Design and Fabrication of Spiral Flat Plate Solar Water Heater Collector

A thesis report submitted to the department of mechanical engineering for the partial fulfillment of the degree of Bachelor of Science in Mechanical Engineering

A Thesis by

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APPROVAL

This is to certify that the project on "**Design and fabrication of spiral Flat plate solar water heater Collector**". By "Mohammad Ali Hossain Mahin, Redoy Kumer, Md. Al Amin Hossan and Md. Rejaul Molla" has been carried out under my supervision. The project has been carried out in partial fulfillment of the requirements of the degree of Bachelor of Science (B.Sc.) in Mechanical Engineering of years of 2023 and has been approved as to its style and contents.

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DECLERATION

We hereby, declare that the work presented in this project is the outcome of the investigation and research work performed by us under the supervision of Md. Minhaz Uddin, Assistant Professor, Department of Mechanical Engineering, Sonargaon University (SU). We also declare that no part of this project and thesis has been or is being submitted elsewhere for the award of any degree.

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ABSTRACT

Solar energy is getting popular nowadays. Most of the technologies have been developed which made solar energy a cheaper and reliable source of energy. Due to pollution and other factors, solar has become the most popular source of energy. Along with power generation, now water heaters are also developed which are working on solar technology. It is a reliable method and can be used in areas which do not have access to wood, coal, and gas. This project is based on fabrication and performance test of a flat plate collector passive solar water heater. In this project, passive water heaters are employed which work in thermosiphon system. To construct the solar water heater has been used the flat plate collector as a solar collector. Flat plate collectors are constructed according to needs and environmental constraints. Based upon this study, a reliable and cost-effective solar water heater was constructed. All the dimensions and diagrams are presented in the relevant chapter. Local materials and manufacturing methods were used to fabricate the solar water heater to limit the cost of the project. At the end the impact of the project was discussed on social, economic, and environmental grounds. From our experiment we find out that we can get most output heat between 1pm to 2pm.

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Nomenclatures

V = Volume of the water tank (m^3)

T_i = Temperature of water at inlet (K)

T_o = Temperature of water at outlet (K)

T_a = Atmospheric temperature (K)

l = Length (m)

h = Height (m)

A_c = Collector area (m^2)

I_T = Irradiance (w/m^2)

C_P = Specific heat of water (J/kg k)

$\dot{m}$ = Mass flow rate of water per second (kg/s)

$\boldsymbol{\rho}$ = Density of water (kg/m^3)

Q_u = The rate of useful energy extracted by the collector (J)

Chapter 1
Introduction

1.1 General:

As a result of the environmental situation caused by the damage burning fossil fuels and their overuse, the ecological balance has been disturbed and pollution has increased dramatically, especially in recent years. All this led to resorting to the use and investment of renewable energies and the constant pursuit of its development. There are many types of sustainable renewable energy, the most important and most famous of which is solar energy, because it is often the basis of itself and many other energies. This project is intended to construct a water heating system by using solar technology. Hot water is an essential requirement in industry as well as in the domestic sector. Water is generally heated by electric heaters. Water heating accounts for approximately one-fourth of the total energy used in a typical single-family home. During the winter, an electric water heater is the single biggest energy user of all domestic appliances. Solar hot water heaters can replace existing conventional water heaters (electric and gas) and can easily be paired with radiant panel flooring, thereby reducing utility bills. Only straight pipes are used in conventional solar water heaters which limit the heat transferring capability. In this work, a solar water heater with spiral water pipe has been fabricated and its performance has been studied. (Bennet T. 2007)

1.2 Background:

Solar water heaters offer a renewable and environmentally friendly way to heat water for various applications, including domestic use, industrial processes, and agriculture. They can significantly reduce energy consumption and greenhouse gas emissions associated with conventional water heating methods. This project explores the design and implementation of a solar water heater system, with a focus on simplicity, efficiency, and cost-effectiveness. The first commercial solar water heater dates to 1896 when Clarence Kemp of Baltimore, Maryland created what he referred to as the "Climax" solar water heater. The design has since improved in iterations to account for the two main issues with solar water heaters: freeze protection and overheat protection. By the 1920s solar water heaters were ubiquitous throughout Florida and Southern California. Interest spiked in the 1960s and again after the 1973 Oil Embargo. Jimmy Carter put solar PV and solar water heaters on the

White House and the industry looked on its way to being a strong contributor to the country's energy portfolio.

Meanwhile, solar water heating was taking off in other parts of the world. In Israel, for example, solar water heaters became popular as there was a fuel shortage in the new country in the 1950s. In the 1970s the energy crisis brought with it a law passed by the Israeli congress, the Knesset, that all new homes (except high rises without adequate roof space) must have solar water heaters. Now there are solar water heaters on 85% of Israeli homes which saves the country an estimated 2 million barrels of oil per year. What do these historic vignettes illustrate? First, the success of solar water heating is directly tied to the price of energy. Cheap fossil fuels inhibit innovation and adoption, whereas fuel shortages and high prices increase these rates. In these cases, the energy crisis spurred installations of solar water heaters. Secondly, government incentives and mandates (or lack thereof) are an effective motivating force for people to make a switch to alternative energy that they would otherwise ignore for an alternative energy technology to experience high rates of adoption, a government incentive or mandate is highly beneficial.

1.3 Objectives:

The objective of the project is,

- Design and construct a passive solar water heater system.
- Evaluate the system's performance under various weather conditions.
- Compare the system's energy savings and cost-effectiveness.
- Assess the environmental impact and sustainability of the solar water heater system.

CHAPTER 2
LITERATURE REVIEW

2.1 Previous work:

There are two types of solar water heater. One is active and the other one is passive. Passive heaters circulate the water through pipe naturally which means using gravity force. This system is not very expensive. Where for active heater there need pump and others equipment to flow the water through pipe. Which is costly than passive heater. Some of the research work done on these is discussed below: Sotiris A. Kalogeria presented a paper which discussed the various types of collectors and their uses. The applications of solar systems are dependent on the type of solar collectors used in the system. Solar collectors include flat-plate, compound parabolic, evacuated tubes, Fresnel lens, parabolic trough, and heliostat field collectors. These different types of collectors are used in different applications in domestic, commercial, and industrial uses. (8)

S.K. Verma presented a paper on which he discussed the circulation of water on a spiral tube and conventional tube collectors. Where he discussed that the efficiency of a spiral tube is more than a conventional tube. FPSC will continue to play a pivotal role in domestic, household, and industrial sector for water heating systems. Solar collectors are vital for direct solar energy conversion to heat being stored in water or in PCM for further use. Also, spiral tube maintenance cost is low.

2.2 Applications:

Solar water can be used for home in winter season or for commercial purpose, some uses are listed below:

- Domestic Hot Water: Solar water heaters are commonly used to provide hot water for bathing, washing dishes, and other household activities. They are particularly useful in homes with high hot water demand.
- Space Heating: In some cases, solar water heaters can be integrated into a radiant floor heating system or used to preheat water for space heating, reducing the reliance on conventional heating systems.
- Hotels and Resorts: Many hotels and resorts use solar water heaters to meet their hot water needs, reducing energy costs and their carbon footprint.

2.3 Comparative Study:

In our exploration of various research studies conducted by different scholars, it's clear that these researchers have employed diverse criteria when assessing the performance, quality, and efficiency of solar water heater systems. These differences in evaluation metrics are a notable aspect of the research landscape.

Our project has a well-defined objective: we aim to design and manufacture a passive solar water heater system that relies on the Thermosiphon process for activation. This ingenious system harnesses the natural forces of gravity and the density differences in water to drive the flow rate effectively. Our chosen design incorporates a flat plate collector.

Currently, we find ourselves in the research phase, where we are diligently studying relevant literature to inform our subsequent design and fabrication processes. We are driven by the overarching goal of developing a passive solar water heater system that not only outperforms existing solutions but also stands out as a cost-effective alternative.

Upon successfully completing the final product, we will proceed with a comprehensive procedure and analysis. This analysis will serve as a critical evaluation, allowing us to compare our system's performance and efficiency with the existing body of work presented in the literature review.

CHAPTER 3
METHODOLOGY

3.1 Design Constraints:

Solar Resource Availability: The system's performance is highly dependent on the availability of solar radiation in the location where it will be installed. Regions with limited sunlight may require larger collector areas or supplementary heating methods.

Climate and Temperature: Extreme weather conditions, such as freezing temperatures or excessive heat, can impact the performance and longevity of solar water heaters. Adequate insulation and freeze protection mechanisms are essential in cold climates.

Space Limitations: The available space for installing the solar collectors and storage tank can be a significant constraint, especially in densely populated urban areas or on small residential properties.

Water Quality: The quality of the water in the area can affect the performance and lifespan of the system. Hard water, for example, can lead to mineral deposits in the collector or tank, reducing efficiency.

Piping and Plumbing: Designing the plumbing and piping system to connect the collectors to the storage tank and distribute hot water throughout the building requires careful planning to minimize heat loss and ensure efficient operation.

3.2 Risk Factors:

Solar water heater systems offer numerous benefits, including energy savings and reduced environmental impact, but they also come with certain risk factors and challenges. Here are some common risk factors associated with solar water heaters:

1.Weather Dependency: Solar water heaters rely on sunlight to function efficiently. Cloudy or overcast days, as well as seasonal variations in sunlight, can reduce their performance.

2.Freezing Temperatures: In regions with cold winters, freezing temperatures can damage solar water heaters. If proper freeze protection mechanisms are not in place, the system may be vulnerable to freezing, which can lead to burst pipes and damage to the collector.

3.Corrosion: Over time, corrosion can occur in the pipes, fittings, and tank of a solar water heater, particularly if the system uses uncoated or poor-quality materials. Corrosion can result in leaks and system failure.

4.Leakage: Solar water heaters may develop leaks in the collector or storage tank over time. Leaks can result in water damage to the building or property.

3.3 System Selection:

There are many types of solar collector that use in constructing a solar water heater and these are discussed below:

3.3.1 Types of Collectors:

A solar collector's main purpose is to absorb solar radiation of the sun and convert it into heat energy by transferring heat to the working fluid. There are mainly two types of solar collectors:

1. non-concentrating solar collectors
2. Concentrating solar collectors (Kalogirou, 2004)

1. Non-concentrating Solar Collectors:

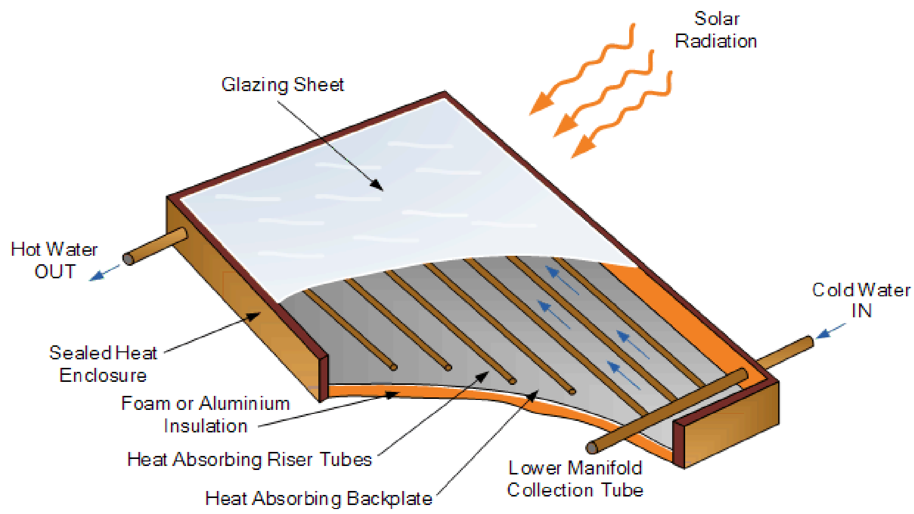
Non-concentrating solar collectors are usually used for low temperature applications. These collectors consist of flat surface which absorbs heat from the sun. The efficiency of Non concentrating collectors is comparatively less but in terms of cost and maintenance these are much feasible. There are a few types of non-concentrating solar collectors. (Kalogirou, 2004; Tian and Zhao, 2013)

i) Flat Plate Solar Collector: Flat plate solar collector is a very basic type of solar collector. It has a flat rectangular surface as an absorber. It is very efficient and convenient for temperatures up to 100°C. (John A. Duffie, 2006) These collectors are classified as liquid type and air type based on their heating application. Flat plate collector is usually set up in the top of a building or a structure or in an open field and it uses both beam and diffused solar radiation for heating up. Figure (a) shows a flat plate collector. Several types of flat plate collectors have been designed since the 1900s by using different types of materials for improvement of performance as well as making it cheaper and more long-lasting. In the later section of this report a detailed discussion about flat plate collectors is given. (Kalogirou, 2004; Jesko, 2008; Amrutkar, 2012; Tian and Zhao, 2013; Chowdhury and Salam, 2019; Fudholi and Sopian, 2019)

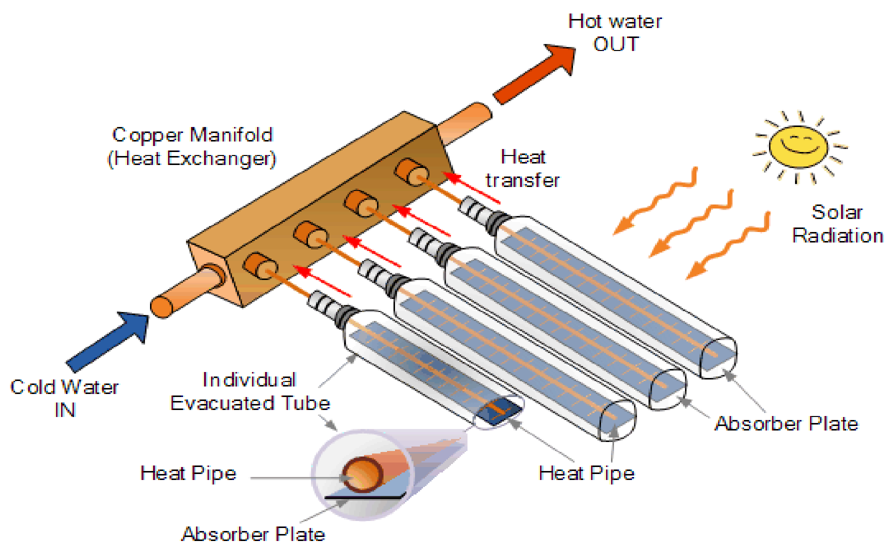
ii) Evacuated Tube Collector: Evacuated tube collector differs from the flat plate collector in construction and operation. Figure (b) shows a flat plate collector. Evacuated collectors are used in climates with high temperatures or where the temperature is too high for flat plate collectors to work efficiently. Evacuated tube collectors consist of a heat pipe inside a vacuum sealed tube. The heat pipe is made of copper for high heat absorbance. In these collectors, liquid-vapor phase change materials are used for high efficiency heat transfer. (Yogi Goswami D., 2000) Another type of collector is present which consists of two concentric annealed glass tubes with vacuum between the layers. The glass tubes are usually made of borosilicate glass. The inner tube works as the absorber of the solar radiation which is coated with selective absorber coating. The vacuum, by creating isolation between the tubes, helps to reduce the heat losses by convection and conduction and hence increases the efficiency of the collector. It acts by the principle of a thermos flask. Evacuated tube collectors can absorb both beam and diffused radiation. (Kalogirou, 2004; Jesko, 2008; Tian and Zhao, 2013)

iii) Solar Pool Collector: Solar pool collectors are the collectors used for heating the water directly using the sun's radiation. These collectors work in a similar way to that of flat plate collectors but are unglazed, not covered with glass. Figure (c) shows a flat plate collector. Solar pool collectors cannot work in freezing temperatures. They are mostly used for heating swimming pool water to 20°-25°C. (Jesko, 2008)

iv) Tank-type Collector: Tank-type collectors are like flat plate collectors in working. They are used for heating water in a tank for domestic and household purposes. Figure (d) shows a flat plate collector. These collectors are set in the tank where water is to be heated and heats the water to a temperature near 50°-60°C. (Jesko, 2008)

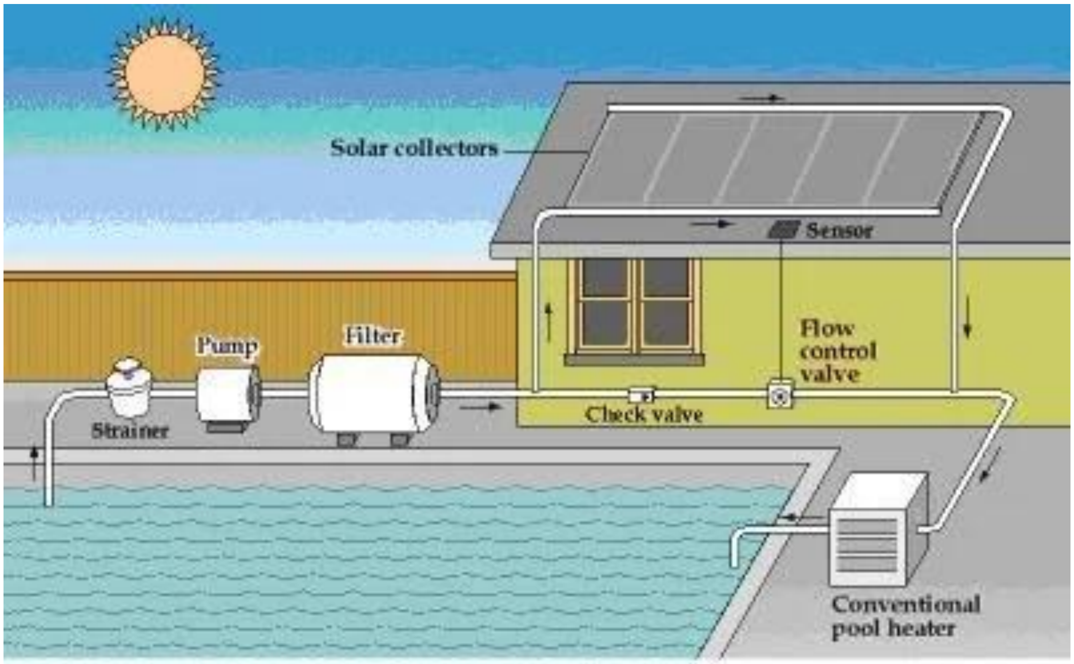


(a)

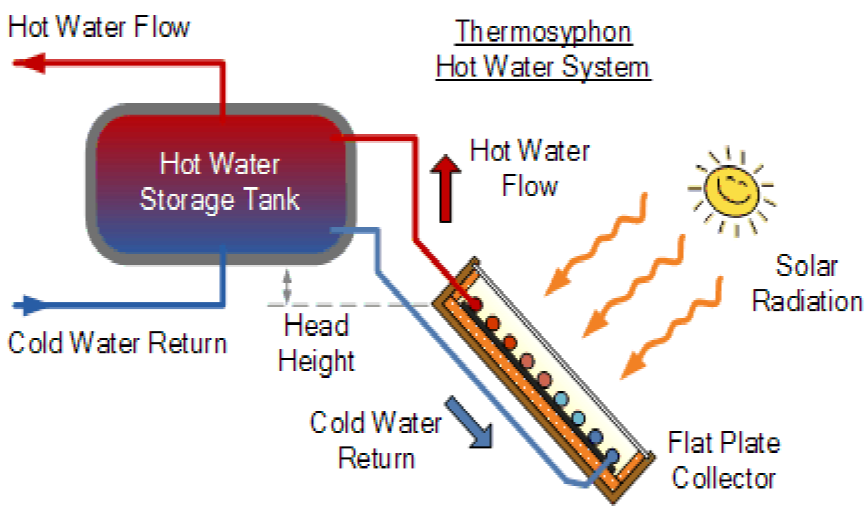


(b)

Figure NO 3.1 (a) Evacuated tube collector (Anon., 2020)
(b) Flat plate solar collector (Anon., 2020)



(c)



(d)

Figure No 3.2 (c) Solar pool heaters (Solar Swimming Pool Heaters, 2020) and (d) Tank type collector (Anon., 2020)

2. Concentrating Solar Collectors:

Concentrating solar collectors are usually used for high temperature applications more than 100°C. Concentrating collectors may be reflectors or refractors. Wide variation is present in their design-parabolic, circular, cylindrical, convex, or concave etc. Concentrating collectors focuses sunlight using lens and mirrors. The collectors may be glazed or unglazed depending on the requirement. There are both sun tracking systems as the sun's position changes with time as well as non-tracking system. It is also divided in two types as line focusing and point focusing. A few types of concentrating collectors are present. (Kalogirou, 2004; Jesko, 2008; Tian and Zhao, 2013) 21

Parabolic Trough Collector: Parabolic trough collector is a line focusing type of solar collector where the radiation of the sun is focused along the focus of the parabolic trough. Parabolic collectors are made by bending a reflective sheet into parabolic shape. An absorber pipe covered with glass tube to protect it from dust and moisture which reduces reflectivity is placed along the focal line and working fluid usually water flows through it. The sun rays are reflected and falls on the absorber tube which heats the working fluid (John A. Duffie, 2006). The absorber or receiver tube is coated with material of high solar radiation absorptance, and the glass layer helps in reduction of thermal losses by convection and radiation. Using one-axis tracking device, which tracks the sun position in one direction only, either east-west or north south, the position and focus of the solar radiation changes with the elevation of the sun. The collector pipe or the trough rotates along the axis of the absorber pipe continuously. Temperatures up to 400°C can be obtained using this collector. Parabolic trough collectors are the most advanced solar collector technologies and mainly used for solar thermal electricity generation. (Kalogirou, 2004; Zondag, 2008; Tian and Zhao, 2013) (Kreider JF, 1991)

Parabolic Dish Collector: It is a point focusing type of solar collector. The receiver is placed at the focus of the concentrator or dish. The sun's radiation is collected at the receiver. (Winston, 1974) It uses two axis sun tracking system. It is used for high temperature works above 1500°C. Working fluid circulates through the receiver. Dish collector is mainly used for small electricity generation using sunlight. It is the most efficient of all collectors. (Kalogirou, 2004; Tian and Zhao, 2013)

Heliostat Field Collector: It consists of a few flat mirrors called heliostats spread over a large region. Altazimuth mounts are used for setting up the mirrors. The heliostats focus the sun's radiation to a common tower usually 500m long. The collector or receiver is placed in the central tower which consists of vertical tubes of flowing water. Up to 1500°C temperature is achievable using this collector. The heliostats are controlled by automated tracking devices to change position with respect to the sun. Heliostat collectors are used for power generation using high temperature steam generated from heating the working fluid. (Kalogirou, 2004; Tian and Zhao, 2013) (Kalogirou, 1991)

Fresnel Lens Concentrating Collector: In this collector Fresnel lens is used. Fresnel lens is flat on one side and provided with linear grooves on the other side. The grooves possess optical quality for which they behave like a common lens. The absorber tube is oriented in such 22 a way that the radiation after refraction through the lens is focused on the tube. (Lorenzo E, 1986) Another type of collector I the linear Fresnel reflector which consists of a linear arrangement of flat or curved elastic mirrors focusing light on a receiver mounted on the top a linear tower. (Kalogirou, 2004; Tian and Zhao, 2013)

In our project, we have used the flat plate collector (FPC) and it is discussed in 3.4.

3.4 Construction of the system:

A typical flat plate solar collector consists of a glazed absorber plate, tubes, thermal insulation, cover strip, insulated casing. Flat plate collectors are usually per monthly fixed on a roof top or an open field and do not require any sun tracking system. The collectors are to be oriented directly towards the equator, facing south in the northern hemisphere and north in the southern.

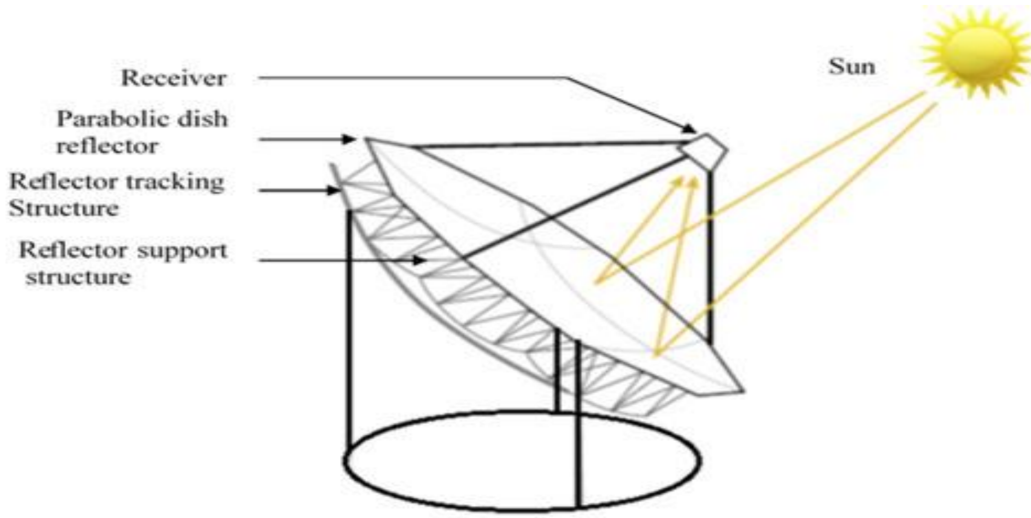
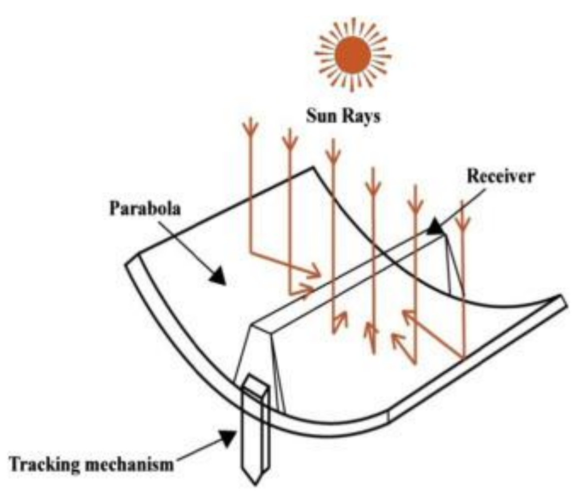
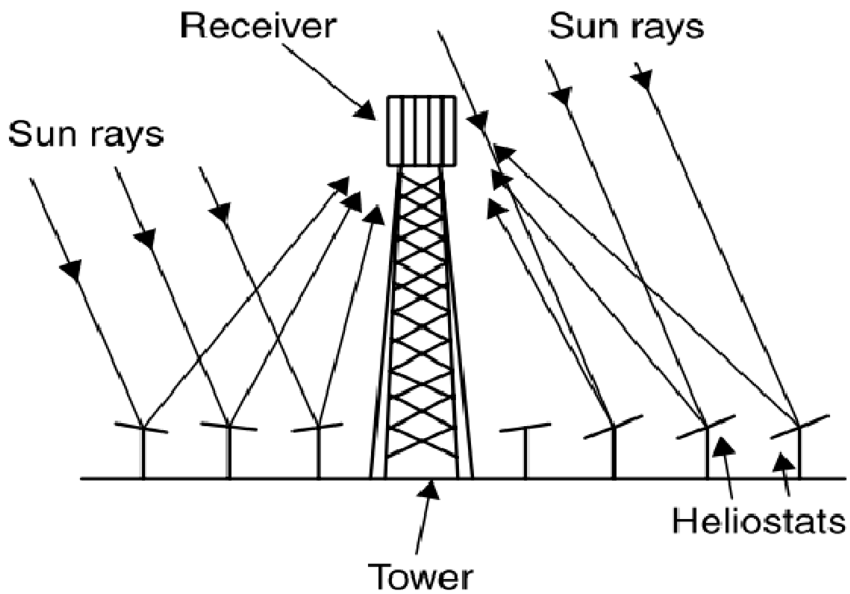


Figure No 3. 3: Parabolic Dish Collector (Manuel J. Blanco,2017)



(a)



(b)

Figure No 3. 4: (a) Heliostat Field Collector (Kalogirou,2004)

(b) Parabolic Trough Collector (M.U.H. Joardder,2017)

The optimum tilt angle of the collector must be equal to the latitude of the location with angle variations of 10–15° depending on the application. A short description of the parts of a typical 24 flat plate collector is given here. (Yogi Goswami D., 2000) (John A. Duffie, 2006) (Kalogirou, 2004)

a) Absorber Plate: The absorber plate is a rectangular sheet made of high heat conducting material, especially copper or aluminum because of their high heat conductivity. It is usually painted black and coated with absorptive material to get the maximum absorption of solar radiation. (John A. Duffie, 2006) This thin layer is highly absorbent to shortwave solar radiation but comparatively translucent to long wave radiation. Another thin layer is provided below the coating with high reflectance to long wave radiation. The absorber plate absorbs the sun's heat energy and transfers that to the working fluid with minimum heat loss. (Kalogirou, 2004; Ibrahim et al., 2011; Amrutkar, 2012; Tian and Zhao, 2013) (John Twidell, 2015)

b) Tubes: Several tubes made of copper are placed on the absorber plate. The working fluid flows through the tubes where they are heated. The copper tubes are positioned parallelly on the absorber plate. (John Twidell, 2015). These are soldered and brazed to the absorber plate so that smooth heat transfer takes place between them by getting maximum surface contact. (Kalogirou, 2004; Ibrahim et al., 2011; Amrutkar, 2012; Tian and Zhao, 2013)

c) Glazing: Glazing refers to covering with glass or plastic having radiative properties. A flat plate collector has single, double, or multiple layers of glazing above the blackened absorber plate. Low iron glass is mainly used for glazing having high transmissivity of short-wave radiation and low or zero transmissivity of long-wave radiation. (John A. Duffie, 2006) The main purpose of glazing is to allow as much as solar radiation possible and create an insulation of the absorber plate with the environment by entrapping radiation to reduce convective losses as well as radiative losses. Transmission of short-wave radiation can also be increased by antireflective coating and surface texture. The glazing materials do not absorb heat like absorber plate. (Kalogirou, 2004; Amrutkar, 2012; Tian and Zhao, 2013) 25

d) Insulation: insulation is provided to the sides and bottom of the flat plate collector to reduce heat loss. Different insulating materials like rubber, cotton, wool is used for this purpose. Insulating substances decrease heat loss from the absorber plate and help in heating the tubes as well as the plate. (Kalogirou, 2004; Amrutkar, 2012)

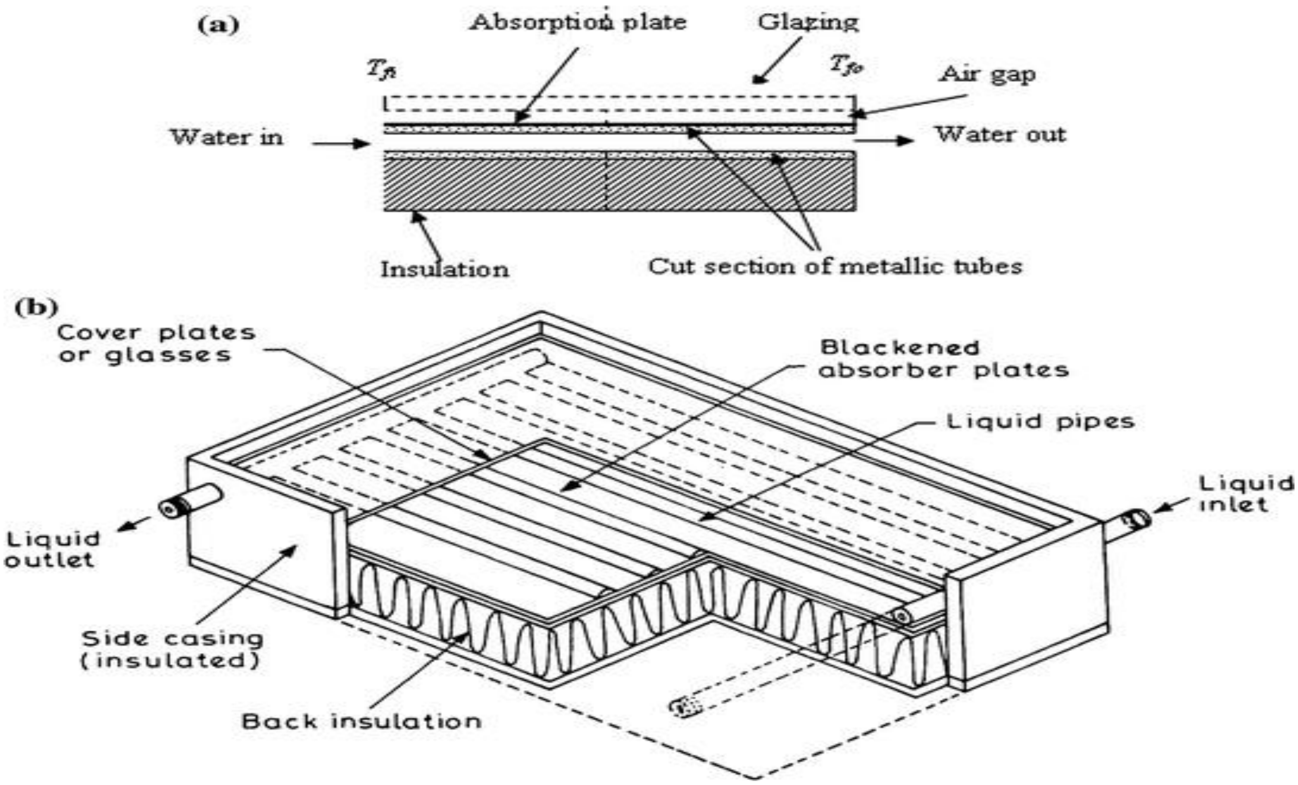


Figure No 3. 5: Parts of a flat plate collector

e) Casing: A steel or wooden casing is used to hold the parts together. In the casing a layer of insulation is provided at the bottom. The absorber plate is placed after that with copper tubes incorporated in it. The sides are also insulated for the reduction of heat loss through convection. (John A. Duffie, 2006) Finally, the glazing is done with glass to provide an air gap between absorber and the atmosphere. All the parts are soldered, brazed, or welded properly to get maximum surface contact and high heat transfer. Casing protects the parts from environmental influences like dust particles, rainfall, moisture etc. (Amrutkar, 2012; Tian and Zhao, 2013) And included other parts with the system for constructing solar water heater such as- Insulation water tank Stand.

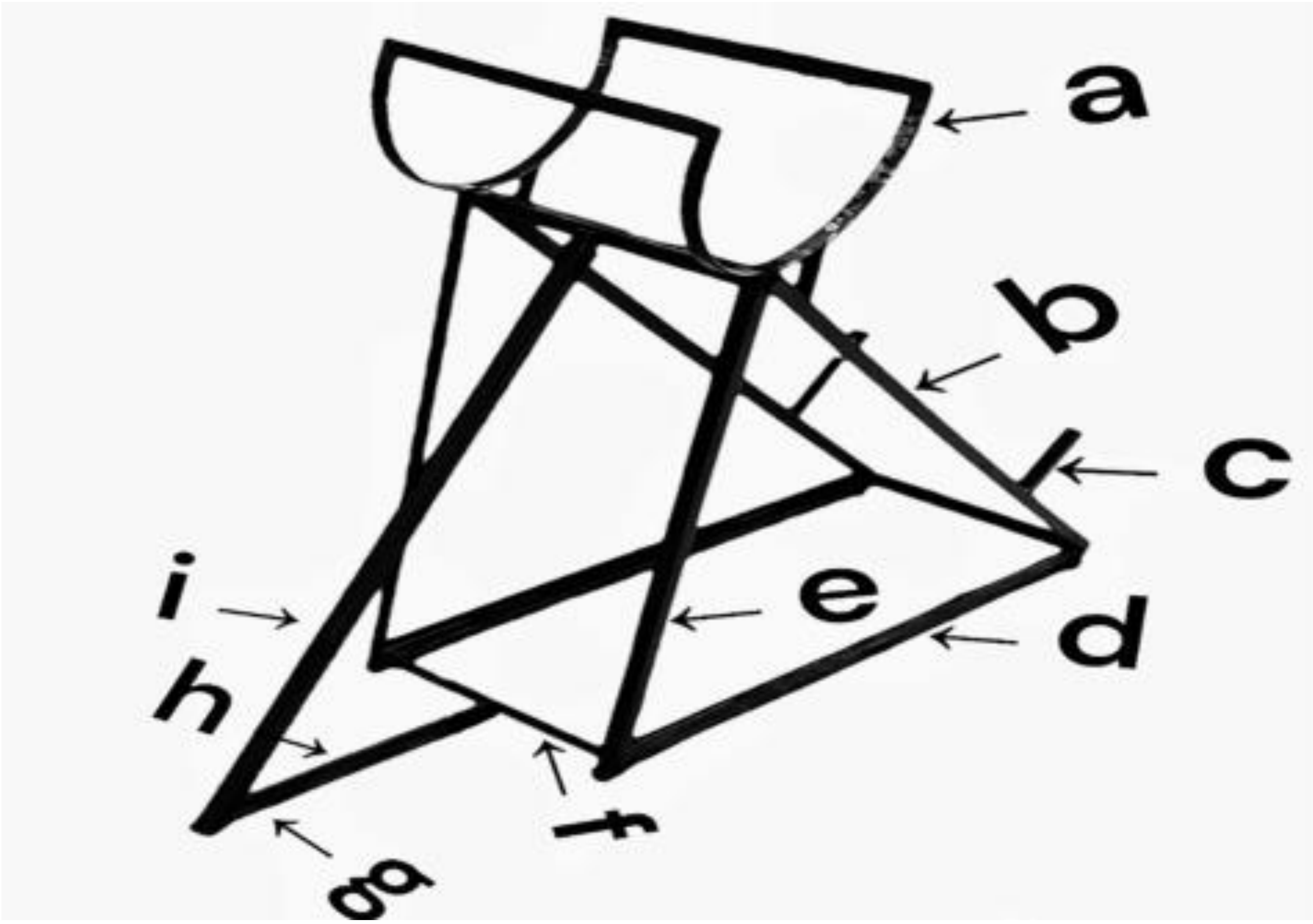


Figure No 3.6: Stand

Dimension of stand and HW tank:

Parts	Dimensions
a	2ft
b	3.75ft
C	.58ft
d	3ft
e	2.5ft
f	1.25ft
g	38^o
h	1.08ft
i	2.5ft

Table 3.1: Dimension of stands

3.5 Experimental set-up and procedure:

Apparatus:

- Celsius scale
- Pyranometer
- Coriolis meter

An absorber plate is attached inside a closed box with glass. Inside the box the copper plate and copper pipe get heated due to sun radiation. From the storage tank the cold water circulates through the copper pipe. The absorber plate absorbed the heat from sun radiation. When water flows in the pipe it starts to get heated and from the outlet pipe the hot water comes out. This is the simple way of working solar water heater.

3.6 Testing method:

A passive solar water heater was fabricated comprising of a flat solar collector and storage tank. The flat collector of 1 m × 1 m was fabricated by using of the 1.3 mm mild copper plate covered with 5 mm thick window glass. 1 mm copper sheet was used as absorber plate. The space between the absorber plate and bottom plate and outer surfaces were insulated with 25 mm tharmocol. This collector was mounted on supporting steel structure. Slots were provided on the structure to change the inclination of the collector. An 8 mm diameter and 1 mm thick copper pipe was used to circulate water. The copper tube was attached to an absorber plate. A horizontal cylindrical storage tank made up with 55-liter capacity was fabricated, insulated with thermocol and mounted on a steel stand. The two ends of the copper tube related to the storage tank.

CHAPTER 4
PROJECT ANALYSIS

4.1 Experimental description:

Operation principle:

Water flows through the spiral shaped copper pipe because of gravity force from cold water reservoir tank to the solar collector where it absorbs radiation in the form of heat energy. This results in density difference which causes heated water to flow through riser to hot water tank via outlet tube which is called convective process. convective process generally has low flow rates through the collector, as the fluid goes through a high temperature rise. This accounts for the low efficiency of convective process. Basically, it is operated naturally by a passive system which does not require any electric motor.

Figure No 4. 1: Flat Plate Collector Passive SWH

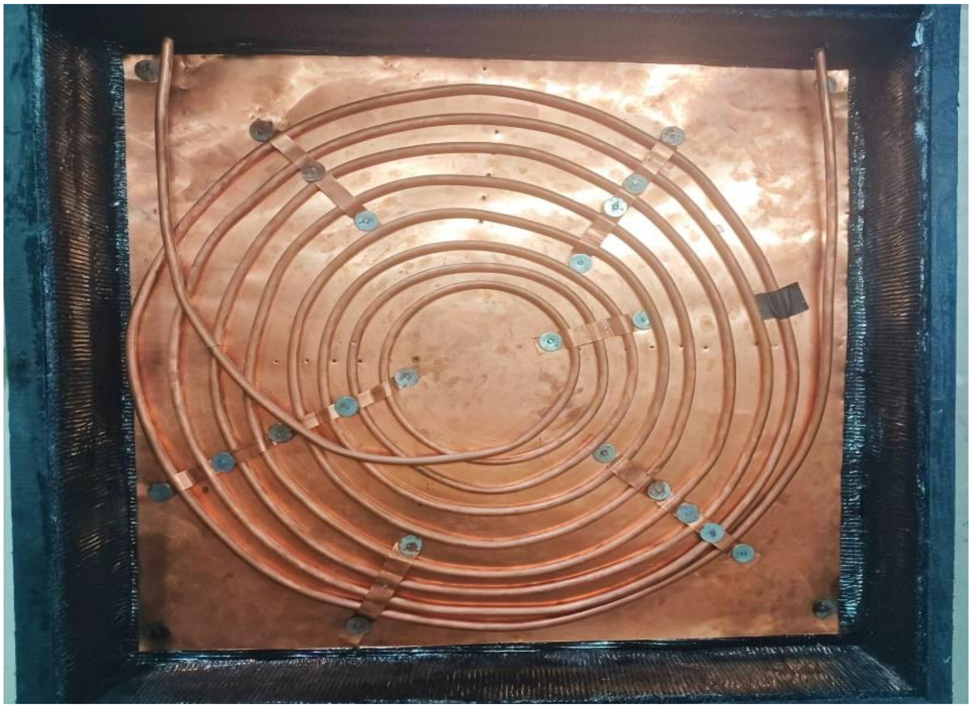


Figure No 4. 2: Construction of FPSC

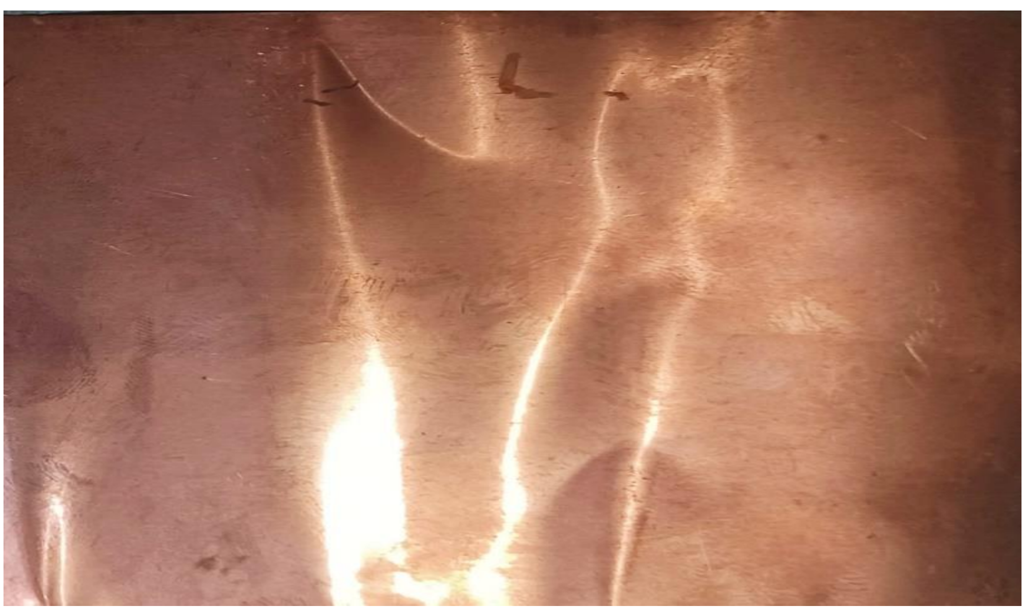


Figure No 4. 3: Copper Sheet Absorber

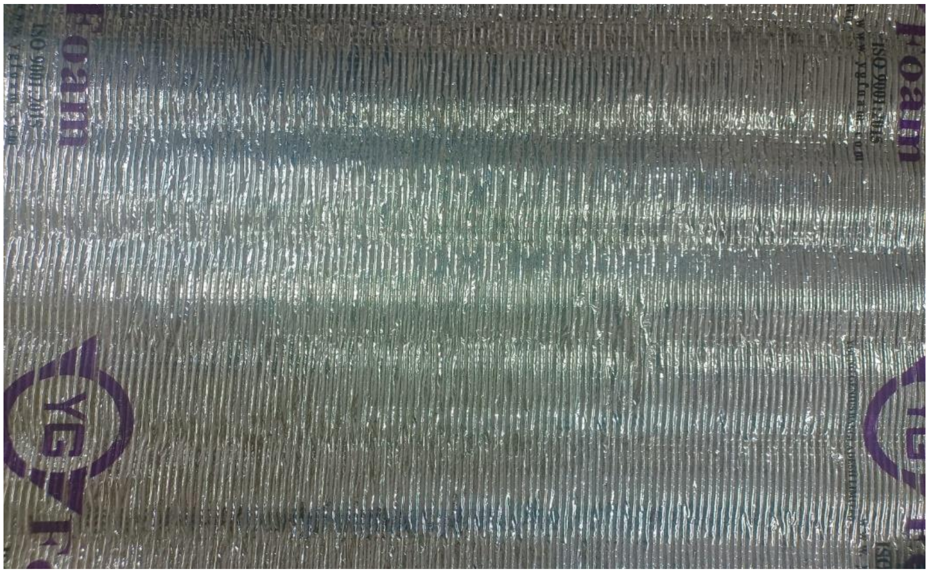


Figure No 4. 4: Insulation Foam Sheet

4.2 Impact of this project:

The use of renewable energy sources is increasing day by day. Implementing a solar water heater project can have several positive impacts on the environment, economy, and society. Here are some of the impacts:

1. Reduction in Greenhouse Gas Emissions: Solar water heaters use sunlight to heat water, reducing the need for conventional fossil fuels like natural gas or electricity. This leads to a significant reduction in greenhouse gas emissions, contributing to mitigating climate change.

2. Energy Cost Savings: Solar water heaters can lead to substantial energy cost savings for homeowners and businesses. By harnessing free and abundant solar energy, users can reduce their reliance on expensive energy sources, resulting in lower utility bills.

3. Energy Independence: Solar water heaters promote energy independence by reducing dependence on external energy sources. This can enhance energy security and reduce vulnerability to energy price fluctuations.

4. Local Economic Stimulus: Solar water heater projects can stimulate the local economy by increasing demand for materials, labor, and services, benefiting local businesses and communities.

5. Reduction in Peak Electricity Demand: Solar water heaters can help reduce peak electricity demand, especially in regions with high cooling or heating loads. This can lead to a more stable and efficient electricity grid.

6. Improved Air Quality: By reducing the use of fossil fuels for water heating, solar water heaters contribute to improved air quality and reduced air pollution, leading to better public health.

7. Promotion of Renewable Energy: Solar water heater projects help raise awareness about renewable energy technologies and their potential, encouraging the adoption of other renewable energy solutions

It's important to note that the specific impacts of a solar water heater project can vary depending on factors such as project scale, location, and local policies. However, in general, these projects offer a range of benefits that contribute to a more sustainable and resilient energy future.

CHAPTER 5

RESULT AND DISCUSSION

5.1 Formula:

- Collector efficiency, $\eta = \frac{Q_u}{A_c I_T} = \frac{\dot{m} c_p (T_o - T_i)}{A_c I_T}$
- Area of collector, $A_c = nwl$
- Mass flow rate, $\dot{m} = \rho v A$
- Tank volume, $V = 2\pi r^2 l$ or $2\pi r^2 h$

Type	Value
Coil of tube (n)	8
The gape from one tube to another (w)	.0254 m^2
Length of absorber (a)	0.6096m^2
Width of absorber (b)	0.6096m^2

Table 5.1: Specification of the collector.

Measured Parameters:

V = Volume of the water tank (m^3)

T_i = Temperature of water at inlet (K)

T_o = Temperature of water at outlet (K)

T_a= Atmospheric temperature (K)

l = Length (m)

h = Height (m)

A_c = Collector area (m^2)

I_T = Irradiance (w/m^2)

C_P = Specific heat of water (J/kg k)

$\dot{m}$ = Mass flow rate of water per second (kg/s)

ρ = Density of water (kg/m^3)

Q_u = The rate of useful energy extracted by the collector (J)

5.2 Data Table:

Time (S)	Irradiance, I_T (w/m^2)	Mass flow rate, $\dot{m}$ (kg/s)	Atmospheric temp. T_a (°C)	Inlet temp. T_i (°C)	Outlet temp. $\mathbf{T_o}$ (°C)	Collector Efficiency, η (%)
10:00-11:00 am	620	0.008	30	27	36	19
11:00-12:00 pm	625	0.0085	32	28	39	24
12:00-1:00 pm	627	0.009	35	30	43	30
1:00-2:00 pm	630	0.01	36	33	48	39
2:00-3:00 pm	610	0.011	35	34	46	41

Table 5.2: Experimental data table

5.3 Calculation:

Efficiency of flat plate collector: Efficiency of a FPC is given by the ratio of the useful gain over some specified time period to the incident solar energy over the same period.

•Collector efficiency, $\eta = \frac{Q_u}{A_c I_T} = \frac{\dot{m} c_p (T_o - T_i)}{A_c I_T}$

Hence, η_1 =.008×1009(309-300)/.609×620=.19 or 19%

η_2 =.0085×1009(312-301)/.609×625=.24 or 24%

η_3 =.009×1009(316-303)/.609×627=.30 or 30%

η_4 =.01×1009(321-306)/.609×630=.39 or 39%

η_5 =.011×1009(319-305)/.609×610=.41 or 41%

• Area of the spiral tube $=\pi\times r^2=\pi\times(.254)^2=.2027\ m^2$

•Area of the absorber, $A_a=0.6096\times 0.6096=0.37129\ m^2$

Now, total Area of the Collector, $A_c=.2027+0.37129=0.57499\ m^2$

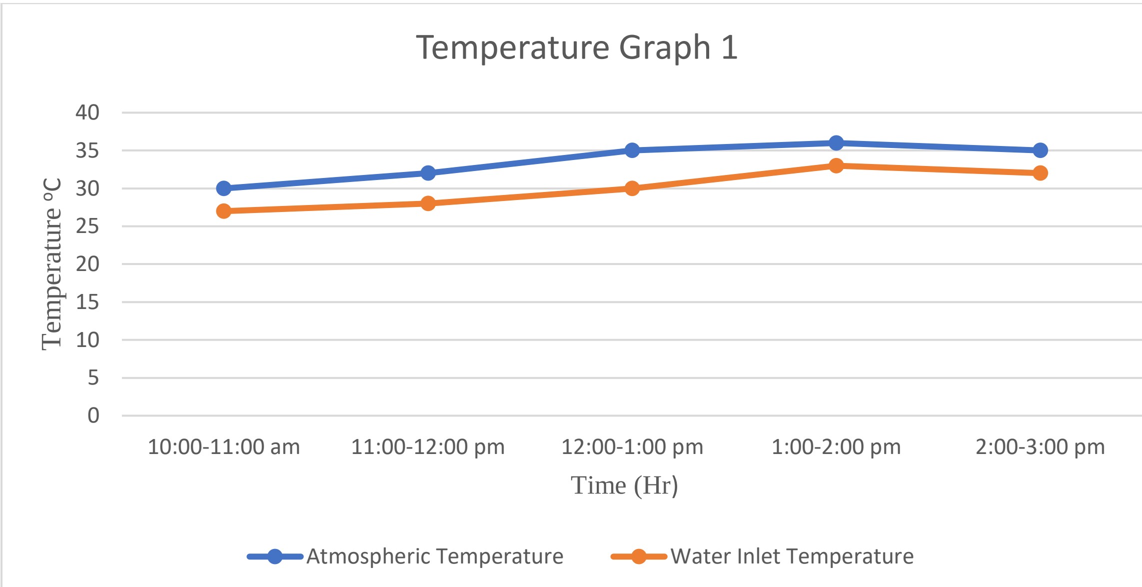


Figure No 5. 1: Water Inlet and Atmospheric Temperature Graph

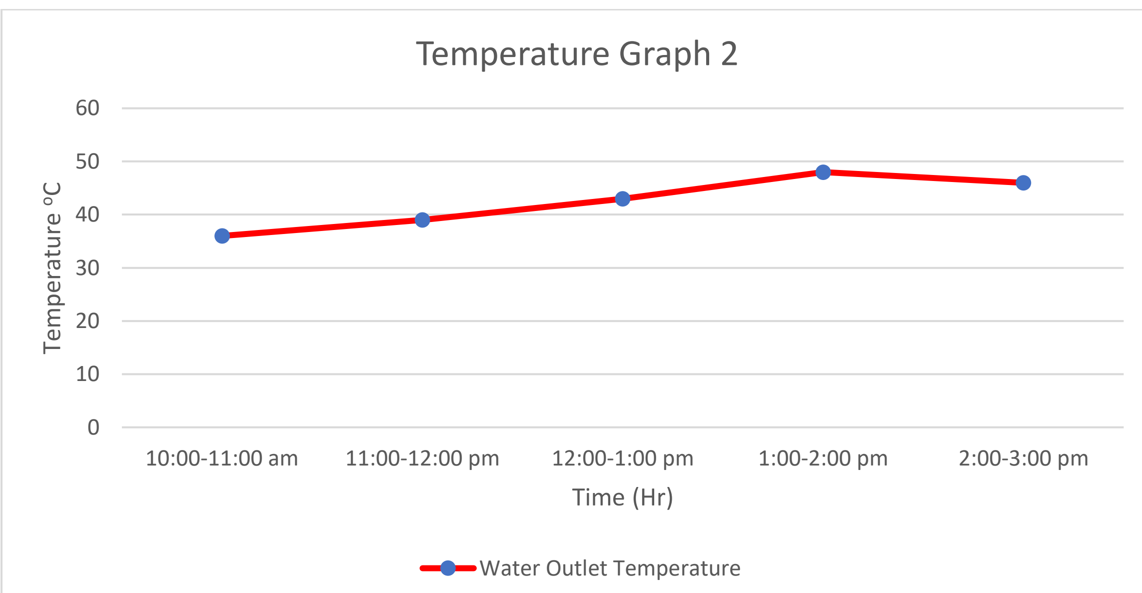


Figure No 5. 2: Water Outlet Temperature Graph

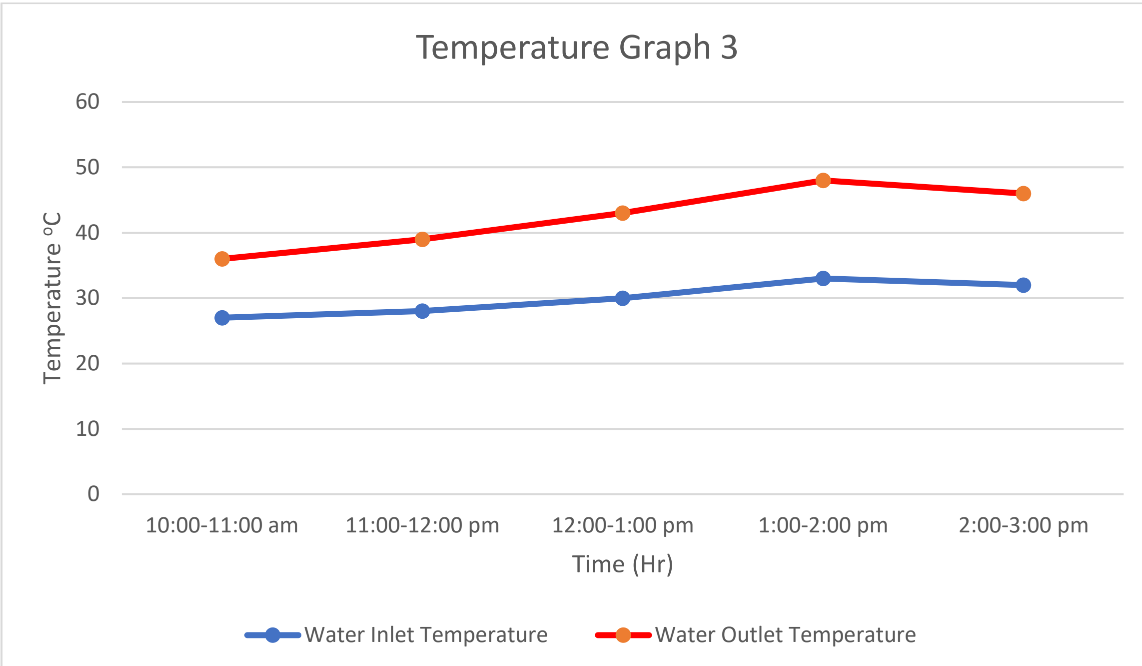


Figure No 5. 3: Water Inlet and Outlet Temperature Graph

From the experiment of FPC at 10:00am to 3:00pm with the respect of time is calculated. The outlet temperature is more at 2:00 pm of the FPCSWH i.e., The highest inlet temperature of water is 48°C at 2:00pm which has 33°C initial inlet temperature. So, there is an increase of 15°C of the outlet temperature. As the time increases output temperature decreases eventually and inlet temperature increases as shown in the above temperature graph 3.

CHAPTER 6
CONCLUSION

Flat plate collectors which are used for solar water heaters are less costly than other heaters and easy to construct. They stay intact for a long time. However, it requires a lot of space to get high energy.

We can see from the result as the time passes the outlet temperature also increases and the highest temperature got at 2:00pm which is 48 ^{o}C. If we use this kind of heater instead of an electric heater, we can save a lot of electricity. As stated earlier, that project was constructed and completed with local needs, it helps a lot to reduce the cost of the project. It reduces the time and cost of the materials and manufacturing.

CHAPTER 7
RECOMMENDATIONS

There are many design improvement ideas which can be implemented. Some of it are given below:

- The collector's material and design should be improved which can provide better efficiency in low sunny areas.
- A heat exchanger can be designed with regional needs and according to the type of applications.
- Such materials should be developed which do not overheat. Overheating effects, the performance of solar water heater

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