wind speed using Psychometer.
2. Calculate the Relative humidity using psychometric chart.
3. Calculate the Absolute humidity and estimate the Dehumidifier capacity.

Specific humidity: It is the ratio of mass of water Vapor to the total mass of air. It is also known as Moisture content.

Absolute humidity: It is the mass of water vapor present in unit volume.

Relative humidity: It is the ratio of mass of water vapor to mass of air in saturation condition.

Saturation ratio: The maximum amount of water vapor that a parcel of air can hold without condensation.

Dry bulb temperature: It is temperature of air recorded by an ordinary thermometer when it is not affected with moisture present in air (DBT)

Sensible heat: Sensible heat is the transfer of thermal energy from warm bodies to cooler ones. Q= mc (T2-T1)

Total Heat = Sensible heat + latent heat

Sheet-1 calculation

Inlet Condition

At wind speed – 3.6m/s

Dry bulb temperature (1)	-	28.5°c
Wet bulb temperature (1)	-	23.5°c
Relative humidity (RH)	-	75%

Outlet Condition

At wind speed – 3m/s

Dry bulb temperature (1)	-	21.5°c
Wet bulb temperature (1)	-	20.5°c
Relative humidity (RH)	-	58%

Sheet-2 calculation

Inlet Condition

At wind speed – 3.2m/s

Dry bulb temperature (2)	-	30°c
Wet bulb temperature (2)	-	26°c
Relative humidity(RH)	-	89%

Outlet Condition

At wind speed – 2.5m/s

Dry bulb temperature (2)	-	23°c
Wet bulb temperature (2)	-	20°c
Relative humidity(RH)	-	54%

Sheet-3 calculation

Inlet Condition

At wind speed – 3.6m/s

Dry bulb temperature (3)	-	29.5°c
Wet bulb temperature (3)	-	26°c
Relative humidity(RH)	-	87%

Outlet Condition

At wind speed – 3.4m/s

Dry bulb temperature (3)	-	21°c
Wet bulb temperature (3)	-	22°c
Relative humidity(RH)	-	51%

Average values

Inlet Condition

Dry bulb temperature (DBT)	-	29°c
Wet bulb temperature (WBT)	-	23°c
Relative Humidity (RH)	-	83%

Outlet Condition

Dry bulb temperature (DBT)	-	22°c
Wet bulb temperature (WBT)	-	21°c
Relative Humidity (RH)	-	55%

DEHUMIDIFIER SELECTION

PARAMETER		VALUE	
ROOM TEMPERATURE (°C)		30	°C
ROOM SIZE (M)	3.5	3.5	M
	2	2	M
	2	2	M
ROOM VOLUME (M^3)----1		14	M^3

PRESENT RELATIVE HUMIDITY (RH%)	83	RH%
ABSOLUTE HUMIDITY (GRAM/M^3) -----2	26	GRAM/M^3

DESIRED RELATIVE HUMIDITY (RH%)	55	RH%
ABSOLUTE HUMIDITY (GRAM/M^3) ----3	17	GRAM/M^3

DIFFERENCE BETWEEN 2 & 3—4	9	GRAM/M^3
MULTIPLY 1 & 4 (GRAM/HR)	126	GRAM/HR
DEHUMIDIFIER CAPACITY (KG/DAY OR LIT/DAY)	5.46	KG/HR

Here We calculated Dehumidifier capacity for modelling purpose whether it is working or not. Now we are working on various air velocities which effect the human comfort by regulating humidity level and air parameters.

We are Analysing the velocity of air & RH% required to get comfort in various seasons and comparing with ASHRAE standards whether the Air cooler is working under standards or not and calculating the factors effecting the Human comfort air.

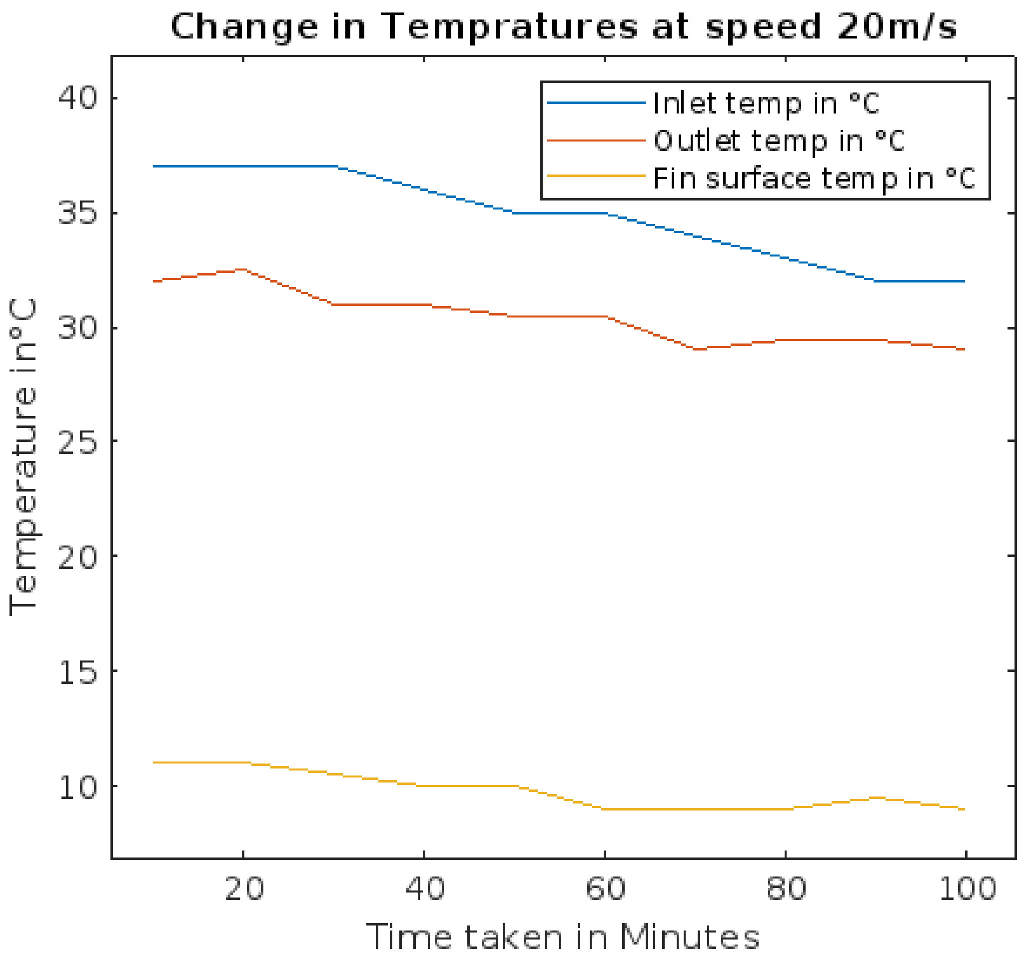


Fig – 12 Change in Temperature at Inlet, outlet and at fin surface with respect to time under forced convection at speed 20m/s

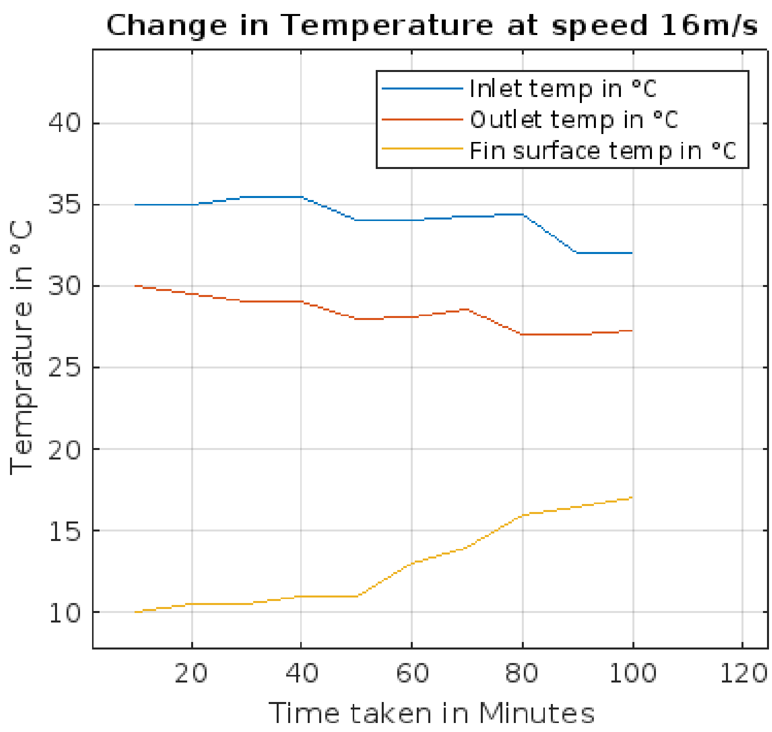


Fig – 13 Change in Temperature at Inlet, outlet and at fin surface with respect to time under forced convection at speed 16m/s

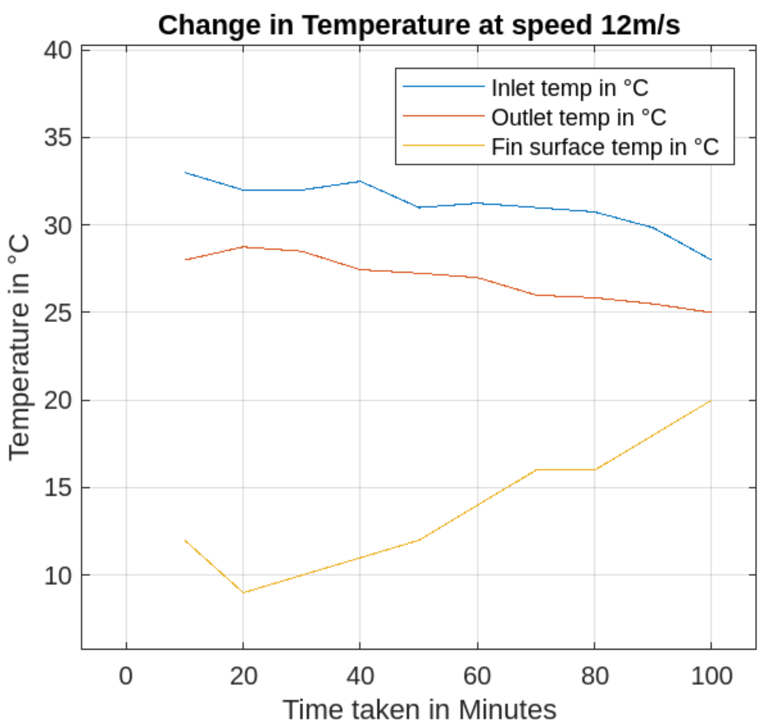


Fig – 14 Change in Temperature at Inlet, outlet and at fin surface with respect to time under forced convection at speed 12m/s

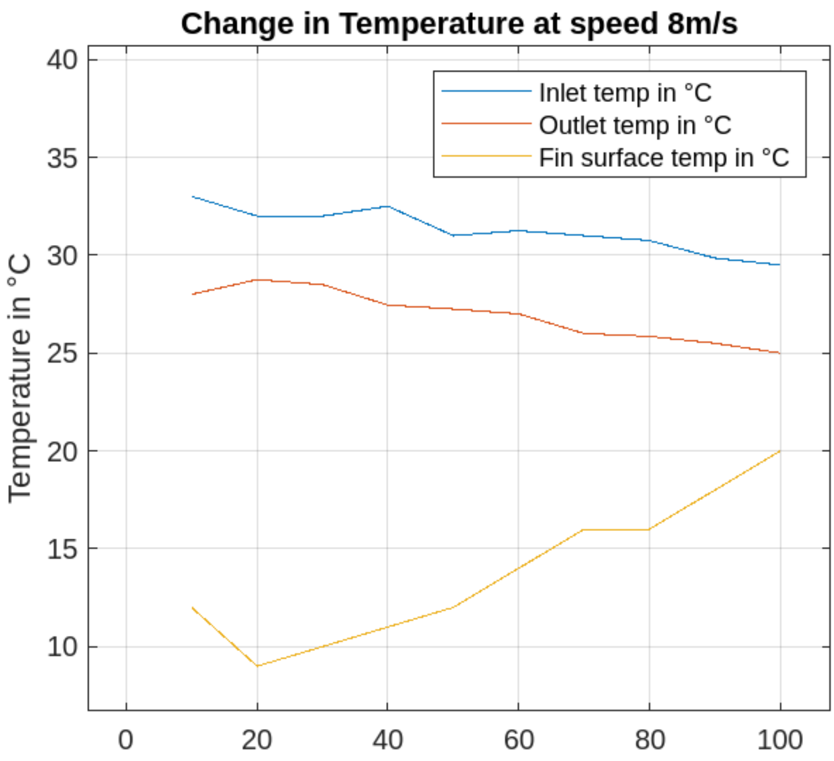


Fig – 15 Change in Temperature at Inlet, outlet and at fin surface with respect to time under forced convection at speed 8m/s

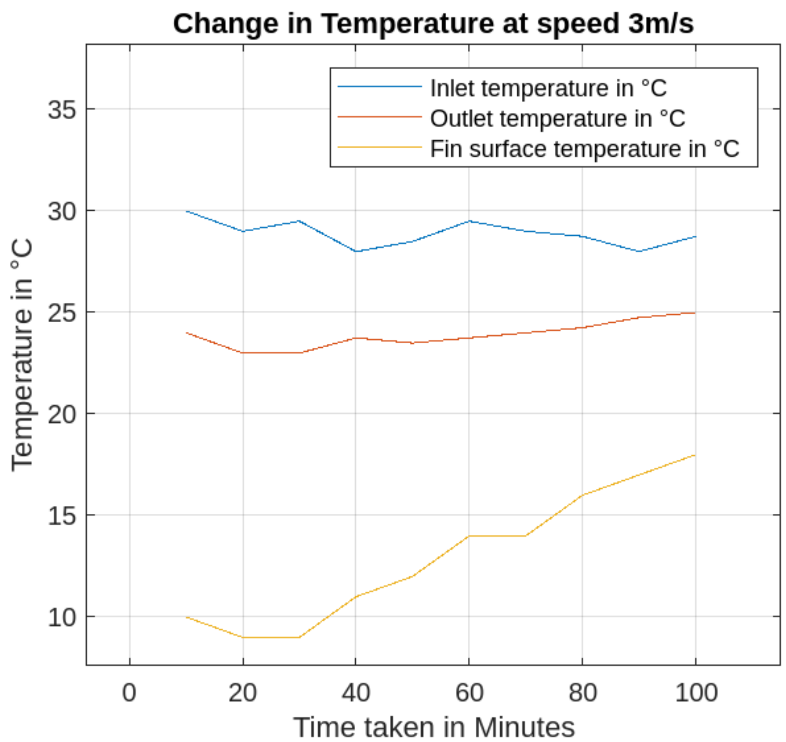


Fig – 16 Change in Temperature at Inlet, outlet and at fin surface with respect to time under forced convection at speed 3m/s

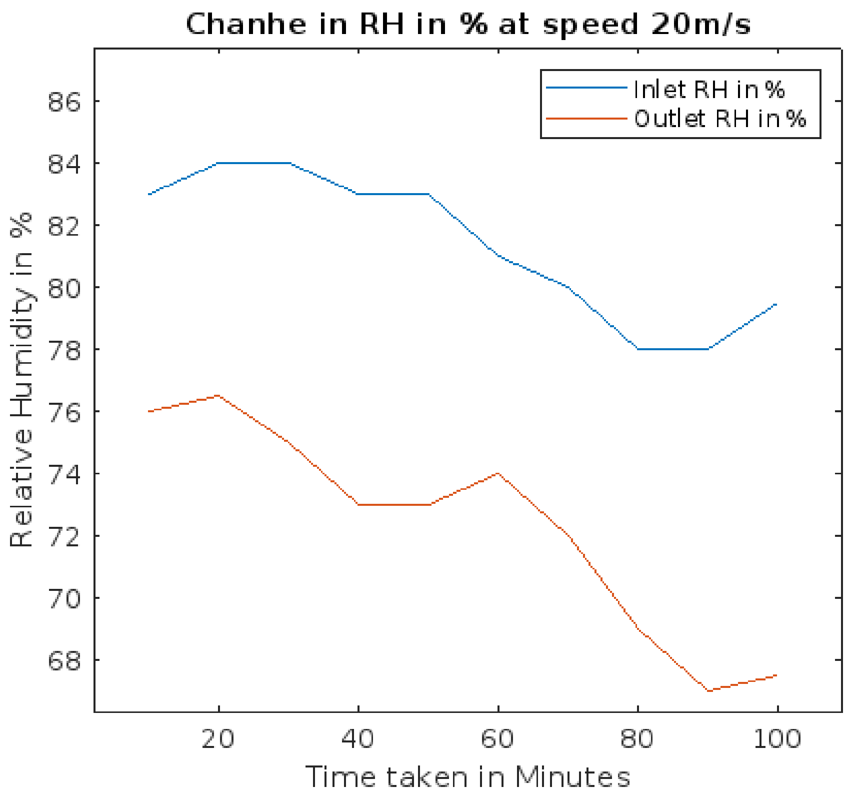


Fig – 17 Change in Relative Humidity at Inlet and outlet with respect to time under forced convection at speed 20m/s

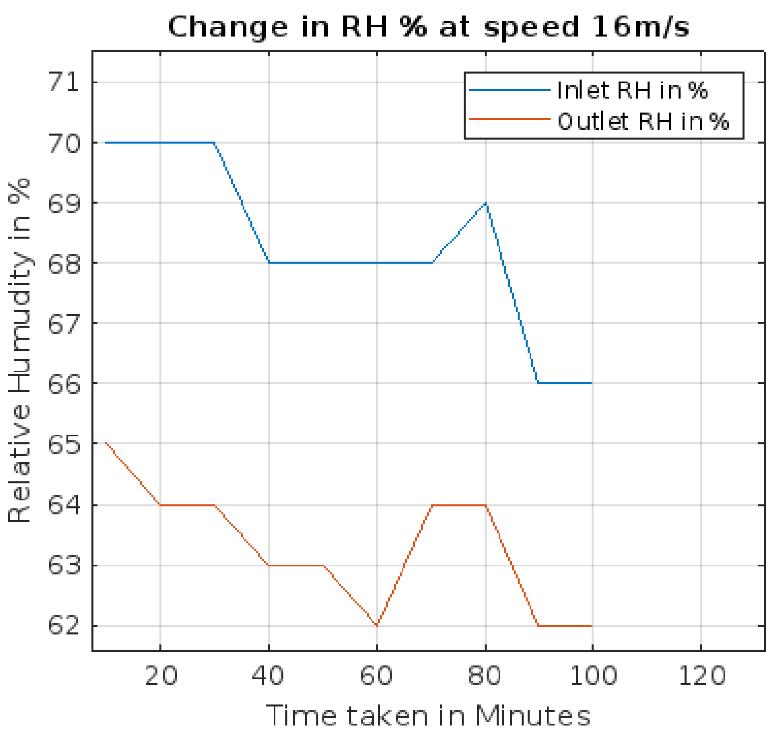


Fig – 18 Change in Relative Humidity at Inlet and outlet with respect to time under forced convection at speed 16 m/s

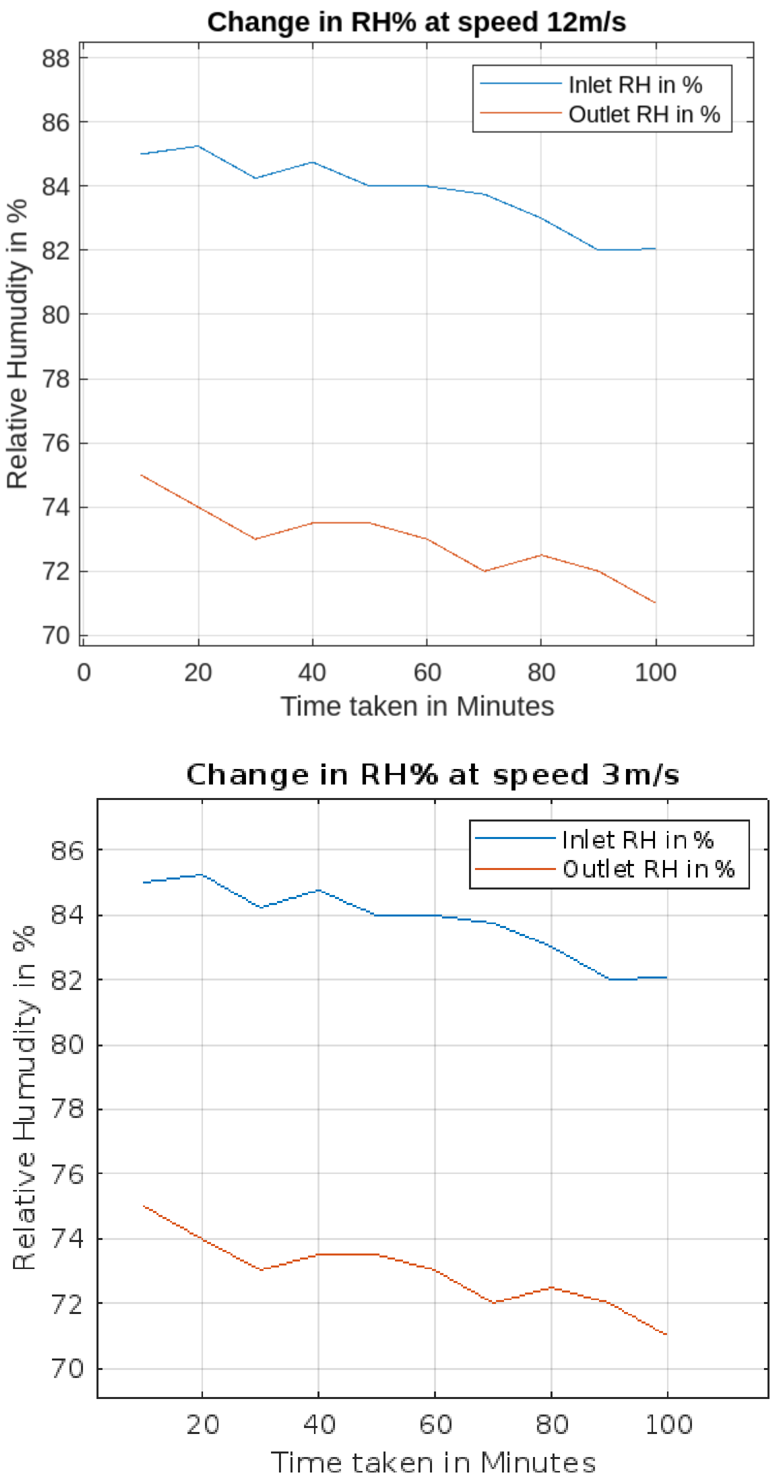


Fig – 19 Change in Relative Humidity at Inlet and outlet with respect to time under forced convection at speed 12m/s

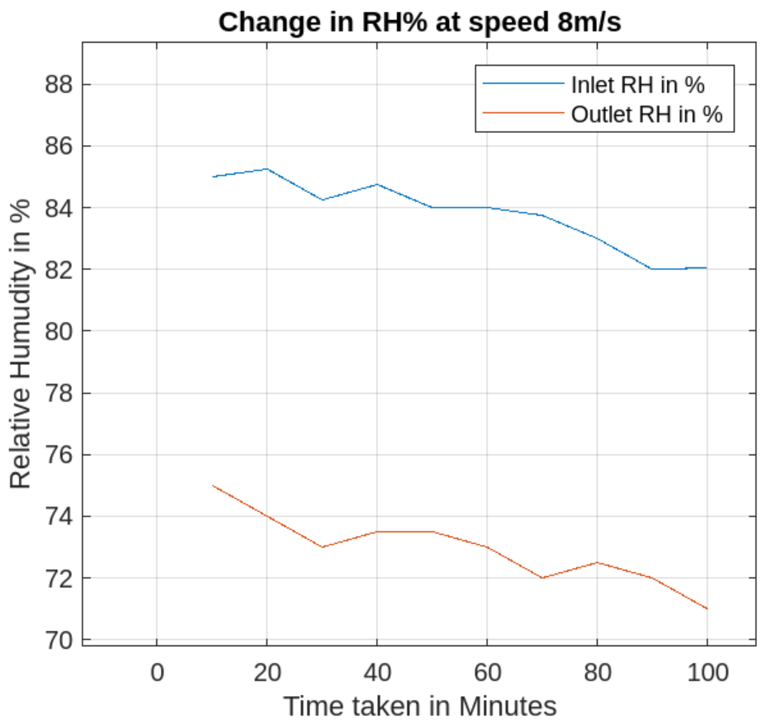


Fig – 19 Change in Relative Humidity at Inlet and outlet with respect to time under forced convection at speed 8 m/s

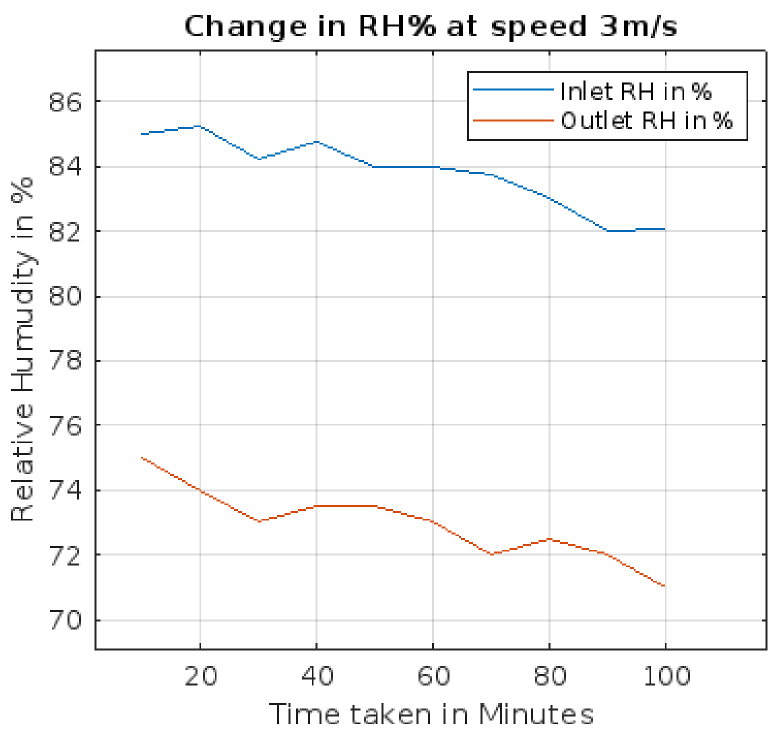


Fig – 20 Change in Relative Humidity at Inlet and outlet with respect to time under forced convection at speed 3 m/s

Standard Ice block testing under Natural Convection:

Ambient Temperature: 27°C

Initial temperature of Ice block: 0.5 °C

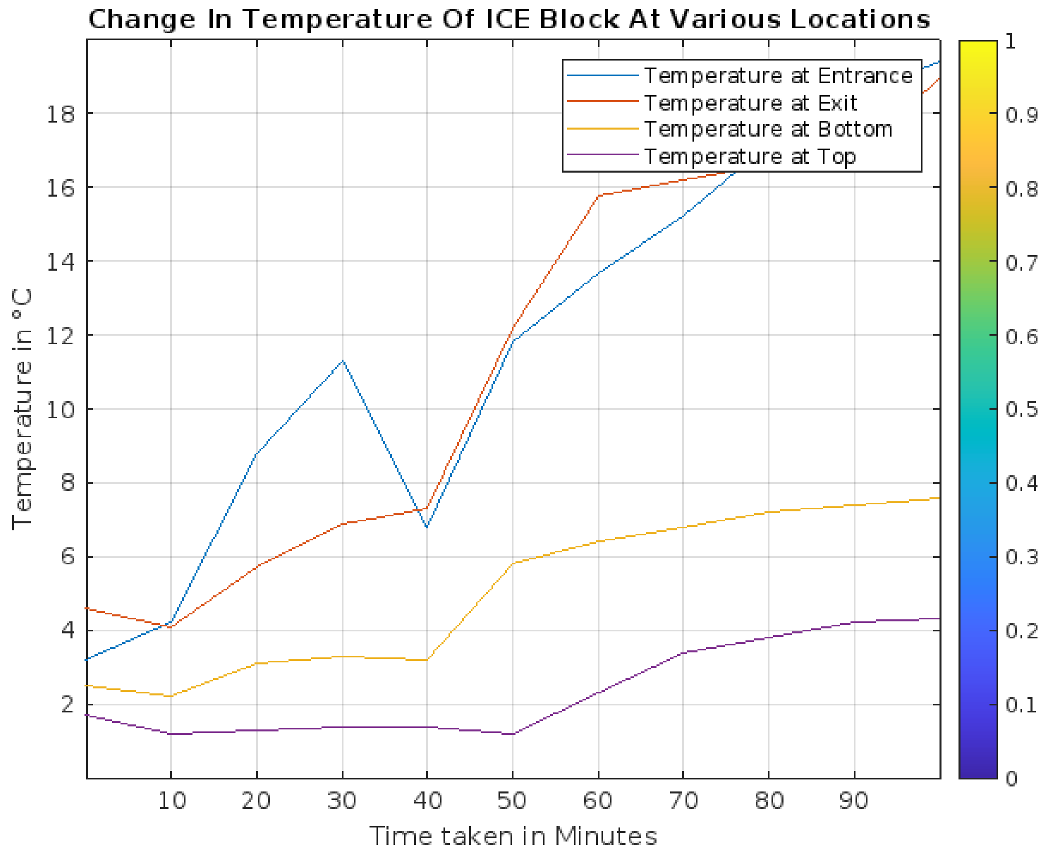


Fig- 21: Change In Temperature Of ICE Block At Various Locations With Respect To Time In Natural Convection

Observations from the modified Heat Exchanger

From the design-1 observations we consider the fan speed i.e.: 12m/s and later change the heat exchanger design and reduced 16% of relative humidity and find the increase in dehumidification capacity from 5.4 kg/hr to 8.28 kg/hr.

Dehumidification Capacity for the Design 2

Parameter	Value	Units	Converted value
Temperature (T) - °C	32	°C	
Present humidity (RH%)	70	%	23.639 g/m3
Humidity to be achieved (RH%)	54	%	18.236 g/m3
Room volume in cubic meter	50	m3	
Air exchange ratio	1		
Results			
Dehumidification capacity	3.45E-01	kg/hr or liter / hour	
	8.28694228	kg/hr or liter / day	

Dehumidifier Selection for Various environment conditions

Dehumudifier Selection (Liters /day)		
Room size		
Area	**500 sq.ft**	**1000 sq.ft**
Extreme Wet	9.1	13.1
Very Wet	8	11.4
Very Damp (Wet and Humid)	6.8	9.7
Moderate Damp (Wet and Humid)	5.7	8

Additional Room conditions to consider:

If any of the below factors are true for you, you'll want to choose a unit with a higher capacity.

- If your home is in a humid climate, add 10 pints.
- If multiple people live or will spend time in the space, add 5 pints.
- If there are multiple doors and windows in the space, add 5 pints.
- If there's a washer and dryer nearby, add 5 pints.

Where 1pints = 0.473 litres

To determine the right size dehumidifier you need, consider the size and dampness of your space, using a hygrometer if necessary. After this, you'll be able to determine the correct pint capacity dehumidifier to handle the humidity in your room.

Dehumidifiers for Offices and Homes:

With summer moving toward what comes first in the mind of individuals is the high dampness with each expanding degrees in the thermometer. In fact, the humidity and the damp air because of high moistness can be peaceful disturbing however the effects are not constrained to simply these things. High humidity can make more complex medical problems than one would ordinarily accept. Homes and workplaces are where average people spend there most of the time and subsequently, it is critical to keep the moistness level of these places in line.

Home dehumidifiers are more commonly available and they help in removing the pockets of moisture from isolated and trapped areas, such as bathrooms, drainage pipes, closets, or air duct vent and shafts. These are areas where the moisture gets clogged and if left uncontrolled they lead to air cracks and algae formation within the house that lead to more detrimental health hazards and may disturb the comfortable lifestyle. Home dehumidifiers are usually refrigerant as they are more apt to suck in the air that’s outside and reheat and exhaust them to maintain the humidity levels. They are also portable in nature and are easy to carry and could be placed in any rooms as you like be it a bedroom or bathroom. They come with various mounting options to wall mount or tabletop designs to fit right into the space available in your house.

According to the location and the needs of your home, they are available in many options and sizes and to suit your budget needs. The dehumidifier for the basement may vary from the dehumidifier in the living room as both have different environmental conditions. So, it is best to choose where to fit the humidifiers before you go out and buy one for your house. A portable dehumidifier can bring relief by stopping the spread of new Mold and by killing existing Mold that happens due to dampened conditions. It filters the air and purifies it, so the living room is healthy and safe. The home dehumidifiers also play an important role in removing the musty smell from the air which comes by moist socks & shoes. It is important to keep the optimal humidity levels for homes as heating the air more than the levels lead to skin cracks. In house dehumidifiers, a central humidistat monitors the humidity levels and regulates the operation of the dehumidifier as per the recommended level of the standard bodies. They also use the existing ventilation plans of the houses to allow appropriate air flow and humidity levels to maintain your living spaces clean, most free, and healthy.

Conclusion

Collecting theoretical data from experiments as per standards, By Considering the motor speed and design of heat exchanger to get desired output and we can get the desired rated Air Cooler which works as Dehumidifier.

It effectively extracts moisture from the air, reducing humidity levels and preventing the growth of Mold and mildew. No more sticky and damp conditions. We can now enjoy a dry and healthy indoor environment. By combining cooling and dehumidifying functions, a Air Cooler with a dehumidifier can offer a versatile solution for areas with high humidity levels. This appliance can lower the temperature and the moisture in the air, creating a more pleasant environment.

Firstly we change the heat exchanger design and found that change in dehumidification capacity and calculated the dehumidification capacity for the 500 sq. Ft and 1000sq.ft area room at various climate conditions, and Analyse the type of Dehumidifier for office and Home.

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