

**FABRICATION AND TESTING THE PERFORMANCE A HEAT
EXCAHNGER SUITABLE FOR AIR CONDITIONING SYSTEM
BASED ON EVACUATED TUBES COLLECTOR**

Dissertation-II

Submitted in partial fulfillment of the requirement for the award of

degree

Of

Master of Technology

IN

MECHANICAL ENGINEERING

By

Rohit Kumar

11307402

Under the guidance of

Mr. Onkar Singh



**DEPARTMENT OF MECHANICAL ENGINEERING
LOVELY PROFESSIONAL UNIVERSITY
PUNJAB
2016-2017**

TOPIC APPROVAL PERFORMA

School of Mechanical Engineering

Program : 1208D::B.Tech -M.Tech (Dual Degree) - ME

COURSE CODE : MEC604

REGULAR/BACKLOG : Regular

GROUP NUMBER : MERGD0214

Supervisor Name : Onkar Singh

UID : 13653

Designation : Assistant Professor

Qualification : _____

Research Experience : _____

SR.NO.	NAME OF STUDENT	REGISTRATION NO	BATCH	SECTION	CONTACT NUMBER
1	Rohit Kumar	11307402	2013	M1326	9501842214

SPECIALIZATION AREA : Thermal Engineering

Supervisor Signature: _____

PROPOSED TOPIC : Fabrication and Testing the performance of a Header (Heat Exchanger suitable) for solar air conditioning system based on evacuated tube collectors.

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	Parameter	Rating (out of 10)
1	Project Novelty: Potential of the project to create new knowledge	7.00
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.00
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.00
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	7.00
5	Social Applicability: Project work intends to solve a practical problem.	8.00
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	7.00

PAC Committee Members		
PAC Member 1 Name: Minesh Vohra	UID: 15783	Recommended (Y/N): NA
PAC Member 2 Name: Vijay Shankar	UID: 16474	Recommended (Y/N): NA
PAC Member 3 Name: Sudhanshu Dogra	UID: 16900	Recommended (Y/N): Yes
DAA Nominee Name: Kamal Hassan	UID: 17469	Recommended (Y/N): NA

Final Topic Approved by PAC: Fabrication and Testing the performance of a Heat Exchanger for solar air conditioning system based on evacuated tube collectors.

Overall Remarks: Approved (with minor changes)

Approval Date: 11 Nov 2017

PAC CHAIRPERSON Name: 12174::Gurpreet Singh Phull

CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled “*fabrication and testing the performance of heat exchanger suitable for solar air conditioning system based on evacuated tubes collector*” in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of Mr. Onkar Singh, Associate Professor Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

Date:

Name: Rohit Kumar

Registration No: 11307402

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

Date:

Name: Mr. Onkar Singh

UID: 13653

COD (ME)

The external viva-voce examination of the student was held on successfully _____

Signature of Examiner

DECLARATION

I, Rohit Kumar, student of **Master of Technology (Mechanical Engineering)** under School of **Mechanical Engineering** of Lovely Professional University, Punjab, hereby declare that all the information furnished in this dissertation reports based on my own intensive research and is genuine. This dissertation does to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university without proper citation.

Rohit Kumar

Registration No.: 11307402

Date:

Acknowledgment

First and the foremost I offer my sincerest gratitude to my supervisor, Mr. Onkar Singh, Assistant Professor, School of Mechanical Engineering, Lovely Professional University, Punjab.

I am thankful to **Mr. Gurpreet Singh Phull**, (HOS) and **Mr. Sudhanshu Dogra** (HOD) School of Mechanical Engineering, Lovely Professional University, Punjab.

I would like to thank all the staff members of School of Mechanical engineering who have been very patient and co-operative with me.

I would also like to extend my gratitude to my seniors

I would like to thank **Lovely Professional University** for giving me opportunity to use their resources and work in such a challenging environment. I am grateful to the individuals whom contributed their valuable time towards my thesis.

Last but not the least, I express my sincere gratitude to my parents and brother who have always supported me throughout all my studies at university and encouraged me with their best wishes.

Abstract

In this report, fabrication and testing of heat exchanger based on evacuated tube collector for solar air conditioning is experimentally investigated. Solar radiation falling on the evacuated tubes in day time is utilized. The water in the evacuated tubes get heated and the hotted water moves up into the header or heat exchanger. The water inside the heat exchanger transfer the heat energy to the PCM unit. This PCM unit stores the thermal energy for the later use when there is no sun light available. In the center, a hollow circular pipe through which air is blown with the help of a blower. At the other end of the heat exchanger hot air comes out which is further used for air conditioning.

INDEX

Acknowledgment	v
Abstract	vi
List of Figures	viii
List of Tables	viii
Introduction	1
Solar energy	1
Flat plate collectors and Evacuated tube collectors	2
Phase Change Materials	4
Heat Exchanger	5
Scope of Study	7
Objective of Study	8
Review of Literature	9
Research Methodology	13
Experimental Setup	15
Measuring Devices and Instruments	18
Experimental Work	19
Expected Outcomes	21
References	22

List of Figures

Figure 1. Flat plate collector	2
Figure 2. Evacuated tube	3
Figure 3. Evacuated tube collector	4
Figure 4. Phase change mechanism of water	5
Figure 5. classification of heat exchnager	6
Figure 8. Diadram of header with PCM unit	16
Figure 9. helical shape copper coil.....	17
Figure 10. schematic diagram of heat exchanger based on evacuated tubes with PCM unit	20

List of Tables

Table 1. properties of acetamide	16
--	----

Introduction

In this modern world population is increasing as result the demands are also increasing for better life. The gap between the supply of energy and the demand of energy is continuously growing. Due to pollution and easy availability, renewable energy is getting attention of many researchers. This is leading to serious consideration to the renewable energy technology.

All these can be control with the more use of renewable energies. With the use of renewable energies the population demands can be fulfilled with building up of natural balance. The global use of renewable energy technology is about 1% of the total global energy production. All around the world many efforts are being carried out to use the renewable sources as much as possible. Numbers of inventions are done which is leading to global warming and green house effect. Further improvements are made in renewable technology for better performance.

Solar energy

Solar energy does not belong to anyone, and it's totally free and available in abundance. Solar energy is the energy which is emitted by the sun in enormous amount. The amount of energy emitted by the sun in one second is more than the people have used. Solar energy is the famous form for renewable energy which is used for many applications. Solar radiation is collected and converted to do some useful work. Researchers are doing experimental study for enhancing the use of solar energy.

Sun is a big star of gas with mostly hydrogen and helium in it. A process called as nuclear fusion occurs inside the core of sun which generates a lot of energy. The temperature and pressure are very high which causes the hydrogen atoms to move apart and the nuclei to fuse together during the nuclear fusion. The four hydrogen atoms nuclei fuse together to form one helium atom, but the helium atom weigh less than the four nuclei of hydrogen atom. Some matter is lost during nuclear fusion and this lost matter is radiated into the space. The distance between sun and earth is 93 million miles radiated energy from the sun takes approximately 8 minutes to reach earth with a speed of 186,000 miles per

second. A very little amount of energy is able to reach the earth surface but that little energy itself is very enormous.

The main challenge is to collect and store the solar energy though it is free of cost and available in abundance. We have to collect solar energy efficient manner because its available only in sun shine hours of the day. Solar thermal collectors are used for collecting the solar thermal energy and which then transfer this thermal energy to the working fluid.

Flat plate collectors and Evacuated tube collectors

Two types of collectors mostly used are Flat Plate Collectors (FPC) and Evacuated Tube Collectors (ETC). Operating temperature range for FPC is 20°C to 80°C and for the ETC is 50°C to 200°C. FPC are more popular because they are simple and have low maintenance cost, but FPCs have low efficiency and low outlet temperature.



Figure 1. Flat plate collector

On the other hand, FPCs comprises of major shortcomings:

- a) Convective heat losses from the glass cover.
- b) Can't track sun light.

These two shortcomings can be overcome using ETCs. The vacuum space between the two concentric glass tubes eliminates the heat losses and tubular design eliminates the sun tracking problem in ETCs, which was in FPCs. ETCs have considerably lower in cost as compared to average FPCs. FPCs are basically designed to work in sunny and warm weather climatic conditions. They are significantly influenced by the weather and their performance gets reduced during cloudy, cold and in windy climatic conditions. The condensation and moisture causes erosion inside the material which can lead to system failure. ETCs are more favorable to unsuitable climatic conditions than FPCs.

In this study, I have used ETC instead of FPC because numerous authors [] have concluded that ETC has greater efficiency than the FPC, especially at low temperature. ETC is made of two concentric glass pipes, the inner pipe and the outer pipe. The outer tube is transparent while the inner tube is coated with a selective coating which helps in absorption of heat radiation. Solar radiation passes through the outer tube and gets absorbed in the inner tube. Property of glass is such that the tubes offer minimal reflection. Vacuum is created between the two tubes because of which sunlight is able to go through the tubes, heat is there but is not able to transfer. The two glass tubes are fused together at one end; the air in-between is pumped out which results in vacuum. This vacuum is very effective. It reduces the conductive as well as the convective losses and also its working is less affected by the wind and in low temperature.

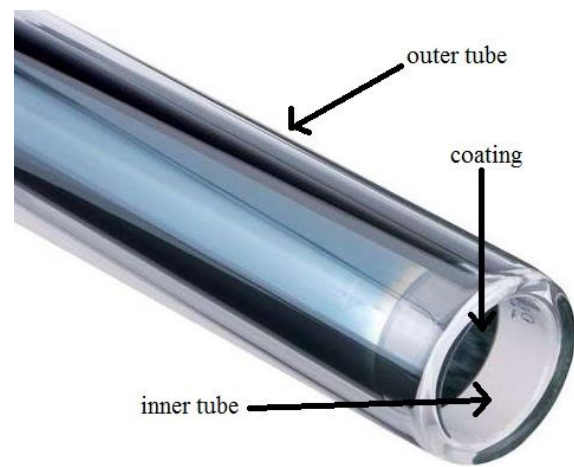


Figure 2. Evacuated tube

ETC is cylindrical in shape which helps in tracking the sun. Throughout the day the angle of incident remains 90° . Even the maintenance cost is low. If a tube gets broken, the system still works with over efficiency. The broken evacuated tube can easily be replaced without shutting down the system. Therefore; they are more suitable for use.



Figure 3. Evacuated tube collector

Phase Change Materials

One way of storing thermal energy is using phase change material (PCM) under the field of thermal Energy System (TES) and it is a clean method. PCM materials are capable of storing heat energy and later on this stored energy is used. Energy is stored and release with the PCM in the form of latent heat during phase changing from solid to liquid or liquid to gas or vice versa.

When PCM is melting, it is absorbing thermal heat energy from surrounding, whereas PCM freezes, it is releasing that thermal heat energy. Storage of thermal energy will improve the overall efficiency of a system. PCM has the property of melting and solidifying at room temperature i.e. why they are broadly use to store thermal energy in several applications like waste heat storage, passive cooled shelters, cooling and heating technology, air conditioning, transport containers for medicine and food, electronic items, catering, energy conservation, etc.

Heat is supplied to the matter in forms of sensible heating and latent heating. If the temperature of the matter changes without any change in its phase is related as sensible heating of matter. Addition or removal of heat energy by the matter or from the matter at constant temperature with change in phase is related as latent heating of matter.

PCM working mechanism of water at 1 atmospheric is as follows:

Consider an ice below 0°C , say -4°C and at 1 atmospheric pressure. Heat is supplied to the ice and the temperature of ice increases to 0°C , this is the sensible heating . now more heat is given to the ice due to which ice at 0°C is converted into water at 0°C . here the temperature remains constant but the is change is the phase that is 0°C , this is the latent heating. Futher more heat is given and the water temperature increases from 0°C to 100°C without any change in its phase, again sensible heating. Heat is futher given and water at 100°C is converted into steamor vapour form at 100°C , which shows the latent heating as the phase change is occurring with increase in temperature.

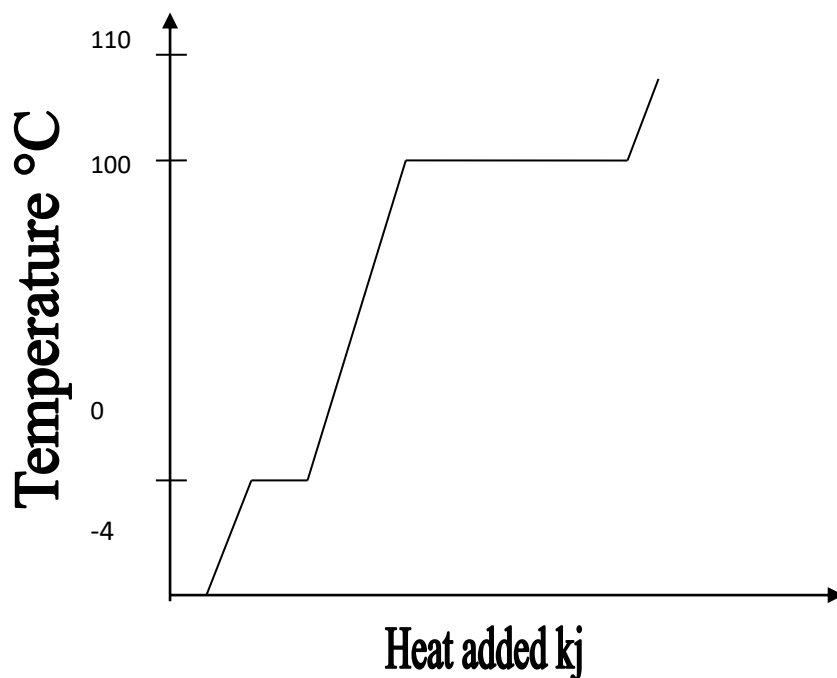


Figure 4. Phase change mechanism of water

Heat Exchanger

Heat exchangers are the devices which are used to transfer or exchange the heat energy between two or more fluids having different temperatures. Heat exchangers have large varieties of application, which includes power generation, refrigeration, waste heat recovery, air-conditioning, industries, food preservation, electronics and lot more applications. Heat exchangers are classified on many criteria.

Classification of heat exchanger

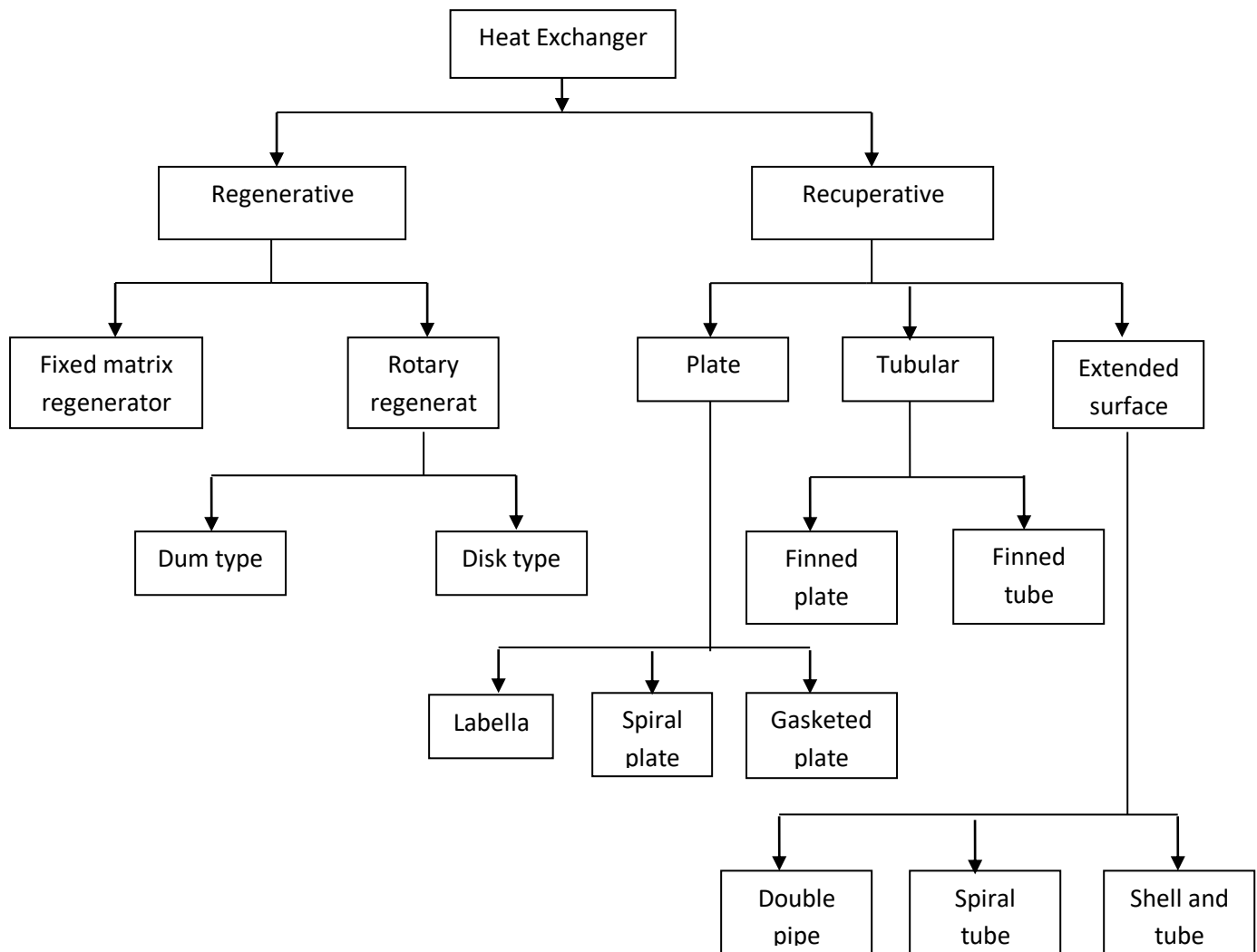


Figure 5. classification of heat exchnager

Scope of Study

Now days, renewable resources are getting more importance in research field due to increase in the pollution in the atmosphere which leads to change the climatic conditions of living beings. Renewable resources do not produce any harmful gases and are safe for the environment. Renewable resource saves lot of money once they are installed. In my study, I'm working on a renewable energy known as solar energy. I will be fabricating and testing the performance of heat exchanger based on solar evacuated tubes for air conditioning . Fact it has a good scope in future. The things required for this heat exchanger are a Phase Change Material, 40 evacuated tubes, glass wool, mild steel and stainless steel. Phase Change Material for storing latent thermal heat energy which is going to be used in off sun shine hours, evacuated tubes for absorbing solar heat, glass wool for insulating the heat exchanger, mild steel for manufacturing of outer body and frame for the setup and stainless steel for fabricating the interior of heat exchanger for preventing corrosion. The PCM which is selected is acetamide because of its properties like melting and boiling point which suits to our required conditions. Acetamide is non reactive and has high density also stores high amount of solar energy.

Objective of Study

- Minimize the electricity cost.
- To store large amount of thermal heat energy from the sun.
- To prevent thermal losses.
- To maintain air conditioning in sunshine hours and even in off-sunshine hours.
- High outlet temperature of air.
- Effective flow velocity of air inside the heat exchanger.
- High difference temperature between the ambient air temperature and air inside the header.
- High absorption rate of solar radiation.
- To maintain air conditioning for long duration of time.

Review of Literature

Vinay et al. [1] investigated studies that have been carried out for the latent heat storage of Phase Change Material (PCM). We need to have a specific analysis system by which we can have results in acceptable range out of numerous results. This review paper includes much analysis which was done on inlet temperature of coolant and mass flow rate of coolant with melting and solidification of Phase Change material within the heat exchangers. Aim of this review paper to study the performance of heat exchangers with PCM as latent heat storage for different conducting parameters with results. A high temperature difference is needed between the air and PCM to melt and freeze material. C.O.P. can be increased using PCM. By increasing the HTF flow rate the charging time can be reduced.

Mayank et al. [2] Studies on the performance evacuated tube collectors and comparison with flat plate collector. The evacuated tube collectors have more advantage than Flat plate collectors because of absence of convective losses in evacuated tubes. It presents how Computational Fluid Domain study of ETC helps is a good way of comparing with the experimental results for validation.

Avadhesh et al. [3] Conducted an experimental study on header integrated with evacuated tubes for heating of air. The length of evacuated tubes as well as the header length was 150 cm. the header consist of a hollow cylindrical pipe in the center and water as a heat collector. Water gets heated from the evacuated tubes and this heat is transferred to the air flowing inside the header. Outlet air temperature highly depends on flow rate and intensity of radiation fall on evacuated tubes. For both, down flow and up flow of air the study have been carried out with similar weather conditions. Down flow configuration is more efficient due to lesser losses. Minimum of 60 degree or high can be achieve with downward flow.

Neeraj et al. [4] studied thermal analysis of PCM based evacuated tubes solar air collector was studied for both charging and discharging modes. PCM used is acetamide. The average minimum efficiency was 17.9% at high flow rate of 0.035kg/s . The average efficiency and total energy of high air flow rate was 1.06 to 1.30 and 1.01 to 1.02 times more in comparison to low air flow rate respectively. These results shows that the PCM

based evacuated tubes solar air collector can be used successfully for air heating in northern India with good quality sunlight.

Sarvenaz et al. [5] Studied solar water heaters are adopted world wide as they are the good renewable energy technology. Evacuated tubes collectors improved by using Carbon Nanotubes sheet coating which increases the energy absorbed from the sun. Octadecane paraffin used as a PCM which has a melting temperature of 28°C and used for increasing the energy accumulation in solar heaters. PCM may not be so effective but by combining carbon nanotubes layers the limitation can be overcome and can be more efficient. In addition, an ideal body surface can be introduced for absorbing maximum of 98% of solar radiation striking the surface. Carbon Nanotubes coating provides extra spectra absorption which increases performance of solar heaters. PCM combined with Carbon Nanotubes which permits heat storage directly on the collectors for more steady output on an unclear day and delay the cooling rate of water. The overheating of solar water heater should be avoided though to care for PCM from thermal degradation.

In this study, Raghurajsinh et al. [6] carried out study in detail for the application of solar energy using evacuated tube collector for hot water generation. The main focus of the study is on using evacuated tube collector with heat pipe technology. This will further enhance the improvement of energy consumption and energy efficiency. This investigation included the thermodynamic equation to find the efficiency and also included the review design parameters with the comparison between evacuated tubes and flat plate collector. This water heating technology can further be used for much other purpose because of its less losses and higher efficiency. The evacuated tube collector with heat pipe technology has best performance as compared to the other types. Evacuated tubes can further be improved so that their performance can be increased.

Adel A. Ghaneim [7] studied on optimization of evacuated tube collector (ETC) for solar cooling of house in summers. Goal was to study ETC for thermal efficiency in hot and harsh climate like Kuwait weather conditions. The vacuum spacing between the outer glass tube and the inner glass tube considerably improves ETC performance. Therefore ETC is used progressively all over the world. Thermal performance of ETC was recorded

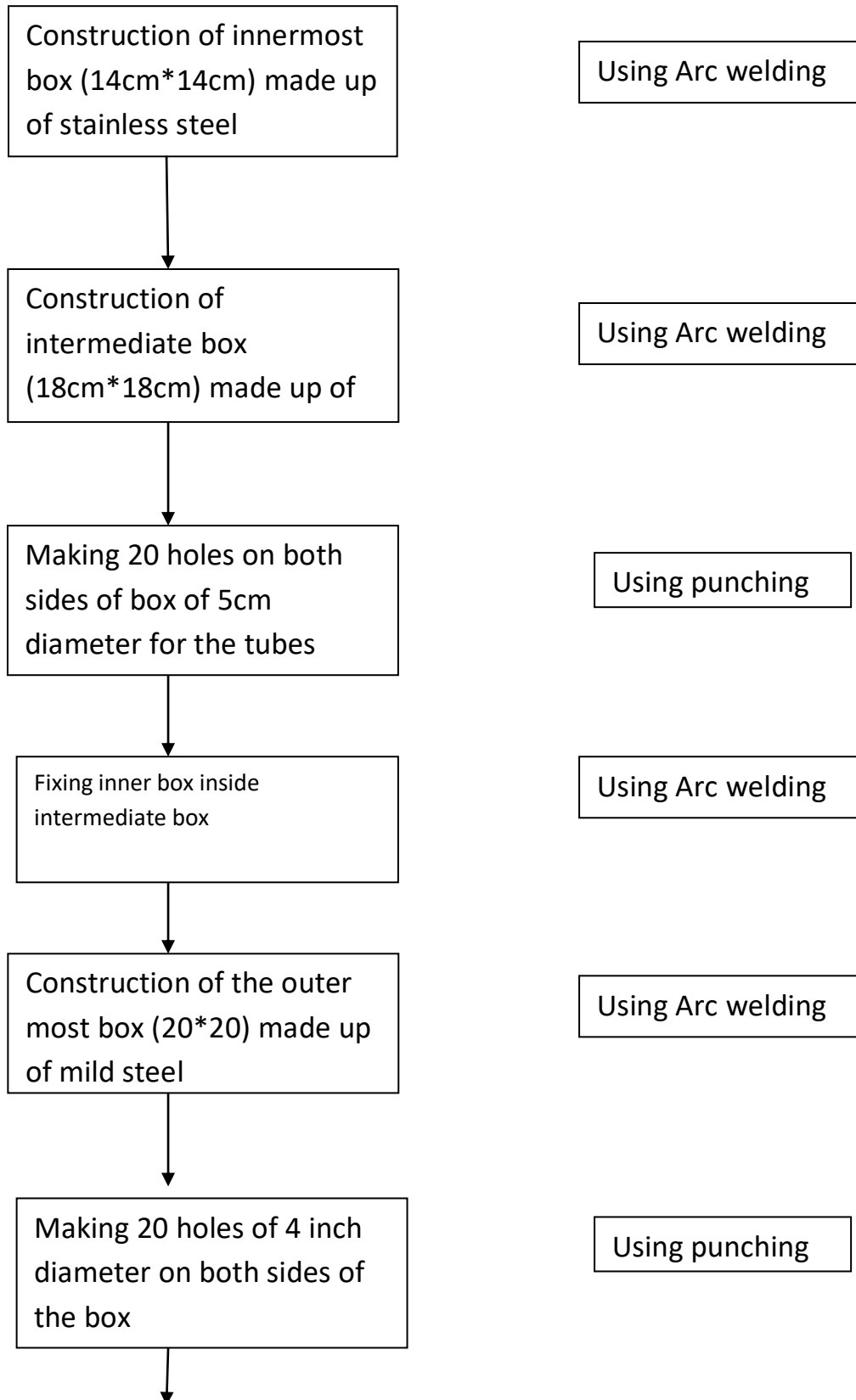
for one year. The predicted numerical results were found out to be in agreement with the obtained results. The optimums of ETC parameters are determined. The results obtained shows that the optimum tube length is 1.5 m because significant efficiency improvement is achieved for different tube diameters studied. The studied came out with results that ETC of area of 54 m², tilt angle of 25 degree, azimuth angle of 0 degree, mass flow rate of 30 kg/h.m² with maximum efficiency value of 0.53 and storage volume of 2.1 m³ provides 80% of air condition demand in a house located in a hot climate conditions like Kuwait.

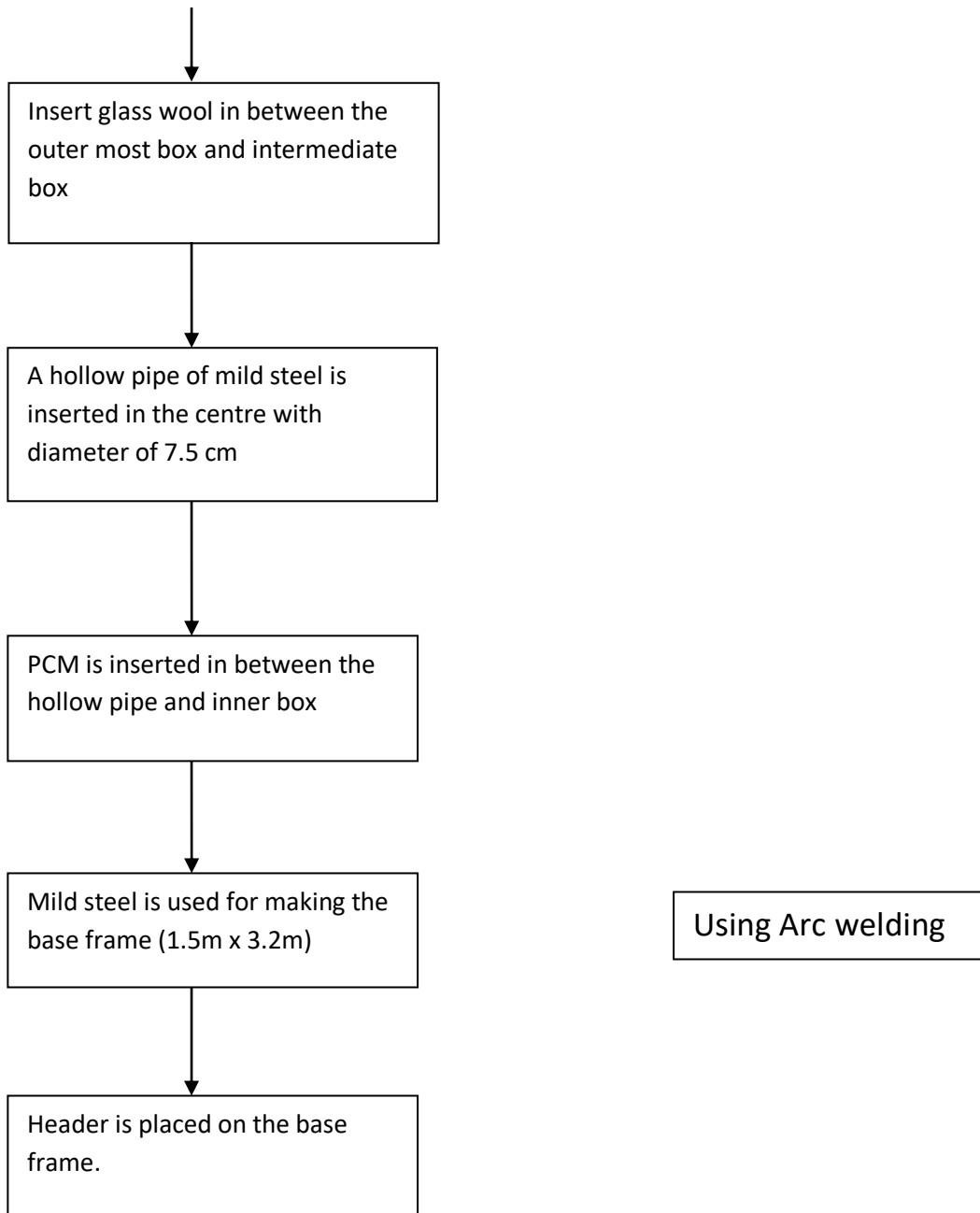
Neeraj et al. [8] investigated an experimental setup for a desiccant dehumidifier based on ETC with PCM. Acetamide is used as a PCM to store the heat energy in sun shine hours and release that energy in off sun shine hours of the day. Between ambient air temperature and outlet air temperature of the ETC with PCM has a maximum difference from 27.8 degrees C to 54.6 degrees C where as at 24:00 hrs , it varies from 12.9 degrees to 19.9 degrees C. Thus PCM can store sufficient amount of heat energy to generate hot air continuously for 14 hours a day from 10:00 hrs to 24:00 hrs. With the increase of air flow rate the difference between the temperature of ambient and outlet air of ETC with PCM unit decreases because the residence time of air reduces. This temperature difference at high flow rate of 127.23 kg/hr is 1.1 to 1.2 times lesser than at low air flow rate of 62.63 kg/hr. In the experimental investigation it was observed that the effectiveness of humidification (E_A), regeneration (E_R) and the dehumidification coefficient of performance are 8.17%, 10.35% and 0.0327 respectively at 16 rph of rotary desiccant wheel with 127.23 kg/hr air flow rate are higher. Dehumidifier effectiveness (E_A), Regeneration effectiveness(E_R) and dehumidification coefficient of performance at higher air flow rate are 1.0 to 1.10 times, 1.01 to 1.25 times and 1.31 to 1.58 times of low air flow rate respectively. Thus with the increase of air flow rate the dehumidifier effectiveness, regenerative effectiveness and dehumidification coefficient of performance increases. Even at 24:00 hrs, dehumidifier effectiveness, regenerative effectiveness and dehumidification coefficient of performance are obtained as 3.36%, 2.98% and 0.0224 respectively.

Amit et al. [9] performed an experimental Investigation on solar water heat exchanger using evacuated tubes with connecting pipes. Evacuated tubes are connected to the connecting pipes. The water gets heated up inside the evacuated tube the hot water flows due to the thermosiphon phenomenon. Ambient air is heated inside the heat exchanger of three different types viz. type 1, type 2 and type 3. The natural circulation flow of water was evaluated for various height of heat exchanger between 1050 mm to 1800 mm from the ground level. 10.7° C was the maximum temperature difference achieved between ambient temperature and hot air temperature by type 2 heat exchanger at 1550 mm from the ground level. The thermal efficiency at different heights from the ground level of heat exchanger can be arranged as $\eta_{1550\text{mm}} > \eta_{1880\text{mm}} > \eta_{1300\text{mm}} > \eta_{1550\text{mm}}$. Thermal efficiency for different types of heat exchangers used can be arranged as $\eta_{\text{type 2}} > \eta_{\text{type 1}} > \eta_{\text{type 3}}$. The efficiency obtained from heat exchanger type 2 at height of 1550 mm was 69.5%.

Avadhesh et al. [10] at different flow rate of 0.0332 kg/s and 0.06175 kg/s studied the experimental comparison between an evacuated tube solar collector and Flat plate solar collector. The setup consists of 40 evacuated tubes with surface area of 4.44 m². A square shaped header with circular pipe in the centre, where hot air flows. Water is the working fluid which is used. Sunlight falls on the evacuated tubes and water is heated up, which flows to the header and heats the air circulating inside the hollow pipe. Another setup consists of a flat plate collector with a surface area of 1.21 m². The absorber plate divides the collector into 2 sections, the upper section and the lower section to minimize the heat losses inside the collector. The temperature difference of ambient air and air outlet temperature was obtained at 38°C by ETC and 19°C by FPC. The ETC at high flow rate of air with downward flow provides best results. In FPC at low air flow rate with upward flow provides best results. The Observed Result showed that air at high flow rate and for high temperature difference of air, ETC is much more effective than FPC evacuated tube system with 40 tubes gives better energy saving.

Research Methodology





Experimental Setup



Figure 6. experimental setup view 1



Figure 7. experimental setup view 2

The experimental setup consist of 40 evacuated tubes, a header also known as heat exchanger in which a PCM , water , glass wool is used. The above figure is the experimental setup. 40 evacuated solar tubes are used for collecting the solar energy in which water will be the working fluid. Every evacuated tube is made up of two co-axial strong borosilicate glass tubes. These co-axial glasses are fused from the one end. Between these two glass tubes air is pumped out to create vacuum. This vacuum helps as a insulator. The outer glass tube of evacuated tube is transparent which permits beam rays to surpass through it with least amount of reflection. The outer surface of the inner tube is coated with a unique selective covering of aluminium nitride to absorb the solar radiation and convert these radiations into heat energy.

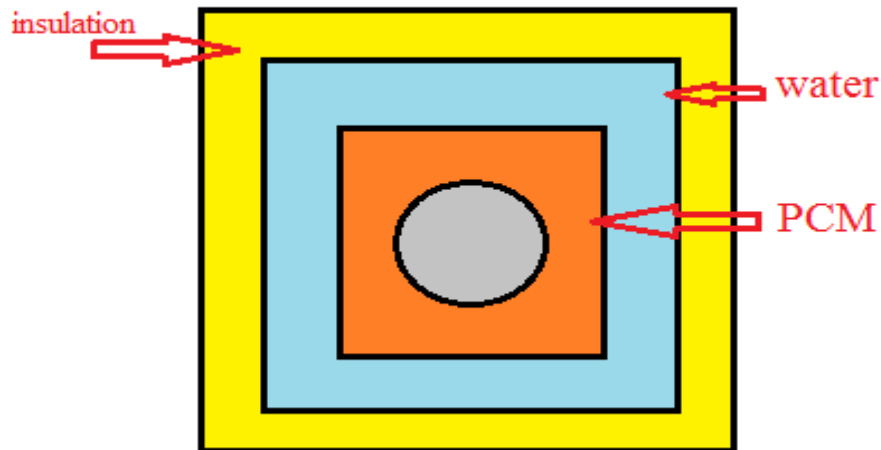


Figure 6. Diagram of header with PCM unit

A header/heat exchanger of two square cross sectional are used in this system structure and which can be seen in Figure. There are three square boxes, outer most box is manufactures from mild steel where as the other two are manufactures of stainless steel. The outer most box has 40 holes, 20 holes on two opposite sides of the box. Header with evacuated tubes is placed over the base frame which is prepared from mild steel. The evacuated tubes are inclined by an angle of 15° relative to horizontal. The open sides of the solar evacuated tubes are inserted inside these holes and the other ends of the evacuated tubes are supported by the base frame. Hollow pipe placed in the center is prepared from stainless steel. Hollow pipe in the center has the diameter of 0.075. Between the inside most square box and hollow pipe is filled with PCM which is acetamide. The acetamide used to fill is around 50 kg. The properties of acetamide is given in table 1. The space between the outer most square box and intermediate box is insulated using glass wool. This insulation is provided to prevent the heat transfer between the heat exchanger and atmosphere. For the safety reason two vents are also provided to reject additional quantity of heat energy into the atmosphere.

Table 1. properties of acetamide

Molecular Formula	C_2H_5NO
Melting Point	81 °C
Boiling Point	222 °C
Latent heat of fusion	263 kJ/kg

Thermal conductivity	0.5W/mK
Density	
Solid	1159 kg/m ³
Liquid	998 kg/m ³

Aluminium sheet has a reflectivity of 88%, this aluminium sheet is used under the evacuated tubes to reflect back the heat radiation which have passed through the gaps between the tubes. These sheets are placed under the tubes on both sides of the header. This will help in increasing the absorption of heat radiation. The size of this aluminium sheet is 1.56m × 1.18 m.

A circular helical shape copper coil is used inside the hollow cylindrical pipe. This would increase the time of air inside the circular pipe due to the provided obstruction of copper coil. The flow rate of air decreases inside the circular pipe which results in raise the temperature of outlet air. The diameter of copper coil used is 0.07 m and length used is 1.5m. the wire diameter of copper wire is 0.006m. the image of the copper coil is shown in the figure .

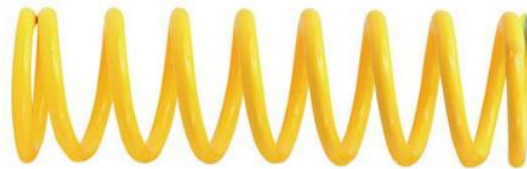


Figure 7. helical shape copper coil

The water in the tubes is heated up by solar radiation falling on the evacuated tubes. This heat energy is then transferred to the PCM. The heat energy then from PCM is transferred to the air blowing inside the hollow pipe and the output let is heated up. A blower of 0.35 KW is used to blowing the air. AC supply is used for powering the blower and the flow rate of air is control using a regulator

Measuring Devices and Instruments

Measuring instruments are such devices which are used for determining the physical quantities. While doing experiments measuring instruments and devices plays a chief role. Without the device it would be very complicated to perform any type of experimentation and no results can be observe or obtain.

Different parameters are recorded during the experiment

- Flow rate of air
- Intensity of solar radiation
- Temperature of ambient air
- Temperature of air coming out of heat exchanger
- Temperature of PCM i.e. acetamide
- Temperature of working fluid i.e. water

Devices used for measuring for these parameters are as follows:

- RTD PT100 thermocouples connected with a digital indicator are used for measuring the temperature of working fluid water, outlet air and acetamide (PCM).
- RTD PT100 has an accuracy of $\pm 0.3^{\circ}\text{C}$. Sling psychrometer has a precision of $\pm 0.5\%$ which is used for measuring dry bulb temperature of ambient air.
- Intensity of solar radiation is measured by a pyranometer with a precision of $\pm 2\text{W}/\text{m}^2$.
- The velocity of air with a precision of $\pm 2\%$ can be calculated with the device called as anemometer.

Experimental Work

In this experimental work, the header and the evacuated tubes are filled with water. This filled water has the temperature of 25°C. on each day, the heat exchanger based on evacuated tube is exposed to the solar radiation of the sun to absorb solar radiation. Reading are taken at an interval of 1 hour starting from 09:00 hour. Solar radiation when falls on evacuated tubes the heat energy is absorbed by the evacuated tubes and water inside is heated up. Due to the density difference hot water flows up and cold water flows down in the evacuated tubes. The heated water goes inside the header through the evacuated tubes which are connected to the outer box. The inner box consist of PCM (thermal energy storage material) which gains the heat energy from the heated water. There is no heat transfer between the atmosphere and heated water. The inner box consists of a hollow cylindrical pipe through which air flows. This air is heated up in the circular pipe by gaining heat energy from thermal storage material (PCM). In the header/heat exchanger the same phenomenon of thermosyphon is used as in evacuated tubes. The hot water inside the header/heat exchanger is at high head and the cold water is at lower head.

The reflection aluminium sheets are placed under the evacuated tubes. To increase the performance of absorption and as result the overall performance will increase. A copper coil is placed inside the hollow cylindrical pipe in which the hot air is flowing. By introducing the copper coil of length 1.5 m the residence time of air and surface area of contact will increase. The diameter of coil is 0.07m and diameter of wire of coil is 0.006m. The copper helps in more extraction of heat energy form the thermal storage material (PCM). All these will increase the temperature of air flowing inside the hollow pipe.

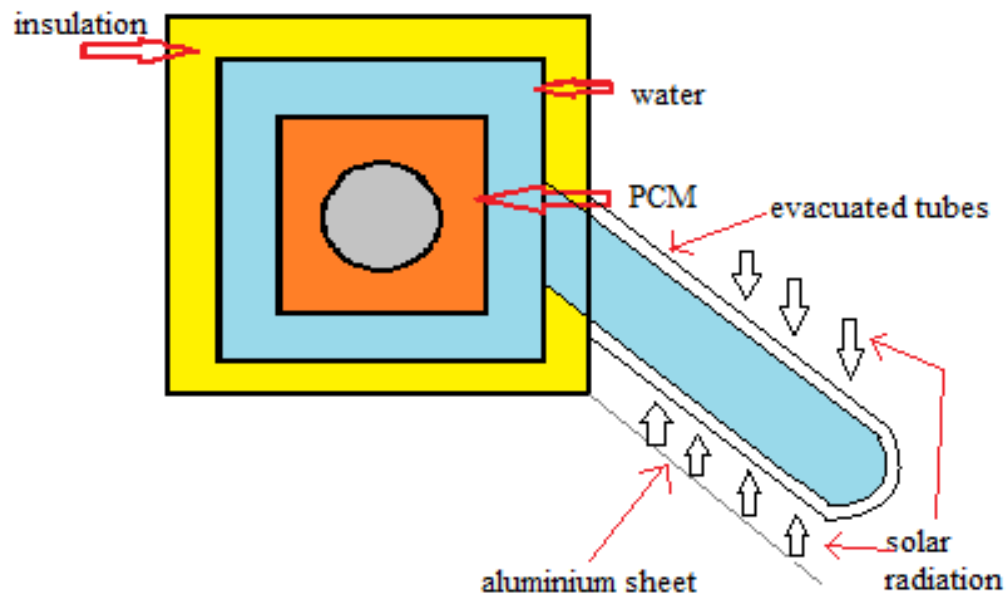


Figure 8. schematic diagram of heat exchanger based on evacuated tubes with PCM unit

Expected Outcomes

In this conducting experimental study, fabrication and testing the performance of a heat exchanger for solar air conditioning based on ETC is to be investigated. A thermal storage material (PCM) is also fitted inside to store the thermal heat energy inside the heat exchanger. A PCM, acetamide is used for storing thermal heat energy during the sun shine hours of the day when solar radiations are available and to generate hot air during the off sun shine hours of the day. All the readings are going to be taken when the ETCs are facing south. This study is carried on a sunshine day

The following expected outcomes can be achieved:

1. A better performance efficiency of fabricated setup of heat exchanger for air conditioning based on ETCs could be observed with high flow rate and with copper coil within the heat exchanger's hollow pipe.
2. The fabricated setup will be able to generate hot air during the off sun shine hours of the day, when there is no solar radiation incidenting on ETCs. Hence, evacuated tube fixed with storage unit can store a large amount of thermal storage energy to heat up the air coming out.
3. Using a copper coil inside the hollow pipe, the outlet air temperature will considerably increase because the residence time of air within the pipe increases due to which the heat energy transfer rate increases between the air and copper coil.
4. A sufficient amount of difference in temperature can be achieved between the heated outlet air temperature and surrounding air temperature.
5. Therefore, the fabricated heat exchanger based on evacuated tubes with PCM unit is very effective in northern Indian climatic weather conditions or in areas with fine quality of sunlight.

References

- [1]. Mr. Vinay B. Choudhari and Prof. R. S. Powar. “A Review On Performance Investigation Of Phase Change Material In Heat Exchanger For Latent Cool Storage”. *IERJ E-ISSN: 2454-9916, Volume-I*.
- [2]. Mayank Patel, Krunal Patel. “A Critical Review Of Evacuated Tube Collector”. *International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974*.
- [3]. Avadhesh Yadav, V.K. Bajpai. “An Experimental Study On Evacuated Tube Solar Collector For Heating Of Air In India”. *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:5, No:7, 2011*.
- [4]. Neeraj Mehla and Avadhesh Yadav. “Thermal Analysis On Charging And Discharging Behaviour Of A Phase Change Material-Based Evacuated Tube Solar Air Collector”. *Indoor and Built Environment 0(0) 1–17*.
- [5]. Sarvenaz Sobhansarbandi, Patricia M. Martinez, Alexios Papadimitratos, Anvar Zakhidov, Fatemeh Hassanipour. “Evacuated Tube Solar Collector With Multifunctional Absorber Layers”. *Solar Energy 146 (2017) 342–350*.
- [6]. Raghurajsinh .B. Parmar a, Kedar Bhojak. “Performance Of An Evacuated Tube Collector With Heat Pipe Technology”. *International Journal of Engineering Research and General Science Volume 4, Issue 3, May-June, 2016*
- [7]. Adel A. Ghoneim. “Performance Optimization Of Evacuated Tube Collector For Solar Cooling Of A House In Hot Climate”. *International Journal of Sustainable Energy, DOI: 10.1080/14786451.2016.1256886*.
- [8]. Neeraj Mehla & Avadhesh Yadav (2016): “Experimental Investigation Of A Desiccant Dehumidifier Based On Evacuated Tube Solar Collector With A PCM Storage Unit, Drying Technology”. *DOI: 10.1080/07373937.2016.1180300*.
- [9]. Amit Kumar and Avadhesh Yadav. “Experimental Investigation Of An Air Heating System Using Different Types Of Heat Exchangers Incorporated With An Evacuated Tube Solar Collector”. *Environmental Progress & Sustainable Energy (Vol.00, No.00) DOI 10.1002/ep*.
- [10]. Avadhesh Yadav* and V.K. Bajpai. “Comparison Of Thermal Performances Of Flat Plate And Evacuated Tube Solar Air Collector At Different Flow Rates: Experimental Analysis”. *Int. J. Renewable Energy Technology, Vol. 4, No. 2, 2013*.