Experimental Investigation of Double Pass Solar Air Heater having Rectangular Duct with the Different Shaped Geometries on Both Side of the Absorber Plate

Dissertation-II

Submitted in partial fulfillment of the requirement for the award of degree

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IN

MECHANICAL ENGINEERING

By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "Experimental Investigation of Double Pass Solar Air Heater having Rectangular Duct with the Different Shaped Geometries on Both Side of the Absorber Plate " 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 (Name Of Supervisor, Designation) 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.

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

Date

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Signature of Examiner

TOPIC APPROVAL PERFORMA

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Sr.No.	**Parameter**	**Rating (out of 10)**
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2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	8.00
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.	8.50
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	8.00
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6	Future Scope: Project has potential to become basis of future research work, publication or patent.	8.00

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PAC Member 1 Name: Minesh Vohra	UID: 15783	Recommended (Y/N): Yes
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INDEX

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LIST OF CONTENTS

Chapter 1

Chapter 2

Chapter 3

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Given that the future of our planet is intricately entwined with the various future options of energy, effective exploitation of non-conventional energy sources is becoming increasing essentially for modern world as fossil fuels are hazardous to environment and cannot sustain supply for long time as they are not renewable. Moreover, demand of energy is increasing rapidly. In this scenario, solar energy is being seen as potential viable resource for ever increasing hunger of the energy for the development of nation and by and large globe. In this dissertation work, effort has been made to demonstrate this reality with proof of statistics from reliable sources. Further more numerous new designs of Solar Air Heater are emerging in various aspects, in different roughness parameters. Extensive review of research done in this field in recent past and the report covered with their design and fabrication as experimental set-up with the all information.

The experimental setup including of a double pass solar air heater duct using discrete W-shaped corrugated artificial ribs for roughness on both sides of the absorber plate with black painted surface has been designed and fabricated.

In future Experimental data related to heat transfer, pressure loss, and thermohydraulic performance will have been determined. Substantial improvement will also be obtained with some penalty of friction losses.

Investigation parameters -

PARAMETERS	RANGE
ANGLE OF ATTACK	30^0,45^0 & 60^0
RELATIVE PITCH RATIO(p/e)	26,13,7 & 16,8,4
RIBS SIZE	D=1.5 & 2.5 CM
REYNOLDS NUMBER	4000-160000

CHAPTER 1

INTRODUCTION …

Predicated on the today's world scenario energy preserving is one the major implementable situation to maintain a stable economic magnification the country. Energy can be type of renewable or non-renewable. Renewable is the form of energy that can be reused and are easily available in nature like solar energy, geothermal energy, wind energy, tidal energy etc. Non-renewable energy comes under the type of energy which is derived from fossil fuels as like coal, petroleum and other sub-parts. The non-renewable energy reservoirs are getting exhausted with the continuous utilization.

(1) SOLAR ENERGY

Solar energy is very easily available form of the renewable energy. The total energy gained from the sun is around 35 thousand times the total energy is being used by human. In India the overall solar intensity coming out from the sun is to be approximately 2000 kWh/m^2 as compared to the world average of 2500 kWh/m^2. But of the total solar energy reaching the earth's surface only 7 to 8% is being utilized, so there is an objective to explore it and utilize it in a more efficient manner. For many years this type of energy source has been utilized for various kind of applications.

The technologies developed from solar energy are divided into active solar and passive solar. The current activated working solar techniques which covers as utilization of photovoltaic systems and concentrated solar power systems is to be used to harness the maximum available solar energy. Passive techniques include the designing of space for natural air flow etc. Solar energy technology includes solar cookers, photovoltaic cell, solar air heater, solar collectors etc. These technologies are emerging in a rapid manner as these technologies are proved to preserve energy in many applications. In 1877 solar energy was utilized to heat a room. [18]

ADVANTAGES OF SOLAR ENERGY

- For daily use, we can utilize it in any form of energy.
- Maintenance and its use is very easy.
- The energy source is long-lasting.
- Less harmful and natural, which is eco-friendly.
- Pollution free and economically efficient.
- Saves fossil fuel depositions.
- Scope of decentralization.

DISADVANTAGES OF SOLAR ENERGY

- Not yet taken on priority level, till now people takes it as secondary option.
- Quantum results varies according to seasons or weather.
- Spares and other required parts are not easily available.
- Need of subsidy because it is cost effective at primary installation.
- Absence of energy in cloudy or eclipse days.
- Energy storage is a big issue.

SOME OF THE APPLICATIONS

Solar air heaters were used till now because producing heat from this process is cheaper as compared to the fossil fuels. We already completed the work over the design and manufacture of solar air heaters that produces heat in a few times with a low budget, and in this way we opened the doors of industry and agriculture field for solar energy. As solar energy can now be utilized in such astronomically immense applications, it can make a consequential impact to the overall energy budget. Those hot air that those sun oriented air warmer handle might a chance to be utilized for:

- **Modern purpose:**
  - air pre-heating for burning of the fills.
  - To drying paper, bricks, coal, nourishment complements, and so forth. (Especially the drying about tan coal might a chance to be exceptionally imperative to force plants). For heating of the space inside control houses, factories, etc.
- **Agricultural purpose:**
  - crop drying processes like grains, fruit, vegetables, meat, etc. Important benefits can be utilized by harvesting of the crop early and drying it with the use of solar heat and we can protect it from rodents, mildew, etc.
  - for greenhouses, animal farms and warehouses.
  - As fruit and other eatable products dryers.
- **Camping purpose:**
  - space heating for emergency relief camps or military camps
  - for recreational camping and expeditions in cold climate.

- **Household purposes:**
  - Space heating in households
  - small driers as cloth driers.
- **commercial purpose:**
  - space heating for public buildings, office buildings, shopping center malls.

(2) SOLAR AIR HEATER

INTRODUCTION-Solar air heater is a type of system driving the outer air through a sealed sun heated collector mounted in an exterior wall or roof, returning the warmer air to the required room or place. The solar collectors are made of high thermal conductive aluminum plates with a nature of great absorptiveness.

Solar air heater was first designed in 1881,it was wooden frame consisting of metallic sheet with a transparent glass which is used to allow maximum radiation inside the collector [18].Its basic principle is to absorb the solar radiation and convert it into thermal energy with the help of absorber plate.[15]

The fluid flowing is air and can be used directly for the various applications. The air entering through the channel of the duct and solar radiation is being absorbed by the absorber/collector plate. The absorbed heat is transferred to the air as it flows along the channel and its temperature goes increase.

The solar air efficiency also depends upon the weather conditions and the result also varies with the climatic parameters in minor percentage, In the literature survey it has to be seen that various researches have already been done on the heat transfer in solar air heater with absorber plates using wires and ribs and studies on the characteristics roughened air duct has already been done.

The present study emphasized on heat transfer analysis of roughened discrete W shaped duct with having different gaping angular arrangements.

PRINCIPLE-Air is basically worked as heat transfer medium in many of the energy conversion systems (like solar air heater). Various types of solar air heater designs are available in the market.

Different absorber includes surface types like inside the glazing includes overlapped type, permeate stacked screen type or mesh spaced type, clear and ebony glass plate type, single smooth metal sheet type, corrugated metal plate type and so on.

In other air passing below the plate or underlying (below down) air, passage reduces bottom heat loss, and one or two covers of glass or transparent plastic provide resistance to topside convective and radiative losses.

WORKING-when the sun arises and the light of the sun incidents on the solar air heating collector, solar absorber inside commence to absorb thermal energy from sunlight. Inner temperature reaches to the setting value immediately, the temp. sensor inside the collector will send a signal to drive fan to do suction of the air in appropriate mass flow rate.

From collector inlet the cold air enters and then will be heated circularly using heat absorbed by the absorber and finally hot air is flown out of collector by the fan, and then enters into the house through air outlet. The heat collector is fitted with thermal absorber, heating insulator and drive device, etc.

(3) SOLAR COLLECTORS

A solar collector is a setup which works to accumulate solar radiations and transfer this energy to a fluid passing in contact with it. The utilization of solar energy requires solar collectors.

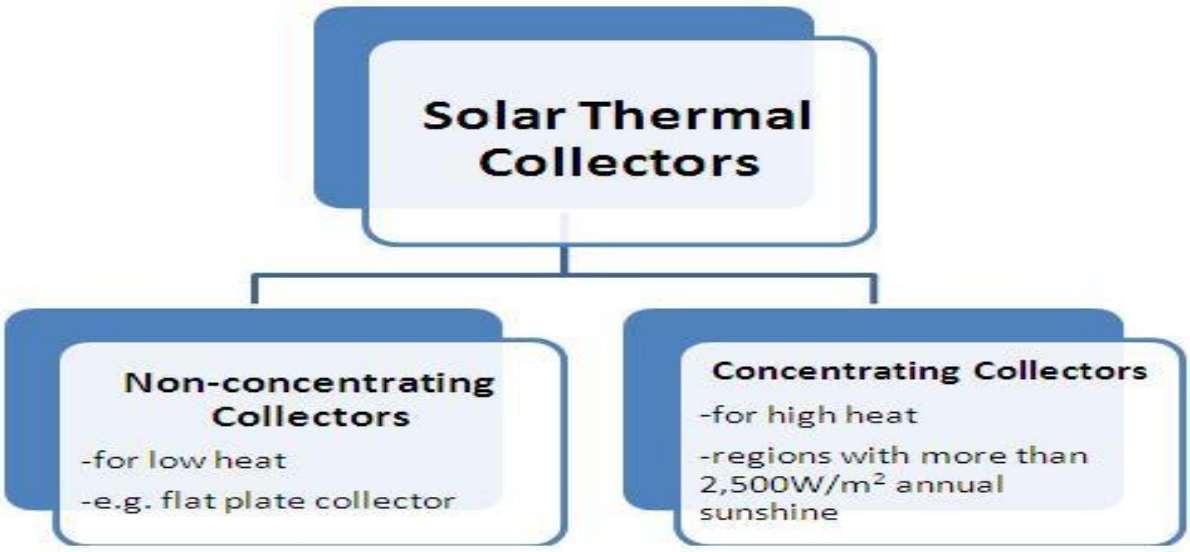


Fig.1 main types of collectors

1. Non-concentrating (Flat plate solar collector).
2. Concentrating (focusing solar collector).

Flat plate collector has the area of interception same like absorption for solar radiations while a concentrating collector mainly has a concave reflecting surface to focus the all part of direct beam radiation on a smaller absorbing area, by which incrementation of the radiation flux occurs.

(3.1) FLATE PLATE COLLECTOR/ NON-CONCENTRATING COLLECTOR

Flat plate collectors are having of five components -

1. A transparent cover called as glazing (ex. Glass plate type)

2. Heat transfer medium such as tunnel, tube arrangement, fixing of fins, flat passage or enclosed channels which works to carry/flow the fluid (air).

3. The absorber plate with having high absorptivity and lesser emissivity.

4. To minimize the heat losses insulation is being provided in all the sides.

5. The casing or cover is used to enclose the other components.

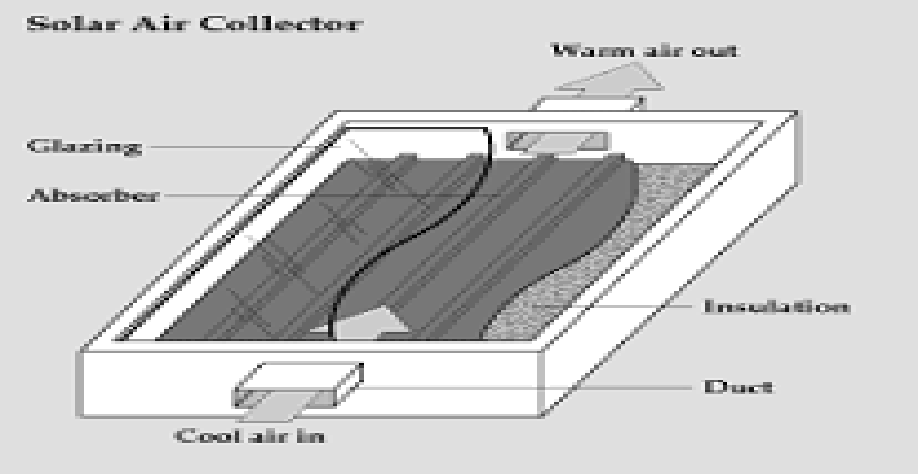


Fig.2 flat plate absorber/collector

For temperatures below about 90°C are being adequate for the flat plate collectors, as they are used for space heating and service water preparing. These are made of rectangular in shape, from about 1.6 to 2.9 m², in area. The collector generally absorbs both the direct as well as diffused type solar incidence radiations. Absorber flat plate is a Simple flat plate collector with a flat surface which has high absorptivity for solar radiations and lesser the emissivity. An absorber plate is a metal plate painted with black color paint to absorb the maximum amount of solar radiations. Air is used to transfer the energy from the plate as a medium. The upper face of the absorber plate is covered with a transparent cover like glass called as glazing so that it transmits shorter wavelength solar radiations from the absorber plate.

Flat plate collectors are of two main types on the hydraulic heat transfer –

(i) Liquid heating collectors.

(ii) Air or Gas heating collectors.

(I) Liquid heating collectors -

The liquid type heating collector included an absorbing surface which absorbs high solar radiation. In commonly a metal plate made up of copper, GI steel or aluminum are to be used as an absorber plate. The thickness of absorber is 1 to 2 mm and tubes diameter ranges from 1 to 1.5 cm. Liquid stores in storage tank flows through these tubes. The heat which is taken out from the absorber plate is being returned to the storage tank. The Different requisitions about level kind authority are flavoring about timber, curing about streamlined products, space heating, Further more crop drying. The fluid warming authority will be indicated on the figure.

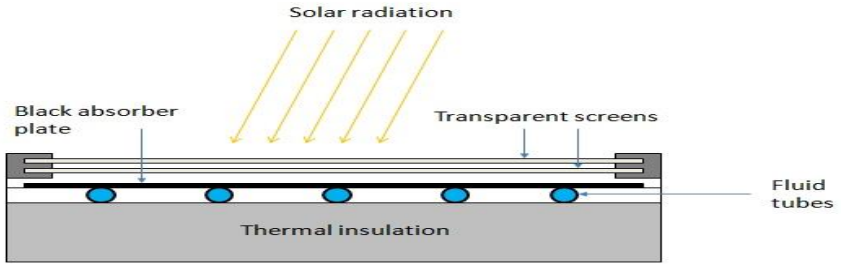


Fig. 3 Liquid heating collector

ii) Air or Gas heating collectors -

Air/gas heating collectors is shown in figure.

This is a typical configuration of flat plate air heating solar collec

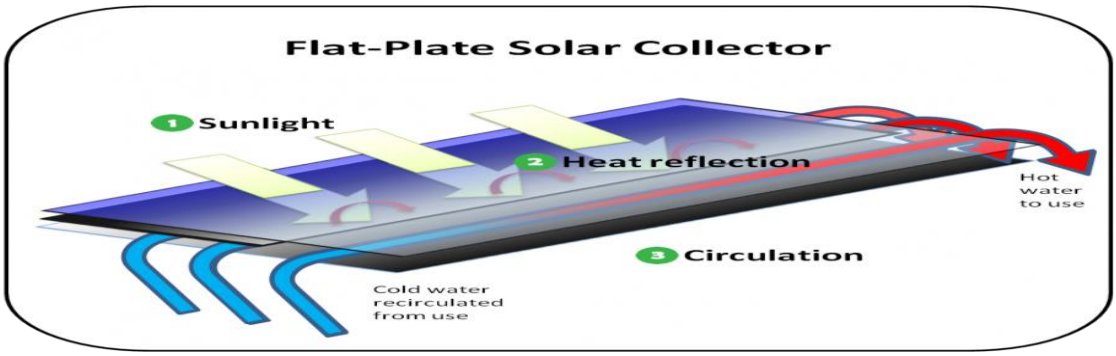


Fig. 4 Solar air collector

(3.2) Air is used as a heat transfer medium in many of the energy conversion systems. Solar air heaters have been made in variety of designs. The glazing joined overlapped, spaced, reasonable and darkened glass plates, single smooth birch metal sheets, stream through stacked screen or mesh, folded metal plates. and others are being used in below the glazing of the absorber. air passing below the plate reduces the downward heat loss.

one or two covers of glass or transparent visual plastic cover provide resistance to upward convection and reduces the radiation losses.

FLAT PLATE SOLAR AIR HEATERS -

(3.2.1) Simple flat plate collector

Simple flat plate collector is the simplest form of solar air heater. It is made of one or two glazing with insulation over the flat plate. The air flow types may be of either above or below or both above and below the absorber plate as shown.

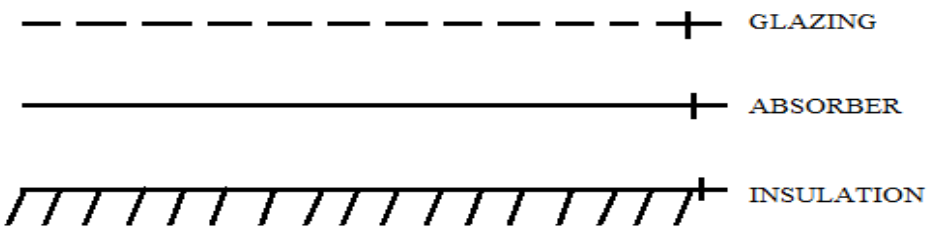


Fig. 5 Simple flat plate collector

(3.2.2) Finned type plate collector

This collector is modified version. Fins are made over the plate or fitted inside the duct to increase the heat transfer coefficient of flat plate absorber. The fins are usually located in the air flow passage as shown in figure.

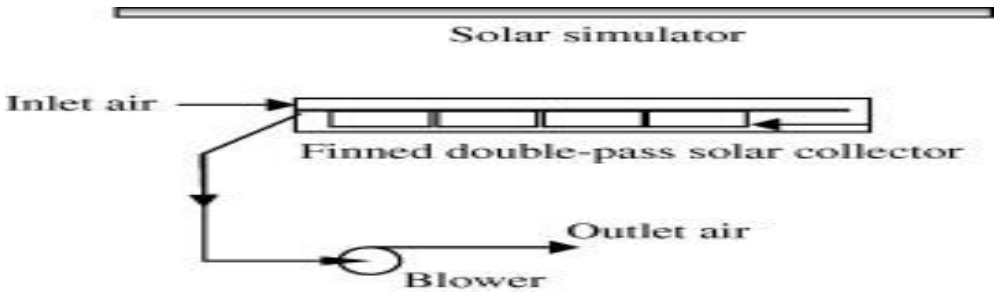


Fig. 6 Finned plate collector

(3.2.3) Corrugated plate collector

This is a restrictive configurational type of the simple flat plate collector. The absorber is corrugated/staggered either of rounded troughs or V-troughs. This configuration increases the heat transfer coefficient as well as the friction factor shown in diagram.

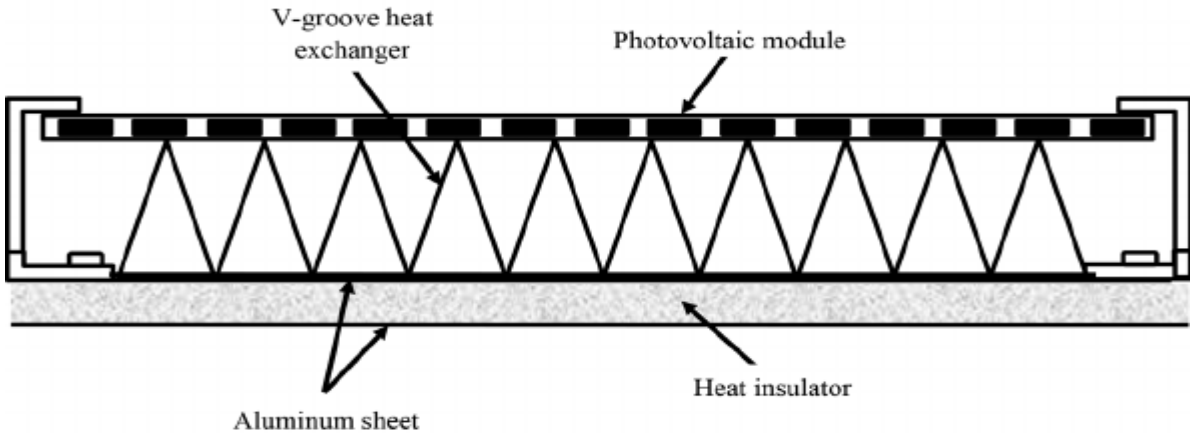


Fig. 7 Corrugated plate collector

(3.2.4) Two-pass way solar air heater

To reduce or decrease the losses in two pass solar air heater as suggested by **Satcunanathan** and **Deonarine** [1]. The air first passed between the covers of a double glass cover heater and then under the absorber plate as shown in Figure below. This results in reduction of outlet glass cover temperature by 2-5°C. This results in reduction of the losses and the efficiency of the collector is increased by 10 to 15% than a conventional heater.

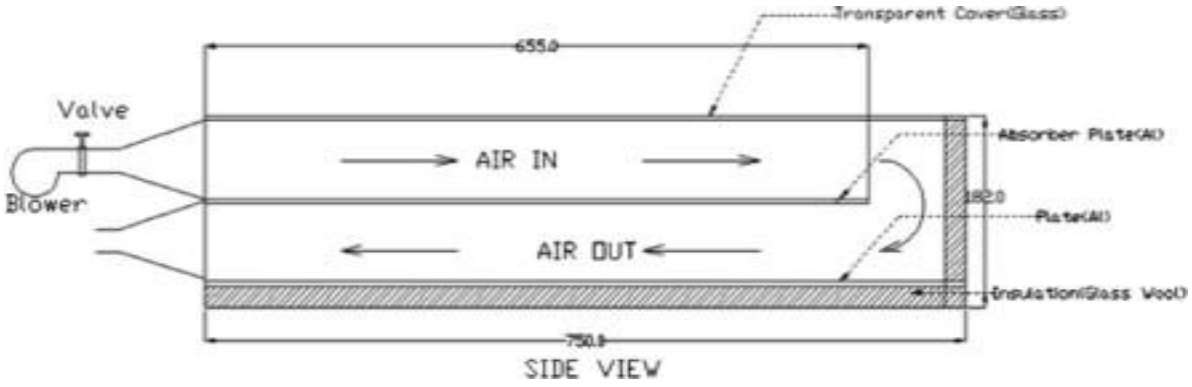


Fig. 8 Two pass way solar air heater

(4) PERFORMANCE ENHANCEMENT TECHNIQUES

The effective performance of a flat plate solar collector is normally depending on the rate of solar flux intensity over any surface, the losses from the absorber plate surface and the rate of convection heat transfer from the absorber plate to the air. This performance can be enhanced in many ways.

The following are some techniques to enhance the performance of solar air heaters-

(4.1) Improvement of heat transfer from the absorber plate

Decrement over the losses can be done by lowering the absorber plate temperature and by incrementing the coefficient value of heat transfer in between the absorber plate and the air flowing from the duct.

This can be achieved by following methods-

- **Without effecting the convective heat transfer coefficient increasing the heat transfer area**
- By the use of the extended surface/fins we can able to increase the heat transfer co-efficient. The absorber plate was designed in such a way that it will obtain/absorb the maximum amount of solar energy to increase the collector efficiency, lower pumping power requires to pass the air through the collector. The literature study result shows that the efficiency more than 80% is obtained with the absorber having the special artificial fins/obstacles.

- **for those air warming collectors with stuffed couch absorbers**.

  Stuffed cot grid absorbs sun based radiation 'in depth' Also need high temperature exchange zone proportion to higher state will volume Also higher the high temperature exchange capacity, bringing about moderately absorber temperature were bring down. These results increase in efficiency of the collector plate. Major disadvantage of this type of collector includes the high initial cost and large pumping power requirement as compared to conventional solar air heaters.

- **By using of artificial roughness increase the convective heat transfer coefficient**

The turbulent flow of the fluid over the heat transfer surface results a high convective efficiency of heat transfer. For getting the excessive turbulence higher power is required for running the fan or the blower (for high mass flow rate generally blower has been used since

long time), So it is desirable that turbulence must be created close to the surface i.e. in laminar sub layer only, so that the heat exchanging will take place and the core of the flow is not highly disturbed, to avoid excessive losses. This can be getting by the use of roughened surfaces or by corrugated surfaces on the air side.

(4.2) Solar air heaters consisting with Thermohydraulic performance

For getting high heat transfer co-efficient attachment of artificial roughness on the rear side of the absorber has comes into picture. This tends to higher the collector efficiency. artificial roughness enhances the thermal performance of solar air heaters, it is being considered. This results in high friction factor and a high pumping power also.

(4.3) Heat losses reduction

For low heat transfer and efficiency of the heater reducing heat loss is one of the major fact. Minimization of heat loss is proportional to increase in the properties of solar heater.

The ways of reducing heat losses from the solar collector are discussed below –

- **By using vacuum gap or an alternative medium**

For minimizing the Convective heat losses optimization is necessary. found from the literature study that using of combined selective surface and a moderate vacuum space increases the daily energy collection by 278% and thus making the collector to operate at 150°C with a daily energy collective efficiency is more than 40%.

- **Using selective type of absorber surfaces**

When the collector plate temperature is much higher than the ambient air temperature, selective surfaces plays an important role. Mainly large quantity of heat losses through the emittance from the collector. The maximum radiation loss appears at wavelength of about $1.01*10^{1}$ microns. The absorbing surface of the collector absorbs the maximum solar radiation between 0.3 microns & 2.5 microns. Results in increase in efficiency of solar collector, also makes it possible to achieve higher temperature.

- **Reduction of convective as well as radiative heat loss**

When operated at moderately high temperatures two or more glazing glasses are used to reduce convective as well radiative heat losses. Surface treatment is also used as for reduction of the radiative loss by reducing the glass reflectance. Glass cover transmits solar radiations having lower wavelengths and eliminates higher wavelength radiation.

CHAPTER 2

SCOPE OF THE STUDY ...

The future aspects are –

- Bio conversion and wind power, which are indirect sources of solar energy.
- Food refrigeration and its storage for the longer time utilization.
- Heating and cooling of residential household.
- Salt preparation by evaporation process of sea water or the inland brines.
- Solar cookers for cooking food.
- Solar stilling process for cleaning purpose on a small community scale.
- hot air drying of agricultural and animal products by using solar heat.
- Solar working pumps for water pumping from bottom to top level.
- Solar furnaces for heating.
- Solar water heating.

CHAPTER 3

OBJECTIVE ...

- For assessing/getting the Nusselt number and frictional co-relational factor value correlations and also for comparing the results with the obtained single pass solar air heater.
- To find out the thermal and thermo-hydraulic efficiency based on the hydraulic diametric parameter.
- To achieve the results of discrete W-shaped ribs which are glued in the absorber plate so that the heat absorption capacity is to be increased.
- Comparing two different designs of the discrete W-shaped absorber plates and checking the best effective results of them.
- The main motive is to increase the heat transfer rate and to improve the efficiency of double pass solar air heater and comparing the both designs obtained results with the single pass solar air heater.

CHAPTER 4

LITERATURE REVIEW ...

A complete and thorough purpose of literature review is to get the background information (related to/thinking about) the problems to be thought about during present study.

The article includes the brief review over the methods used for the improvement or increase of the heat flow or heat transfer coefficient (from one place to another). Various kind of ways of doing things would be found by the survey of the literature which is used to rise the forced convection heat transfer using turbulence phenomena (from one side to another side). The flow should be full of violently swirling manner nearer to the surface of the heat flow to get higher amount of heat transfer value.

However, blower or fan give the energy demanded to create such kind of disturbing situation called as turbulence.it results too much demand of power for flow of air through duct, which also increases the friction factor. So, it is required to reduce such losses of power to increase its effective efficiency.

Due to this roughness, generation of edge-related turbulent layer along with smaller laminar sub-layer happened on the plate surface. Very high resistance is offered to flow of heat due to this laminar sub-layer. By Increasing the heat transfer rate and the friction factor we can be able to break the laminar sub-layer.

It will further increase the thermo- liquid-related hydraulic performance and the thermal efficiency of DPSAH.

Ramadan and El-Sebaii et.al. [3] experimented the double-pass solar air heater with packed bed, in which the air is initially send forcefully into the packed bed placed over the upper channel formed in between the lower cover and the absorber plate, and is then flow is again circulated in the reverse manner by the lower side channel, formed between the absorber plate and back surfaces.

S.K. Singal et. al. [4] investigated experimentally the thermal performance of SAH with using of roughness element in the form of blend of transverse ribs and inclined ribs and attached on the absorber plate. The heat transfer co efficient and frictional characteristics is being first calculated and then compared with the smooth ducts available values. It was reported that under same stream conditions the geometry with P/e value of 8 results in maximum thermal efficiency. Further it was also accounted for that the maximum heat transfer coefficient found for the best thermal performance.

Pongjet Promvonge et. al. [5] investigated over solar air heater for the thermal performance of turbulent pipe flows over absorber plate having triangular (isosceles), wedge (right-triangular) and rectangular designed ribs. The main aim of this study was to develop the experimental data accessible on different triangular rib shapes (i.e. right-triangular and isosceles). It was reported that the staggered triangular rib ought to be connected rather than the rectangular.

M. Samiev et.al. [6] investigated the solar air heating collector for finding the efficiency using a very simple moving plate heating model. It was reported that the static efficiency η can be about 0.5 for surrounding air temperature t_a = 40°C, for t_a value of 50°C the η is around 0.45, and t_a value of 60°C the η is around 0.37.

Akpinar and Kocyigit et.al. [7] found those efficiency of the sun based collectors relies straightforwardly on the sun based radiation, surface geometry of the collectors and the development of the air flow offering. Those Determination goes is, those biggest irreversibility might have been happening toward the sun based air warmer and clinched alongside nonattendance from claiming obstacles in the place authority efficiency will be exceptionally low. the limit layer arrangement during those absorber plate surface known as those viscous sub-layer which may be in turn purpose for the low high temperature exchange rate.

Sukhmeet Singh et. al. [8] investigated the correlations in between friction factor and heat transfer coefficient of solar air heater with discretized V – down ribs as artificial corrugated roughness on the absorber plate. He examined the rectangular duct heated the one wide wall and artificial roughness provided as V – down ribs subjected to consistent heat flux which is having Reynold Number (Re) shifted from 5000 – 14000, It was reported that maximum increment in Nusselt number (Nu) is 3 and maximum increment in friction factor (f) is 3.1 when contrasted with smooth pipe. It was likewise reported that in the scope of parameters concentrated, these co-relation shows the estimations of f and Nu with average absolute variation of 2.1% and 3.1% respectively.

Prashant Dhiman et.al. [9] investigated analytically the solar air heater having packed bed roughness element placed in a novel parallel shape for finding/getting out the thermal resultant performance. A mathematical model was developed to do analytical work over the solar heater thermal performance, and calculation has been done by utilizing a developed PC code that uses an iterative arrangement method. It was reported that the difference between the results after simulation and exploratory information with a mean blunder is of 9.2%.

Brij Bhushan et. al. [10] air heater, weight drop, What's more, stream wonder for conduit. It might have been known that there may be gigantic scope for future examination of double pass heater with sun oriented air warmer facilitated with unpleasantness component for absorber plate surface on both upper and easier side. Those The majority amazing effectiveness may be obtained In those conduit depths Also impostor stream rate for air may be comparable clinched alongside both those upper conduits What's more bring down the [10] investigated the correlations factor in between Nusselt number and friction factor (f)for SAH with roughness element in the shape of protrusions/dimples applied over the absorber plate. It was examined that so as to foresee execution of the framework having such sort of roughened absorber plate, correlations of Nusselt number and friction factor as a function of framework and working parameters have been produced by utilizing trial information. It was reported that maximum increment in Nusselt number and friction factor had been found 3.8 and 2.2 times separately in contrast with smooth duct.

Sunil Chamoli et. al. [11] investigated utilizing absorber plate which will be falsely roughened from both of the sides on the upgrade of the execution those twofold pasquinade sun based air warmer. It incorporates those high-temperature exchange increment, the configuration from claiming twofold pasquinade sun based conduit.

K. Kalidasa Murugavel et. al. [12] has investigated experimentally the DPSAH with storage of the thermal energy. Paraffin(wax) in aluminum rod and hollow (cylindrical) capsules was used as a medium of thermal storage on the absorber plate. The experimental study has been done to do the performance of the DPSAH. It has found that the paraffin wax as energy storage material in solar air heater transfers nearly high temperature air for the duration of the day and additionally the efficiency is higher in mid evening hours and the capsules available on the absorber plate of double pass solar air heater was best in efficiency.

Abhishek Saxena et. al. [13] investigated the outline Also execution of a sun-oriented air warmer for long-hauling heat capacity. The primary target from claiming this will be with expansion the heat exchange rate What's more about raising the effectiveness of straightforward sun based air warmer. The computation of the warm execution of sun based radiator needed to be been carried out by using some parts alternately components by working it around both characteristic Furthermore constrained convection.

An adaptable barrel sort plastic SAH might have been suggested by Abdullah What's more Bassiouny [14]. Those investigations were done with SAHs of hardware shapes Hosting 0. 5 m breadth. They discovered those come about the temperatures of the outlet air might have been expanded bit by bit Concerning illustration sun oriented illumination expanded bit by bit. The conclusion hails will be that outlet air temperature might have been expanded Concerning illustration those wind stream rate might have been diminished. Experiments are conducted by Sopian et. al. [15] looking into a twofold pasquinade SAH for and without steel downy Similarly as a porous networking in the SAH channel. Their SAH need you quit offering on that one glass blanket What's more as blackened painted metallic plate as an absorber. They stated utilizing the porous networking expands those outlet temperatures and the SAH efficiency. Those twofold pasquinade SAH with the porous muscle to attain 20% rise in the effectiveness relative of the SAH without the porous networking.

Nima Mirzaei et. al. [16] investigated the solar air heater for finding the best arrangement by outline and examination of try different things with single pass and double pass solar air collectors with wire mesh layers and ordinary and punctured covers rather than an absorber plate. The porous media were placed in a way that it reaches a high porosity (0.83) and a small pressure drop around the collector. The main purpose of this study was to tentatively explore the performance of solar air heater and recommend the arrangement which prompts to the maximum thermal efficiency. The design and investigation of experimental technique are used to frame the same solar based collector and the information was dissected with IBM’s Statistical Package for the Social Sciences (SPSS) software.

Ravi Kant Ravi et. al. [17] has done the research for the enhancement of the performance of the double pass solar air heaters (DPSAHs) various methods are used. The performance of a

traditional solar air heater (SAH) can be improved by lowering down the misfortunes occurs over the collector surface by giving the best possible insulation and expanding the convective heat transfer coefficient in between working fluid and the heat collecting surface by increasing the heat transfer area. This heat transfer area can be enlarged by double pass system. He utilized packed bed materials (PBMs), corrugated absorbing surfaces, and extended surfaces. The aim of this research was to review various heat transfer increment methods utilized in DPSAHs. It was likewise reported that in case of finned DPSAH, number and orientation of the fins, fin height were found to be the critical parameters and in the event of artificially roughened DPSAH, roughness geometry and height, and fin height was considered as the important parameters.

Satyendra Singh et. al. [18] has investigated the double pass solar air heater with packed bed as roughness element for getting the better result of thermal performance. The thermal analysis result increases significantly compared with the packed bed when porous material is applied in the lower channel and solar air heaters except the packed bed. It was reported that that there is significant raise in the heat transfer value with packed bed solar air heaters and thus thermal efficiency increases.

Subhash Chander et. al. [19] investigated the solar air heater with multi-gap V-down ribs along with zig zag ribs attached on one side of the absorber plate as roughness element for validation of the friction factor, heat transfer, and thermo-hydraulic analysis properties of stream in a rectangular duct. It was reported that the 2 peaks for Nusselt number related to the P/e of 6 and 12 and decrement in the Nusselt number was noted for increment in the e/D_h more than 0.044 and the maximum increment reached in Nusselt number and thermo-hydraulic performance was of 3.34 and 2.45 times separately.

S. soni et. al. [20] investigated the double pass solar air heater by using of baffles and longitudinal fins for the increment of the thermal performance. It was reported that the maximum sun based radiation got in the metallic wiry sponge type double pass solar air heater when contrasted with the solar air heater with baffles and longitudinal fins and the greatest effectiveness had been picked up in the double pass solar air heater with metallic wiry sponge when contrasted with the other.

Abhishek priyam et.al. [21] experimented the analytical study to increase the performance of finned absorber solar air heater.by forming the transverse positioned flow channel in between the wavy fins attached with absorber plate having the constant heat flux. for getting the collector efficiency the corelative expression has been developed and by changing the mass flow rate and the fin spacing comparing its effect with the plain simple solar air heater.

Chii-Dong Ho et.al. [22] has found design of a new type of recycling double pass solar air collector which incorporates a V type corrugated absorber to the conventional one for increasing the effective efficiency. under the V corrugated plate air has been blown, due to which the turbulence intensity and the heat transfer coefficient are enhanced. then the theoretical prediction and the experimental results has been compared with simple double pass solar air heater.

Kaushik Patel et. al. [23] investigated the double pass solar air heater using fins, baffles and porous media to get the improved thermal efficiency and get the impact of various kind of media for the increment of efficiency of double pass solar air heater. The impacts of major parameters air velocity, temperature difference, mass flow rate, pressure difference of the air had been watched for these perform contemplate. It was observed that the maximum efficiency was getting by the absorber material when it is uncoated metallic wiry sponge in the solar still. It was lower cost effective and availability in the market was easy.

CHAPTER 5

EXPERIMENTAL SETUP & ACCESSORIES ...

(5.1) INTRODUCTION- It has been observed from the literature review of the double pass solar air heater that the application of using artificial roughness on the absorber plate which is used in solar air heater enhancement of the thermal performances. The artificial roughness on the absorber plate increases the friction factor and the heat transfer rate in between the plate surface and the flowing fluid near the surface. Various experimental analytical and software basis studies have been going on single pass and double pass solar air heater to display the impact on the heat transfer enhancement by integrating the various shaped artificial roughness. Artificial roughness has been provided by using ribs, machining, insertion of inverted tapes, corrugated delta shaped restriction etc. Various researchers give the result by the conclusion that ribs gluing/pasting is one of the efficacious and effective methods to make the artificial roughness on the surface of the absorber plate of a solar air heater. The different shapes like straight inclined, transverse, delta, V, W etc. are developed and glued over the surface of the absorber plate to increase the heat transfer coefficient value as well as the friction factor.

(5.2) SET-UP AND EQUIPMENT INFORMATION-

The diagram of the experimental set-up has shown in the fig.9. The experimental Set-up includes –

- A double pass rectangular wooden duct,
- A suction blower,
- The rectangular planum,
- Pressure measuring devices Ex. u tube manometer,
- Temperature measuring devices Ex. thermistor,
- solar efficient simulators.

DESCRIPTION –

A double pass rectangular wooden duct -

To examine the effect of artificial roughness it is very necessary to design and make the double pass rectangular duct by fabrication used in the double pass solar air heater. The cross section of duct is rectangular and is fabricated from the wood. The aspect ratio of the duct is 45:45. The dimensions given to the rectangular duct are 2000 mm × 280 mm × 30 mm. Total height given to the rectangular duct of Sunmica lamination of 1 mm thick has glued over the top of the plywood to make a smoother surface. A 70 mm gap is also provided for proper air circulation inside the ractangular duct of 2000 mm lengh.

A glass sheet of thickness 4 mm and 50 mm height is being used so that the solar radiation can incident easily and effectively on the absorber/collector plate.Fig.10 includes duct and fig.11 is showing the sectional view of the ductdouble pass air heater is 50mm. The duct includes an entry domain, test domain and a minute gap inside it so that the air can move up easily.

(Test section is = 1600 mm)

Suction blower –

The suction blower is a machine (motor) which blows the air from outlet side by suction of the air from its inlet. The suction of air is being done by using of the blower through the bottom part of double pass rectangular duct. The capacity of suction blower used is 3 HP. This air moves upside of the top part of the rectangular duct from the gap provided just beyond after the testing domain. Fig 12 is showing the suction blower.

Rectangular block (shaped) planum –

It is a cubic type wooden box having closed and insulated by all the sides. The exhaust air then passed from the flexible pipe which is made up of Galvanized Iron type material and linked to the mixing chamber which is named as plenum. Where for getting the constant temperature (reading) of the exhaust air from the duct has been stored and used the outlet air as per requirement. it also known as a distributor for the use of distributing the hot air constantly inside the room. Fig.10 includes planum.

Orifice meter –

The orifice meter having a flat orifice plate with circular hole drilled inside. The standardized orifice plate is placed in the GI pipe. It is used to get the air mass flow rate.

Pressure measuring devices (Ex. u tube manometer) –

Manometer is a Pressure measurement device which is used by liquid columns in vertical or inclined way inside the tubes**.** A U-tube type manometer is attached with the pipe to know the pressure drop values.

Temperature measuring devices (Ex. Thermistor) –

Temperature measuring devices are used to measure the required area or surface temperature we used thermistor which is a resistance thermometer. If temperature of the body increases the resistance goes decrease and vice versa for the decreasing temperature.

Solar efficient simulators –

Artificial setup of electrical halogens to produce solar intensity. The main aim of this is to simulate the spectral and spatial solar radiation distribution of sun based radiations into a plane of a solar system. Solar simulator includes six halogen lamps having intensity of 500W each.the heat flux intensity is measured by pyrometer. About 900W/m^2 energy will produced. This setup is used for getting the constant solar temperature. Fig. 13 shows the pictorial view of solar simulator.

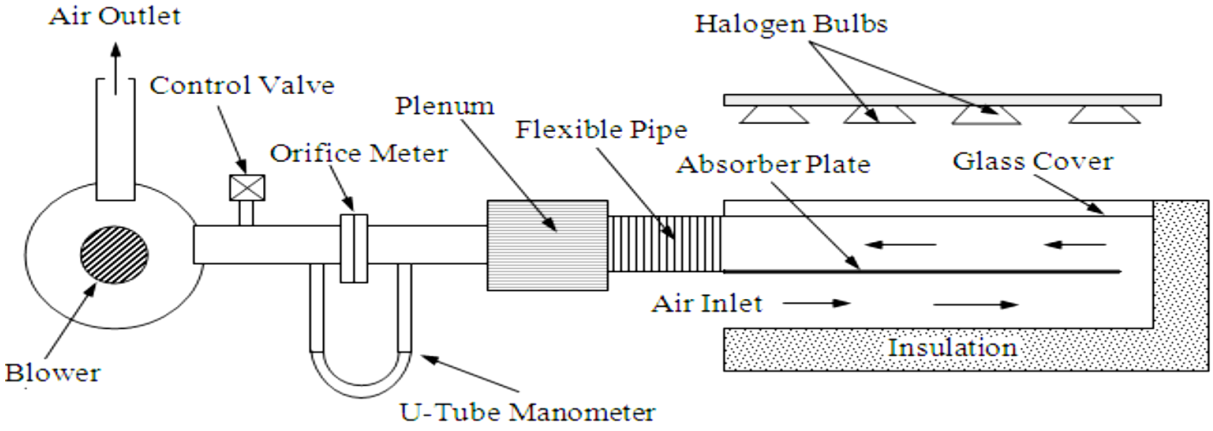
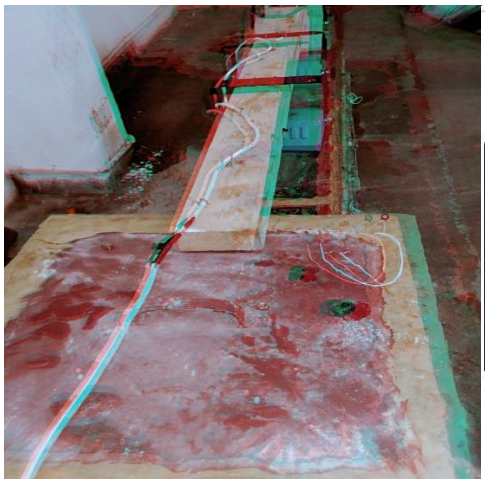


Fig.9 Experimental set-up diagram



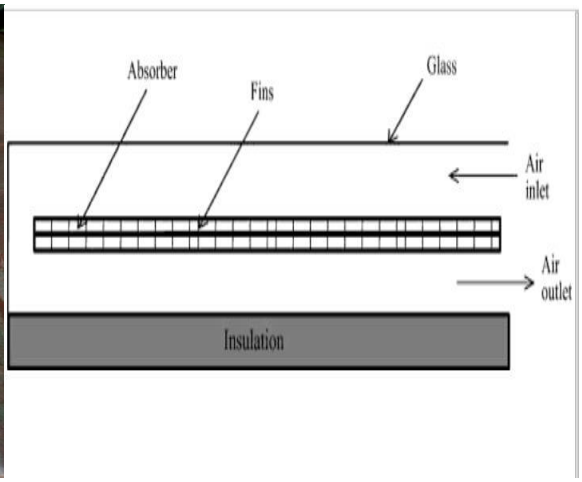


Fig. 10 solar air duct and planum **Fig.11 sectional view of duct**

Fig.12 suction blower

Fig.13 solar simulator with constant intensity

Chart 1 - description of the equipments :-

Sr. No.	Equipment	Material	Dimension	Capacity
1.	Duct dimention	Wood	2000 × 280 × 30 mm	-
2.	Absorber Plate collector	GI Sheet	1600 × 280 mm	-
3.	Thick Pipe	GI	90 mm dia.	-
4.	Flexible Pipe	Plastic	550 mm length	-
5.	Projection type Manometer	-	0.01mm LC/ 100 divisions	-
6.	Centrifugal suction Blower	-	-	3 HP, 3 phase, 230 V and 2800 rpm
7.	Solar Simulator	-	-	900 W/m²
8.	Thermistors	RTD(10D-9)	-	-
9.	Glass Sheet	Glass	3 mm – thickness	-

(5.3) DATA INTERPRETATION -

The data needed to calculate the heat transfer coefficient, Nusselt number and friction factor have been given below [33] –

- **Mean Plate Temperature -**

$$T_p = \frac{T1 + T2 + T3 + T4 + T5 + T6 + T7 + T8 + T9 + T10 + T11 + T12}{12}$$

T_f, overall mean temp as arithmetic mean of air temperature at entry and exit domain

$$T_f = \frac{T13 + T14 + T15 + T16}{4}$$

- **Velocity of Air through Duct (V) –**

$$V = \frac{\dot{m}}{\rho HW}$$

- **Mass Flow Rate of Air ($\dot{m}$) -** $\dot{m} = C_d A_0 \sqrt{\frac{2\rho\,(\Delta P_0)}{1 - A}}$

- **Hydraulic Diameter (D_h) -**

$$D_h = \frac{4A_c}{P}$$

- **Reynolds Number (Re) -**

$$Re = \frac{\rho V D_h}{\mu}$$

- **Friction Factor (f) -**

$$f = \frac{2(\Delta P_{duct}) D_h}{4\rho L V^2}$$

- **Heat Transfer Coefficient (h) -**

$$h = \frac{Q_u}{A_p(T_p - T_f)}$$

Where, "T_p" and "T_f" are the mean absorber plate and the fluid inlet and exit temperatures, respectively, heat transfer rate (Q_u) to the air is given by,

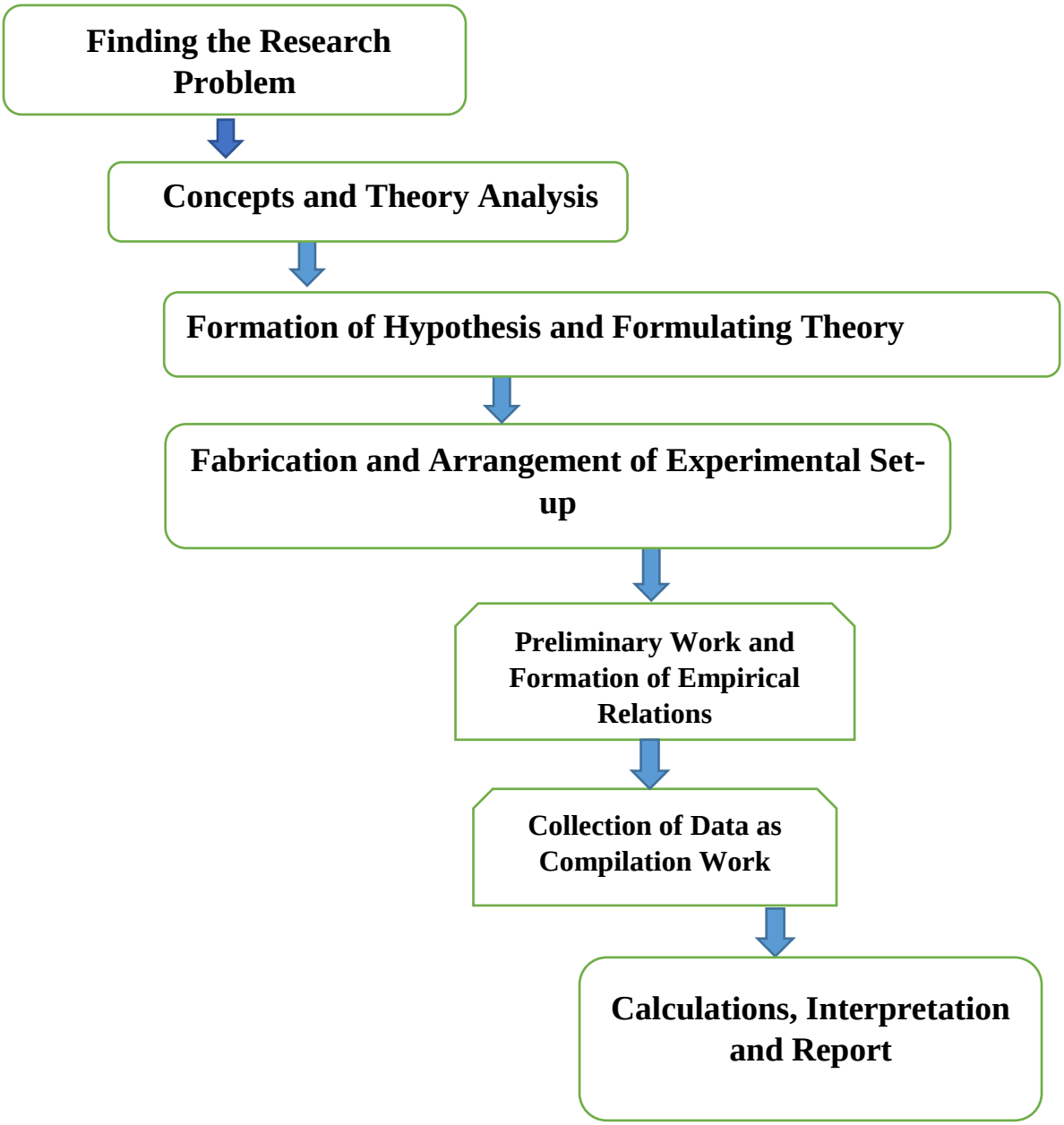
$$Q_u = mC_p(T_o - T_i)$$

- **Nusselt Number (Nu) -**

$$Nu = \frac{hD_h}{k}$$

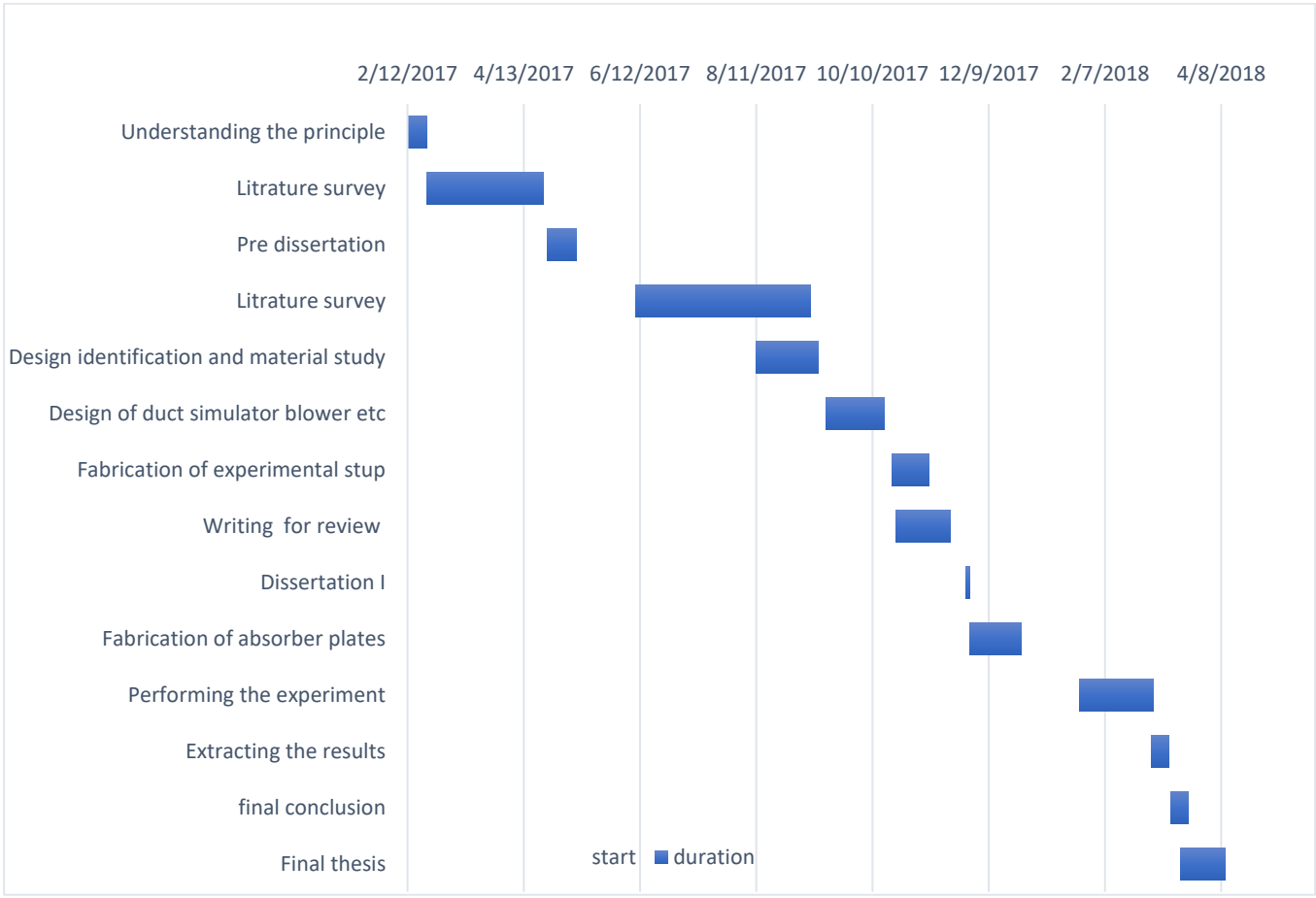
CHAPTER 6

RESEARCH METHODOLOGY …



CHAPTER 7

TIMELINE AND WORK PLAN …



CHAPTER 8

RESULTS AND DISCUSSION …

Various types of graphical correlations will be produced to show the effectiveness in Nusselt number and Reynolds number with the friction factor for different angle of attack and pitch conditions.

Also at the end graphs will be produced for showing the effect of Thermal and Thermohydraulic efficiencies for different roughness parameters.

CHAPTER 9

CONCLUSION …

The motive of doing the research on this field is to improve the collector's efficiency having discrete W shaped ribs as artificial roughness in solar air heater using double pass arrangement.

Experimental study is to be done on Double pass solar air heater using Discrete W-shaped ribs and is to be compared with that of Single pass solar air heater of the same design and duct.

After reading literature and doing some preliminary research and experiments on the set-up, it has been observed that the double pass solar air heater having same dimensions and hydraulic diameter is much better in performance than the single pass solar air heater. Which would be shown in the final report.

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CHAPTER 10

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