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"Experimental Analysis of Solar Water Heater, with Heat Exchanger"

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Abstract: *Solar energy is a very large, inexhaustible source of energy. The power from the sun which is intercepted by the earth is tremendously larger than the present consumption rate on the earth of all the commercial energy sources. Therefore the fabrication of such a solar water heater is done which can utilize this energy in a better way. Square shaped aluminium tube coated with a black paint constitutes the solar absorber on the above collector. The copper heat exchanger is placed between solar collector and water tank. To improve its efficiency distilled water is made to flow through the collector and then its testing is carried out and some desirable results were acquired.*
Keywords: *Solar water heater, Collector, Heat exchanger.*

I. Introduction

Solar energy is a clean and abundant energy resource that can be used to supplement many of our energy needs. Solar energy can be utilized as a wonderful source of heat in many forms, such as solar water heating. 'Solar Water Heating System'(SWHS) is now recognized as a reliable product that saves substantial amounts of electricity or other conventional fuels, and leads to peak load reduction and prevents emission of carbon dioxide, a major green house gas.Thus in principle, solar energy could supply all the present and future energy needs of the world on a continuing basis. This makes it one of the most promising unconventional energy sources. Although the initial cost of solar water heaters are higher, but the fuel i.e. (sunshine) is free. As well it is environmental friendly. The Present work is regarding that project which is one step from our side to make solar energy more usable in an efficient manner.Solar water heaters can operate in any climate. Its Performance varies depending, upon how much solar energy is available at the site, and also on how much cold water is coming into the system. The colder the water is the more efficiently the system operates. In almost all climates, you will need a conventional backup system. In fact, many building codes require you to have solar water heaters which are made up of collectors, storage tanks, and depending on the system, electric pumps.

Nomenclature
Heat Exchanger

A : area of copper tube inside the heat exchanger
C_{pc} : specific heat of cold water
C_{ph} : specific heat of hot water
ΔT_{lm} : log mean temperature difference
h_i : inside heat transfer coefficient
h_o : outside heat transfer coefficient
K : Thermal Conductivity (W/m-K)
m_c : mass flow rate cold water
m_h : mass flow rate hot water
Q_c : heat gained by cold water from hot oil
Q_h : heat delivered by hot oil to cold water
T_{c1} : Inlet temp. Of water
T_{c2} : outlet temp. Of water
T_{h1} : Inlet temp. Of oil
T_{h2} : Outlet temp. Of oil
U : overall heat transfer coefficient

Salient Details And Solution

In this we have modified the design of solar collector and have placed the heat exchanger in between the solar collector & the water tank. Conventionally, the collectors have the vertical tubing's, but in this type of collectors most of the available space cannot be utilized and because of which most of the valuable solar energy get wasted. To minimize these wastages we are using here square shaped solar collector instead of vertical shaped, by which it can utilize the maximum space of the available area of the collector.Conventionally water use to flow directly through the collector. But due to it scale formation takes place which creates some problem, and we have to maintain it timely. In order to minimize this problem primary liquid flowing through the solar collector is distilled water which heats with the help of solar radiations. Then it passes from the heat exchanger & exchanges its heat with secondary fluid which is required water. So the water gets heated. Primary fluid flows in cycle so again it gets moved towards the collector. There is requirement of an electric pump to make flow the water in conventional 'solar water heater'.

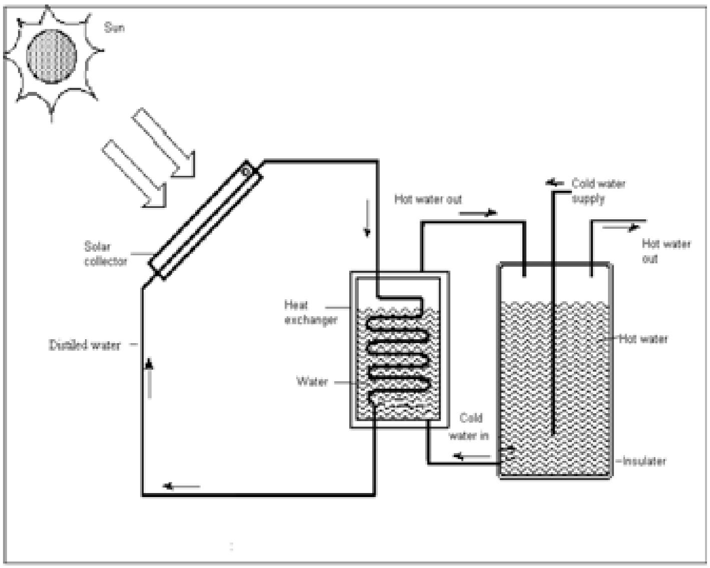

Fig. 1: experimental setup for the solution.

To eliminate the external power source we utilize the application of 'Thermo-Siphon' phenomenon, distilled water flows by siphon principle so that there is no requirement of electricity or any other external power. The components which are utilized in this arrangement are described as follows:

Solar Collector: Solar Collector is of 1 m^2 area and is utilized for absorbing the solar radiation and heat the distilled water which is coming from the heat exchanger. Collector tubing's are fabricated by copper, as it is a highly heat conducting material.

Heat-Exchanger: The distilled water coming from the solar collector is then passed through the heat exchanger, where it delivers the heat to the normal water. So water gets heated and distilled water gets cooled which is again supplied to the solar collector.

Collecting Tank: Collecting tank is just to collect the hot water which is coming from the heat exchanger and it is provided whenever required.

Tubing's: Tubing's are of copper and are generally used to provide the connections between the solar collector and the heat exchanger, then again between heat exchanger and the water tank.

Calculation

Heat Exchanger

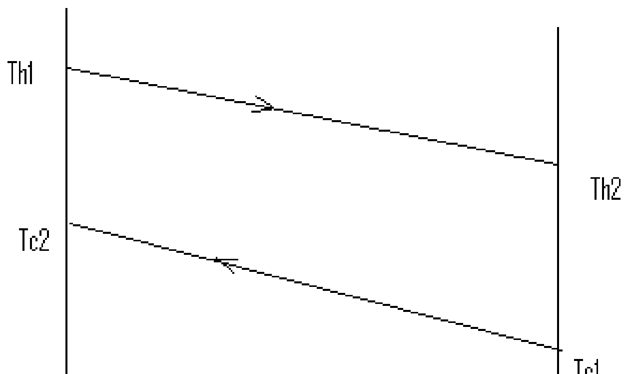

Fig. 2: temperature profile of counter flow heat exchanger

Log Mean Temperature Difference,

: $\Delta T_{lm}= [(T_{dwh2}-T_{wc2})-(T_{dwh3}-T_{wc1})] \div \ln [(T_{dwh2}-T_{wc2})/ (T_{dwh3}-T_{wc1})]$ ------- Equation (1)

The heat transfer to the water is given by,

: $Q_C=mc \text{ X } C_{pc} \text{ X } (T_{wc2}-T_{wc1})$ ------- Equation (2)

(Assuming this total heat is transferred by distilled water)

The heat transfer by the distilled water is given by

: $Q_h=m_h \text{ X } C_{ph} \text{ X } (T_{dwh2}-T_{dwh3})$ ------- Equation (3)

From this, mass flow rate of hot distilled water can be calculated.

The overall heat transfer coefficient (U) can be calculated taking into consideration the temperature ranges of distilled water and water. The formula to calculate overall heat transfer coefficient is

: $1/U= (1/h_i) + [(A_o/A_i) \text{ X } (1/h_o)]$ ------- Equation (4)

As the thickness of the tube is neglected, the factor (A_o/A_i) can be assumed to be equal to unity. Inside and out side heat transfer coefficient can be calculated by taking into consideration the various relations for Nusult number, Reynolds number and Prandtl number.

Total heat transfer is given by,

: $Q=U \text{ x } A \text{ x } \Delta T_{lm}$ ------- Equation (5)

Where, $A= n\Pi dl$

Where, n= number of passes and here it is equal to 1

d=diameter of the tube, l=length of the tube

Hence, length of tube can be calculated.

Testing

The preliminary testing of the fabricated solar water heater was carried out on 30th March 2016 in the collage premises by making use of distilled water as a primary fluid to heat water. In this testing distilled water was passed through the collector and heat exchanger tubing's. And then the readings of the different temperatures of the test is being obtained and shown in the following TABLE 1 below.

Table 01: Testing of fabricated Solar Water Heater

Time	T_{atm}	T_{dwh1}	T_{dwh2}	T_{dwh3}	T_{wc1}	T_{wc2}	T_G	T_{Gl}	T_{Al}	Condition of atmosphere
9:00A.M.	31.8	33.9	45.3	35.3	31.2	36.5	38.6	37.3	38.9	Sun shines & cloudy atms
9:30A.M.	31.8	33.9	48.1	38.1	31.2	38.5	40.3	39.6	40.5	Better sunlight
10:00A.M.	32.2	37.5	46.2	34.2	31.2	39.2	43.4	41.5	43.6	Better sunlight
10:30A.M.	32.7	38.1	48.5	35.5	31.2	40.1	47.6	43.4	52.1	Better sunlight
11:00A.M.	33.2	36.6	54.1	42.1	31.2	44.8	50.7	43.7	54.6	Better sunlight
11:30A.M.	34.9	35.2	63.6	42.5	31.2	46.5	55.1	44.7	58.1	Better sunlight
12:00noon	35.1	36.3	65.2	41.6	31.2	48.5	57.2	55.9	62.9	Better sunlight
12:30P.M.	35.3	36.2	65.2	44.5	31.2	48.1	59.0	51.1	63.4	Better sunlight
1:00P.M.	37.8	37.0	66.2	45.5	31.2	50.5	58.4	52.0	64.0	Better sunlight
1:30P.M.	38.6	37.2	67.2	47.0	31.2	50.2	60.5	50.5	64.1	Better sunlight
2:00P.M.	37.0	35.2	52.5	47.9	31.2	50.5	46.4	43.3	54.0	Sun completely vanished
2:30P.M.	35.2	34.9	51.9	46.9	31.2	49.9	37.6	39.5	44.4	About to rain
3:00P.M.	35.3	34.9	48.6	42.9	31.2	46.6	36.5	35.5	37.9	Raining slightly
3:30P.M.	36.5	37.7	48.2	36.9	31.2	45.2	38.8	38.6	41.1	Sun shines, Heavy wind flow and raining slightly
4:00P.M.	35.6	31.4	48.5	43.0	31.2	45.5	37.3	36.7	37.8	Cloudy atms and dilute sun rays
4:30P.M.	35.8	36.5	46.5	48.9	31.2	44.5	36.6	38.5	37.0	Cloudy atmosphere
5:00P.M.	34.5	34.5	46.0	42.6	31.2	44.0	38.8	37.2	40.4	Slight sunshine

- After testing the specimen according to the readings we plotted the graph between time and temperature of the water which we have achieved, and which is shown in the following Fig. 3.

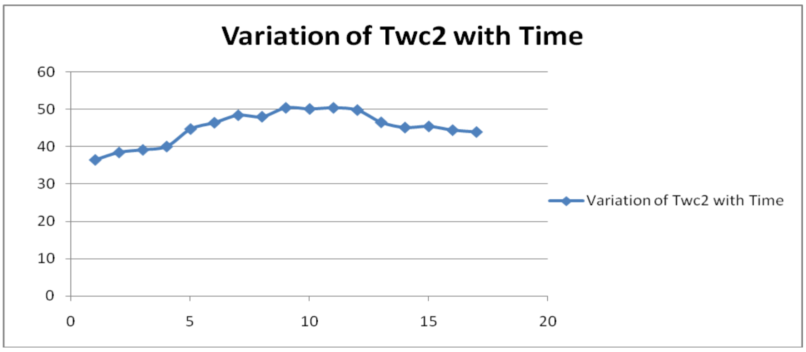

Fig3: Variation of Twc2 with Time

- According to the readings available with us we can see that during afternoon we can get the higher temperature of water, which is bit more than 50°C.Graph plotted between inlet temperature and outlet temperature of collector is shown in Fig. 4

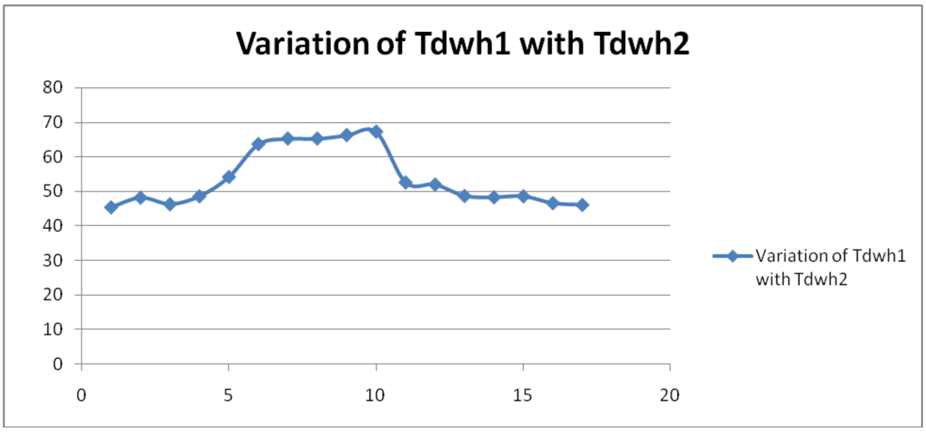

Fig 4: Variation of Tdwh1 with Tdwh2

- Graph plotted between inlet temperature and outlet temperature of heat exchanger is shown in Fig. 5

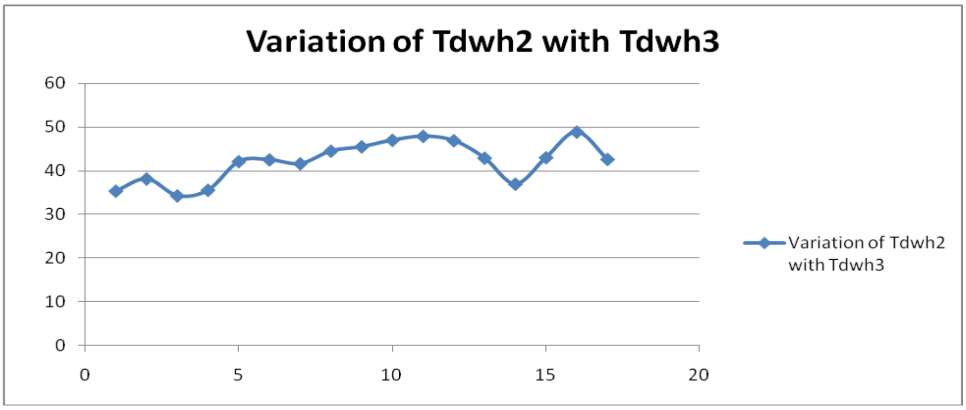

Fig 5: Variation of Tdwh2 with Tdwh3

II. Results And Discussion

We have fabricated the Solar Water Heater with Heat Exchanger and tested it experimentally as discussed above for varies conditions of the atmosphere and found that we get favorable results with good sun light. It gives the temperature more than 50^{0}C, However when the sun is completely vanished and also during cloudy weather, the specimen gives satisfactory results.

III. Conclusion

The fabricated model of 'SOLAR Water Heater With Heat Exchanger', on which the experimental testing was performed and the results were obtained. Testing was done on 30th March 2016 from 9:00 A.M. to 5:00 P.M. During testing we were able to get better sunlight and sun shine for few hours. And then we had a cloudy atmosphere, sun was completely vanished and it was about to rain which was accompanied by heavy wind flow. So by nature's grace, we got all our required conditions for the testing of the collector. Finally we have concluded that in any condition this water heater works and gives satisfactory results. Its Maintenance is also reduced because no scale formation is there since we are using distilled water. This 'Solar Water Heater' can work without any external power source, its efficiency is also better, and it can be developed at a very cheaper rate.

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