Influence of Inner Tube Diameter on Thermal Performance Evaluation of Evacuated Tube Solar Water Heater

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Abstract:

The sun is the source of all energy. The solar energy can be used for heating and cooking purpose. The utilization of solar energy for heating of water is common application but efficient water heating is the toughest because it depends on whether condition and to overcome such difficulty various modifications have been proposed by different researcher in terms of modification in pipe shape or in terms of change in the material of absorber plate etc. and so the objective of present work is to evaluate thermal performance of Evacuated Tube Collector (ETC) solar water heater with two different inner diameter of 20 mm and 18 mm with 40 mm same outer diameter in case of two ETC experimental set up.

***Keywords**: Solar Energy, Evacuated Tube Collector, Water Heating, Absorber Plate*

I. INTRODUCTION

Solar power for solar thermal power has been the most interesting of the renewable energy sources, based on recent industrial development and environmental impacts. Parabolic trough concentrators are used in the majority of available commercially solar power plants. Solar energy is an exhaustible form of energy that has the ability to satisfy a large portion of all nations' future energy requirements while causing the least amount of environmental damage. Solar energy for solar thermal plants is the most attractive of unconventional energy sources, based on recent industrial development and environmental impacts. Solar energy has been described as a potential renewable energy source for the future. The use of solar thermal resources is important for environmental sustainability and traditional energy savings. As the developments in the United States and Japan reveal, millions of households around the world are predicted to utilise solar energy in the coming years. Cooking/heating, distillation, power storage, cooling, and refrigeration all use this electricity.

Tubes that have been evacuated Rows of parallel, clear glass tubes make up collectors. Each tube is made up of a glass outer tube and an inner tube, or absorber, that is coated with a selective coating that absorbs solar energy while preventing heat loss by radiation. The air in the gap between the tubes is drained ("evacuated") to provide a vacuum, which prevents conductive and convective heat loss. They're best seen in very cold environments or in conditions where there's a lot of darkness. They're often used in industrial settings because rising water temperature or steam are needed, where they're more cost-effective.

Budihardjo, G.L. Morrison [1] studied experimental data of optical and heat loss characteristics, as well as a simulation model of thermo syphon circulation in single-ended tubes, were used to analyze the energy effectiveness of liquid evacuated tube solar water heaters.

Y. Taheri, Behrooz M.Ziapour,K.Alimardani [2] made the use of black coated sand in a modern solar water heater technique was investigated, and the findings showed that the collector averaging regular efficiencies of more than 70%.

N.M. Nahar [3] says the maximum efficiency of the device is 57 percent when focusing on the impact of various things on the output of solar water heater. The predicted output at different Indian stations showed that warm water is only needed for domestic usage during the winter season, and that can offer 100 L of warm water at a mean temperature of 50–70 ^{0}C, that can be kept at 40–60 ^{0}C until morning use the next day.

K.K. Chong, K.G. Chay, K.H. Chin [4] shows a stationary V-trough collector was used to study solar water heaters. The efficiency of a solar water heater device can be improved by combining the solar absorber with a simple V-trough reflector. The optical examination, experimental testing, and cost analysis of a fixed V-trough solar water heater device are all detailed in this article.

Rakesh Kumar, MarcA.Rosen [5] carried out thermal testing of an integrated collection tank solar water heater with a corrugated absorber surface was done. In this study, the absorber's surface is assumed to be pressure treated, with slight indentation depths, rather than plane. In addition to providing more surface area exposed to solar radiation, the changed surface has a longer characteristic duration for thermal conductivity from the absorber to the sea. The corrugated surface solar water heater is found to operate at a higher temperature over a lengthy span of time than that of the plane surface.

Hussain Al-Madani [6] experimented with a cylinder - shaped solar water heater The cylinder - shaped solar water heater's performance was determined. During the trial, the highest value was discovered to be 41.8 percent. This demonstrates the system's capacity to transform solar energy into heat that can be used to heat water. As opposed to the flat plate collector, the cylinder - shaped solar water heater is more cost efficient, according to an economic report.

S. Jaisankar, J. Ananth, S. Thulasi, S.T. Jayasuthakar, K.N. Sheeba [7] studied various methods were investigated in order to improve the thermal performance of solar water heaters. A brief discussion of the shortcomings of current knowledge, the research deficit, and proposed improvements is also included. Most of the passive heat transmission methods that has been utilised is twisted tape. While it is commonly used in heat exchangers, its usage in solar water heaters is restricted.

Runsheng Tang, Yanbin Cheng, Maogang Wu, Zhimin Li, Yamei Yu [8] focused on two sets of thermosiphon domestic solar water heaters were investigated for the impact of water temperatures in the storage tank and height differential between collector loop contacts at the tank on freeze safety of flat-plate collectors on moonless days in terms of output temperature of the water of the thermosiphonic reverse flow from the collector (known to as Tout) (DSWH). The output temperature of the water of reverse flow from collectors rose as the temperature of the water in the thermosyphon DSWH tank increased, but the rise was not important.

Jinbao Huang ,Shaoxuan Pu, Wenfeng Gao, Yi Que [9] demonstrated its applicability and promote its widespread use in China, the thermal efficiency of the thermo syphon solar water heater with only a mantle heating system was investigated. The thermal efficiency of a thermo syphon flat-plate solar water heating system with a mantle heat exchanger was studied, and an energy equation with a "heat exchanger penalty factor" was proposed theoretically. The thermo syphon plain solar water heater with a mantle heat exchanger will achieve a mean regular performance of up to 50%, which is lower than thermo syphon plain solar water heaters without heat exchanger but higher than all glass evacuated tubular solar water heaters, according to experimental findings.

C.C. Chien, C.K. Kung, C.C. Chang, W.S. Lee, C.S. Jwo, S.L. Chen [10] says about a two-phase thermo syphon solar water heater was investigated experimentally and theoretically. The efficiency of this revolutionary solar water heater is investigated experimentally at various solar radiation levels of intensity and tilt angles. According to the findings, the system's highest charge performance is 82 percent, which is better than that of traditional solar water heaters.

Behrooz M. Ziapour, Vahid Palideh, Ali Mohammadnia [11] investigated photovoltaic–thermal (PVT) package is a mixture of a photovoltaic (PV) board and a thermal collector for heat and electricity co-generation.

Because of its clear and compact design, an integrated collector-storage solar water heater (ICSSWH) device is a promising choice for solar water heating in a variety of climates. The proposed concept is inert. As a result, it does not depend on a photovoltaic-powered water pump to keep water flowing within the collector.

Behrooz M. Ziapour, Azad Aghamiri [12] studied about an integrated collector–storage solar water heater (ICSSWH) was it found to be less expensive than other solar systems. Numerical simulation and validation of an effective ICSSWH method was performed. The greater standard of stratification in the storage unit was used to model the baffle plate form of a two trapezoid ICSSWH method. The numerical software was run on both gloomy and clear days. The findings of the current scheme were then linked to other simulation and experimental values.

Nosa Andrew Ogie, Ikponmwosa Oghogho, and Julius Jesumirewhe [13] centred on a narrow absorber layer, incorporated with beneath grids of liquid carrying tubing, and mounted in an enclosed casing with a translucent glass mask, with a hot and cold container integrated in the device. Since the radiation released by the absorber layer cannot pass into the material, the temperature of the glass rises. The thermo syphon theory heats the water and causes it to drain into a holding tank.

II. EXPERIMENTATION

In the present work first of all three evacuated tubes made from 20 mm inner diameter and 40 mm outer diameter glass with 1 m length; also three evacuated tubes of 18 mm inner diameter and 40 mm outer diameter tubes with 1 m length are fabricated. These three tubes are connected with water tank made from mild steel with black coating having dimension s of 6” diameter and 15” length from where cold and hot water is recalculated in the system as per the principle of convective current. The ‘K’ type thermocouples are used to measure the temperature of water temperatures at inlet and outlet as well as body temperature too. The measuring flask with capacity of 1000 ml is used to measure mass flow rate water.

2.1 List of Components

- K type thermocouples with temperature indicator
- 15 mm broad twisted MS strip
- 20 lit water tank
- Evacuated tube 1m long 20 mm ID and 40mm OD
- Evacuated tube 1m long 18 mm ID and 40mm OD
- 1000 ml measuring flask

Fig. 1 Assembly of Solar Water Heater

2.2 Experimental Methodology

In the first phase of work two experimental set up are placed in the north south facing and K type thermocouples are located at inlet and outlet of water to measure temperature after interval of 30 minutes for low, medium and high flow rate.

III. RESULTS AND DISCUSSION

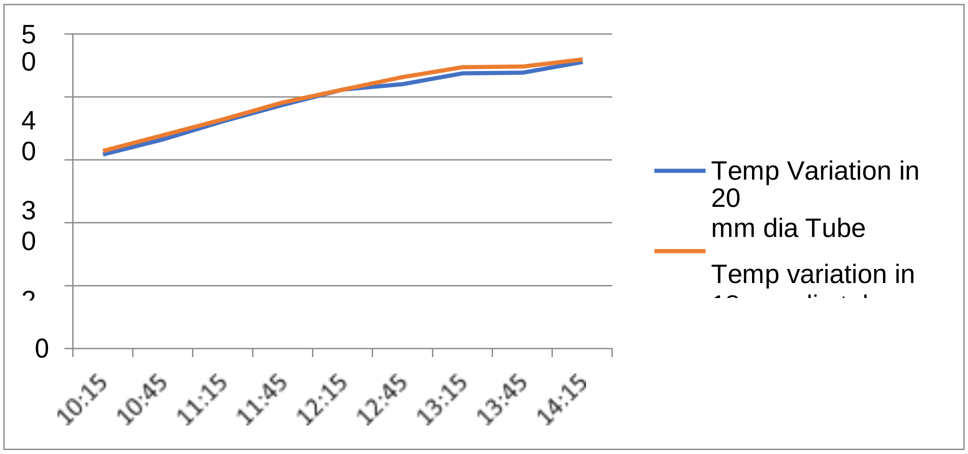

Fig.2. Temperature Variation for Low Flow Rate

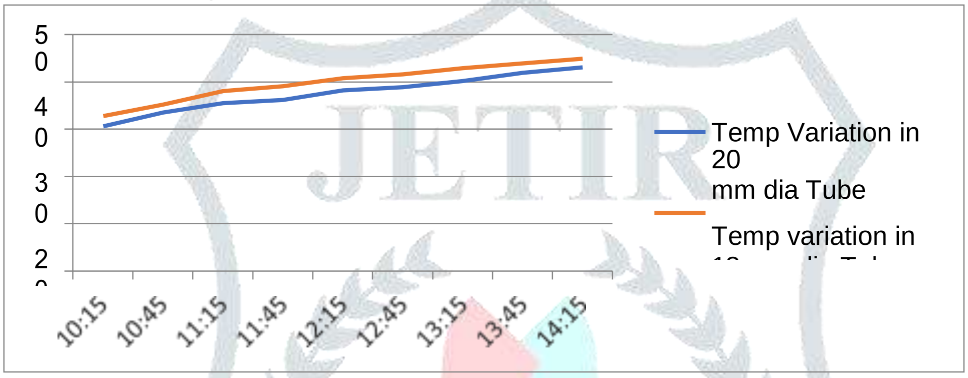

Fig.3 Temperature Variation for Medium Flow Rate

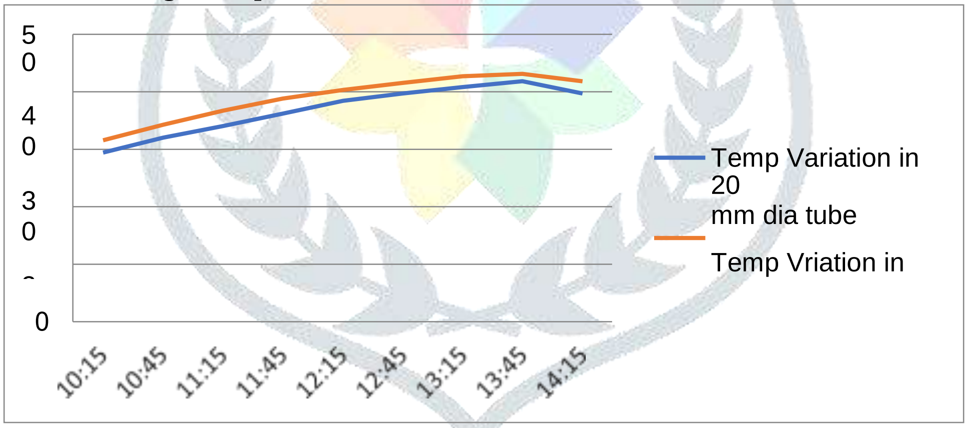

Fig. 4 Temperature Variation for High Flow Rate Table 1 Mass

Flow Rate of Water for Solar Water Heater

Flow	Time Required to fill 1000ml Flask (s)	Flow Rate (lps)
Low	735	0.00136
Medium	695	0.00144
High	617	0.00162

1. It is apparent from observation that temperature benefit is higher in low and medium flow rates as compared to large flow rates.
2. Since this is a compact laboratory model with a 10 L volume and a shielding glass layer, the temperature increase in both situations is almost 1 ^{0}C.
3. As compared to a 20 mm inner tube diameter, an 18 mm inner tube diameter has a greater temperature benefit owing to further heat accumulation.
4. Owing to the limited scale of the set up and the usage of just three evacuated tubes with black coating on tubes, the average

temperature differential either with or without twisted tape with respect to the time is only 2 ^{0}C.

IV. CONCLUSION

The major conclusions of present work are

- Heat can be absorbed more efficiently via the evacuated pipes.
- Since there is an evacuated tube through which vacuum is provided in annular space, solar water heaters do not lose heat through water to air due to convection.

Due to more gap between inner and outer tube in case of 18 mm inner diameter evacuated tube more heat is penetrated which is responsible to increment in temperature.

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