Performance Study of an Indigenously Built Flat Plate Solar Water Heater

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Abstract: A 60 liter capacity flat plate solar water heater has been designed and constructed with locally available material. The size is selected considering the daily requirement of a small family. In performance evaluation we have recorded water temperature of the solar water for consecutive hours during the mentioned sun shine period. During June-July period the maximum water temperature obtained was 71°C. Evening and morning water temperature were taken to estimate the heat loss during non sun shine hour. Amount of thermal energy capture from incoming available solar radiation and its thermal heat transfer to water was evaluated for the local environment. A chemical test was also carried out to study the corrosion and water contamination within the solar water heating system. The performance of thermo siphon, thermal insulation of water tank, collector radiation absorption and leakages of the collector were also being studied.

Since it is an on going experimental work, design and modification to improve the device performance and cost reduction for the construction is still continuing. The performance of the solar water heater will be measured over a certain period of time to draw the final conclusion.

Keyword: Solar water heater, thermosyphon, flat-plate collector

1. Introduction

The per capita energy consumption in our country is one of the lowest amongst the sub continent [1]. In crisis conditions energy usage should be appropriate and meticulous. Our technology for energy harvest, conversion and efficient application is still lacking behind with that of developed world. We should give emphasis for the development of indigenous technology. In Bangladesh there is ample thermal energy available from the sunshine [2]. Where, solar water heating for domestic as well industrial usage could be an effective way of saving conventional energy [3]. It could be a contributing factor for the environment. Utilization of solar thermal energy is relatively in a nascent state in our country. Therefore, before taking any wider initiative in this field smaller units should be tried first in terms of performance evaluation.

Due to the nature of solar energy, two components are required to have a functional solar energy generator. These two components are a collector and a storage unit [3, 6]. The collector simply collects the radiation that falls on it and converts a fraction of it to other forms of energy. The storage unit is required because of the non-constant nature of solar energy; at certain times only a very small amount of radiation or no radiation will be received.

A flat plate collector is one of the important types of solar collector because of its wide range of potential application. It is basically a black surface that is placed at a convenient angle to the daily motion of the sun, and provided with a transparent cover; appropriate insulation around the sides and rear can quite effectively act as an energy converter. Water is used as heat transfer fluid. Such collectors are adequate for heating a working fluid at temperature around 70°-80°C and this is at present the economical way to use solar energy for water heating.

A system of capacity 60 litre (maximum) is designed and fabricated mostly by the locally available materials. This is a non-pump system, designed on a thermosyphon circulation basis. In this system a flat plate collector is coated with ordinary black coating. This type of system is basically useful when the water to be heated is soft or dissolved solid content is not high.

2. Experimental Setup

The general assembly incorporates two major components- the collector, and the storage tank.

Collector: We have used an indigenously built flat-plate type collector for this experiment. It consists of four components:-

a) Flat-plate absorber: The main purpose of the absorber is to intercept and absorb the solar energy. The absorber pipes we used have a capacity to hold 14 liter water at a time. The material used is selective coating MS (mild steel) sheet. A black coating of low reflectivity was used for further improvement.

b) Transparent cover: The cover allows solar energy to pass through (convection) but reduces heat loss from the absorber. We have used a 3-4 mm thick, 108cm × 100cm tempered glass sheet as our cover.

c) Heat-transport fluid: The fluid, flowing through tubes, removes heat from the absorber. We have used water as our working fluid.

d) Heat insulating backing: Its main purpose is to provide thermal insulation to the system. Glass wool and cork sheet were used for insulation purpose.

Collector Housing: The exterior box, which integrates the other components that make up the collector. The box is made of a layered assembly of rubber and metallic sheet compacted by sealing gasket.
The whole collector setup is shown in Fig.1.

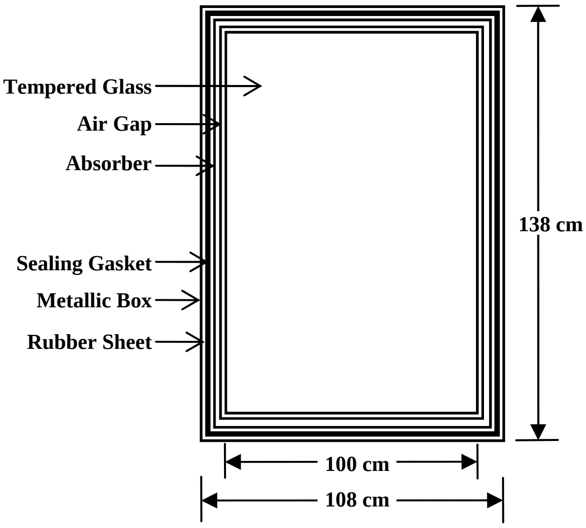

Fig. 1 Flat plate collector constructional components.

Water Storage Tank: A cylindrical tank of 80 cm length and 40 cm diameter has been used in this experiment. It is a multilayered tank with the outer covering made of MS (mild steel) sheet with powder coating. The innermost layer is made of SS (stainless steel) sheet, while the space in between is filled with layers of glass wool and cork sheet, as seen in Fig.2. The intermediate assemblage is provided for insulation purpose.

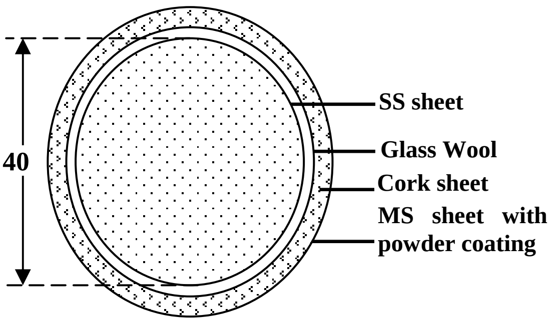

Fig. 2 Cross-section of the storage tank.

A close loop water circulation system has been introduced into the system. The close loop system allows the transport fluid - water in this case - to flow from the storage tank to the collector. The working fluid then is heated up through solar insolation and circulates back to the storage tank while cold water from the storage replaces it. Schematic diagram of the single-phase thermosyphon type flat–plate collector with insulated water tank is shown in the Fig. 3.

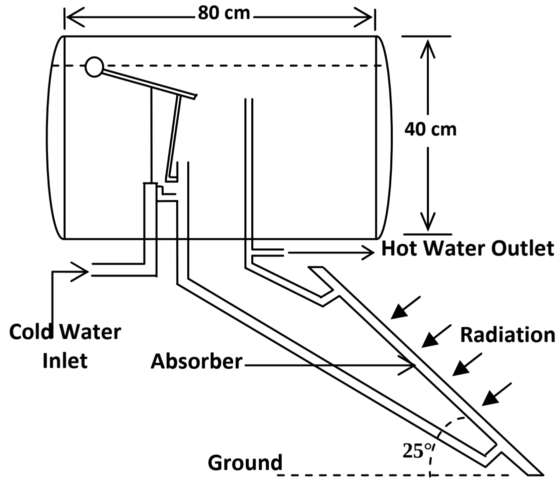

Fig. 3 Schematic diagram of the experimental setup of the solar water heater.

3. Working Procedure

The thermosyphon system is installed at Renewable Energy Research Centre (RERC), Energy Park, University of Dhaka, Bangladesh where the average solar radiation is in the range of 4.5-5.5 kWh/m^2 per day. After construction the flat-plate collector has been settled at a tilted angle of 25 degree (on 12 July, 2009) facing south on a supporting structure. The angle of tilt is determined through optimization. The setup does not allow flexibility in axis tracking. So a fixed angle of tilt is determined which allows maximum absorption of solar insolation throughout the year. RERC lies in 23.7° latitude east. The general angle of tilt is to be in the range of (latitude ± 15) degrees [4]. Considering this, the collector has been set at an angle of 25° with respect to the ground level. During the experiment, instantaneous solar flux (global radiation) was measured by a Pyranometer. At about 60 minute's interval, solar insolation, water temperature in the water tank is recorded carefully. To get a better comparison we have worked on several days throughout the month of June-July. Data have been collected for different weather condition as well as with different amount of storage water.

Water samples have been collected for every experimentation day with different acquired water temperatures. These sample water have been subjected to various tests to realize any kind of contamination due to solar insolation from the storage unit, or the absorber unit.

4. Experimental Results and Discussion

A series of experiments were conducted under various conditions and a range of conclusions were drawn from them. Firstly, to realize the maximum achievable water temperature, the setup was exposed to solar radiation over a period of one week. Data were collected at regular intervals on the days of experimentation, at different weather conditions.

The first experiment was conducted on 12th July, 2009. The storage tank was filled with 20 liters of water with initial water temperature of 30.5°C. The collector was then exposed to solar radiation from 10 a.m. to 5 p.m. Maximum water temperature was found to be 71°C. It was observed that the actual temperature of the output water was not readily available through the outlet. The initial water that was drained from the storage tank gave a considerable lower temperature (referred to as 'output water temperature – initial' in Table-1). The Stable water temperature was only obtained once a minimum of one liter water has been drained out of the storage tank (referred to as 'output water temperature – final' in Table-1). The data obtained are shown in Table-1.

The maximum water temperature acquired dwindled noticeably with the change in the weather condition as seen from Table-2. Temperatures obtained were comparatively much higher on sunny days than those in rainy condition.

Table-1: Performance of the solar water heater over six hours

Time	Output water temperature (°C)		Solar Insolation (W/m^2)
	Initial	Final	
10:30	-	32	795
11:30	32	34	1018
12:30	44	56	1091
13:30	45	63	947
14:30	42	63	466
15:30	39	66	214
16:30	38	71	415

Table-2: Maximum water temperature achieved at different weather conditions.

Date	Maximum Water Temperature achieved (°C)	Weather Condition	Ambient temp. (°C)
12/7	71	Very Sunny	34.3
13/7	63	Sunny	32.8
15/7	62	Sunny	32.8
16/7	59	Mildly Sunny	32
18/7	62	Sunny	33
19/7	56	Cloudy/Rainy	31.6
20/7	66	Sunny	33.2

Water temperature also varied profoundly with the variation in the amount of storage water. Maximum water temperature was clearly higher when the amount of storage water was comparatively less. The following graph (Fig.4) shows the variation in maximum temperature at different amount of storage water. Maximum temperature gathered was 71°C with 20 liter, while it was only 47°C when experimented with 50 liters of storage water.

To obtain a more practical result, a final experimentation was conducted where 50 liter water was drawn out and refilled instantaneously over a 5 hour period at a 0.167lt/min rate, and at a regular interval of 0.5 hour. The maximum water temperature found under this test was 47°C. The result has been shown in Fig.5

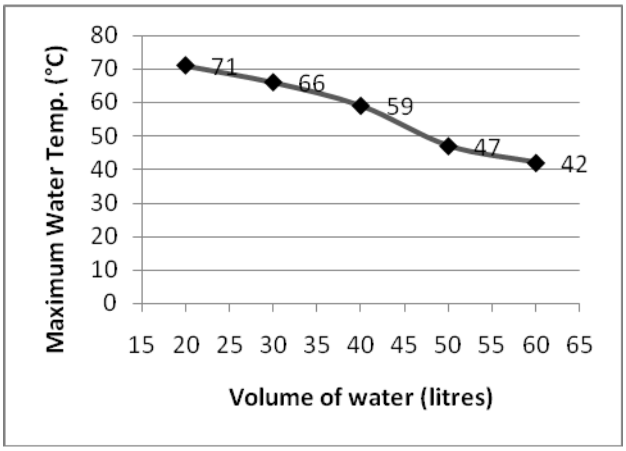

Fig. 4: Storage water volume vs. maximum water temperature curve

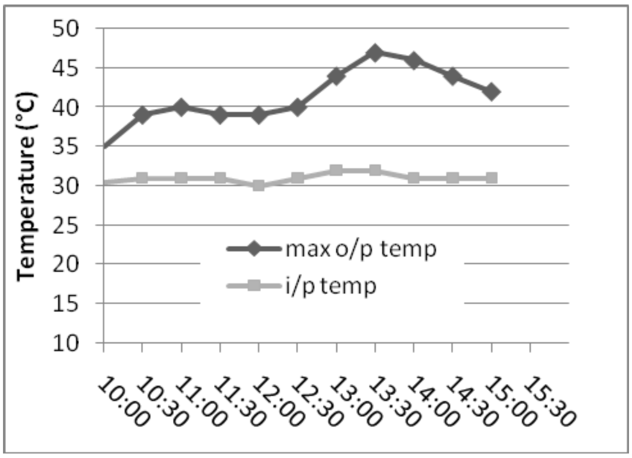

Fig. 5: Variation of output water temperature with 5 liter/.5 hour circulation rate

4.1 Water treatment

Water samples have been collected at different stages of the experimentation period with varying degrees of water temperature. The conductivity and pH values of the samples were found to increase steadily with time. The initial water with which the experiment was started had a temperature of 30.5 °C, pH value of 6.85 and conductivity of 706 µS. The final sample that was obtained on the eighth day of the experiment had a temperature of 56 °C, pH value of 7.59, and conductivity of 710 µS. The maximum temperature acquired throughout the experiment was 71 °C. This sample had pH value of 7.5 and conductivity of 626 µS.

To compare with a practical case, water from the same input source (temperature 31°C, pH 6.57, conductivity 733 µS) was manually heated up to 70 °C with the help of an electric water heater. This heated sample gave a pH value of 7.20 and conductivity of 727 µS.

5. Conclusion and Future Works

The indigenously built solar water heater provides a maximum rise of temperature of 40°C within a span of four hours provided the weather condition is sunny (solar insolation is of the range of 700 – 1000 W/m^2/hr). In normal condition (average solar insolation is of the range of 600 W/m^2 over 4-5 hours) it has been able to steadily provide a 30°C rise in water temperature. A 60%

increment in output water temperature was obtained as storage water amount was reduced from maximum 60 liters to 20 liters. With ambient temperature in the range of 30-32°C, the maximum increase in water temperature was 15°C at a 5liter/.5hour circulation rate.

Heat loss during sunless hours (5:00 pm – 9:00 am) was measured on several days with varying degrees of weather condition. The percentage of heat loss ranged from 32 – 34%, independent of weather condition. Better insulation is to be introduced in order to minimize this loss parameter.

The differences in temperature obtained through the experiment with the Solar Water Heater, and that in ordinary heating process were compatible. Theoretically the pH value of water decreases with the rise in water temperature [6]. This correlation was found to be maintained to some degree in the experiment. At any rate, the pH readings obtained were all within safety range of usable water.

This is an ongoing experiment. The results obtained till now are promising. However data have only been collected for a period of two months. To realize actual performance efficiency, data have to be collected throughout the year, especially for the three distinct seasons – winter (November - February), summer (March - July), and autumn (August - October). Performance variation with and without glazing/insulation is another aspect that should be measured to realize economic efficiency. Pre-installed units both at RERC and other locations have provided significant change in efficiency with the removal of glazing and insulation [1]. Structural adjustment in the form of providing variable axis of tilt can be introduced to acquire solar energy more proficiently.

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