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Comparative Thermal Performance Studies of Serpentine Tube Solar Water Heater with Straight Tube Solar Water Heater

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Abstract: *Energy is essential for living and vital for development of all. The global economy thrives on energy. Affordable energy directly contributes to increase productivity, reducing poverty and improving betterment of life. Global population is increasing day by day, which, in a way is leading to the utilization of natural resources and fossil fuels. The solar energy, wind energy and bio mass are three major sources and out of these three energy sources solar energy is the easiest source to extract useful energy because the wind energy can be useful particularly in coastal area where there is high wind velocity and energy extraction bio mass needs either chemical conversion or thermo chemical conversion process. The objective of present work is to carry out comparative study for thermal performance of the straight tube solar water heater with the proposed serpentine solar water heater by using K type thermocouples at appropriate location of both experimental set up to observe the change in water temperature with 20 lt water capacity are be carried out simultaneously in case of two set up are be fabricated.*
Keywords: *Energy, Fossil Fuel, Serpentine Solar Water Heater, straight tube solar water heater, Solar Energy*

I. Introduction

The increasing need of energy consumption, shrinking resources and rising costs of fossil fuel will have significant impact on our standard of living for future generations. In this situation, the development of alternative, cost effective sources of energy has to be a priority. One of the major renewable energy resources is the solar energy which sun emits to the earth. Since ancient time, the solar energy is always remaining prime source of our uses. The solar energy is the most capable of the alternative energy sources. Due to increasing Demand for energy and rising cost of fossil type fuels (i.e., gas or oil) solar energy is considered an attractive source of renewable energy that can be used for water hearing in both homes and industry. Heating water consumes nearly 20% of total energy consumption for an average family. Solar water heating systems are the cheapest and most easily affordable clean energy available to homeowners that may provide most of hot water required by a family. Solar heater is a device which is used for heating the water, for producing the steam for domestic and industrial purposes by utilizing the solar energy. Solar energy is the energy which is coming from sun in the form of solar radiations in infinite amount, when these solar radiations falls on absorbing surface, then they gets converted into the heat, this heat is used for heating the water. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases.

II. Solar Water Heating System [1]

SWH systems are generally very simple using only sunlight to heat water. A working fluid is brought into contact with a dark surface exposed to sunlight which causes the temperature of the fluid to rise. This fluid may be the water being heated directly, also called a direct system, or it may be a heat transfer fluid such as a glycol/water mixture that is passed through some form of heat exchanger called an indirect system. These systems can be classified into three main categories:

(A) Active Systems:

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. So, the Active systems are also called forced circulation systems and can be direct or indirect. The active system is further divided into two categories:

- Open-loop (Direct) Active System
- Closed-loop (Indirect) Active System

(1) Open-Loop Active Systems

Open-loop active systems use pumps to circulate water through the collectors. This design is efficient and lowers operating costs but is not appropriate if the water is hard or acidic because scale and corrosion quickly disable the system. These open-loop systems are popular in non-freezing climates.

(2) Closed-Loop Active Systems

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water stored in the tanks. Closed-loop glycol systems are popular in areas subject to extended freezing temperatures because they offer good freeze protection.

(B)Passive Systems

Passive systems simply circulate water or a heat transfer fluid by natural convection between a collector and an elevated storage tank (above the collector). The principle is simple, as the fluid heats up its density decreases. The fluid becomes lighter and rises to the top of the collector where it is drawn to the storage tank. The fluid which has cooled down at the foot of the storage tank then flows back to the collector. Passive systems can be less expensive than active systems, but they can also be less efficient. Thermo siphon system is the best example of passive systems.

(C) Batch systems

Batch System (also known as integral collector storage systems) is simple passive systems consisting of one or more storage tanks placed in an insulated box that has a glazed side facing the sun. Batch systems have combined collection and storage functions. Depending on the system, there is no requirement for pumps or moving parts, so they are inexpensive and have few components in other words, less maintenance and fewer failures.

S. Sadhishkumar et al [2] summarizes the previous works on solar water heating systems with various heat transfer enhancement techniques include collector design, collector tilt angle, coating of pipes, fluid flow rate, thermal insulation, integrated collector storage, thermal energy storage, use of phase change materials, and insertion of twisted tapes. The enhancement of heat transfer in the solar collector with twisted tape is found to be better than the conventional plain tube collector. In solar water heating systems twisted tape has been used as one of the passive techniques to augment the heat transfer. Twisted tape has been used in heat exchangers but their applications are limited in solar water heating systems. **Sharad B. Parekh et al[3]** aims behind performance evaluation to find new material as solar thermal absorber and develop the feasible technology. The collection system consists of polycarbonate sheet with relatively low mass flow rate. **S.Rajasekaran et al[4]** prepared three experimental set up. One of set up was by replacing copper tubes with epoxy –polyether coating stainless steel and aluminium tubes with copper oxide coating material pipes in the flat –plate solar collector, the cost of the system is found to be reduced by 30%. Result recorded that the collector outlet temperature is the function of solar irradiance and time. The maximum collector efficiency was obtained at 13.00 hour in all three experiments. The experimental results revealed that the performance of the solar water heater by using all materials produced the efficiency of around 40 % to 47 %.**Budihardjo,G.L.Morrison [5]** studied the thermal performance of water-in-glass evacuated tube solar water heaters and is evaluated using experimental measurements of optical and heat loss characteristics and a simulation model of the thermo syphon circulation in single-ended tubes.**Raj ThundilKaruppa R., Pavan P and Reddy Rajeev D. [6]** studied the performance of sandwich type solar water heater in which pipes through which water is flowing placed in the cavity of absorber plates to enhance the rate of heat transfer.**Eze J. I. and Ojike O. [7]** investigated the thermal efficiency of a passive solar water heater is undertaken. The solar water heater has two storage tanks and is used for cold and warm waters, respectively. Here copper pipes are placed in the spiral form only.

III. Experimental Setup

Detail of Set up

In the present experimental setup following parts may be used

1. Copper pipes of 1/2 inch diameter, 20 gauge thickness and 1 m length. (3 nos.) as Risers
2. Copper pipes of 1/2 inch diameter, 20 gauge thickness and 0.5 m length. (2 nos.) as Headers
3. 0.5 mm thick MS sheet of dimensions 1m X 0.5 m as Solar heater (Straight Tube).
4. 0.5 mm thick MS sheet of dimensions 0.75m X 0.5 m as Solar heater (Serpentine Tube).
5. Plain glass with above mention size and 3 mm thick (2 nos)
6. K type thermocouple (6 nos)
7. Digital Temperature indicator
8. Serpentine copper coil with ½” ID

9. Wooden box of above mentioned dimension will be used as a insulation box as well as structure box.
10. 2 mm thick wooden sheet will be attached at the bottom of MS sheet to reduce heat leakages from the bottom of absorber plate

Experimental System Descriptions

The solar radiation passes through the glass in front of the absorber plate and strikes the flat black surface of the absorber plate where the solar energy is absorbed as heat (i.e., by increasing the internal energy). This causes the flat-plate collector to become very hot, and so the water contained in the risers and headers bounded to the plate also absorb the heat by conduction. The water inside the tubes (risers/headers) expands and so becomes less dense than the cold water from the storage cylinder. On the principle of thermosyphon, hot water is pushed through the collector and rises by natural convection to the hot water storage tank and cold water from the cold water tank simultaneously descends to the bottom header of the collector by gravity pull. Therefore, there is circulation as a result of an increase in temperature and volume of the warmer water to the hot water storage tank. The circulation continues as hot water goes out, while cold water comes in.

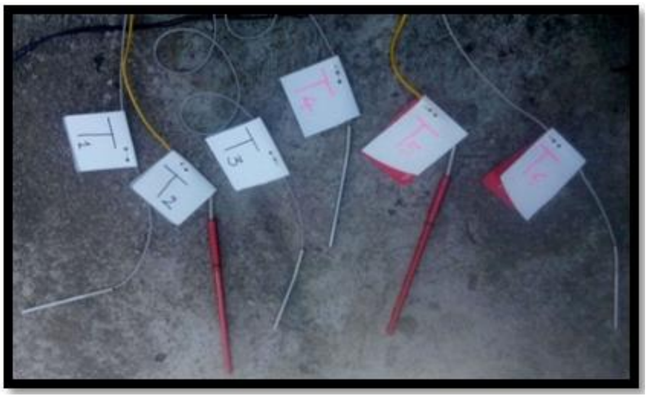

Fig 1 Thermocouples

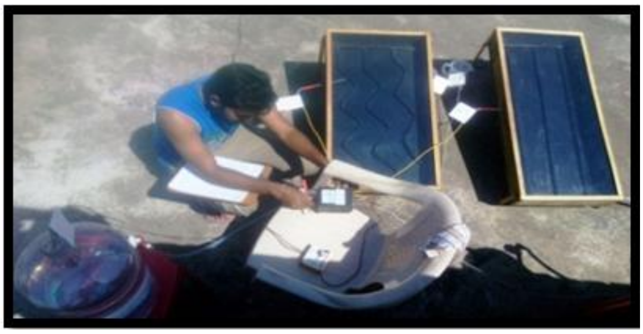

Fig 2 Experimental set up with All Instruments

III. Results and Discussions

The cold water tanks for the SWHs were filled with water after proper filtration. The valve was opened to allow water flow to the circulating pipes, which are made of riser and header pipes, through the carriage pipe (i.e., the inlet pipe). The water was heated up from the heat supplied by the absorber plate to the tubes; hence, by virtue of density difference between the cold water and hot water (i.e., the cold water goes down, while the hot water comes up), a flow is initiated (thermo syphon or natural convection). The hot water flow for both the SWHs was measured using stop watch and flask. Hot water flow rate at outlet was also measured for both SWHs. The Experimental readings are given in Table 1.

Table 1 Experimental reading for 20th March 2015

CONVENTIONAL SWH				
TIME (hh:mm)	**$\square_1$ (ml/sec)**	**$T1_{in}$ (°C)**	**$T2_b$ (°C)**	**$T3_{out}$ (°C)**
11:20	3.33	32	50	47
11:35	3.33	33	52	40
11:50	3.33	34	51	41
12:00	3.33	35	52	39
12:30	3.33	35	54	38

01:05	3.33	35	55	42
01:20	3.33	37	55	44
01:30	3.33	36	56	46
01:40	3.33	37	58	47

Table 2 Experimental Reading for 20th March 2015

SERPENTINE SWH				
TIME (hh:mm)	**□$_2$ (ml/sec)**	**T4 $_{in}$ (°C)**	**T5$_b$ (°C)**	**T6 $_{out}$ (°C)**
11:20	3.5	32	51	45
11:35	3.5	33	52	42
11:50	3.5	34	52	42
12:00	3.5	35	54	41
12:30	3.5	35	54	42
01:05	3.5	35	56	44
01:20	3.5	37	57	44
01:30	3.5	36	58	45
01:40	3.5	37	58	49

Conventional SWH: $T1_{in}$= Inlet Temp, $T2_b$= Body Temp., $T3_{out}$= Outlet Temp
Serpentine SWH: $T4_{in}$= Inlet Temp, $T5_b$ = Body Temp., $T6_{out}$= Outlet Temp.

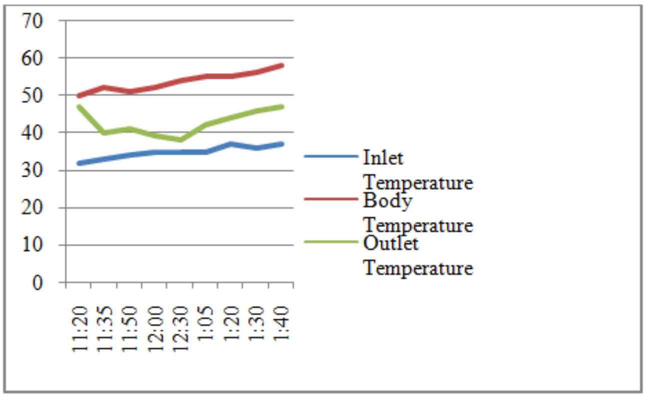

Fig. 3 Temperature attained by Straight Solar Water Heater

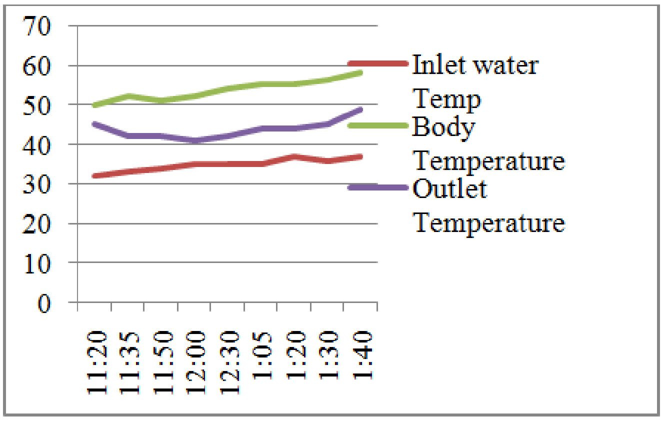

Fig. 4 Temperature attained by Serpentine Solar Water Heater

From the results, water inlet and outlet temperature, collector temperature and hot water flow rate was measured from 11:00 AM to 2:00 PM. Line charts are prepared for the readings and the data are analyzed.

Figure 3 and Figure 4 show the temperature attained during the experimentation for conventional and Serpentine SWHs. The temperatures are measured by keeping mass flow rate almost equal and constant to compare the SWHs efficiently.

In Figure 3 and Figure 4 it is seen that the temperature increases in both the SWHs. The temperature of the Conventional SWH is higher with low mass flow rate compare to Serpentine SWH. As the Time reaches around 2: 00 PM the water outlet temperature of Serpentine SWH is higher than Conventional SWH as shown with the red circle in the figure.

IV. Conclusion

Experiments have been performed during the months of March, April and May and the efficiency is found highest in the month of May as the atmospheric temperature is high in May compare to other months. The maximum temperature attained by the system is 49°C. As it is a conceptual design there is further scope of improvement in efficiency by designing a serpentine tube for optimization.

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