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Thermal Performance Evaluation of Evacuated Solar Water Heater with Twisted Tapes

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Abstract - *Solar water heating systems using vacuum tubes made of borosilicate glass with special coating to absorb the solar energy are called as Evacuated Tube Collector system (ETC Systems).Vacuum tube, as shown in the sketch, is the main component, which absorbs solar energy. The vacuum tube is an assembly of two concentric, borosilicate glass tubes. Air between the gap of two glass tubes is evacuated. It results in high level of vacuum, which acts as the best insulation to minimize the heat loss from inner tube. The black coating on the inner tube absorbs the solar energy and transfers it to the water. The water on upper side of Vacuum Tube becomes hot and thus lighter, so it starts moving upwards in the tank. At the same time cold water, which is heavy, comes downward from the tank and is stored at the bottom. The phenomenon is called as natural Thermosyphon circulation, which occurs in every tube.*

Key Words: Evacuated Tube Collector, Twisted tapes, Thermosyphon System, Solar Water Heater, Heat Loss, Vacuum tube

1. INTRODUCTION

It is the most popular utilization of solar energy. In this, usually there is a collection device, which is directly exposed to the solar radiation. This can be an absorbing type or concentrating type. In the former case, there is a dark surface exposed to sun, which absorbs radiation. Absorbed energy is then transferred to a fluid (like air or water), which is in contact with the absorber. In the later case solar radiation is concentrated to a focal point and the heat energy is transferred to the fluid [2].

- Solar radiation is an alternative energy source for numerous industrial and domestic applications. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat. Hence the domestic sector can lessen its impact on the environment is by the installation of solar flat collector for heating water. Conventional natural circulation flat plate solar water heaters are the most economical and large scale use of solar energy all over the world. Its thermal performance and efficiency which depends on its design parameters, thickness, type of insulation, number and type of glass covers, spacing between absorber and inner glass. Apart from these parameters its performance also depends on climatic and operational parameters.
- The circulation of the water in solar water heater is natural circulation due to the density differences between the hot water and cold water. The block diagram of solar water heater is shown in figure. Solar water heating systems use collector panels to capture the suns radiation and convert it into useful heat in the form of hot water. A solar collector coupled with solar water storage reduces the fuel needed for domestic hot water. Solar thermal systems could make a contribution to space heating as well as providing hot water. Water flows through tubes that are attached to a black metal absorber plate [4] [5]. The plate is enclosed in an insulated box with a transparent window to let in sunlight. The heated water is transferred to a tank where it is available for home, commercial or institutional use.

1.1 Problem Summary

Solar collectors are one of the simplest and most popular devices used to convert solar radiations into heat which is further utilized for the purpose of heating water. But these types of collectors suffer from heat loss due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases.

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[3].

1.2 Objective

In the present work two set-ups will be fabricated out of which one will be conventional ETC solar water heater and in the other set-up twisted tapes are inserted inside the glass tubes and comparison of their thermal performance will be carried out [1].

Reason behind the insertion of twisted tapes is to make the flow of water turbulent inside the tubes [1].

2. CONSTRUCTION DETAILS

- In the present work from glass material evacuated tube is fabricated having inner diameter of 18 mm and 40 mm with length of 1000 mm.
- Having storage tank of 10lt capacity with 150 mm diameter and 600 mm length made of GI coated material.
- Twisted tape made of copper strip 1 mm thick 1200 mm long with 180 mm pitch and 10 mm width.
- Two set up has been fabricated one with twisted tape insertion and one without twisted tape insertion.
- The digital K type thermocouples are used for temperature measurements.
- The frame is made from angle section of 25 mm X 25 mm X 5 mm. The main water supply tank is 20 lt capacities.

Fig -1: Experimental Set-up

3. WORKING PRINCIPLE

Solar water heating systems using vacuum tubes made of borosilicate glass with special coating to absorb the solar energy are called as Evacuated Tube Collector system (ETC Systems). Vacuum tube, as shown in the sketch, is the main component, which absorbs solar energy. The vacuum tube is an assembly of two concentric, borosilicate glass tubes.

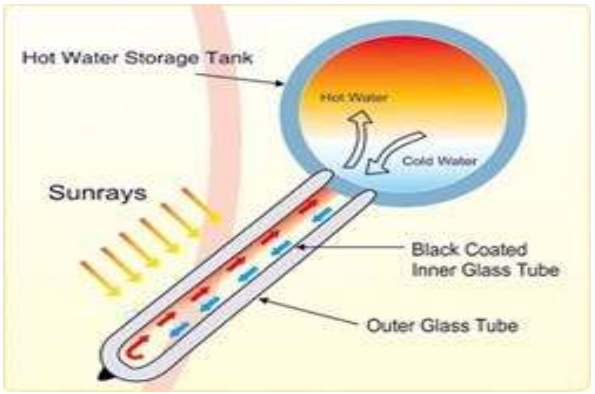

Fig -2: Working Principle of Evacuated tube Collector

Air between the gap of two glass tubes is evacuated. It results in high level of vacuum, which acts as the best insulation to minimize the heat loss from inner tube. The black coating on the inner tube absorbs the solar energy and transfers it to the water.

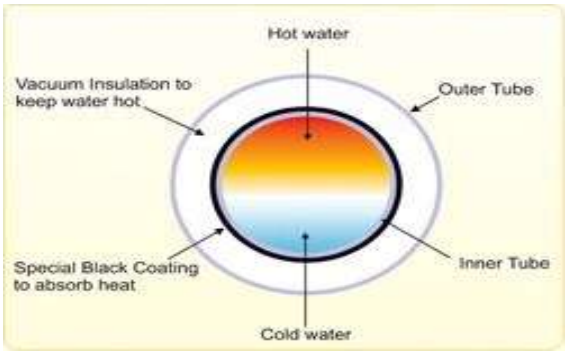

Fig -3: Showing vacuum gap between two tubes

The water on upper side of Vacuum Tube becomes hot and thus lighter, so it starts moving upwards in the tank. At the same time cold water, which is heavy, comes downward from the tank and is stored at the bottom. The phenomenon is called as natural Thermosyphon circulation, which occurs in every tube [2] [5].

4. METHODOLOGY

In the present work first of all the flow rate of both the set-up will be adjusted and made equal. Then the outlet temperature of the water coming out from both the set-up will be measured at regular intervals within a particular time limit. Readings will be taken for three different flow rates i.e. low, medium and high.
And finally their thermal performance will be compared.

5. OBSERVATIONS

Table -1: Readings

Time	Temperature without Twisted Tape	Temperature with Twisted Tape
Flow Rate = 0.0375 kg/s		
10:15	30.9	31.5
10:45	33.3	34
11:15	36.2	36.5
11:45	38.8	39.2
12:15	41.2	41.2
12:45	42.1	43.2
13:15	43.8	44.8
13:45	43.9	44.9
14:15	45.6	46
Flow Rate = 0.0512 kg/s		
10:15	30.6	32.8
10:45	33.5	35.2
11:15	35.5	38.1
11:45	36.2	39.1
12:15	38.2	40.8
12:45	38.9	41.6
13:15	40.2	42.9
13:45	41.9	43.9
14:15	43.1	44.9
Flow Rate = 0.0625 kg/s		
10:15	29.5	31.6
10:45	32.1	34.3
11:15	34.1	36.8
11:45	36.3	38.9
12:15	38.5	40.4
12:45	39.8	41.6
13:15	40.9	42.8
13:45	41.9	43.2
14:15	39.8	41.9

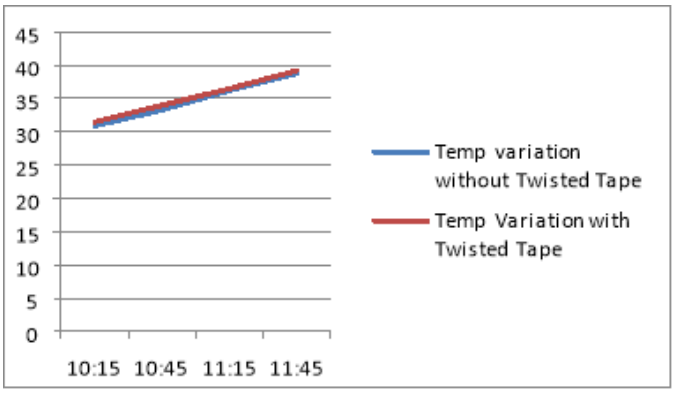

Chart -1: Temperature variation for low flow rate

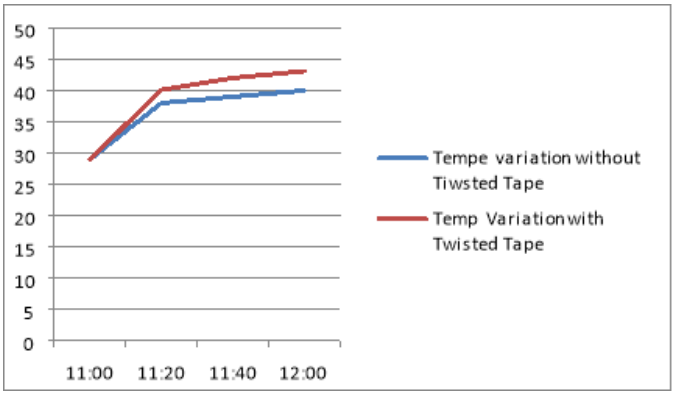

Chart -2: Temperature variation with medium flow rate

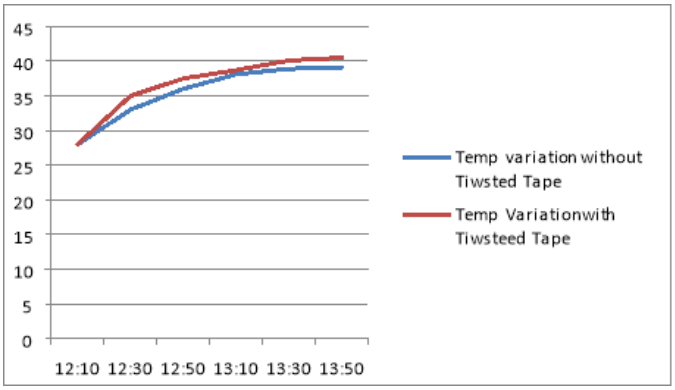

Chart -3: Temperature variation with high flow rate

6. RESULTS

- From observation Table it is clearly observed that in low and medium flow rate temperature gain is better in both the cases compare to high flow rate.
- In the present work temperature gain in all cases are almost 10 ^{0}C because it is small experimental model of 10 lt capacity with covering glass sheet.
- Compare to without twisted tape in case of with twisted tape better temperature gain can be obtained due to turbulence in the flow.
- The average temperature difference in case of with and without twisted tape with respect to time is 1 ^{0}C only due to small size of set up and only two evacuated tubes are used.

7. CONCLUSIONS

The major conclusions of present work are:

- There will be more heat collected through evacuated tube.
- Solar water heater must not lose the heat from water to air due to convection, because of there is evacuated tube in which vacuum is created in annular space.

- Due to introduction of twisted tape there will be more heat transfer because of water passing through swirling action means turbulence in the flow get created.

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