Experimentally investigation of desalination system using solar humidification/dehumidification Principle

M Tech Dissertation

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Experiment investigation of desalination system using solar humidification dehumidification principle

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Dedicated to my Parents and all teachers

Lovely Professional University Jalandhar, Punjab

CERTIFICATE

I hereby certify that the work which is being presented in the dissertation entitled **"Experimentally investigation of desalination system using solar humidification dehumidification principle "** in partial fulfillment of the requirement for the award of degree of **Master of Technology** and submitted in Department of Mechanical Engineering, Lovely Professional University, Punjab is an authentic record of my own work carried out during period of Dissertation under the supervision of **Mr. Minesh Vohra**, **Assistant Professor**, Department of Mechanical Engineering, Lovely Professional University, Punjab.

The matter presented in this dissertation has not been submitted by me anywhere for the award of any other degree or to any other institute. .

Date: **(Inder Preet Singh)**

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

Date: **(Mr. Minesh Vohra)**

Supervisor

-

The M- Tech Dissertation examination of **Inder Preet Singh,** has been held on_________________

Signature of Examiner

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I am very thankful to my supervisor Mr. Minesh Vohra for giving me this great opportunity to work under his supervision. His invaluable guidance continues boosting me and constant support makes confidence to me. He always helped me when, I stuck to any conceptual problem during my study. He enhanced my knowledge how we desalinate water using solar energy. I would also like to thanks to Mr. Sanjeev Kumar for his continuous supervision on my research work. Finally, I would like to say that without their kind support and helpful guidance i would not able to complete my work.

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Abstract

This Experiment deals with the desalination of saline water with the help of solar energy as a renewable source, based on the principle of humidification-dehumidification. As the name imply Solar Humidification Dehumidification Desalination System, involve the heating of saline water and collecting the condensed vapor (distillate) to produce Drinkable water. Suitable and economic solar collector and humidifier dehumidifier were designed and construct to investigate the different environmental and operating condition on the productivity of fresh water. Different variables are examined like mass flow rate of saline water and mass flow rate of air. Experimental Set-up consists of a solar water heater (parabolic trough collector of Single Axis), air pre-heater (flat plate collector), a spray humidifier and dehumidifier module. The performance of the HDDS depends mainly upon the humidification of the air, the output temperature of the collector, mass flow rate of the inlet air into the air heater and the sprayed water temperature in the humidifier unit. The productivity of the system increases with increase of the day time till optimum value and then decreased. The maximum production of water found 7.7 kg during the experiment.

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Nomenclature

$T_{air, in}$	inlet temperature of air in the humidifier
$T_{c,in}$	inlet temperature to the collector
$T_{c,out}$	Outlet temperature from the collector
T_{atm}	Atmospheric temperature
M_a	Mass flow rate of air
M_w	Mass flow rate of water
FPC	Flat plate collector
RH	Relative humidity
HDDS	Humidification-Dehumidification Desalination System
f	focal length
Ψ_{rim}	Rim Angle
X, Y	Coordinate
R	Curve
C	Concentration Ratio
α	Angle
L	Length
W	Width
A_a	Collecting Area
A_r	Absorbing Area
RO	Reverse Osmosis

CHAPTER 1

1.1 Introduction

The sun radiates energy uniformly in all the direction in the form of electromagnetic waves. The sun provides the energy needed to sustain life in our solar system. It is clean, never-ending, abundantly available source of energy. The drawbacks of are that it is a weaken form of energy, also peak solar insulation (incident solar radiation) often coincides with peak day time demand, it can be well matched to suit commercial power needs, the output of sun is 2.8×10^{23}kw/year. The energy reaching the earth is 1.5×10^{18} kwh/year.

Various source of energy find their origin in the sun as mentioned below:

(A) Wind energy

(B) Biomass energy

(C) Tidal energy

(D) Ocean wave energy

(E) Ocean thermal energy

(F) Fossil foil and other organic chemicals

(G) Hydro energy

Solar energy can be use directly into two ways (1) by collecting the radiant heat and using it in a thermal system is known as Solar Thermal and (2) by collecting and converting it directly to electrical energy using a photovoltaic system is known as Solar Photovoltaic System.

(1) Solar thermal system provides thermal energy for various processes. In the regions of cold climate a large amount of low grade energy is essential to heat air for comfort, and hot water for washing, cleaning and other domestic and industrial needs. Various industrial survey shows up to 24% of all industrial heat is consumed for heating fluids to a moderate temperature. Thus, solar energy is best suited for low grade thermal application. Even in high

temperature heating application a significant amount of fuel can be saved by using solar energy for pre heating (up to temperature 180^0c). Due to this region manufacture of solar water heaters has become a successful industry in several countries. It can also be converted and utilized as mechanical and electrical energy in the same way as in any conventional thermal system.

(2) Solar photovoltaic (PV) systems transfer solar energy direct into electrical energy, the basic conversion devices used is known as solar photovoltaic cell or a solar cell. Although light sources may also produce photovoltaic electrical energy. A solar cell or PV cell basically an electrically current source, determined by change of radiation. Solar cell is first produce in 1954 and rapidly developed to provide power for space satellite based on semi conductor electronics technology. Its global application were considered seriously after oil crisis of 1973 when a real needs of alternative energy sources was felt globally for the first time. A solar cell is the most expensive component in the solar PV system (about 60% of the total cost of the system) though its cost is falling slowly. Commercial photocell may have efficiencies in the range of 10-20% and can produce electrical energy of 1-2kwh per m^2 day in ordinary sunshine. As the photovoltaic has no moving part so it gives almost free maintenance for long period and can be used unattended at inaccessible locations.

1.2 Solar distillation (Desalination of water)

Fresh water (water with less than 500 ppm salt content) is one of the basic necessities for humans. Industry and agriculture also require without which they cannot succeed. People depend on rivers, lakes and underground water resources to fulfill his need of fresh water. Because of rapid industrialization and the population sudden increase, the demand of fresh water has increased extremely. With the rise in the standard of living, the average per capita consumption of water also increased. Due to climate changes and less rainfall in many parts of world, fresh water, which was available in the abundant from river, lakes and ponds, is becoming limited. Also, the available resources are getting polluted due to discharge of industrial effluences and sewage in large quantities. Thus due to climate change, pollution and over consumption, at present more than 2000 million people have no regular access to adequate safe water. In some villages, people travel up to 30 km to collect fresh water. According to one estimate, about 79 per cent of water available on earth is salty, 20 per cent brackish (less salty water from wells) and only one percent is fresh. Therefore, conversion of brackish or saline water to fresh water though distillation process using solar energy is a good idea where plenty of saline water and sun are available.

The use of solar energy for desalting sea water and brackish well water has been established in several moderate-sized pilot plants in united state, Greece, Australia and several countries. The idea was first applied in 1872 at Las saline, Chile, in the plant supplying drinking water for animals working in nitrate mining areas and for transport. The conversion device is known as solar still.

1.3 Desalination technologies

Types of technologies that are used for desalinate of water is classify into two category as thermal and membrane technology. Both technologies need power to operate and to produced desalinate water. These technologies further sub divided as:

Table No1: Different Technologies of Desalination System

THERMAL TECHNOLOGY	THERMAL TECHNOLOGY
Multi-Stage Flash Distillation (MSF)	Electro dialysis (ED)
Multi-Effect Distillation (MED)	Electro dialysis reversal (EDR)
Vapor Compression Distillation (VCD)	Reverse Osmosis (RO)

1.3.1 Thermal technology

Thermal technologies, as the name mean the heating of sea water and collecting the condensed vapor (distillate) by dehumidification process or by cooling it to produce pure water. Thermal technologies not used for brackish (water having less salt) water desalination, because of the high costs concerned. They are only used for seawater desalination and are sub-divided into three groups

(a) Multi-Stage Flash Distillation (MSF)

In this process distillation take place through multi stage chamber. In which each stage is having progressively lower pressure. The water that to be purified is heated under high pressure and then it goes to first flash chamber where the pressure is less, causing the water to boil quickly resulting in rapid evaporation or flashing. This process will occur continuously at each stage. Because the pressure at each stage is lower than previous one. The vapor that are that are generate by this process converted into flash water by dehumidification process or by from this process, small vapour converted into water.

(b) Multi-Effect Distillation (MED)

In this process, distillation take place in a series of vessels and this process is based on the principle of evaporation and condensation. In MED process, pressure is reduce than ambient pressure to boil water at low temperature, so the water vapour at the beginning of vessel serves as heating medium for the second and so on. The performance ratio of process depends upon the no: of vessels. More the no: of vessels more will be the performance of the system. MED could be classified into two categories as horizontal tube and vertical tube or vertical stacked tube.

(c) Vapor Compression Distillation (VCD):

Vapour compression distillation process is not used separately it is used with the combination with other process such as MED. The heat for the feed water comes from compression of vapour rather than direct exchange of heat from the steam. Usually a mechanical compressor is used to generate the heat for the evaporation.

1.3.2 Membrane technology

This technology can be subdivided into two broad categories: Electro dialysis/Electro dialysis Reversal (ED/EDR), and Reverse Osmosis (RO).

a) Electro Dialysis (ED) and Electro Dialysis Reversal

Electro Dialysis is a voltage driven technology, in which electrical potential is used to pass the salt from the membrane leaving fresh water behind as product water. Electro dialysis was introduced than 10 years before the RO system. ED generally has been used for brackish (water having less salt) water to desalinate.

General principle used for ED

- Most salts dissolved in water are ions (either positively or negatively)
- Since similar poles repels each other and dissimilar poles attract each other

(b) Reverse Osmosis (RO)

Reverse osmosis is a new process that is widely used now a day. In this process pressure uses as a driving force to push saline water through a semi permeable membrane to distinguish the fresh water and concentrated brine steam. Nan filtration is also a membrane process that is used for the removal of salt ions (calcium, magnesium, sulphate) but RO is used for the removal of sodium chloride.

Osmosis is an ordinary phenomenon by which water from a low salt concentration passes into a more concentrated solution through a semi-permeable membrane. When pressure is applied to the solution with the higher salt concentration solution, the water will flow in a reverse direction through the semi-permeable membrane, leaving the salt behind. This is known as the Reverse Osmosis process or RO process.

1.4 Objective of the Experiment

(1) To desalinate the saline water based on the principle humidification-dehumidification desalination system.
(2) To calculate the values and design the different components of HDDS like parabolic trough collector, air heater and humidifier and dehumidifier chamber

(3) To find out the performance and productivity of the desalinate water by using HDDS.

(4) To compare the experiment results by varying the mass flow rate of the saline water and mass flow rate of the air.

CHAPER-2

LITERATURE REVIEW

2.1 Introduction

Potable or fresh water is one of the requirements of the human life. Due to increase of the population the requirement of the fresh water also increase. According to one estimate, about 79% of water available on the earth is salty, 20 % is brackish (less salty water from wells) that means 99% water has no utilize for us, and the remaining 1% is fresh water. So there should be any method that converts this salty water into fresh one for the use of human. Desalination is the process that converts salty water to the fresh water. The idea was first applied in 1872 in a plant supplying drinking water for animals working in nitrate mining areas and for transport. The conversion device is known as solar still.

2.2 Review of previous work

Efat Chafik [2002] was revealed a new process for desalinate seawater by heating the air up to a temperature between 50^{o}C-80^{o} C using solar energy. The moderate heated air will be humidified by injection of sea water on it to increase the humidity of air. Later on, by cooling or by dehumidification process fresh water (free from salt) will be extracted. The maximum temperature of heated air will not be exceeding than 80^{O} C because of the material (polymer) constrained. The main feature of the process was successive loading of air with vapor up to a relative high humidity, such as 10 or 15 wt%, which was done by a new process heating/humidifying technique.

Imed Houcine at al [2003] was revealed a new desalination process working with an air multiple effect humidification dehumidification method and investigates the principle parameter by experiment. The experiment set up consist of eight stage air solar collector heating-humidification system, heat exchanger, spray humidifier and dehumidifier system to simulate the seawater experimentally.

Efat Chafik [2004] developed a new process for solar desalination. The main idea was in this process to humidify air in several stages in order to load more water vapors, to obtain more desalinate saline water (sea water). For economical and suitable process several equipments had developed like collector, humidifier and dehumidifier in order to use this desalination process.

M.S Hatamipour and Eslamimanesh [2008] has done Economical study of humidification-dehumidification desalination (HDD) system with small scale reverse osmosis (RO) system to estimate the benefits of humidification-dehumidification desalination over RO system and investigate that energy recovered by HDD unit to be 75%. Exact and clear economic analysis results were obtained using COMFAR III software for different economical parameters (fixed investment cost, operating cost, energy cost, fixed investment cost).

A.M.I Mohamed and El-Minshawy [2011] revealed theoretical investigation on desalination system based on air humidification- dehumidification desalination principle. The study showed that, parabolic trough collector is suitable to drive planned desalination system. A comparison study shows that production time of desalinate water and performance depends upon different seasons (winter, spring, summer and autumn). The productivity of Desalinate water (fresh water) also increases by day time till a best possible value and after that decrease. The highest fresh water productivity is found42%, when high direct solar radiation (in summer season) falls on the collector. At the beginning period of time (8:00 am-11:00 am) in winter and autumn the collector thermal efficiency is lower than summer and springs and this is reduced in the last period of solar time (2:00 pm-5:00pm).

Pradeep Kumar KV et al [2013] done experiment study of parabolic trough collector with its sun tracking system is that designed and manufactured to investigate increase the efficiency and to reduce the cost of the electricity. To increase the performance of solar concentrator different types of reflector materials and absorbing material were analyzed. The shift of focus was motivated by the need to assess long term system performance and to reduce cost by using different types of reflector material and absorbing material. The new result shows that characteristic curve of tested aluminum (Al) is lower than that of mirror collector. Under dry weather condition, mirror collector efficiency is higher than that of aluminum.

Naser K. Nawayseh et al [1997] found that desalinate of saline water using solar energy with humidification-dehumidification process is the efficient method for obtaining fresh water. A simulation model is express and then used to optimize the unit performance by studying the effect of different parameters like condenser and humidifier area and operating condition like feed water flow rate. The results show that it is very important to decide proper humidifier and condenser area and flow rate of the feed water.

Cemil Yamal & Ismail Solmus [2006] found theoretically that under different operating condition and design parameter the effect on the performance of solar water desalination. For this, simulation has done and a mathematical model was developed using MATLAB software. The desalination unit is configured by a double pass flat plate solar air heater with two glass cover, humidifying tower, storage tank and dehumidifying exchanger. The productivity of the system increased by 8 percent by using double pass solar air heater and decreased by 30 percent without double pass solar air heater under same conditions. The productivity of the unit increased with increase in mass flow rate of air at constant mass flow rate of water.

J Orfi et al [2006] did theoretical study of solar desalination system using humidification-dehumidification process which is positive technique of producing fresh water. The productivity of fresh water depends upon the mass flow rate of saline water and mass flow rate of air. It is possible to produce more than 40 L fresh water per m^2 of solar collector surface area by adjusting the parameter.

Guofeng Yuan et al [2011] presented a system of 1000L/ day which is based on solar humidification-dehumidification. The system design and construction has been done by Chinese academy of science and HIMIN solar co. Ltd based on research. In this system a Air pre heater of 100 m^2, a solar water collector of 12 m^2, a humidification dehumidification system, a pre heater and post treatment system was used. The result shows that when solar intensity reaches to 550 W/m^2 then water production is 1200

L/day. The production cost of fresh water is about 19.2Yuan/ m^3 that is find out by economical analysis.

Y J Dai et al [2001] presented a mathematical model to produce more fresh water from saline water by reusing of saline water after evaporation, recovering condensation heat and forced air flow was expected. The model was experimentally validated for numerical simulation. The effect of flow rates, temperature of feed water, air and cooling water was studied to optimize the performance. The daily production of fresh water was 6 kg/m^2 /day with 20 mega joule solar energy.

Shaobo Hou and Hefei Zhang [2007] presented a hybrid solar desalination process of basin type unit and multi effect humidification dehumidification unit. The solar vacuated tube collector is engaged with multi effect humidification- dehumidification desalination process. The saline water first goes to multi effect humidification-dehumidification desalination unit and after that is reused to basin type unit. The result shows that system gain output ratio (GOP) will rise by 2-3 at least through reusing the rejected water.

A.S Nafey et al [2003] did numerical investigation of a humidification dehumidification desalination process using solar energy. The system consists of a solar air heater, a concentration solar water heating collector, humidifying tower and dehumidifier exchanger. Two separate loops represent the HDD system, the first loop represent heating the feed water and second for heating air. A mathematical model was constructed to study the productivity of fresh water by varying the system configuration, weather and operating conditions. The result shows that the productivity of fresh water is strongly influenced by cooling tower, air flow rate and solar energy incident through a day and weather conditions like ambient and wind speed shows very small effects.

Sandeep Parkash et al [2003] discovered desalination of saline water using solar energy is best method as compared with energy derived from heat and natural gas. The overall efficiency is higher in case of solar desalination based on the humidification- dehumidification process.

Said Al-Hallaj et al [1998] did water desalination using solar energy by closed air cycle humidification-dehumidification process. The hot air from flat plate collector either obtained by forced or free convection is humidified and then latent heat of condensation was removed in the condenser for obtaining the fresh water. Two different units of different design were constructed and results show productivity of these two units higher than the single basin stills. The experiments also shows that mass flow rate of water has strong effect on unit production. This is because of increase in mass flow rate increase the coefficient of heat transfer as well as collector efficiency.

Hisham ettouney [2005] found that desalination using humidification dehumidification process as a promising technique for small capacity production plants and analyzed the four different configurations for water desalination system using humidification dehumidification process. The four configurations include the mechanical compressor system, conventional system, the desiccant system and membrane air drying system. Analysis show the main drawback of these four system that is due to the large amount of air together with water vapour products reduced the efficiency of the system.

M.M Farid et al [2002] found during simulation that producing fresh water using solar desalination is a successful renewable energy resource. The system performance of such type of desalination unit increases by varying the mass flow rate of feed water.

Hassan E.S Fath and Ahmad Ghazy [2001] had done a numerical study to find out the performance of solar desalination using humidification dehumidification system. The study show that the effect of different environmental parameter (Solar intensity, ambient temperature and wind speed), operational parameter (air circulation flow rate, feed water rate and temperature) and design parameter (solar heater base insulation, the humidifier and dehumidifier effectiveness) on the productivity of the desalination system. The results indicated that the dehumidifier effectiveness has an insignificant influence on system productivity and also with increase in the solar intensity and ambient temperature and decreased wind speed increase the system productivity.

Santosh vyas and sunil Punjabi [2014] had done experiment for testing the performance of flat plate solar air heater with simulated solar radiation intensity of 6000 $w/m^{2.}$ In the experiment set up 1m×0.5m×0.1m test cell was fabricated. Three different designs of ribs of absorber tested with artificial solar radiation and in natural convection and performance of these design compared on the basis of overall thermal efficiency. The overall thermal efficiency of these three designs has been found as 14.91%, 17.24% and 20.04% respectively.

Amir Hermatian et al [2012] had done study on flat plate collector of area 2×1 m^2 and thickness of 0.5 m in the form of window shade for increasing the air contact area. The experiment was conducted for a week to check the efficiency during which atmospheric conditions were almost uniform. Both natural and forced convection results were conducted and found that collector efficiency in forced convection lower than that of natural convection.

Vernon and Simon [1974] first introduced the commercial application of solar heat collector. In this Experiment Study they proved that it is a possible to reduce the power cost which used for cooling and heating purpose of any building by integration of solar heat collector, they also got that the collector efficiency is varied from temperature to temperature and directly proportional to outer heat losses, at 2000 F temperature they record collector efficiency up to 58%. The efficiency of solar heat collector is depending on the intensity of the solar radiation and surrounding air temperature.

Henriks Putans et al [2011] done experiment on flat plate collector with cell polycarbonate sheet having 4 mm thickness used as absorber. During the experiment the maximum temperature reached at 80^0C at the intensity of solar radiation of 800 w/m^2 and ambient temperature of 32 ^{0}C. The efficiency of flat plat collector reached 33-60 % during the experiment and observed that it is depend upon the intensity of solar radiation and ambient temperature.

CHAPTER 3

3.1 Introduction

This chapter is related to the experiment work that is performed to investigate the desalination process using humidification dehumidification process and to find out varies factor that are affecting the performance of the desalination unit. This experiment is performed at lovely professional university, jalandhar, Punjab (N31^o 15' 17.98'') (E 75^o 42' 56.382") 56 block terrace.

3.2 Problem formulation

As described in chapter 1, Fresh water (water with less than 500 ppm salt content) is one of the basic necessities for humans. Industry and agriculture also require without which they cannot succeed. People depend on rivers, lakes and underground water resources to fulfill his need of fresh water. Because of rapid industrialization and the population sudden increase, the demand of fresh water has increased extremely. With the rise in the standard of living, the average per capita consumption of water also increased. Due to climate changes and less rainfall in many parts of world, fresh water, which was available in the abundant from river, lakes and ponds, is becoming limited. Also, the available resources are getting polluted due to discharge of industrial effluences and sewage in large quantities. Thus due to climate change, pollution and over consumption, at present more than 2000 million people have no regular access to adequate safe water. In some villages, people travel up to 30 km to collect fresh water. According to one estimate, about 79 per cent of water available on earth is salty, 20 per cent brackish (less salty water from wells) and only one percent is fresh. Therefore, conversion of brackish or saline water to fresh water though distillation process using solar energy is a good idea where plenty of saline water and sun are available.

The use of solar energy for desalting sea water and brackish well water has been established in several moderate-sized pilot plants in united state, Greece, Australia and several countries. The idea was first applied in 1872 at Las saline, Chile, in the plant supplying drinking water for animals working in nitrate mining areas and for transport. The conversion device is known as solar still.

1. Non conventional resources are available in nature free of cost
2. They produce no or very less pollution to the atmosphere so we can say that they are environment friendly.
3. They are inexhaustible
4. They have a low gestation period.

3.3 Experiment set up

The photograph of solar humidification dehumidification desalination system is shown in figure. It consists of parabola trough collector, air preheater and humidifier and dehumidifier chamber. The experiment set up consist of following components

- Parabola trough collector
- Air pre heater (flat plat collector)
- Humidifier dehumidifier chamber

Figure1: Experiment set up of desalination system

3.3.1 Parabola trough collector

A parabolic trough collector is a type of solar collector that comes under a thermal energy collector. PTC was constructed by mirror usually coated silver or polished aluminum with a receiver tube. Sunlight reflected by the mirror is concentrate on receiver tube, receiver tube absorbs the incoming radiation and transforms them into thermal energy, the latter being transported and collected by a fluid medium circulating within the receiver tube. The trough mainly aligned on a north-south axis but we can also aligned on east-west axis, but this reduced the overall efficiency of the collector, due to cosine loss, but in east-west case we only requires the trough to be aligned with the change in season, that avoiding the need for tracking motor. There is error in PTC due to the daily motion of the sun across the sky.

3.3.1.1 Basic Terminology of parabola trough collector

- **Solar Concentration Ratio**

The total amount of solar concentration achieved by a given collector is termed as Solar Concentration Ratio. It is defined as ration of averaged radiant solar flux integrated over the receiver area to flux incident in the collector aperture. It directly relates the reflector quality. A higher concentration ratio allows the collector to reach a higher working temperature with minimal thermal loss, but requires higher manufacturing precision too. A very carefully constructed and adjusted collector may reach an effective concentration ratio as high as 100.

- **Tilt Angle:**

Tilt angle is defined as the angle subtended by the focal line of trough collector with horizontal. Collectors based on heat pipes can have a strong tilt dependency and this must be considered when testing such collectors. Normally slopes below 20°-30° should be avoided but this cannot be taken as a general rule.

- **Rim Angle (Ψ_{rim}):**

The rim angle is defined as the angle subtended by the edges of the reflector at the focus.

- **Collector Acceptance angle:**

Collector acceptance angle is defined as the sensitivity of the solar parabolic trough collector to tracking misalignment.

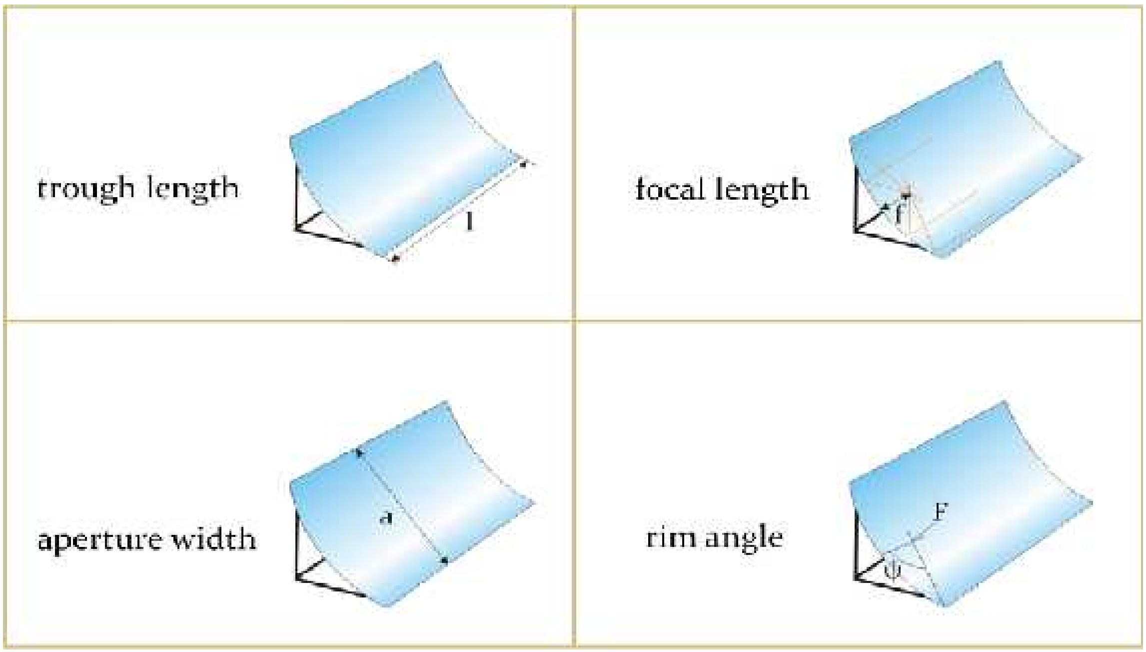

Figure2: Geometrical parabolic trough parameter

Parabolic trough collector used in this experiment consists of a reflector sheet; receiver and a glass cover (glazing). Highly polished aluminum sheet is used as a reflector which is in the shape of parabola. The material of the receiver is a copper because it is a good conductor of heat. The solar radiations reflected by the parabolic reflector are focused on the receiver tube for heating the saline water flowing through the copper tube.

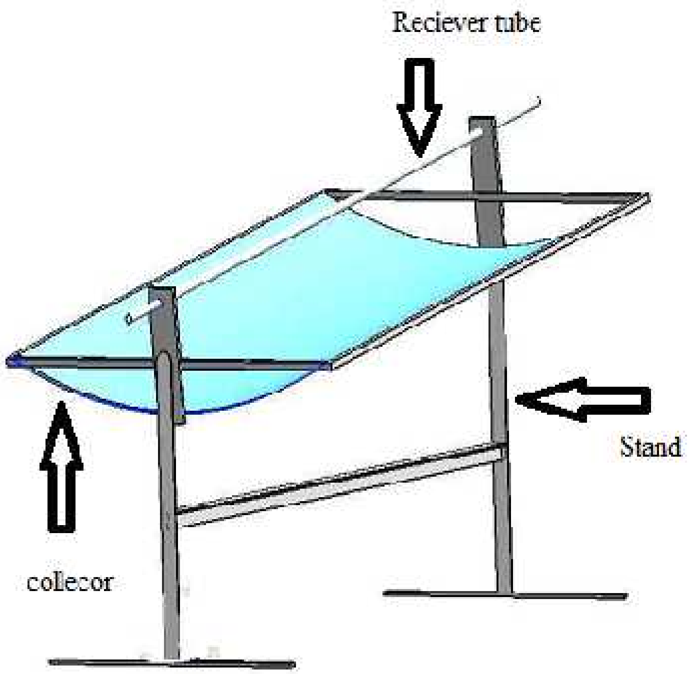

Figure3: Solar Parabolic Trough Collector

The collector is designed with parabolic equations.

Consideration the sample parabolic equations:

$$X^2 = 2Ry \quad (1)$$

$$f=R/2 \quad (2)$$

The sheet is 1200 mm wide, has a curve of R, and focal length "f" is half of R,

Therefore, α is

$$R \cos \alpha = R/2 \quad (3)$$

$$\cos \alpha = (R/2)(1/R) \quad (4)$$

$$\boldsymbol{\alpha = 60°}$$

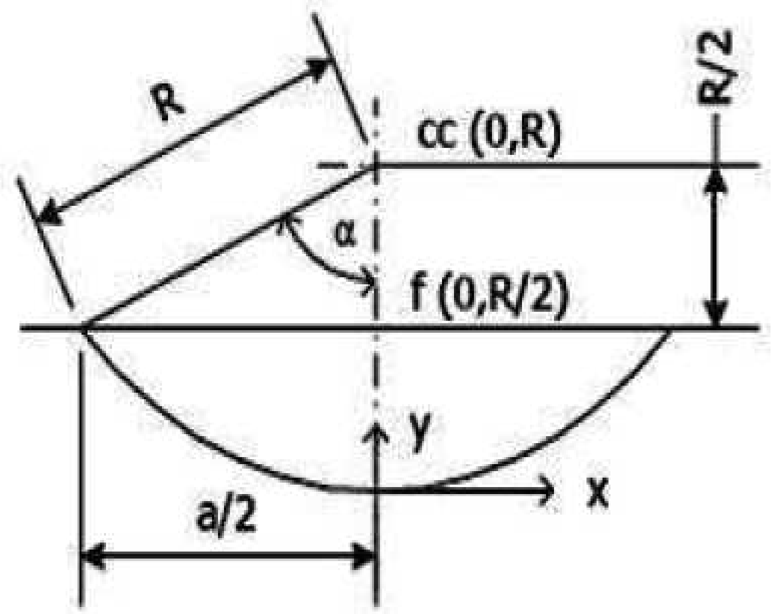

Figure 4**:** Schematic representation of a parabolic system

To find R (Radius),

$$2\pi\ R/3 = 1200$$

$$2\pi\ R = 3600$$

$$R = 3600/2\ \pi$$

$$\mathbf{R=573\ mm}$$

We know that from equation (2) focal length,

$$f=R/2$$

$$f=573/2$$

$$\mathbf{f=286.5mm}$$

Table 2: specification of parabolic trough collector:

Design of the PTC	Dimensions
Collector length (m)	1200
Collector width (m)	1200
Collector area (m)	
Rim angle (degree)	180
Focal length (m)	0.3

Absorber diameter (m)	0.025

3.3.1.2 Receiver tube is used for heating the saline water flowing through it. All solar radiations are concentrating on the receiver tube for the transfer of heat coming from sun. In this experiment the material of the tube is copper because copper is a good conductor of heat.

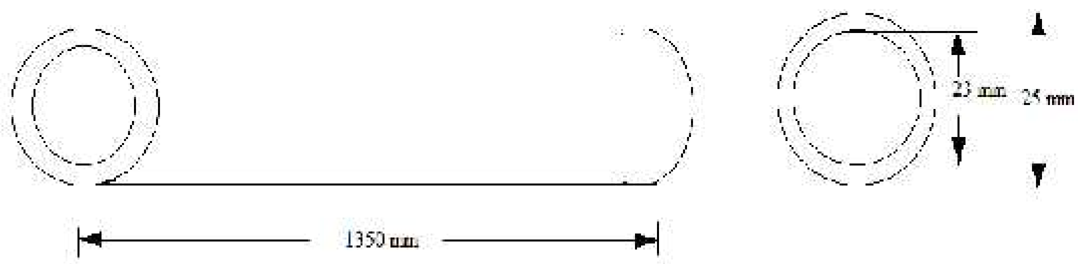

Figure5: Absorber tube

Table3: Specification of absorber tube

Specification	Value
Outer Diameter of absorber	25 mm
Inner diameter of absorber	23 mm
Length of the absorber	1350 mm
Material of the absorber	Copper

Table3:Specification of the absorber

3.3.2 Air heater in this experiment set up flat plate collector is used as air heater because a flat plate collector is simple in construction and does not require any sun tracking, therefore it can be properly secured on a rigid platform, and thus becomes stronger than those requiring flexibility for tracking purpose. As the collector is installed in the open air and exposed to atmospheric disturbances (storm, rain), the flat plate collector is more likely withstand harsh open-air conditions. Due to its simple design it requires less maintenance.

The principle disadvantage of flat plate collector is that because of absence of optical concentration, the area from which heat is loss is large so that high temperature cannot be attained.

A solar air heating collector is similar to liquid flat plate collector with change in configuration of the absorber and tube. The value of heat transfer coefficient between the absorber plate and the air is very low. For this region, the surfaces are sometimes roughened or longitudinal fins are provided in the air flow passage. V shaped, matrix etc. are some of other variations of shapes of absorber plate.

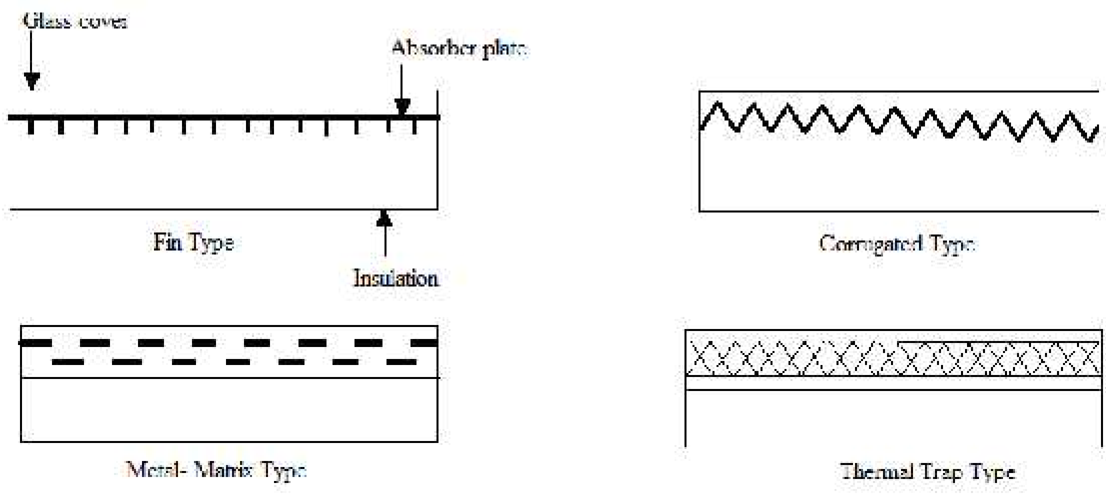

Figure6: Various types of flat plate air heating collector

3.3.2.1 Advantages of air flat plat collector:

1. It is compact and simple in construction so require very less maintenance.
2. Corrosion is not possible because working fluid is air
3. Leakage of air from duct is less.
4. Possibility of freezing of working fluid is eliminated
5. The pressure inside the collector do not become very high

3.3.2.2 Disadvantage of air flat plate collector:

1. Heat transfer between the absorber plate and air is poor
2. There is less storage of thermal energy due to low capacity.

In this experiment flat plate collector of volume 1.02m×1.02×0.06m is design and fabricate. The material of the absorber is polycarbonate sheet having area 1m×1m and thickness is 0.06m and thermal conductivity in the range of 0.19-0.22w/mk.

3.3.2.3 Design and Fabrication of Flat plate Collector

The model of flat plate collector is designed using solid works software as shown in figure. The shape of the flat plate collector is rectangular. The angle of inclination with the horizontal for the FPC was 30^0. The flat plate collector is fixed with support stand at bottom for easy man oeuvre as shown in figure 9.

3.3.2.4 Component of flat plate collector there are six components that are used for the fabrication of FPC as follow

- Absorber sheet
- Baffles
- Insulation
- Transparent cover
- Manifold
- Blower

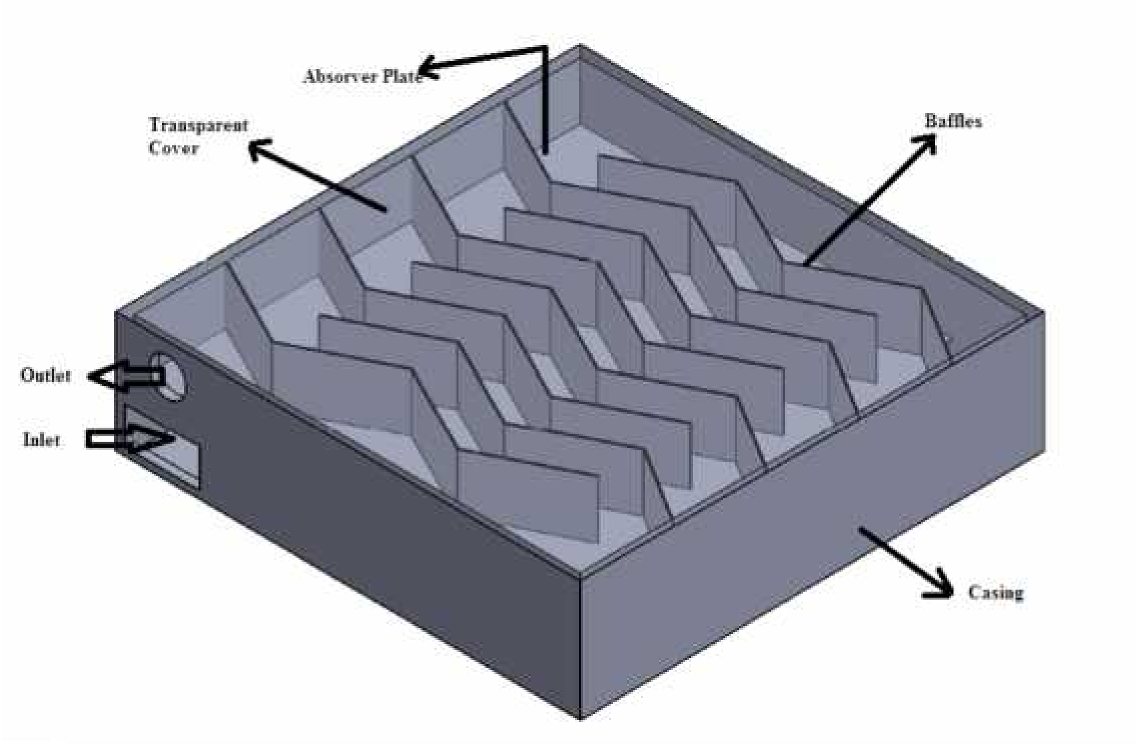

Figure7: Model of Flat Plate Collector in Solid Works

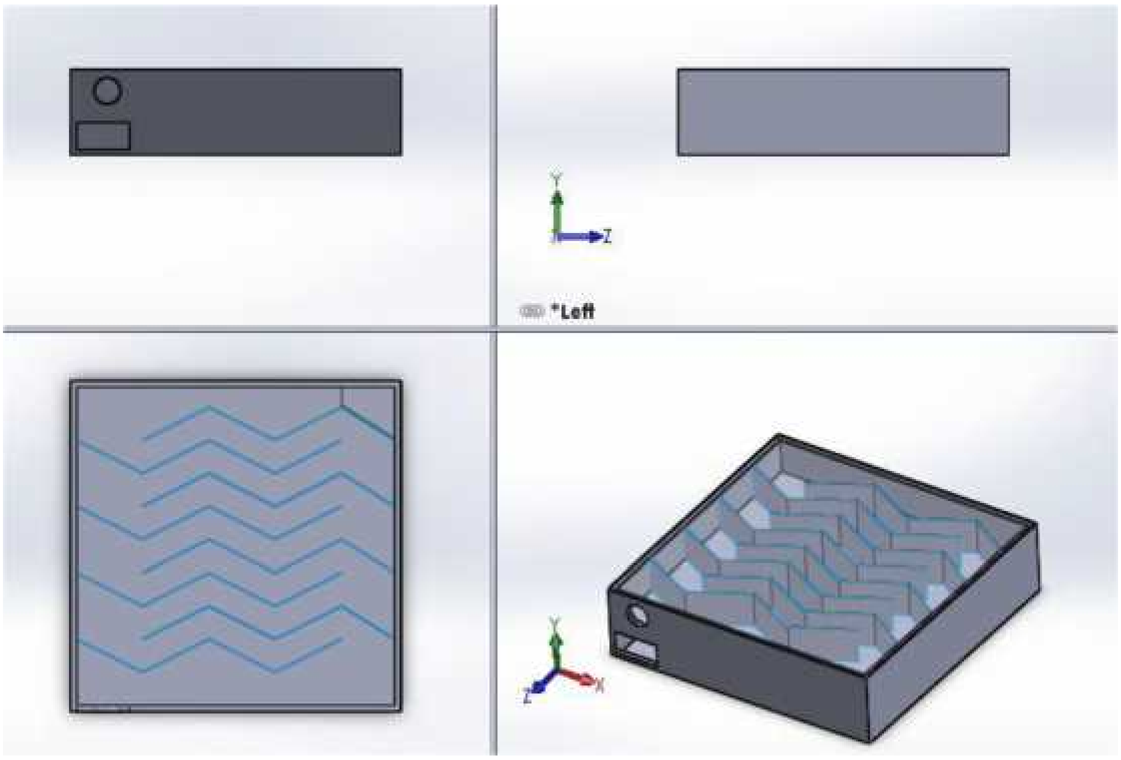

Figure8: Different view of FPC

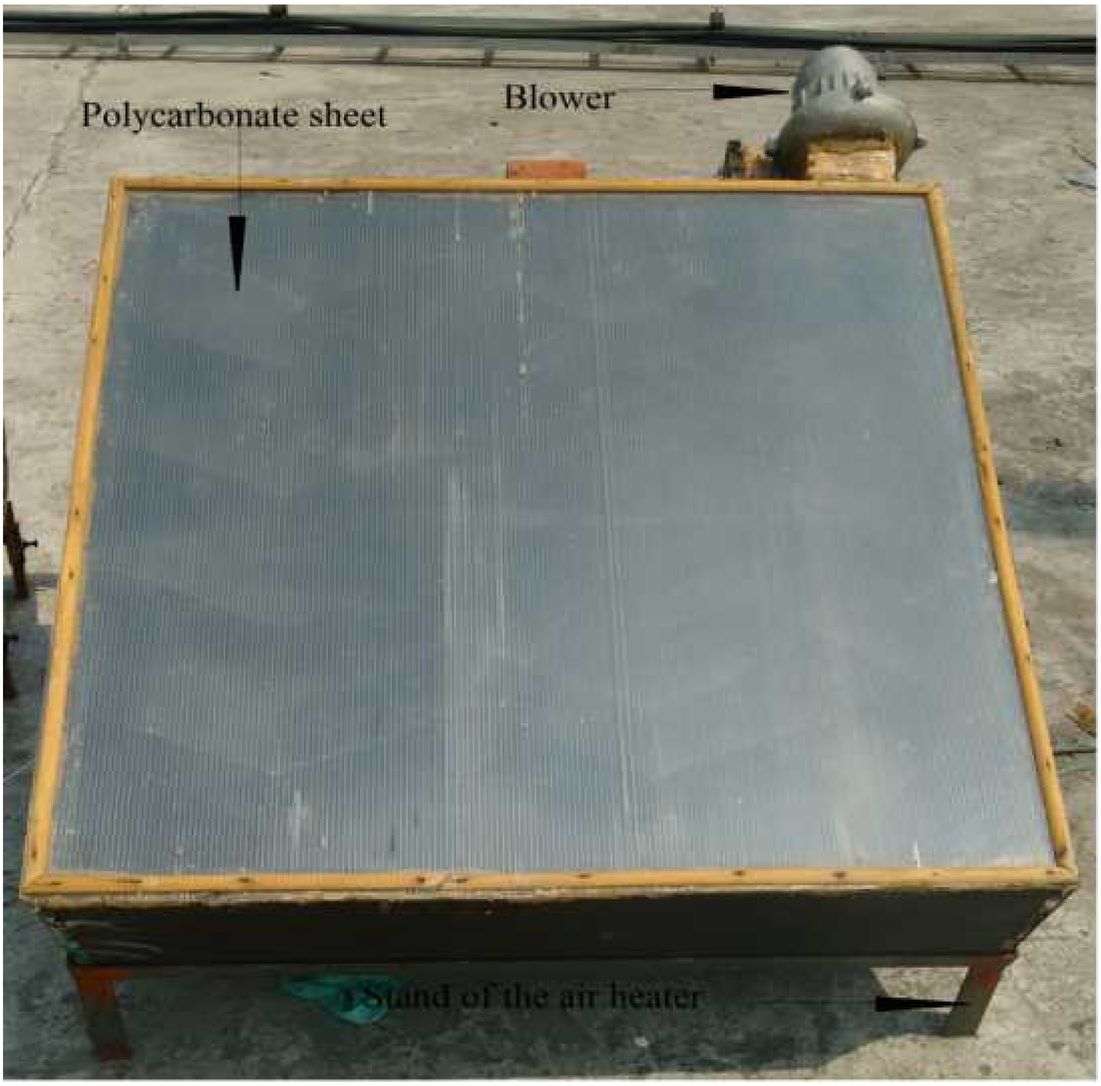

Figure9: flat plate solar air heater

Table4: Material of the flat plate collector of air heater

Components	Material
Outer casing	Wood
Baffles	Aluminum
Insulation	Glass wool, Thermocol
Selective coating	Black coating
Material of absorber plate	Polycarbonate sheet

Table5: specification of solar flat plate collector

Component	Specifications
Dimension of the collector	1.02m×1.02×0.06m
Dimension of the absorber plate	1m×1m×0.06m
Thickness of the absorber tube	0.06m
Thermal conductivity of the material	0.19-0.22w/mk
No of flow paths	2
Baffle angle	90
Bottom insulation thickness	0.019m
Conductivity of the insulation	0.06 w/mk

3.3.3 Humidifier dehumidifier chamber used in the experiment was made up of wooden block having partition. One side is used as humidifier and second side is used as dehumidifier. The hot water that is coming from the collector is sprayed to the humidifier chamber where the hot air is coming from the flat plate collector. The humidity inside the humidifier is increased due to sprayed of hot sea water, then the air that is contained the water vapours flows to the dehumidifier where a condenser is used to condense the water vapors having fresh water.

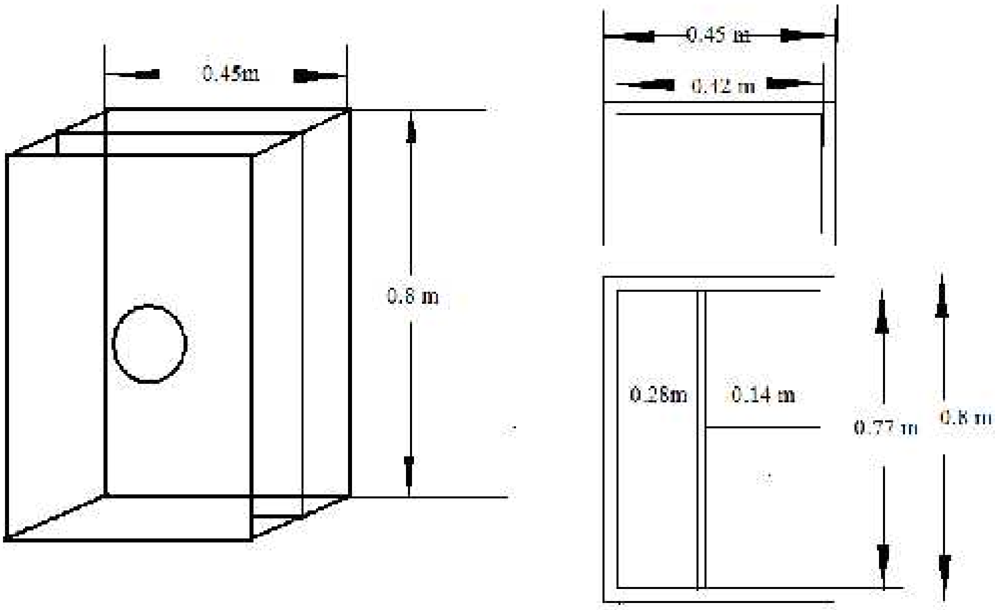

Figure10: humidifier dehumidifier

Pump is used in the experiment for the circulation of saline water from the water container to the condenser that is used in the dehumidifier and then further to move the saline water to the collector.

Figure 11: pump used for circulation of water

Table6: specifications of pump

Unit	Specification
Voltage	12 normal (9-14.4V)
Ampere	2.1A
Pressure	4.8 bar
Flow rate	2.6 lpm (maximum)

3.4 Measuring instruments

There are different types of instruments are used for measuring the different temperatures like atmospheric temperature, inlet and outlet temperature of the collector and inlet air temperature, humidity and intensity of radiation.

- PT-100
- RTD
- Humidity detector
- Sling phycrometer
- Anemometer
- Intensity of light (solar intensity)
- Ph value

3.4.1 PT 100 Thermometer also known as resistance thermometer used to determine temperature by correlating the resistance of the RT element with temperature. The material of RT is typically platinum, nickel or copper. The material has a predictable change in resistance as the temperature changes and it is this predictable change that is used to determine temperature

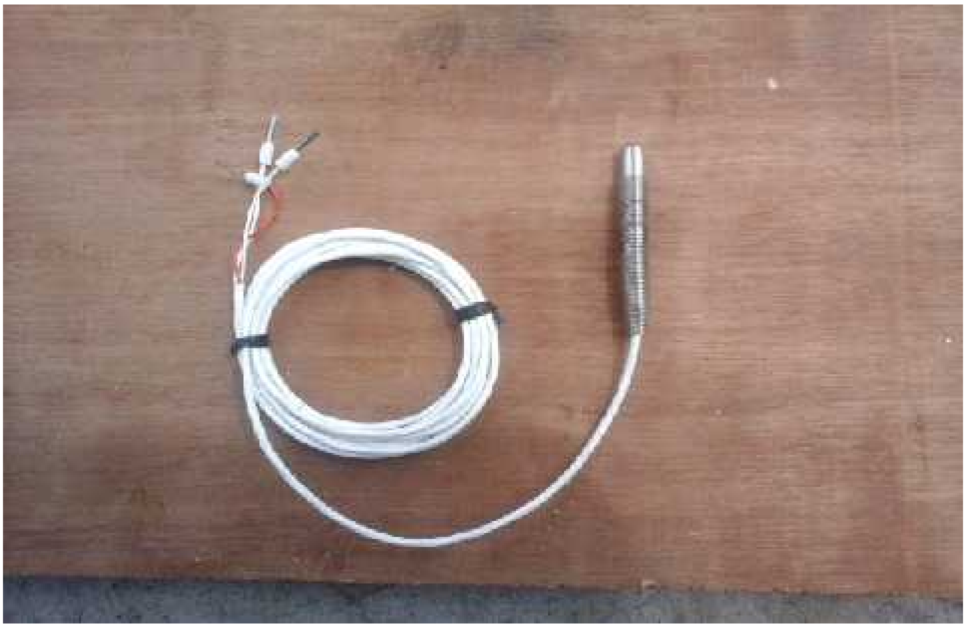

Figure12: PT 100 thermometer

3.4.2 Resistance temperature detectors (RTD): used to display the temperature of the resistance thermometer. Inlet temperature of water that is entering into collector, outlet temperature of water and temperature of air are measured with the help of RTD PT100 thermocouples which are connected with a digital temperature indicator that shows the temperature with a resolution of 0.1^{o}C.

Figure13: RTD (Resistance Temperature Detector)

Table7: Specification of RTD

Model	Nutronics DTL-200M
Range	800 ^{o}C
Sensor input	Platinum
Supply	230 V/AC

3.4.3 Humidifier meter Instrument used to find out the humidity in the air. This instrument is used in the experiment to find out the humidity in the humidifier chamber where the hot saline water and hot air mix together and increase the humidity inside the humidifier chamber. The humidity measuring range of the instrument is 10%-99% RH with accuracy of ±5%.

Figure14: Humidity Detector

Table8: Specification of humidity detector

Temperature measurement range	-10^{o}C - +50^o C
Temperature measurement accuracy	±1^{o}C
Temperature resolution	±0.1^o C
Humidity measuring range	10 % - 99 % RH
Humidity measuring accuracy	±5 % RH
Humidity resolution	1%

3.4.4 Sling psychrometer used for measuring the atmosphere temperature and having a temperature range of 0^{0}C to 50^{0}C. It is manually operated measuring instrument. Two thermometers are fitted into the plastic casing that is measuring the dbt (dry bulb temperature) and wbt (wet bulb temperature) of the surroundings atmosphere. A cotton piece is provided for the wbt measurement. Rotating screws are provided for the turning of the instrument. Each reading is taken by rotating the instrument 10 to 15 times.

Figure15: sling psychrometer

3.4.5 Anemometer is used to check the mass flow rate of air and it is a common weather station instrument. As the wind blows, it spins the fan blades and a tiny generator to which they're attached, which works a bit like a bicycle dynamo. The generator is connected to an electronic circuit that gives an instant readout of the wind speed on a digital display. The anemometer used in this experiment is having range between 0.0-45.0 m/s with resolution of 0.001.

Figure16: Anemometer

Table9: specification of anemometer

Unit	Wind velocity	Resolution	Lowest point of start value	Accuracy
m/s	0.0-45.0	0.001	0.3	±3%±0.1
Km/h	0.0-140.0	0.001	1.0	±3%±0.4

3.4.6 Intensity of light The value of direct solar radiation is taking from the online data available on the NREL (national renewable energy laboratory). NREL is a government-owned, contractor-operated facility and it is funded through the U.S. Department of energy. This arrangement allows a private entity to operate the lab on behalf of the federal government under a prime contract. NREL receives funding from Congress to be applied toward research and development projects. NREL also performs research on photovoltaic (PV) under the National Center for Photovoltaic.

NREL has a number of PV research capabilities including research and development, testing, and deployment. NREL campus houses several facilities dedicated to PV research

3.4.7 pH value is the measurement of a liquids level of acidity or alkalinity. The pH scale having two runs from 0.0 to 14.0 and from 2.0 to 10.0 with 7.0 being neutral. Acids have low pH values with anything lower than a 7 and alkaline solutions have high pH with anything above a 7. If the solution has an equal amount of acidic and alkaline molecules, the pH is considered neutral. There is a general rule in chemistry that to how salts affect solution of pH. If the salt of a strong base and weak acid is dissolved in water it will form an alkaline solution, whereas, the salt of a weak base and strong acid will form an acidic solution

The ph value for salt water is in the range of 7.5-8.4. Measuring of pH in the salt water more difficult than pH in fresh water. The pH paper tests are not suitable for measuring pH in salt water.

Method commonly used to measure the pH of salt water that is colorimetric means to measure colors. Colorimetric means to measure color. In the colorimetric method, chemicals are added to the water sample and those chemicals react with the water to produce a color change. The color indicates the pH of the water. The color can be measured visually or electronically. The colorimetric method does not work when the water is already colored because it contains dissolved organic matter or large amounts of algae. Colorimetric test kits are inexpensive and can cover a wide range of pH values.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, the obtained results from the experiments work carried out to investigate the performance under different condition of lovely professional university, jalandhar, Punjab by varying the flow rate of saline water and mass flow rate of air. The experiment is conducted in the last days of April and starting month of May. Most of the days the ambient temperature in the range of 32^0C to 38^0C. Every day the solar collector is exposed in the solar radiation at 9:00 AM and readings were taken from 9:30 AM to 4:30PM at an interval of every 30 minutes.

The experiment was conducted with four different days 28, 29 of April and 01, 04 of May. Four different cases were considered to determined the performance of the desalination system like high flow rate and low flow rate of air and high mass flow rate of water and low mass flow rate of water.

4.2 Result obtained from experiment

As discussed above, the obtained results from the experiment work carried out to investigate the performance of desalination system under different condition of lovely professional university, Punjab by varying the flow rate of air and flow rate of saline water. In the experiment result four cases are to check the performance of the HDD system as discussed below.

4.2.1 Day 1: low flow rate of saline water and low flow rate of air (28/04/15)

The measured values like ambient temperature, intensity of radiation, collector inlet and outlet temperature, air through solar flat plate collector during a day in April (28/04/15) at lovely professional university are shown in figure. Although the measured values shows sinusoidal trends with shifting of solar intensity after every half an hour.

On 28 April, experiment was conducted and found that the maximum intensity of light was 1287 w/m^2 at 12:30 PM and the ambient temperature in the range of 32^0C to 38^0C. The maximum temperature of saline water and air were 63^0C and 62^0C respectively.

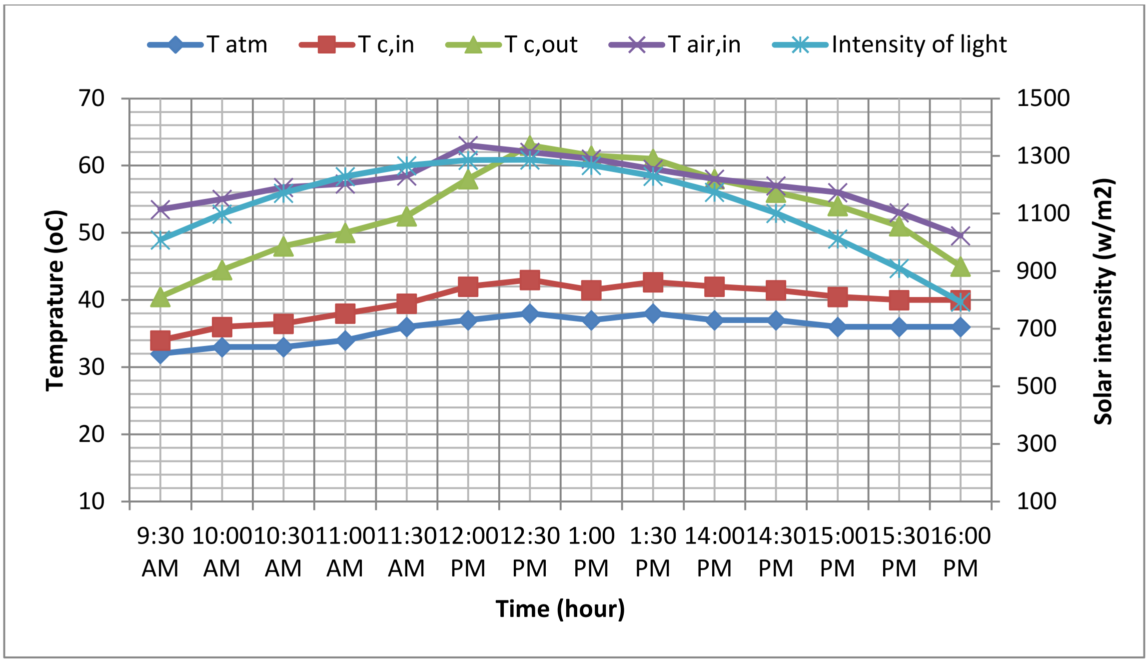

Figure 17: variation of temperature of water, air and intensity of light w.r.t time

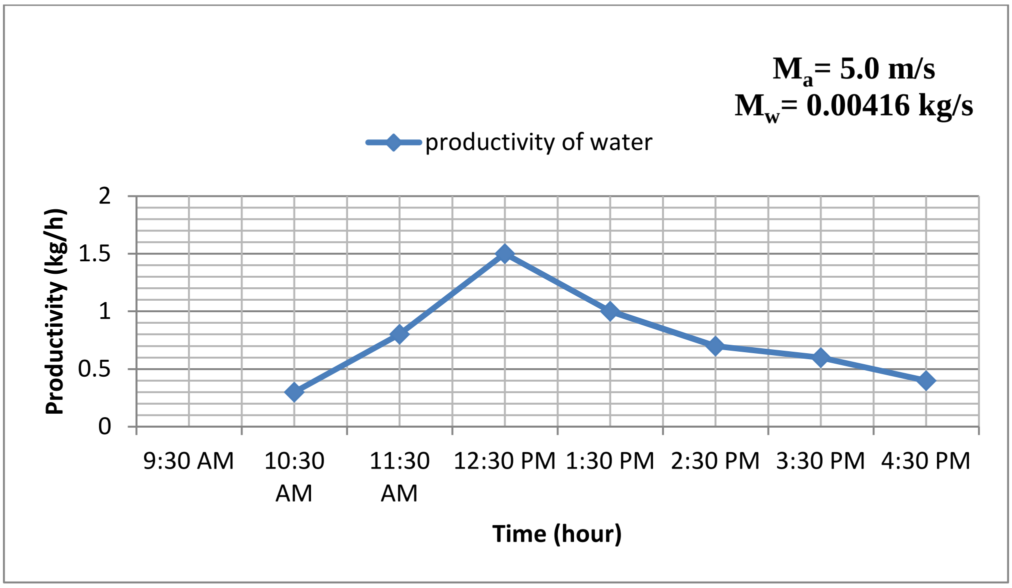

Figure 18: The productivity variation through the day (28/04/15)

During the day 28 April, mass flow rate of air (M_a) and mass flow rate of water (M_w) were kept 5.0 m/s and 0.00416 kg/s respectively. The maximum production of fresh water during the day was 1.5 kg and the total production of fresh water was approximately 4.9 kg.

4.2.2 Day 2: High flow rate of water and low flow rate of air (01/06/15)

On 01 May, experiment was conducted and found that the maximum intensity of light was 1291 w/m^2 at 12:00 PM and the ambient temperature in the range of 30^{0}C to 35^{0}C. The maximum temperature of saline water and air were 57^{0}C and 66^{0}C respectively. The mass flow rate of water and mass flow rate of air were kept 0.00834kg/s and 5.0 m/s during the whole day and conducted the reading after every half an hour.

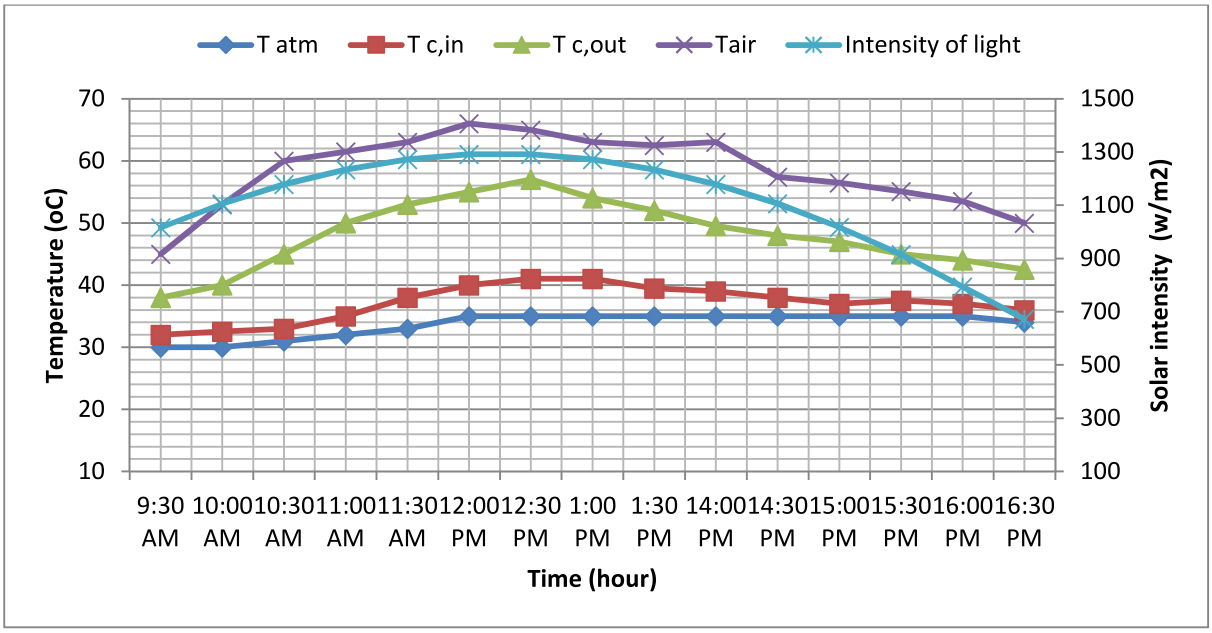

Figure 19: Variation of temperature of water, air and intensity of light w.r.t time

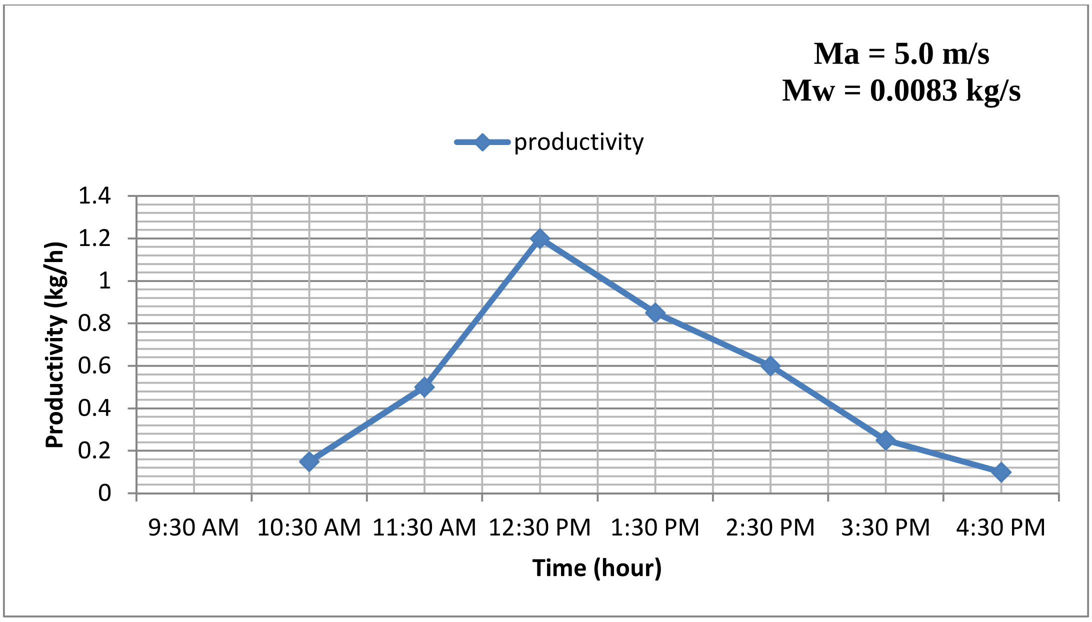

Figure20: The productivity variation through the day (28/04/15)

During the day 1May, mass flow rate of air (M_a) and mass flow rate of water (M_w) were kept 5.0 m/s and 0.0083 kg/s respectively. The maximum production of fresh water during the day was 1.2 kg and the total production of fresh water was approximately 3.65 kg.

Due to increase in the mass flow rate of water, the temperature of the saline water inlet to the humidifier is decrease, leading to decrees the vaporization that will decrease the productivity of water.

4.2.3 Day 3: low flow rate of water and high flow rate of air (29/04/15)

On 29 April, experiment was conducted and found that the maximum intensity of light was 1288 w/m^2 at 12:00 PM to 12:30 PM and the ambient temperature in the range of 29^{0}C to 38^{0}C. The maximum temperature of saline water and air were 60^{0}C and 61.5^{0}C respectively. The mass flow rate of water and mass flow rate of air were kept 0.0042kg/s and 8.0 m/s during the whole day and conducted the reading after every half an hour.

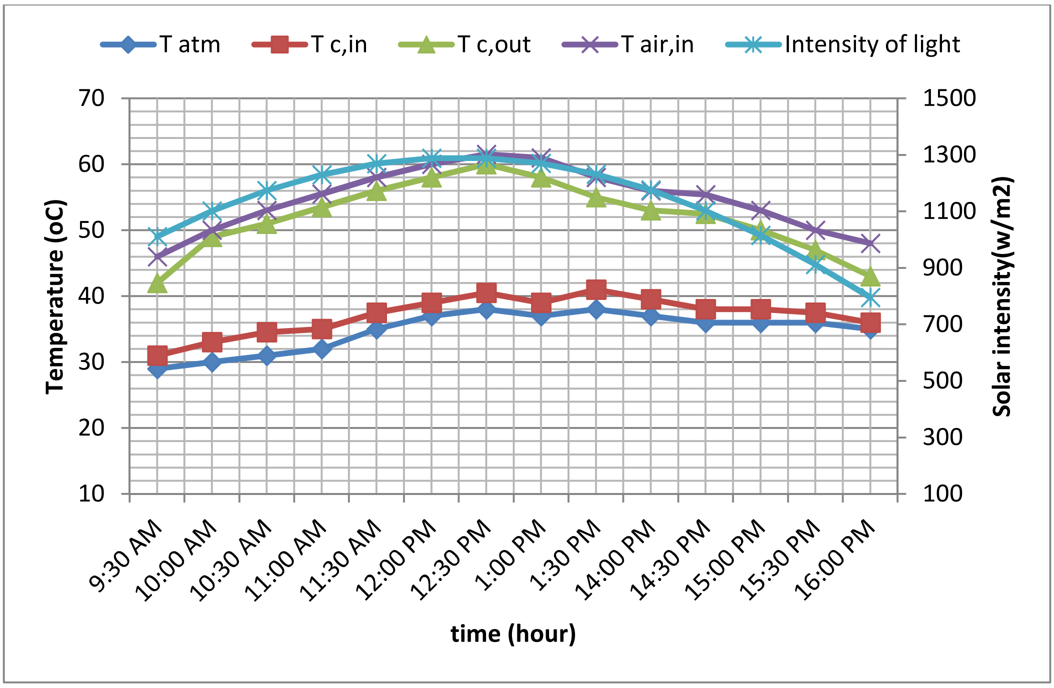

Figure21: variation of temperature of water, air and intensity of light w.r.t time

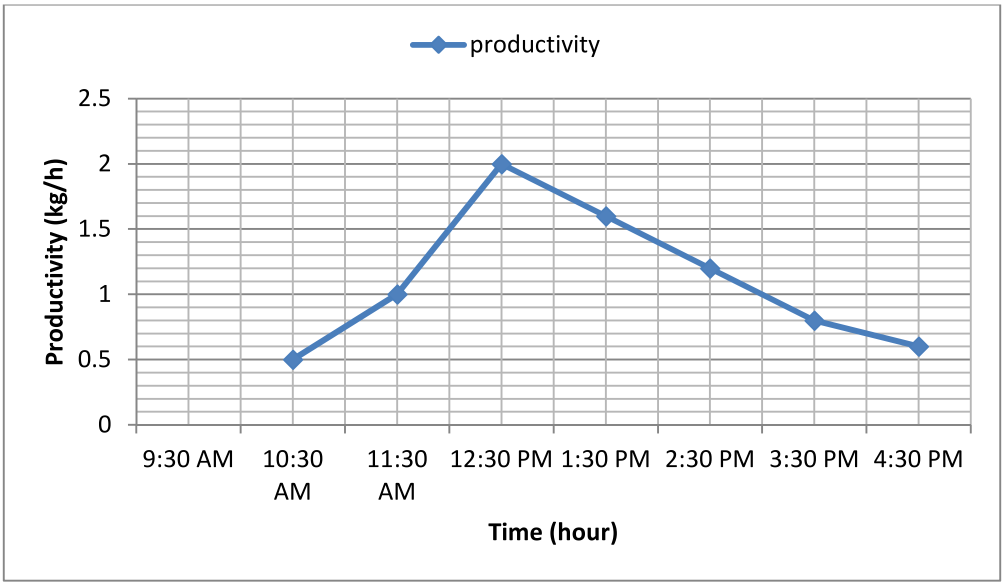

Figure22: The productivity variation through the day (29/04/15)

During the day 29 April, mass flow rate of air (M_a) and mass flow rate of water (M_w) were kept 8.0 m/s and 0.0041 kg/s respectively. The maximum production of fresh water during the day was 2.0 kg and the total production of fresh water was approximately 7.7 kg.

This increase in the production of fresh water may be due to increase in the mass flow rate of air increase the mass and heat transfer coefficient and increase the water vapour and hence increase the production.

4.2.4 Day 4: High flow rate of water and high flow rate of air (04/05/2015)

On 4 May, experiment was conducted and found that the maximum intensity of light was 1295 w/m^2 at 12:00 PM to 12:30 PM and the ambient temperature in the range of 32^{0}C to 39^{0}C. The maximum temperature of saline water and air were 62^{0}C and 64^{0}C respectively. The mass flow rate of water and mass flow rate of air were kept 0.0084kg/s and 8.0 m/s during the whole day and conducted the reading after every half an hour.

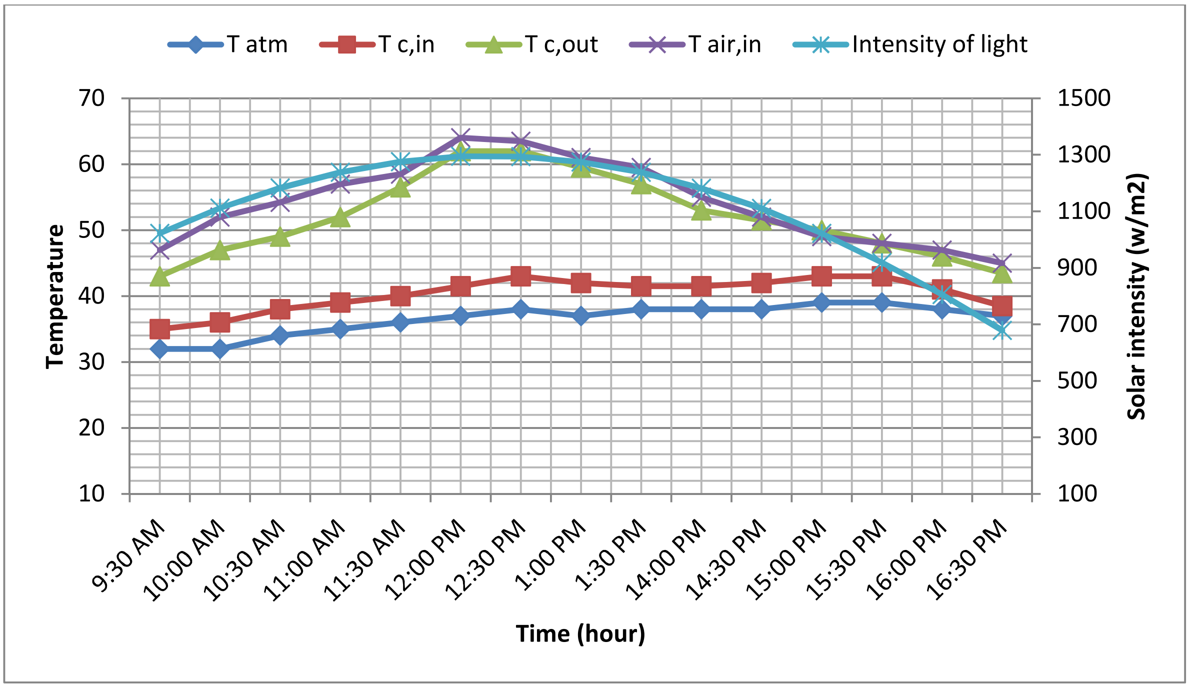

Figure23: variation of temperature of water, air and intensity of light w.r.t time

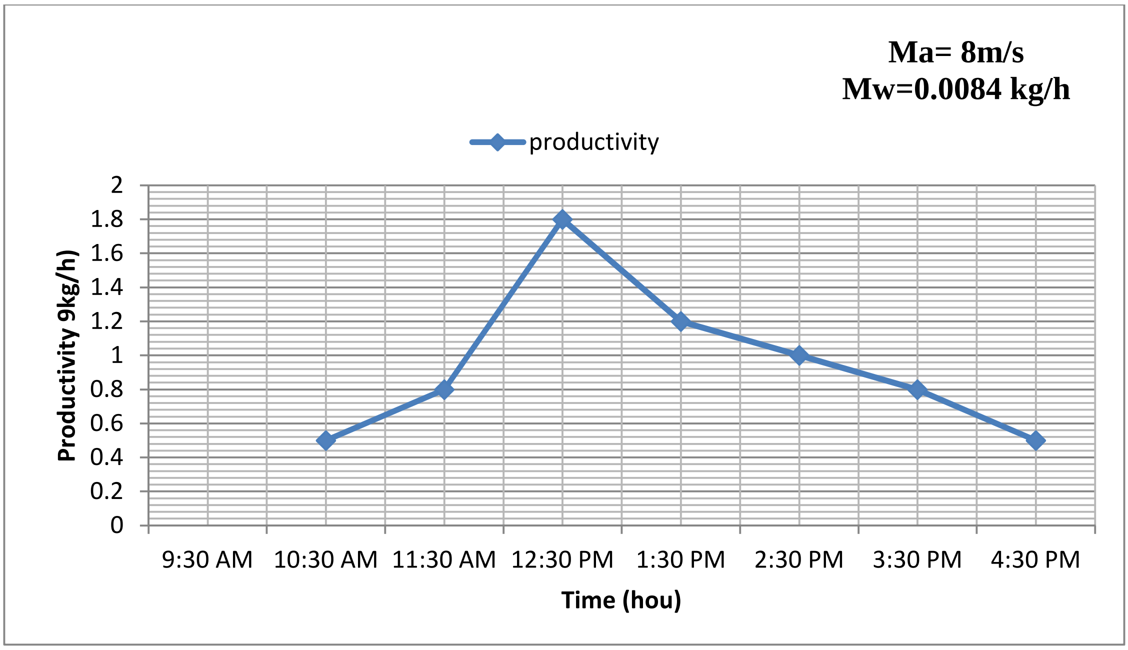

Figure24: The productivity variation through the day (04/05/15)

During the day 04 May, mass flow rate of air (M_a) and mass flow rate of water (M_w) were kept 8.0 m/s and 0.0084 kg/s respectively. The maximum production of fresh water during the day was 1.8 kg and the total production of fresh water was approximately 6.5kg.

This decrease in the production may be due to increase in mass flow rate of saline water to 0.0084kg/h , the temperature of the saline water inlet to the humidifier is decrease, leading to decrees the vaporization that will decrease the productivity of water.

4.2.5 Effect of saline water flow rate on unit productivity

Figure 25 shows that the variation of productivity of fresh water with increase in mass flow rate of saline water. In the first case when the mass flow rate of saline water was 0.0042 kg/s then total accumulative production of fresh water was 7.7 kg and when the flow rate of saline water is increased to 0.0084 kg/h then the productivity of water is 6.5kg. This decrease in the productivity because due to increase in the mass flow rate of water, the temperature of the saline water inlet to the humidifier is decrease, leading to decrees the vaporization that will decrease the productivity of water.

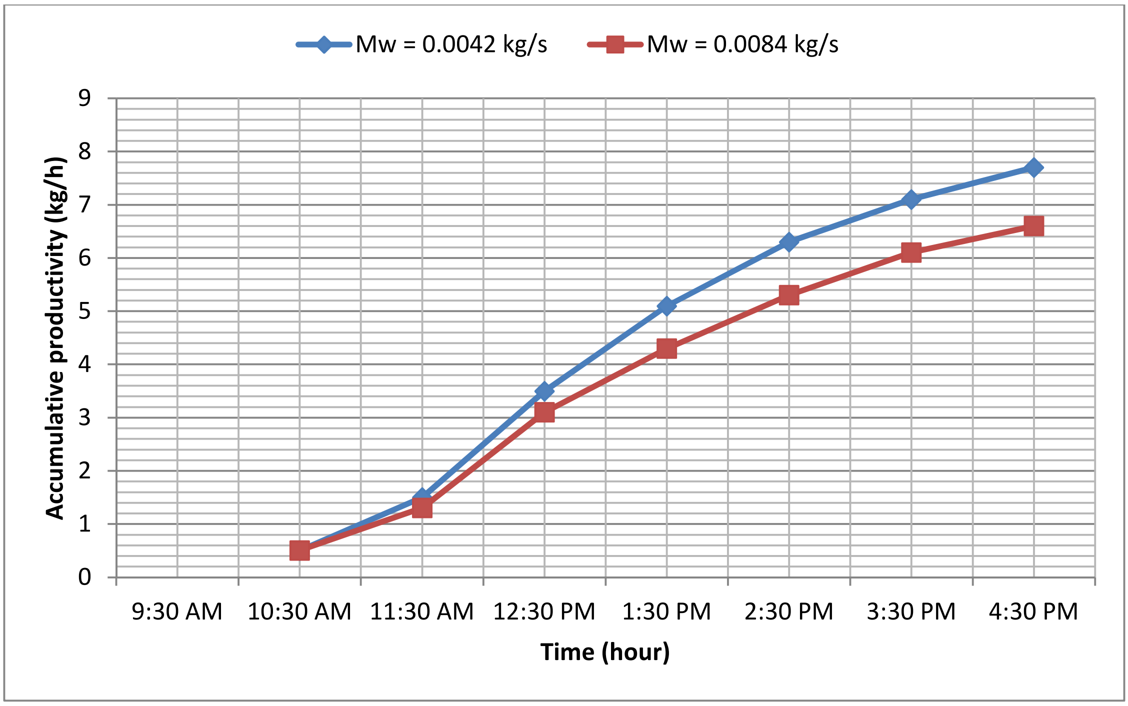

Figure 25: Effect of mass flow rate of saline water

4.2.6 Effect of air flow rate on unit productivity

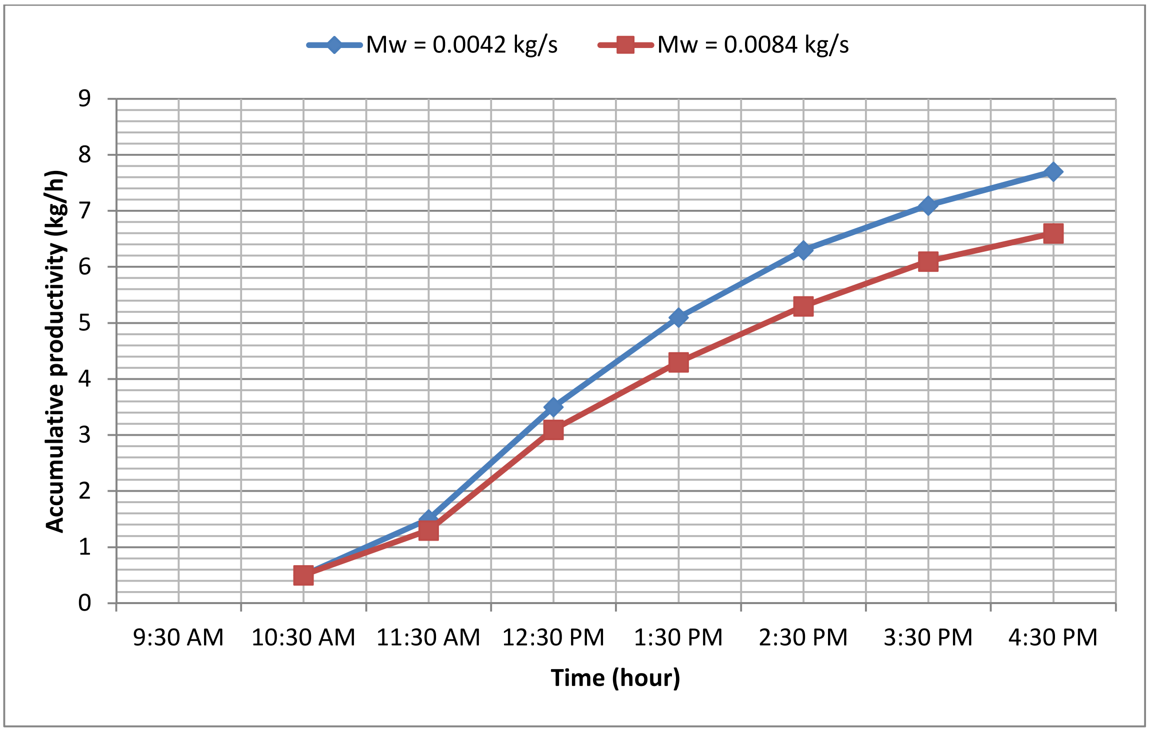

Figure 26: Effect of flow rate of air on productivity

Figure 26 shows that effect of flow rate of air on unit productivity keep the mass flow rate saline water same. In the first case when mass flow rate of air was 5.0 m/s then the accumulative productivity of fresh water was 4.9 kg and in second case when the flow rate of air was 8.0 m/s then total accumulative productivity was 7.6 kg. This increase in productivity of water due increase in the mass flow rate of air increase the mass and heat transfer coefficient and increase the water vapour and hence increase the production.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE OF WORK

5.1 Conclusion

In this experiment result different parameter are considered to check the unit productivity like mass flow rate of saline water and flow rate of air. From the result found that there is strong effect of saline water temperature and air temperature to the humidifier on unit production. Either increase flow of air or decrease flow rate of water increase the productivity of fresh water

- With the increase in saline water and air temperature increase the unit productivity
- With increase in flow rate of air increase the heat transfer coefficient and mass transfer coefficient result in more water vapour in the air.
- With increase in solar intensity both the air temperature and saline water temperature increases.

5.2 Scope of study work

Many results and information's have been obtained through this experimental study. These results are new and may contribute a little to the field of utilization of renewable energy. In this experimental set up, many components are used. Rigorous practices on their design parameters and a depth study on their properties and behaviors have been taken into the consideration. Apart from these, there may be some advanced scopes of the present work. The related future work may be as follows:

- By using evacuated tube relatively cupper tube as a receiver we may get more temperature of saline water that may be increase the unit productivity.
- By increasing the area of the reflector we may get more temperature of the water.
- By increasing the number of spray nozzles in the humidifier may increase the water vapour so we can get more fresh water.

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Appendix

This section includes the observation that is conducted during the experiment work from day 1 to day 4. The data is tabulated from day 1 to day 4 respectively. Every day the mass flow rate of saline water and flow rate of air is different.

Table1: Data for day 1 when mass flow rate of water 0.0042 kg/s and air flow rate 5.0 m/s

time (t)	T atm (^{0}C)	T c,in (^{0}C)	T c,out (^{0}C)	T air,in (^{0}C)	Intensity of light (w/m^2)	Ma (m/s)	Mw (L/h)	RH (%)
9:30 AM	32	34	40.5	53.5	1009	5.0 m/s	15 L/h	82
10:00 AM	33	36	44.5	55	1099	5.0m/s	15 L/h	89
10:30 AM	33	36.5	48	56.8	1172	5.0 m/s	15 L/h	88
11:00 AM	34	38	50	57.3	1229	5.0 m/s	15 L/h	89
11:30 AM	36	39.5	52.5	58.5	1267	5.0 m/s	15 L/h	90
12:00 PM	37	42	58	63	1286	5.0 m/s	15 L/h	86
12:30 PM	38	43	63	62	1287	5.0 m/s	15 L/h	88
1:00 PM	37	41.5	61.5	61	1268	5.0 m/s	15 L/h	89
1:30 PM	38	42.7	61	59.5	1231	5.0 m/s	15 L/h	71
14:00 PM	37	42	58	58	1175	5.0 m/s	15 L/h	71
14:30 PM	37	41.5	56	57	1102	5.0 m/s	15 L/h	69
15:00 PM	36	40.5	54	56	1013	5.0 m/s	15 L/h	54
15:30 PM	36	40	51	53	910	5.0 m/s	15 L/h	48
16:00 PM	36	40	45	49.6	794	5.0 m/s	15 L/h	47
16:00 PM	35	39	43	48.7	667	5.0 m/s	15 L/h	47

Table: Data for day 2 when mass flow rate of water 0.0042 kg/s and air flow rate 8.0 m/s

time (t)	T atm (^{0}C)	T c,in (^{0}C)	T c,out (^{0}C)	T air,in (^{0}C)	Intensity of light (w/m^2)	Ma (m/s)	Mw (L/h)	RH (%)
9:30 AM	29	31	42	46	1011	8	15	83
10:00 AM	30	33	49	50	1101	8	15	88
10:30 AM	31	34.5	51	53	1174	8	15	77
11:00 AM	32	35	53.5	55.5	1230	8	15	84
11:30 AM	35	37.5	56	58	1269	8	15	72
12:00 PM	37	39	58	60	1288	8	15	71
12:30 PM	38	40.5	60	61.5	1288	8	15	56
1:00 PM	37	39	58	61	1270	8	15	53
1:30 PM	38	41	55	58	1232	8	15	57
14:00 PM	37	39.5	53	56	1176	8	15	56
14:30 PM	36	38	52.5	55.4	1103	8	15	56
15:00 PM	36	38	50	53	1015	8	15	56
15:30 PM	36	37.5	47	50	912	8	15	55
16:00 PM	35	36	43	48	796	8	15	55
16:30 PM	34	35	40	45	669	8	15	54

Table3: Data for day 3 when mass flow rate of water 0.0084 kg/s and air flow rate 5.0 m/s

time (t)	T atm	T c,in	T c,out	Tair	Intensity of light	Ma	Mw	RH
9:30 AM	30	32	38	45	1016	5	30 l/h	75
10:00 AM	30	32.5	40	53	1105	5	30 l/h	85
10:30 AM	31	33	45	60	1178	5	30 l/h	92
11:00 AM	32	35	50	61.5	1234	5	30 l/h	82
11:30 AM	33	38	53	63	1272	5	30 l/h	82
12:00 PM	35	40	55	66	1291	5	30 l/h	82
12:30 PM	35	41	57	65	1291	5	30 l/h	82
1:00 PM	35	41	54	63	1272	5	30 l/h	80
1:30 PM	35	39.5	52	62.5	1234	5	30 l/h	92
14:00 PM	35	39	49.5	63	1179	5	30 l/h	82
14:30 PM	35	38	48	57.4	1106	5	30 l/h	76
15:00 PM	35	37	47	56.5	1018	5	30 l/h	75
15:30 PM	35	37.5	45	55.1	915	5	30 l/h	73
16:00 PM	35	37	44	53.5	794	5	30 l/h	73
16:30 PM	34	36	42.5	50	673	5	30 l/h	73

Table4: Data for day 4 when mass flow rate of water 0.0084 kg/s and air flow rate 8.0 m/s

time (t)	T atm	T c,in	T c,out	T air,in	Intensity of light	Ma	Mw	RH
9:30 AM	32	35	43	47	1022	8 m/s	30L/h	71
10:00AM	32	36	47	52	1111	8 m/s	30L/h	75
10:30AM	34	38	49	54.2	1183	8 m/s	30L/h	86
11:00AM	35	39	52	57	1238	8 m/s	30L/h	86
11:30AM	36	40	56.5	58.5	1276	8 m/s	30L/h	85
12:00 PM	37	41.5	62	64	1295	8 m/s	30L/h	87
12:30 PM	38	43	62	63.5	1294	8 m/s	30L/h	86
1:00 PM	37	42	59.5	61	1275	8 m/s	30L/h	84
1:30 PM	38	41.5	57	59.5	1238	8 m/s	30L/h	85
14:00 PM	38	41.5	53	55	1182	8 m/s	30L/h	80
14:30 PM	38	42	51.5	52	1110	8 m/s	30L/h	78
15:00 PM	39	43	50	49	1022	8 m/s	30L/h	75
15:30 PM	39	43	48	48	919	8 m/s	30L/h	74
16:00 PM	38	41	46	47	805	8 m/s	30L/h	72
16:30 PM	37	38.5	43.5	45	679	8 m/s	30L/h	71