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FABRICATION AND PERFORMANCE TEST OF A FLAT PLATE COLLECTOR PASSIVE SOLAR WATER HEATER

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Declaration of authorship

It is stated that the project work on ‘Fabrication and performance test of a flat plate collector passive solar water heater’ has been performed under the supervision of Md Ali Azam, Lecturer of Sonargaon University. To the best of our knowledge and belief, we declare that neither this project nor any part thereof has been submitted anywhere else for awarding any degree, diploma, or other qualifications except where due reference is made in it itself.

We, further undertake to indemnify the university against any loss or damage arising from breach of the foregoing obligation.

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We used to Express our sincere appreciation and heartiest gratitude to our supervisor Md. Ali Azam, Lecturer Department of mechanical engineering, Sonargaon University for his continuous lecture, individual suggestions, patient hearing and giving sufficient time for discussion, guidance and encouragement throughout the progress and preparation of this project work.

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Authors.

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 the 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 works 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 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 project. At the end impact of the project was discussed on social, economic, and environmental grounds.

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List of 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 Project Definition

This project is intended to construct a water heating system by using solar technology. There are various design and manufacturing constraints but here the most general and efficient way would be used. It includes thorough study of the mechanism of the solar water heater. After designing such mechanism, the heater would be manufactured, and the results would be presented. Solar energy technology is used in various places in different ways. It is used to produce electricity and it provides energy which is used to cook food. Solar systems are designed in such a way that water can be heated to any temperature. But at domestic levels water can be heated up to 60 ºC. Evacuated types of solar heaters and glazed plate heaters are the most common types of solar powered water heaters used in the world.

There are two types of solar water heating system, like- 1. Active system. It is also two types: 1. Direct (Open-loop) system. And 2. Indirect (Close-loop) system

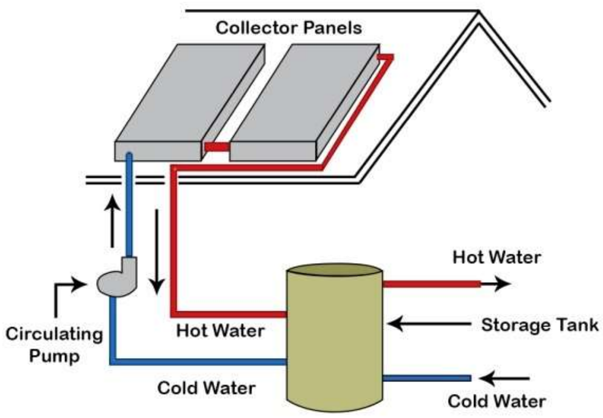

Figure No 1.1: Open loop active system

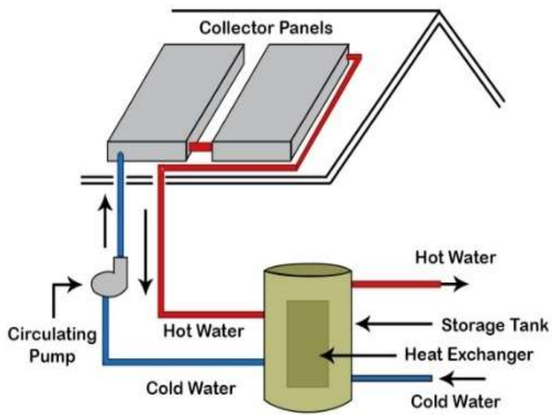

Figure No 1.2: Close loop active system

This need circulating pump. 2.Passive system. It is also two types: 1. Thermosiphon system and 2. integrated collector storage. These not need circulating pump. In this project, passive system will be used. Cambridge International Dictionary of English state that passive is a behavior that not acting to influence or change a situation and let other things to take control. Passive solar water heater is a system for heating water using solar radiation and the flow of the water inside the system is passive. This means that the water flow is not prolog by any mean of mechanical and electronic devices such as pump. (C. Tuminaro 1990). Passive solar water heating systems have no moving parts and operate using local water pressure and solar radiation. There are no pumps or controls to maintain and no electrical energy is required to make it function. The mechanism of our solar heater will resemble as shown in figure:

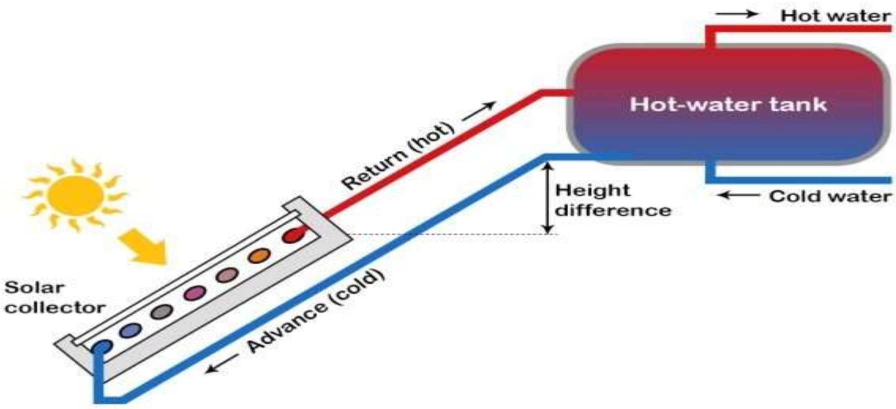

Figure No 1. 3: Thermosiphon system WH

1.2 Background:

From the beginning of the life on earth, sun has been the most powerful force of nature. It is one of the reasons of the existence of life on earth and contributing a lot as a basic energy source. Due to its large benefits and size, it is regarded as the god in some of the religions. In the past no major benefit was taken by humanity. But as the needs of the human are increasing and other reliable sources are decreasing. Now humans are shifting towards renewable energy sources and sun is one of the biggest sources of renewable energy. In the same way solar energy is used to heat water in the industries, steam is produced by using modern techniques. In California, first solar water heater was utilized to heat the pool water in 1970 (Bennet T, 2007).[1] To get benefit of solar energy first started by Romans and Greeks. They built their house in such a way that solar light directly falls in and warmed their houses. But modern applications of solar energy started in 1883 as the Charles Frits developed first solar cell. In 1970s Europe and Israel invested in solar technology and reduced the cost of photovoltaic cell to compete the oil sector which was dominated by the Arab countries (Ken Butti, John Perlin, 1980).[2] In 1983 about 60% of the households in Israel were using solar heaters to warm the water. By now around 90% of the houses in Israel are using solar water heaters. European countries are investing in solar energy and after China, Germany is producing solar energy. In the 19th century people used wood and other exhausted sources to heat the water. In some areas it was difficult to heat water as the availability of coal, wood and gas was not enough or some areas did not have access to these sources. So, a black painted container was filled with water and exposed to sun. But the main flaw in this system was as the sun set, the water got cooled (Charles Smith, 1995).[3] Solar heaters are divided into two main types. One is passive while the other is active. In passive systems, radiation or heat of the sun is directly used. This heat is either drops on the storage tanks or this heat is transferred to tank which is placed above collectors (Roger Taylor, 2006).[4] Active solar systems are divided into two types. One is direct and other is indirect. In direct active systems, heat is absorbed by the collectors. These collectors may be in any shape. Water is being pushed with the help of pumps to circulate in the pipes surrounding the heat collectors. After heating the water is taken back to the storage tanks. In indirect systems, water is heated with the help of some heat exchanger. In domestic indirect solar heaters, water is heated inside the heat exchanger and then transferred to the storage tank (Harrison J. Tiedman T. 1997).[5] Performance of the solar water heater is affected by the many factors. These includes ambient conditions, collector arrangement and fluid flow rate. It the atmosphere is clear, then sun will fall directly on the collector. Temperature determines the thermal loss from the collector. Area of solar collector and its orientation determine the absorption capacity of collector. In direct systems, if the flow rate of fluid is low then water is heated evenly while low heat transfer occurs if the flow rate is high (Kalogirou, S.A, 2004).[6]

1.3 Objectives of the project:

The main objectives of the project are as follows:

➤ To study, construct, and analysis of the passive solar water heating system according to the domestic applications.

➤ To calculate the efficiency of the flat plate collector for analyzing of the performance.

➤ To fabricate the passive solar heating system with the economical and easily available materials.

1.4 Applications:

Solar water heater can be used in domestic, commercial, and industrial applications. They are enlisted below:

•Domestically hot water is used in bathing, washing of utensils and clothes and cleaning floors. Water requirement for a house depends on the number of family members. For a 4 members family, each consuming approximately 25 liters, on average above 100 liters are required.

• In commercial applications, a large quantity of water is required. For this purpose, large scale heating systems are used.

•In industries water is used to preheat the boiler water. Hot water is also used in food processing industries.

• Space heating and cooling.

• Low temperature cycle for power generation.

• Military laundry facilities.

1.5 Advantages Vs Disadvantages:

Advantages	Disadvantages
Not require electric energy.	High installation cost.
Water heating bill saving.	Depend on climate.
Low maintenance.	Only heats air and water.
Environmentally friendly.	Chance of tube degradation.
Safe, free, and clean energy.	

Table 1: Advantages and disadvantages of SWH

CHAPTER 2: LITERATURE REVIEW

2.1 Previous work:

As discussed previously that there are two types of solar heaters. One is active and passive. Passive heaters circulate water by using natural means like gravity or natural circulation. These systems are less expensive. While the active solar heaters use pumps and other equipment to force the flow rate and thus it is costly and difficult to repair. 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 the 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. Following is the comparison presented by him for different collectors (Kalogeria, S.A, 2004). [6]

Motion	Collector type	Absorber type	Concentration ratio	Temperature range (°C)
Stationary	FPC	Flat	1	30-80
	ETC	Flat	1	50-200
	CPC	Tubular	(1-5)	60-240
Single-axis tracking	LFR	Tubular	(15-45)	60-260
	PTC	Tubular	(15-45)	60-300
	CTC	Tubular	(10-50)	60-300
Two-axis tracking	PDR	Point	(100-1000)	100-500
	HFC	Point	(100-1500)	150-2000

Table 2: Comparison of different collectors and Collector data

K. Sivakumar used elliptical flat heat collector and placed this collector at 11^o to the horizontal. In this experiment condenser to evaporator length ratio, different flow rates and many inlet conditions were analyzed. Five evacuated pipes made of stainless steel were used. Tube was made of copper while the methanol was used as a working fluid for this setup. The experiment analyzed that ratio of lengths of condenser to evaporator of 0.1764 achieved greater efficiency

(K. Sivakumar, 2005). [7] Hussain Al-Madani presented research on evacuated and cylindrical tubes. Collectors consist of copper coils and water circulates in them. Different experiments were taken, and it was concluded that maximum difference of temperature occurred has a value of 27.8 ºC. This value shows the efficiency of 42 % (Hussain, Al-Madani, 2006).[8] K. S. Ong worked on different solar water heaters. He and his friends used different collectors and tanks with various sizes and designs. They used short and long terms experiments and performances of different solar collectors was assessed. They concluded that in natural convection hear pipe system water was heated up to 100 ºC. They used different absorber and collector types and give the results as shown in the figure. (K. S. Ong W. L. Tong, 2011).[9]

Motion	Collector type	Absorber type	Concentration ratio	Temperature range (°C)
Stationary	FPC	Flat	1	30-80
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Two-axis tracking	PDR	Point	(100-1000)	100-500
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Table 3: Collector data with different collector type

2.2 Comparative Study:

As we have discussed various works of different researchers. They all used different criteria to assess the performance of solar water heater systems. They all used different criteria to assess the quality and efficiency of solar heater. In this project the aim of our project is to build a passive solar water heater which is activated by the Thermosiphon process and the flow rate is caused by the gravity and the density difference of the water. Flat plate collector is used. Now we are in the study period, and then must fabricate the passive solar heater final product which will be cost-effective more than the others system. When we will reach the final product, then suitable procedure and analysis will be carried out and will be discussed with the work presented in the literature review.

CHAPTER 3: METHODOLOGY

3.1 Design Constraints:

There are different design constraints which were considered while designing solar water heater. This project is experimental based and would have following design constraints and then will be discussed one by one:

•Safety

•Cost

•Weight

•Serviceability

•Efficiency and Performance

•Solar water heater consists of many parts which will be discussed in the next section. On part which will collect the solar heat is called collector. Collector has its direction towards the sun. There is a possibility of damage to collectors as other parts will be within the housing. Collector material should have great strength which can bear the impact of possible winds and other damaging things.

•Solar water heater will be made using the locally available materials and manufacturing techniques. Those parts which are costlier to manufacture or not available locally would be purchased. The cost will be minimized by using machines which are available in the lab.

•Solar water heater will be placed on the roof or at a place where sunlight is available. So it must be placed in open. Extensive winds or wind blows can damage the solar heater. It must have sufficient weight so that it can be firmly placed on the ground.

•It is stated earlier that all the materials and parts will be purchased from the local markets. Manufacturing processes will also be carefully choosing which have low manufacturing cost. Quality was enhanced by purchasing the parts which can be manufactured locally. Materials will be chosen which have high efficiency and more capacity of absorbing heat.

3.2 Risk Factors:

There are many factors which can be considered as damaging factors for the design of solar water

heater. Some of which are listed below:

•Cost

•Safety

•Leakage

•Corrosion

Solar water heater would be manufactured using the local sources. Some of the parts which cannot be manufactured will be bought either from the local market or international. These parts will increase the cost of the water heater. In the lab we do not have big machines which can manufacture complex geometries. So, these parts will be manufactured by local vendors. So, cost might also be higher due to this reason. Solar water heater will be kept outside in the sunlight. There is a chance of damage from violent winds and some other factors. Leakage is another big problem which can occur due to poor welding. Corrosion is another big problem which can damage the metal parts and the heat exchanger.

3.3 System selection:

There are various types of system as solar collector that are commonly used in constructing solar water heater and these are given below:

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:

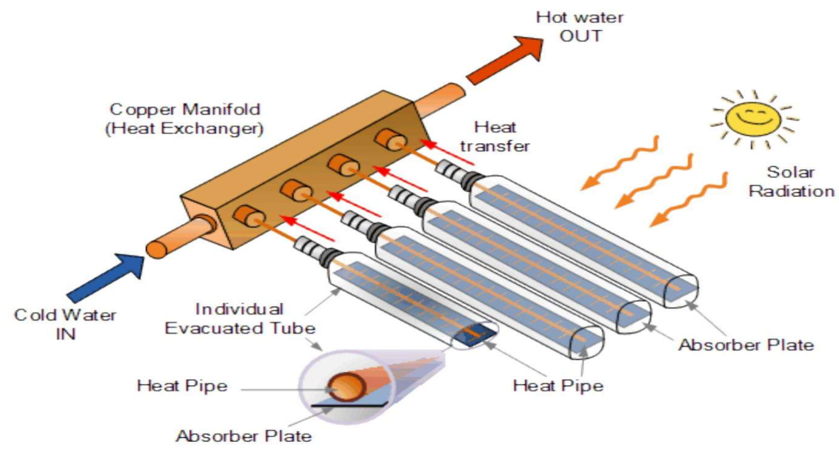
Non-concentrating solar collectors are usually used for low temperature applications. These collectors consist of flat surface which absorbs heat from the sun. The efficiency of non-concentrating collectors is comparatively less but in terms of cost and maintenance these are much feasible. There are a few types 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 detailed discussion about flat plate collectors is done. (Kalogirou, 2004; Jesko, 2008; Amrutkar, 2012; Tian and Zhao, 2013; Chowdhury and Salam, 2019; Fudholi and Sopian, 2019)

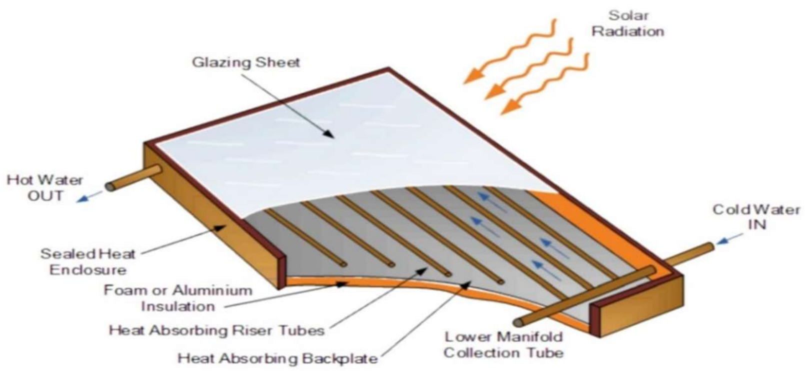
ii. Evacuated Tube Collector: Evacuated tube collector differs from the flat plate collector in construction and operation. Figure (b) shows a flat plate collector. Evacuated collectors are used in climates with high temperature or where the temperature is too high for flat plate collector to work efficiently. 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-vapour 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 tube 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 collector 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 sun's radiation. These collectors work in a similar way as 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 temperature. 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)

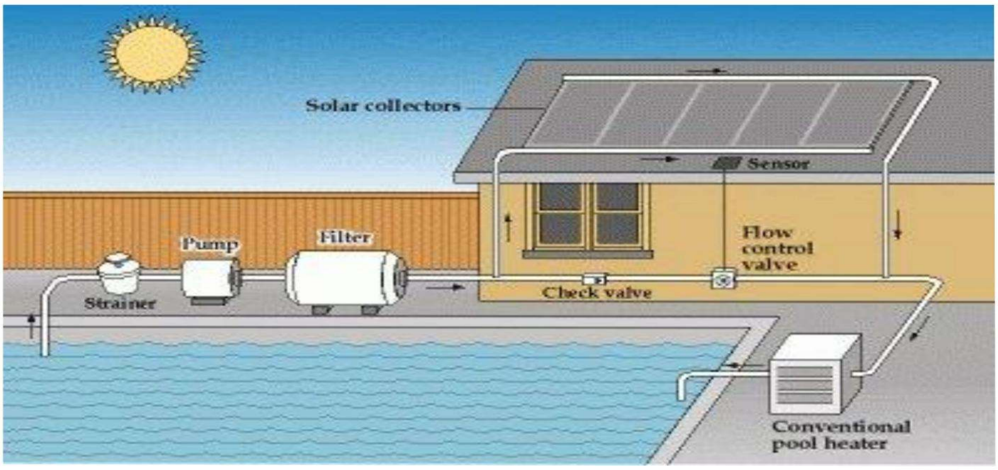


(b)

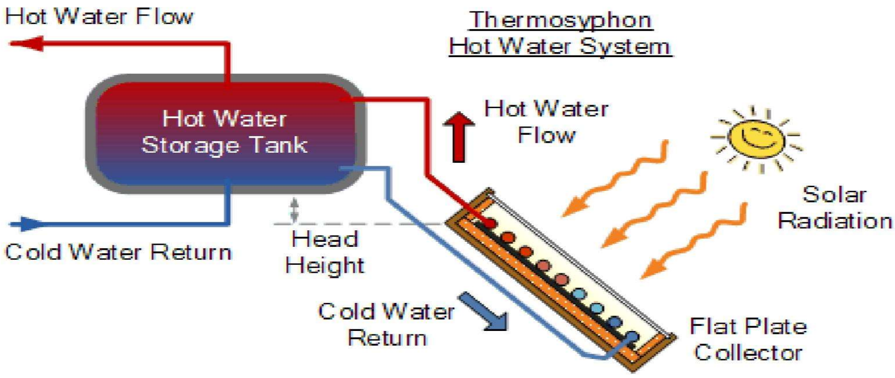


(a)

Figure No 3. 1 (a) Flat plate solar collector (Anon., 2020), (b) Evacuated tube collector (Anon., 2020)



(c)



(d)

Figure No 3. 2.iii, iv: (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 maybe glazed or unglazed depending on the requirement. There are both sun tracking system 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)

i. 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 are rotated along the axis of the absorber pipe continuously. Temperature 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)

ii. 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 iscollected 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 among all collectors. (Kalogirou, 2004; Tian and Zhao, 2013)

iii. 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 consist of vertical tubes of flowing water. Up to 1500°C temperature is achievable using this collector. The heliostats are controlled by automated tracking device 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)

iv. 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 the behave like a common lens. The absorber tube is oriented in such a way that the radiation after refraction through the lens is focused at 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 does 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.

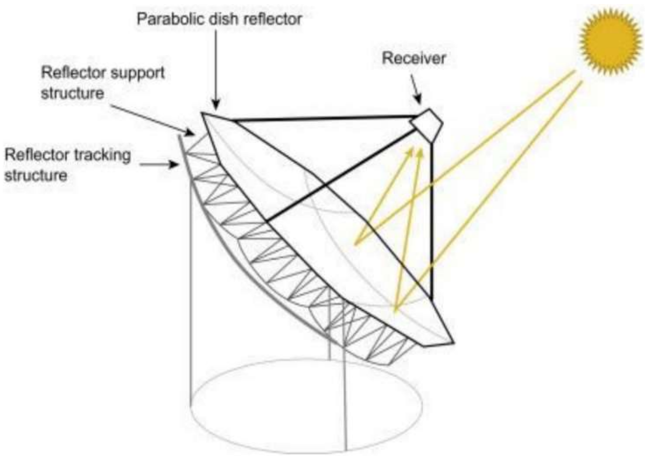


Figure No 3. 3: Parabolic Dish Collector (Manuel J. Blanco,2017)

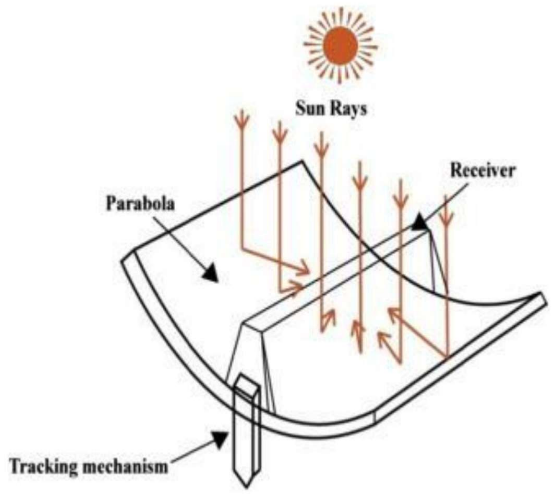


Figure No 3. 4: Parabolic Trough Collector (M.U.H. Joardder,2017) Figure 3.4.3: Heliostat Field Collector (Kalogirou,2004)

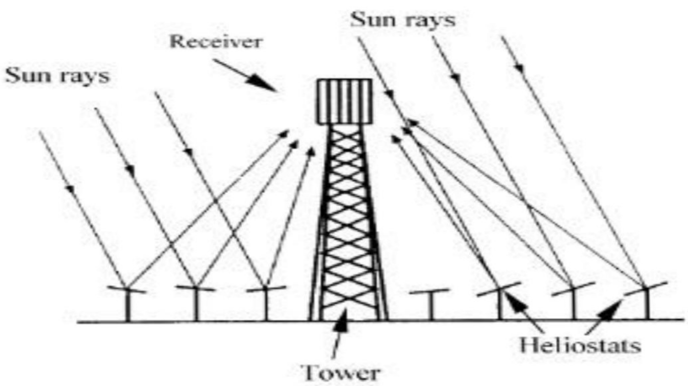


Figure No 3. 5: (a) Linear Fresnel Reflector, (b) Compact Linear Fresnel Reflector (Kalogirou,2004)

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 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 in 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 transfer 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. (John A. Duffie, 2006) (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 does not absorb heat like absorber plate. (Kalogirou, 2004; Amrutkar, 2012; Tian and Zhao, 2013)

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 helps in heating the tubes as well as the plate. (Kalogirou, 2004; Amrutkar, 2012)

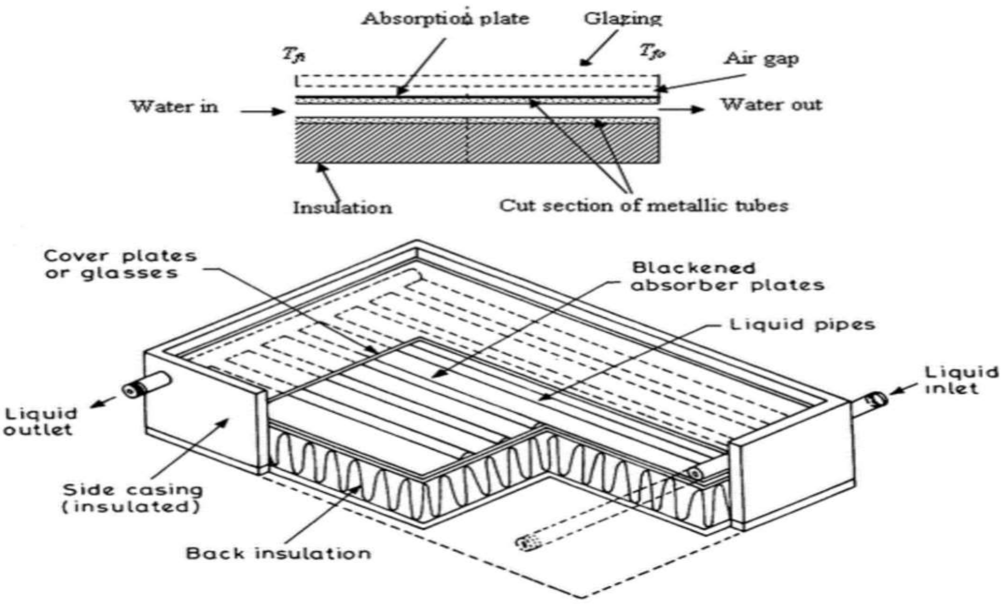


Figure No 3. 6: Parts of a flat plate collector

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 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 others parts with the system for constructing solar water heater such as-

• Insulation water tank • Stand

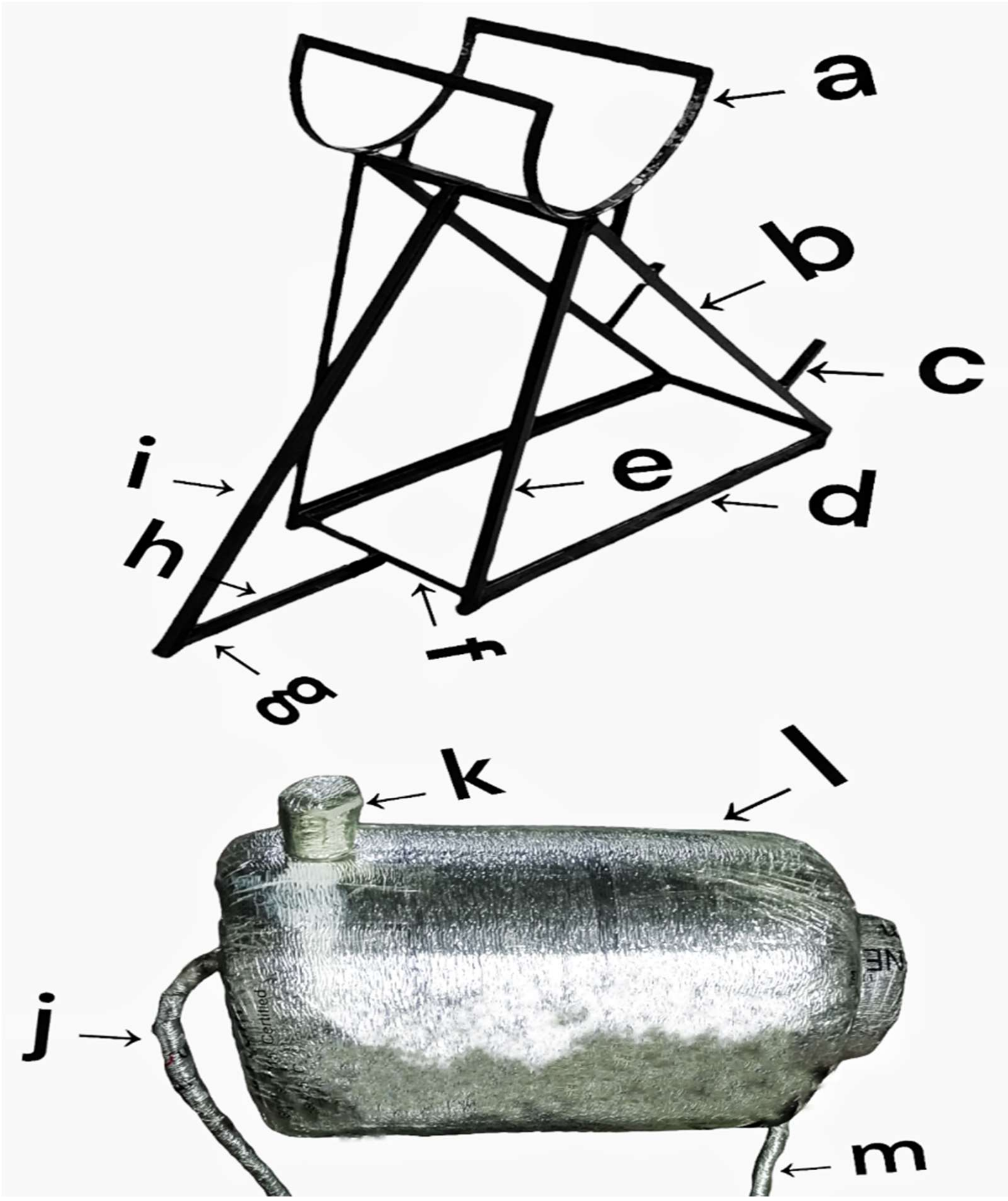


Figure No 3. 7: Stand and HW Tank

Dimensions of Stand and HW Tank:

Parts	Dimensions
a	2ft
b	3.88ft
c	4in
d	2.97ft
e	2.5ft
f	1.5ft
g	40°
h	1.5ft
i	2ft

Table 4: Dimensions of Stand

Parts of Tank	Name
j	Hot water outlet tube
k	Orifice
l	Hot water insulation tank
m	Cold water inlet tube

Table 5: Parts name of HW Tank

3.5 Experimental set-up and procedure:

Apparatus:

- ➤ Celsius scale
- ➤ Pyranometer
- ➤ Coriolis meter

Testing method:

The storage was filled with 15 liters of water and working fluid tubes were filled with working fluid through the working fluid tank. The working fluid is supplied from the working tank which flows inside the tubes in the collectors and then to the solar water storage tank A part of incidence solar radiation on the glass cover is reflected to atmosphere and remaining is transmitted inside the solar collectors and the solar radiation is absorbed by the working fluid. Due to the absorption of solar radiation, working fluid temperature increases and the working fluid starts emitting long wavelength radiation which is not allowed to escape to atmosphere due to presence of glass cover. Thus, the temperature above the working fluid inside the solar collectors becomes higher. The insulation provided at the bottom and all the sides of solar collectors and glass cover serves the purpose of reducing direct convective losses to the ambient and to create greenhouse effect, which further becomes beneficial for rise in working fluid and solar collectors' temperature respectively. The heated working fluid moves upward due to decrease in density whereas the colder working fluid settled at the lower portion due to more in density. After 1 hour consecutively the temperature of water (working fluid) at outlet is measured.

CHAPTER 4: PROJECT ANALYSIS

4.1 Experimental description:

Operation principle:

Water is caused by gravity to flow from cold water reservoir to the solar collector where it absorbs radiation in the form of heat energy. This result in density difference which causes heated water to flow through riser to hot water tank via outlet tube which is called thermo-syphon process or convective process. Thermo-syphon systems generally have low flow rates through the collector, as the fluid undergoes a high temperature rise. This accounts for low efficiency of thermo-syphon systems. Basically, it is operated naturally by passive system which does not require any electric motor.

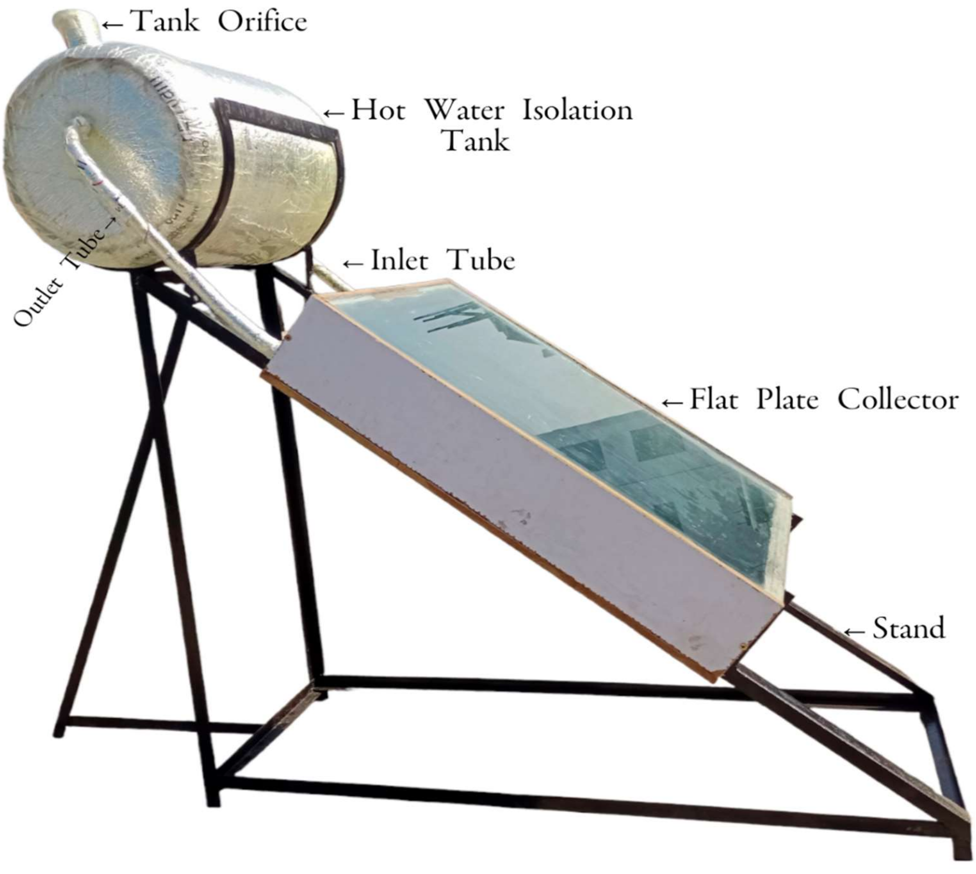


Figure No 4. 1: Flat Plate Collector Passive SWH

Figure No 4. 2: Steps of the Construction of FPSC

Figure No 4. 3: Copper Sheet Absorber

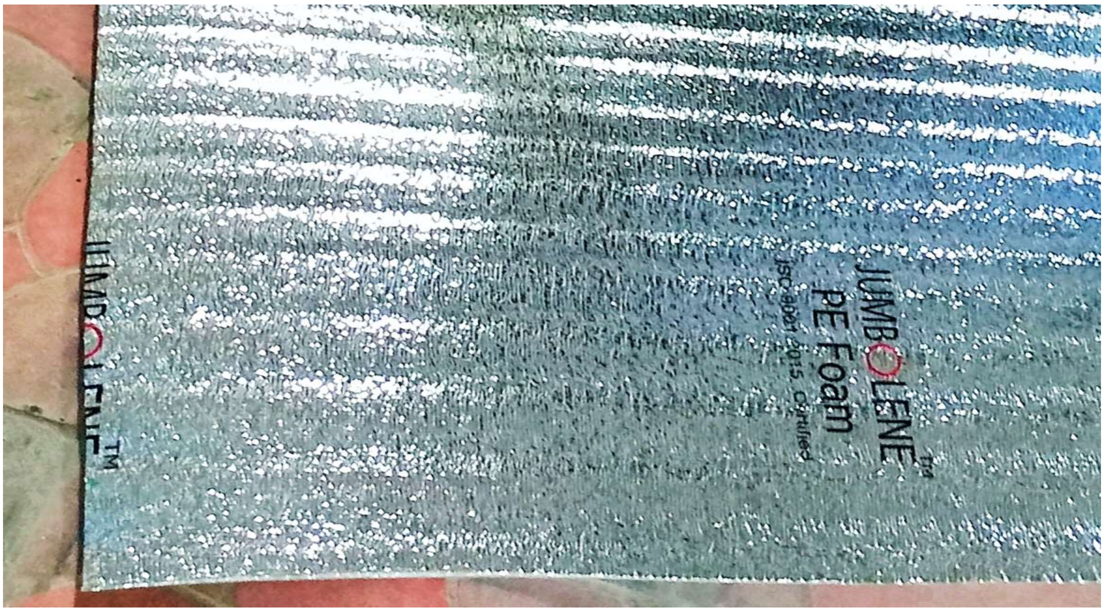


Figure No 4. 4: Insulation Foam Sheet

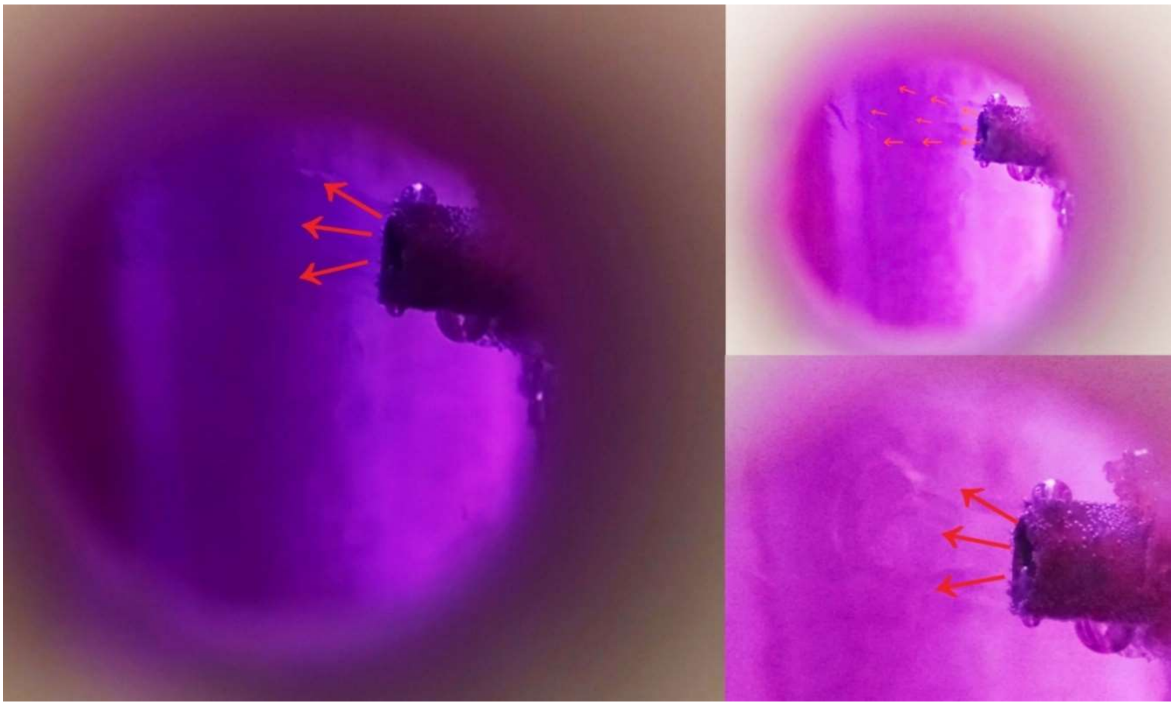


Figure No 4. 5: Hot water flowing moments through the outlet tube to the Tank

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
Number of tube (n)	15
The gape from one tube to another (w)	0.0508 m^2
Length of each tube (l)	0.35 m^2
Length of absorber (a)	0.6858 m^2
Width of absorber (b)	0.254 m^2

Table 6: 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)

4.2 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)	Inlet temp. $\mathbf{T_o}$ (°C)	Collector Efficiency, η (%)
10:30-11:30 AM	610	0.006	24	25	32	15
11:30-12:30 PM	615	0.007	25	27	38	28
12:30-1:30 PM	617	0.0075	27	28	43	41
1:30-2:30 PM	620	0.008	28	31	46	44
2:30-3:30 PM	600	0.0085	28	32	44	39

Table 7: Experimental data table

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

Hance, $\eta_1 \ \frac{\dot{m}_1 c_p (T_{o_1} - T_{i_1})}{A_c \ I_{T_1}} = 0.006 \times 1009 \ (305 - 298)/0.441 \times 610 \ = \ 0.15 \text{ or } 15\%$

Similarly, η_2= 0.007×1009 (311-300)/0.441×615 = 0.28 or 28%

$\eta_3 = \ 0.0075 \times 1009 \ (316 - 301)/0.441 \times 617 \ = \ 0.41 \text{ or } 41\%$

η_4 = 0.008×1009 (319-304)/0.441×620 = 0.44 or 44%

η_5 = 0.0085×1009 (317-305)/0.441×600 = 0.39 or 39%

• Area of the collector tube, A_T = n w l = 15×0.0508×0.35 = 0.2667 m^2

•Area of the absorber, $A_a = a \times b = 0.6858 \times 0.254 = 0.174\ m^2$

Now, total Area of the Collector, $A_c = 0.2667 + 0.174 = 0.441 m^2$

• Tank volume, V= $\pi r^2 l = \pi \times (0.23)^2 \times 0.61 = 0.101 m^3$(Owing to be cylindrical tank)

4.4 Impact of our Project:

The renewable technologies are increasing day by day. These technologies provide safe, reliable, and cheap sources of energy. Solar technologies are improving and became famous in every field. Solar water heaters are becoming famous in the world. Impact of solar water heater is discussed on social, economic, and environmental grounds.

➤ **Social:** Hot water is the need of almost every person. It is used in bathing, cleaning, and cooking. Solar technology is ever growing field which have great opportunities. So, solar water heaters provide social benefits like health, and advancement of technologies. It improves the social standards of people, education and provides opportunities to communicate.

➤ Economic**:** It is one of the forms of renewable energy consumption. It also uses its own source which is the Sun and does not depend on energy sources of the state. It is cheaper and utilize local sources which increases the productivity of the local markets. It reduces the risks of energy shortages. It also lowers the burden on fossil fuels like gas and oil. Renewable energy technologies like this one can have great impact on economy of regions. It can increase regional development and create jobs for the locals. Only drawback is the high initial investment in these projects.

➤ **Environmental:** Solar water heaters have a great impact on improving the environment. It reduces the carbon emissions by using the clean energy. It creates awareness about climate change by using renewable technology and discouraging oil and gas. Solar water heater can limit greenhouse gases and reduces the water and air pollution.

CHAPTER 5: RESULT AND DISCUSSION

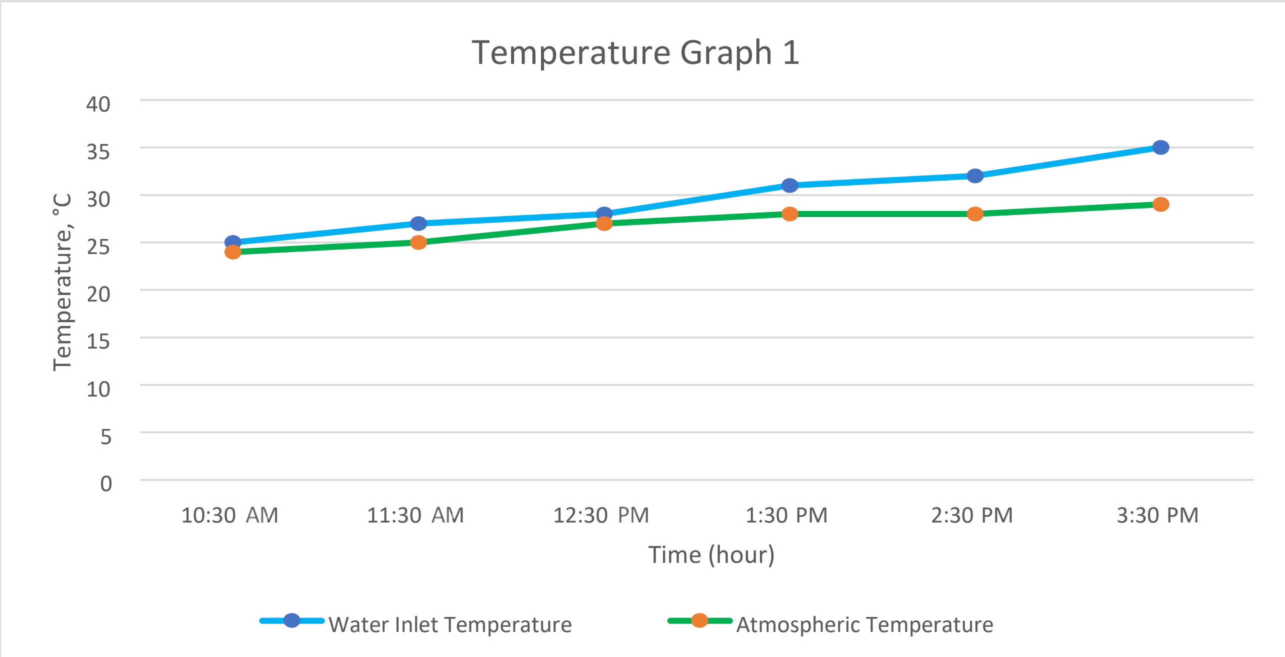


Figure No 5. 1: Water Inlet and Atmospheric Temperature Graph

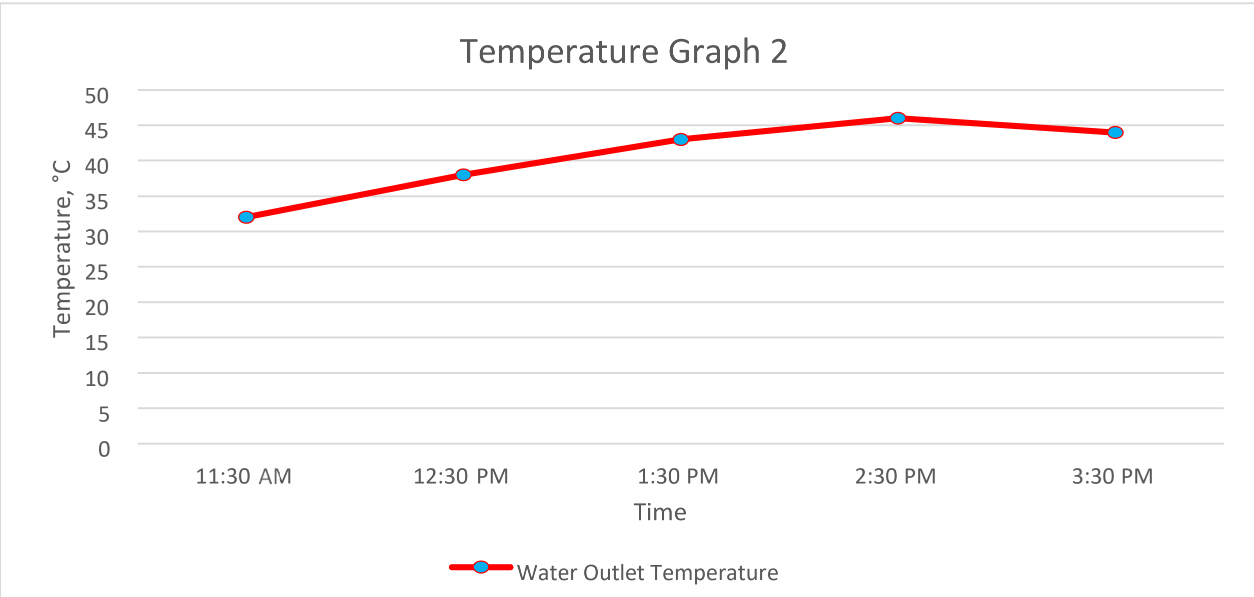


Figure No 5. 2: Water Outlet Temperature Graph

From the experiment of FPC at 10:30am to 3:30pm with respect to time is calculated. The outlet temperature is more at 2:30pm of the FPCSWH i.e., 46°C which has 32°C initial outlet temperature and the highest inlet temperature of water is 35°C at 3:30pm which has 25°C initial inlet temperature. So, there is an increase 14°C of the outlet temperature and 10°C of the inlet temperature. As the time increases output temperature is decreases eventually and inlet temperature is increase as shown in the above temperature graphs 1 and 2.

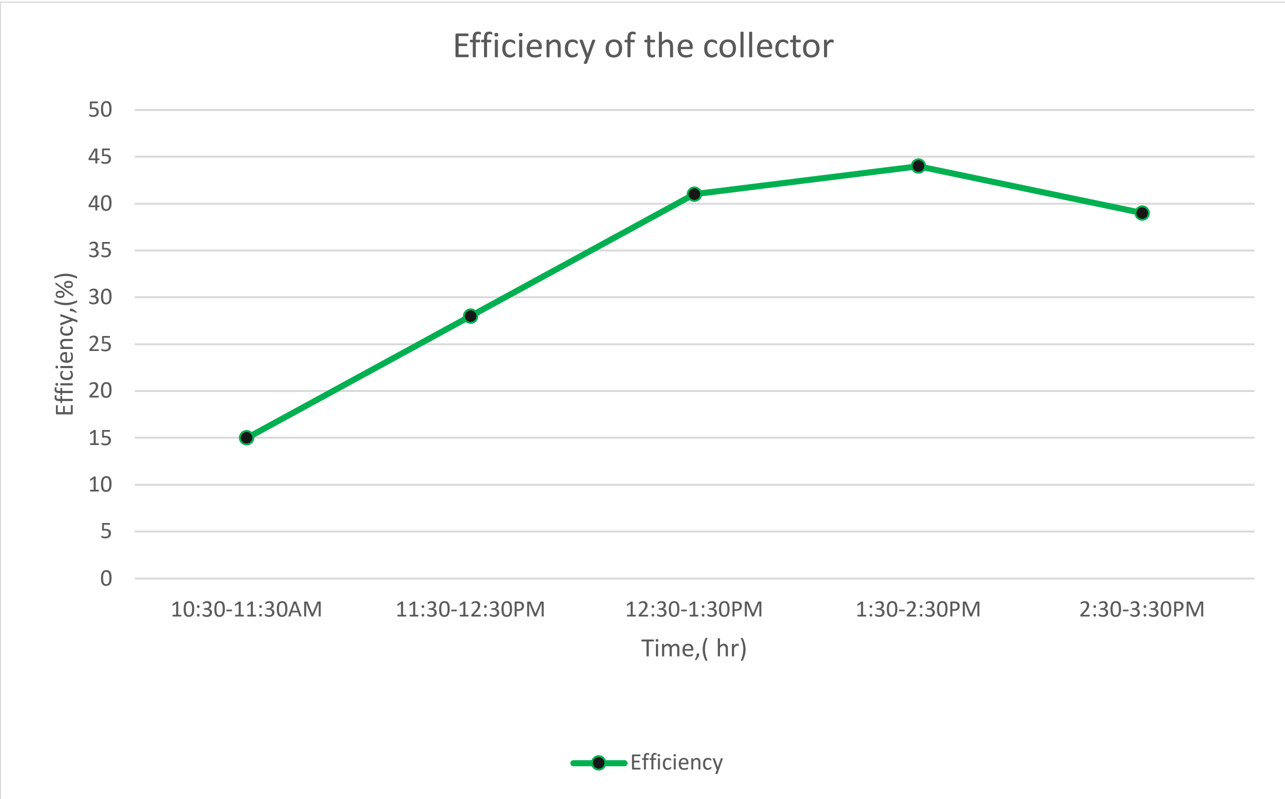


Figure No 5. 3: Graph of Collector Efficiency

Similarly, the efficiency is also more at 2:30 of the collector i.e., 44% and gradually decreases as time increases as shown in the above efficiency graph. We can say that from these graphs output temperature and Efficiency were maximum of the Solar Flat plate collector at 2:30pm 46°C and 44% respectively. When we have experimented of our project, it was Winter season January,2023. If it remained summer season, the efficiency of the solar collector would have been more. Consequently, it would have been more affordable or cost-effective.

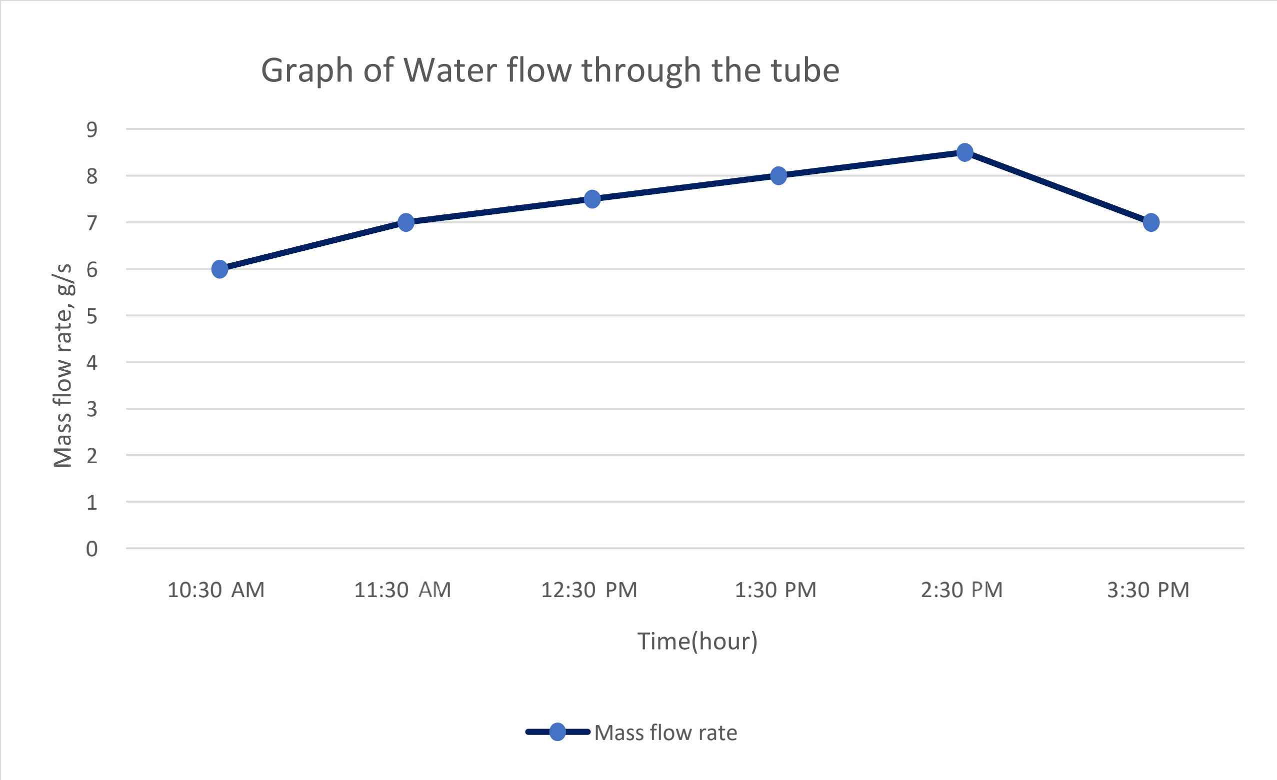


Figure No 5. 4: Graph of water flow through the tube

Here we can see, the mass flow rate is increased gradually. It is high at 2:30 PM and low at the beginning at 10:30 PM. Eventually, it starts begin fallen at 3:30 PM.

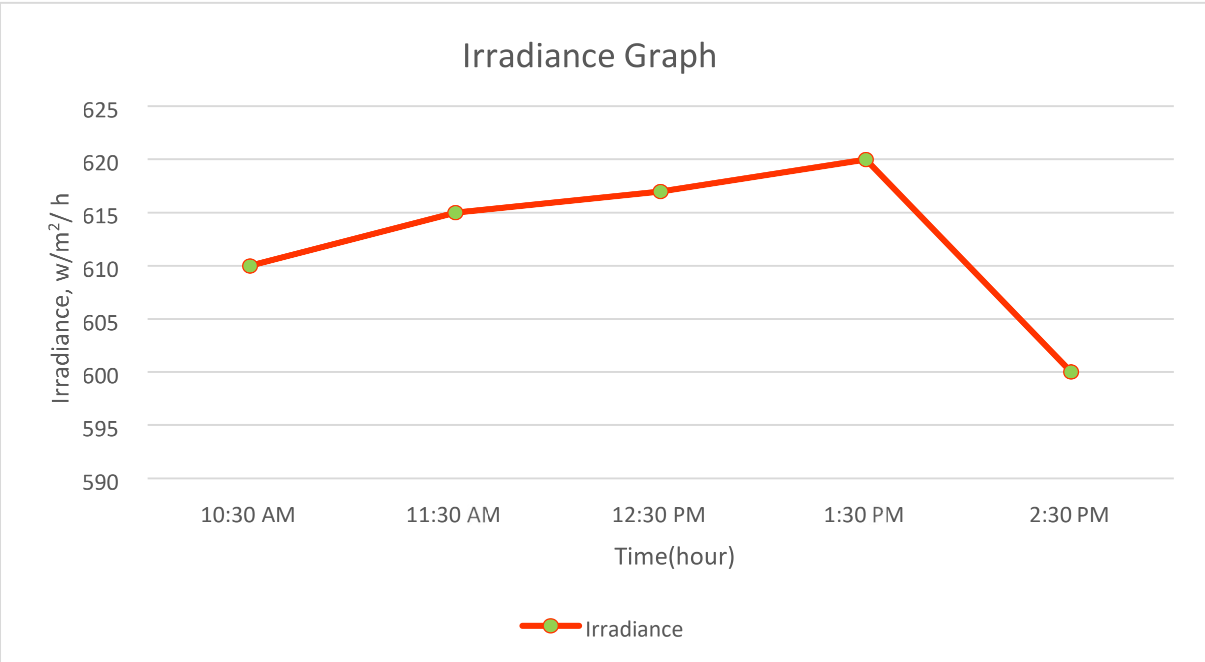


Figure No 5. 5: Irradiance Graph

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion:

Flat-plate collectors which are used for water heating, are long lasting, and in long term they are cheaper than other water heating systems. However, they require large areas if high energy output is a requirement.

We can see from our results that when the intensity of the solar radiation was more, then Temperature and flow rate increased and it decreased when the intensity of solar radiation decreased. The results showed that the maximum temperature, flow rate and efficiency were at 2:30PM i.e.,46°C,0.0085kg/s and 44%.

As stated earlier that project was constructed and completed with local needs, it helps a lot to reduce the cost of project. It reduces the time and cost of the materials and manufacturing. It was a good project which involved five (5) people. It was a great privilege for us to work in this project and complete it within time. We learnt many important skills from various sources which were used in achieving goals of the project. Cost effectiveness was the main objective which was fulfilled throughout the project. We learnt to work more in less time.

6.2 Recommendations:

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

➤ Collector material and design should be improved which can provide better efficiency in low sunny areas.

➤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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