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# Solar Water Heating System - Robust Design

Mr. Manish D. Dhumane, Prof.Sachin M. Walukar, Miss. Ashwini Kuttarmare , Mr. Prawesh Kumre , Mr.Suraj Mahabudhe , Mr. Shubham Uikey and Mr. Shubham Dafre.

Department of Mechanical Engineering

Suresh Deshmukh College of Engineering

Selukate, Wardha, India

## ABSTRACT

*Heating water for domestic purpose is a simple and effective way of utilizing solar energy. The initial cost of solar water heating system is high. But we get zero green energy cost. This paper discusses improving the performance of a flat plate solar energy collector by changing the design parameters of the number of riser tubes and the arrangement of riser tubes in the zig-zag pattern from the existing flat plate collector system. Experiments were conducted using the copper tube in header and riser with different dimensions. The performance shows that the efficiency is 59.09% when increasing the number of riser tubes and its 62.90% in the zig-zag arrangement (Z- Configuration) of the riser tube. Nowadays this system produces higher efficiency than the existing conventional flat plate collector.*

***Key words:*** *Solar flat collector, Heat Transfer, Riser tube, Water heating.*

## 1. INTRODUCTION

Using sun's energy to heat water is not a new idea. More than one hundred years ago, black painted water tanks were used as a simple solar water heaters in a number of countries.

Solar water heating technology has greatly improved during the past century. Today there are more than 30 million $m^2$ of solar collectors installed around the globe. Thousands of modern solar water heaters, are use in countries such as China, India, Germany, Japan, Australia and Greece. In fact in some countries the law actually requires the solar water heaters be installed with any new residential construction project.

Health and social communities in developing countries are institutes that daily use large quantities of hot water. When such communities are situated in areas that are hardly accessible, they mainly use wood fuel for water heating. Because firewood supply becomes an ever-growing problem, it is sensible to look for an alternative source of energy. Given the fact that solar radiation is present in abundance, it seems justified to manufacture self-made hot water systems.

In addition to the energy cost savings on water heating, there are several other benefits derived from using the sun's energy to heat water. Most solar water heaters come with an additional water tank, which feeds the conventional hot water tank. Users benefit from larger hot water storage capacity and the reduced likelihood of running out of hot water. Hot water is essential to both industries and homes. It is required for taking baths, washing cloths and utensils, and other domestic purposes in both rural and urban areas. Hot water is also required in large quantities in hotels, hospitals, hostels and industries such as textile, paper and food processing of dairy and edible oil. Solar water heating system can heat water from ambient temperature to temperatures over 90$^{o}$C depending on the collectors type employed in a given locality. Using solar collector to heat the water can easily attain required temperature.

## 2. OBJECTIVE

- To increase heat transfer rate.

  Heat transfer rate is increase by increasing contact surface area by using zig-zag tubes. As area is directly proportional to heat transfer.

- To create turbulent flow.

  Turbulent flow is directly relates with the Reynolds number. And Reynolds number is directly proportional to heat transfer.

- To reduce thermal losses.

## 3. LITERATURE REVIEW

Now-a-days, 80% of energy is produced by the fossil fuels, and this massive exploitation is leading to the exhaustion of these resources and imposes a real threat to the environment, mainly through global warming and acidification of water cycle. The distribution of fossil fuels around the world is uneven. Middle East countries possess more than half of the known oil reserves. This fact leads to economical instabilities around the world, which affect the whole geopolitical system. The impact it has on the environment as well as on humans cannot be disputed. The increase in the rate of combustion of oil and coal will accelerate the deforestation rate. Keeping the above in mind, as well as the fact that the oil is running dry fast, alternatives should be explored. Renewable energy is one of the most promising alternatives to the above problems. The amount of heat delivered by solar system is 7 kW/m2 in a day.

Solar collectors are commonly used for active conversion of solar energy into heat. Solar water heating system is a natural solar thermal technology. In solar water heating systems, incident solar radiation is converted into heat and transmitted to a transfer medium such as water. Solar water heating is often viable for replacement of electricity and fossil fuels used for water heating. Flat plate collector is an extension of the basic idea of solar energy collector in an oven like box; here riser tubes are connected with the header tube and is placed inside the box under absorber plate. The water enters from the bottom side of the plate and gets heated in the collector area and the hot water is given out. Flat plate collector was first implemented in 1920 at Florida, and in 1953 first prototype was made.

Soteris A. Kalogirou [1] performed an analysis of the environmental problems related to the use of conventional sources of energy and the benefits offered by renewable energy systems. The various types of collectors including flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field collectors were followed by an optical, thermal and thermodynamic analysis of the collectors and a description of the methods used to evaluate their performance. The thermal performance of the solar collector was determined by obtaining values of instantaneous efficiency for different combinations of incident radiation, ambient temperature, and inlet fluid temperature.

Bukola O. Bolaji [2] performed design and experimental analysis of flow inside the collector of a natural circulation solar water heater. The result shown was that the system performance depends very much on both the flow rate through the collector and the incident solar radiation and the system exhibited optimum flow rate of 0.1 kg/s-m2.

Fanney and Klein [3] performed side by side experimental investigations to evaluate the influence of the thermal performance of solar domestic hot water systems. The system was a direct solar hot water system utilizing a natural circulation return tube to the storage tank. Result of the system show improvements in the overall system performance as a result of lowering the collector fluid flow rate.

Volker Weitbrecht et al., [4] performed the results of an experimental study conducted in a water solar flat plate collector with laminar flow conditions to analyze the flow distribution through the collector. LDA- measurements were carried out to determine the discharge in each riser, as well as pressure measurements to investigate the relation between junction losses and the local Reynolds number. Analytical calculations based on the measured relations are used in a sensitivity analysis to explain the various possible flow distributions in solar collectors.

Duffie, J.A and W.A. Beckman [5] performed annual simulation to monitor the thermal performance of a direct solar domestic hot water system operated under several controlled strategies. According to [5], higher flow rate leads to higher collector efficiency factor. However, it also leads to higher mixing in tank and therefore, a reduction in the overall solar water heating system efficiency.

Wang X.A., Wu. L.G. [6] performed several collectors with parallel connection and which can be interpreted as a single collector where the number of risers must be multiplied by the number of collectors and were analyzed. Various studies reviewed above have shown the importance of performance improvement of the collector in solar water heating. In this study fluid flow system of a density gradient solar water heater is designed and constructed with the aim to reduce the cost and to bring out better efficiency.

## 4. PROBLEM STATEMENT

- In flat plate collector parallel tubes are used, therefore the heat transfer to the water is less due to the less surface contact area.
- In parallel flat plate collector the flow of water is laminar this will tends to low heat 6rtransfer.
- In flat plate collector, the mass flow rate of fluid is less due to low temperature difference.

## 5. CONSTRUCTION AND WORKING

### 5.1. Using solar energy

The plexiform influence of solar radiation on life on earth can be used for several purposes. Proven applications for among other things generating electricity, water heating, cooking, and crop drying with solar energy exist. Small amounts of electricity can be generated with so-called P.V.-systems (Photo-Voltaic). These systems can be reliable energy providers for remote areas (in which sometimes hospitals and clinics are situated). P.V.-systems are rather expensive. For maintenance and repair you need the manufacturer's assistance. P.V.-systems can be used for: • Lighting; • Cooling boxes for storing medicines and blood plasma; • Radio communication and T.V.

For solar powered water-heating technical appliances are rather simple and much cheaper than P.V.-systems. Institutions like hospitals require a substantial supply of hot water 24 hours a day. Because the use of solar radiation is limited to the daily hours of sunshine, it is necessary to construct a hot water system that collects as much heat as possible during the daytime and preserves the collected heat as much as possible after sunset. For this reason a hot water system has been figured out which is named the thermo-syphon system, or the system based on natural circulation.

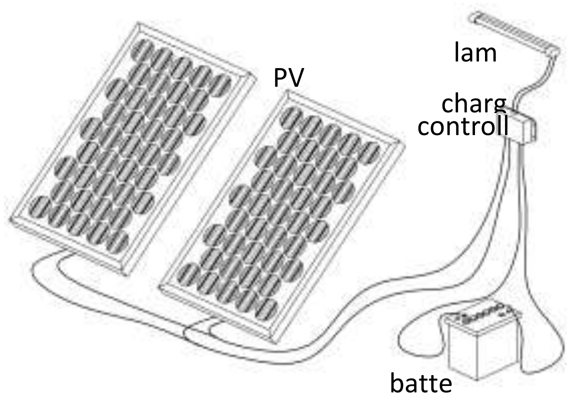


**Figure1. Solar Heater Layout.**

### 5.2. Parts of the solar water heater

The solar water heater consists of the following parts.

1. An insulated **storage tank**, in which the heated water from the collector is stored. The storage tank must be put higher than the top of the collector.
2. An insulated pipe connecting the lower part of the collector and the upper part of the storage tank.
3. An insulated pipe connecting the lower part of the storage tank and the bottom of the collector.
4. A **cold water inlet** connecting an existing water supply system to the storage tank. Usually the cold water inlet runs via a buffer tank with a floating gauge.
5. An insulated **hot water outlet** running from the storage tank to the tap.
6. A vent (air escape pipe) to prevent overpressure, caused by air or steam.
7. The solar **collector,** in which water is heated by solar radiation.


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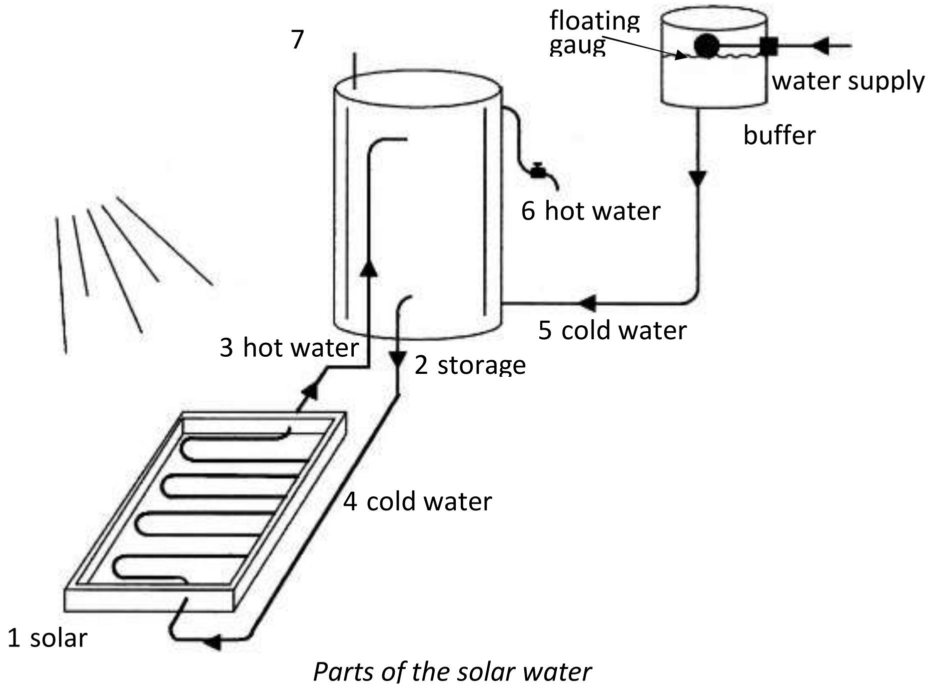


**Figure 2** ***Parts of the solar water***

## 5.3. Working principle of the solar hot water system

When solar radiation heats the collector, the water inside will be heated as well. The heated water starts rising through the connection on top of the collector to the insulated storage tank. Heated water entering the storage tank displaces cooler water that is in turn forced via the connection to the bottom of the collector. In this way a circulation comes into being. We call it natural_circulation or thermo-syphon principle. The cold water entering the collector will be heated again by solar radiation. Because the water temperature inside the collector becomes much higher than inside the storage tank, the natural circulation continues as long as the sun heats the collector. Consequently, the water inside the storage tank will get hotter and hotter. Depending on the amount of solar radiation and insulation, the system can produce water temperatures between 40 and 70 degrees Celsius.

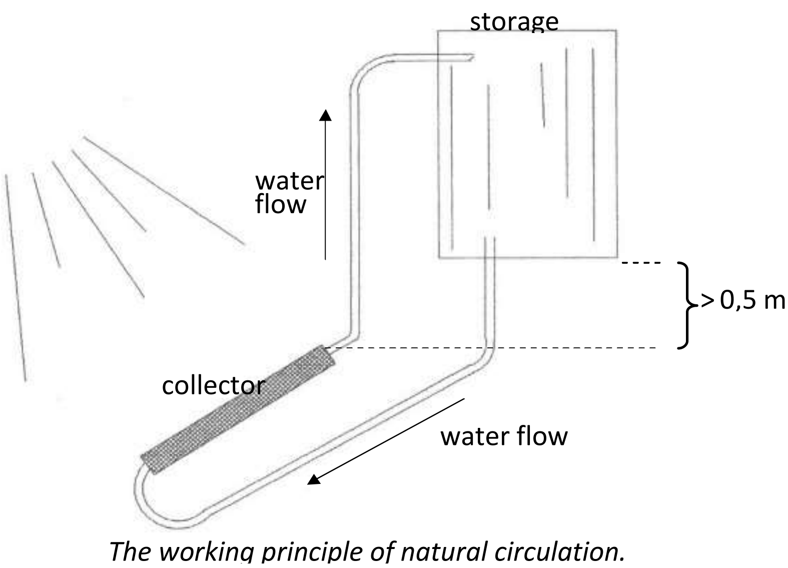


**Figure 3 The working principle of natural circulation.**

### 5.4. The use of hot water systems

If we want to use the hot water in the storage tank, we have to tap it. When hot water is tapped, the storage tank must be refilled. Therefore the storage tank is connected via a buffer tank to an existing water supply system (for instance a big rainwater tank or a borehole). The buffer tank is provided with a floating-gauge or ball-valve. When tapping a bucket of hot water, the system will be refilled automatically via this floating gauge.

The efficient use of a hot water system depends on the daily need. For various institutions like hospitals, rehab centers, children homes etc. different quantities of hot water at different temperatures and for different purposes are required. The efficiency of the hot water supply depends on the way in which it is organized and controlled by the management of the concerning institute. The average heating up period per system per day can be put at 6 hours. When a system is properly insulated, hot water can be drawn 24 hours a day. So even at night hot water can be used. Practice has shown that solar powered hot water systems are especially useful for laundries and washing patients. With optimal use of a solar powered hot water system, a saving of up to 70% of the usual firewood consumption can be achieved.

### 5.5. Construction of the solar collectors

A solar collector consists of 4 parts:

1. The absorber

This is a dull-black painted metal body on which the zigzag pipe containing the water is fixed. The black coating absorbs almost all the solar radiation that falls on it. The collected radiation is transformed into heat and simultaneously heats the water inside. Temperatures of 100 ºC or more can be reached.

2. The casing or collector box

The absorber is put into a box made of wood with a depth of 10 to 15 cm. The absorber is adjusted about half way the total depth so that there is sufficient space underneath as well as above the absorber.

3. The insulation layer

The space underneath the absorber is filled with insulation material that retains the heat of the absorber. Usually the insulation layer should be about 5 cm thick.

4. The cover sheet

To retain the heat in the collector, the box is covered by glass. Thickness of the glass-sheet must be at least 4 to 5 mm. The glass-sheet allows sunshine to pass through without absorbing too much solar radiation. Also, it prevents the cooling of air by wind.


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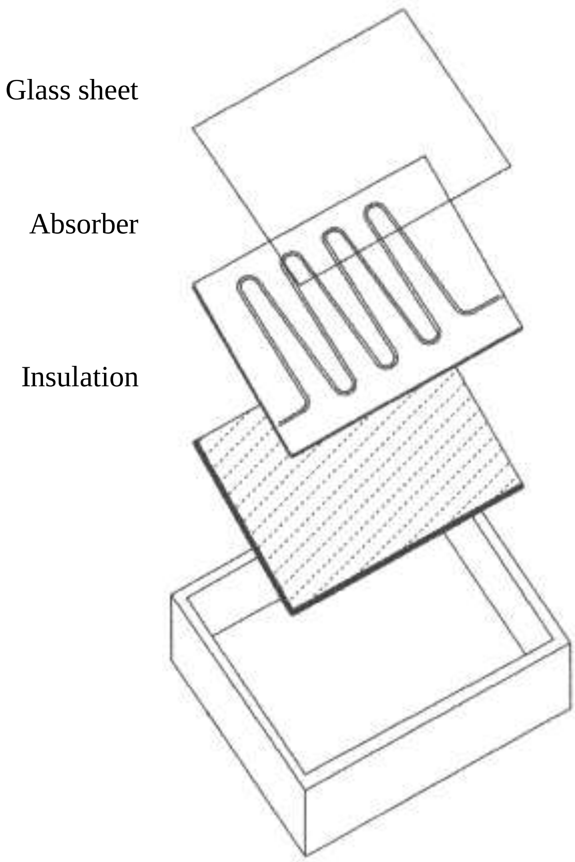


**Figure No. 4 The casing or collecting box**

## 6. CAD MODEL OF FABRICATION

**Figure**

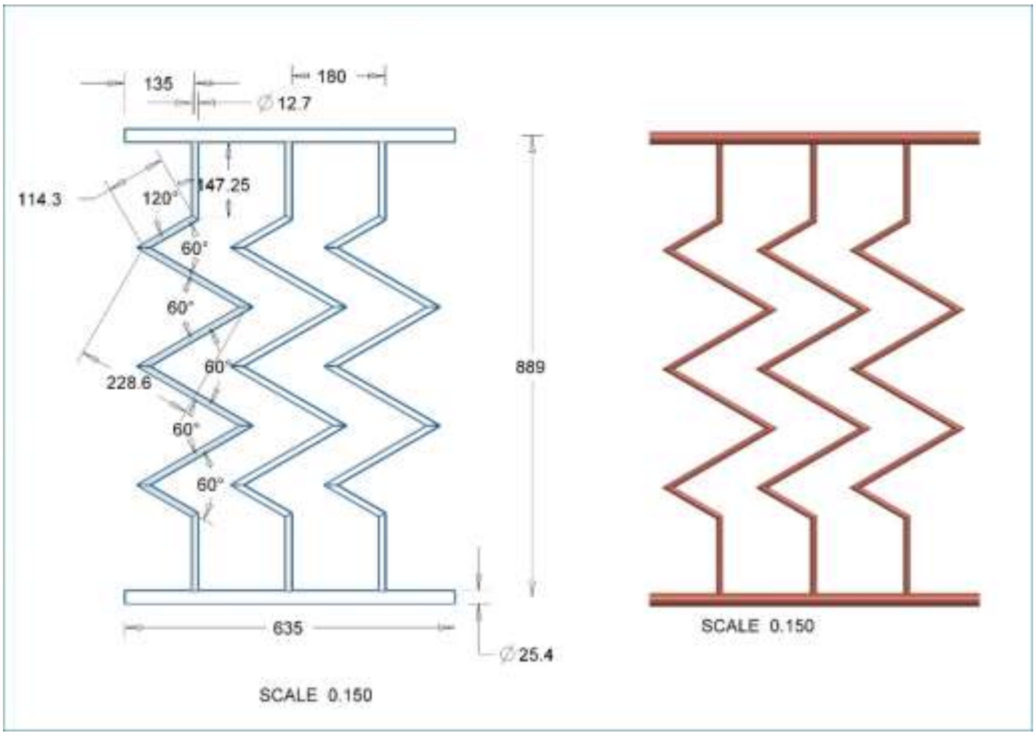


**Figure No. 5 Cad Model Of Fabrication**

## CONCLUSION

Experimental investigation have been carried out on straight riser tube and zigzag riser tube on heat transfer enhancement , friction facto. From the graphs plotted, following conclusions are made .

- The heat transfer in tube with zigzag riser tube is found to be more as compared to straight riser tube.
- The relative decrease in friction factor for zigzag riser tube is 1.39% than straight riser tube.
- The relative increase in Reynolds number for zigzag Riser tube is 6.31% higher than straight riser tubes .

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