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An Experimental Study of the Heat Pipe based Evacuated tube Collector for Water Heating

[1] Dr. Rajneesh Kaushal
[1] Assistant Professor, Mechanical Engineering Department, NIT Kurukshetra

Abstract: **-- The objective of the present study is to enhance the heat transfer & efficiency of the Heat Pipe based Evacuated Tube water heater. Heat Pipe based Evacuated Tube collector is made of Borosilicate glass of 58 mm outside diameter and 49 mm inside diameter and length of 1800 mm. The Heat pipe of Evacuated Tube collector is made of copper with length 2000 mm and 12 mm outside diameter and 10 mm inside diameter. The experimental set up is situated 29° 58' N and 76° 53' E at NIT Kurukshetra. The results expressed that Heat Pipe based Evacuated Tube water heater is more efficient than without Heat Pipe based Evacuated Tube Water heater. The Heat Pipe based Evacuated Tube collector efficiency is 72 % and water outlet temperature is 64°C in summer and 52°C in winter. The present research is also focused on the use of various fluids in Heat Pipe.**

Keywords **- Evacuated Tube Collector, Renewable Energy, Solar Radiation, Ethylene Glycol, Collector Efficiency.**

I. INTRODUCTION

Around the world and in particular during cold seasons a large amount of energy is spent in heating water for domestic and industrial applications. A typical household (in a developed nation) spends on an average around 15 kWh each day on water heating [1]. Most of this demand is met through electric resistive heating or burning fossil fuels such as liquefied petroleum gas (LPG), natural gas, kerosene oil, etc. This is true for several developing countries as well. There is research also into alternative ways to heat water for domestic purposes. In India, the for several reasons such as a steep increase in CO2 emissions since 1994 and a lack of continuous electric supply (in many population centers) as well as loss to the government in providing over-subsidized LPG, there has been a movement towards harnessing solar energy for water heating. Over the past decades, energy utilization has increased remarkably due to the advancement in domestic and industrialization processes [2]. Due to this gap between the energy supply and demand has increased [3]. Apart from that, the consumption of fossil fuel gives unfavorable effect to the environment due to increase in C02 emission. All of these factors have the major concerns on the needs of a sustainable energy. Thus, renewable energy such as solar energy has begun to attract more attention than before [4]. Moreover, to achieve sustainable development and reduction in global warming renewable energy such as solar energy provides optimistic solution [5]. Photovoltaic systems and solar collector are the applications of solar energy.

1.2 Evacuated Tube Solar Collector:

Evacuated Tube collector consists of series of borosilicate glass tube with each tube copper heat pipe is inserted. The Heat pipe is generally made of copper with a black chrome coating and containing a fluid either water, ethylene glycol and the mixture of water and ethylene glycol [6]. When Evacuated Tube collector collects heat from the sun than transfer it into the heat pipe due to this temperature of the fluid inside the tube is rises, which undergoes evaporation and condensation process. The condenser section tip of the heat pipe is connected to the header of the water storage tank for heat transfer to the water.

The Heat Pipe based Evacuated Tube collector has high efficiency, low cost and losses than the Flat Plate collector. The Heat Pipe based Evacuated Tube collector does not require any external power for working operation because it works on the principle of thermosyphon phenomena.

1.3 Heat Pipe: Heat pipe is based on evaporation and condensation process. The heat pipe collects heat from the collector's and then transfer it to the evaporator and condenser section. The condenser section of the heat pipe is connected to the header of the collector for the heat exchange process as shown in fig. 1.

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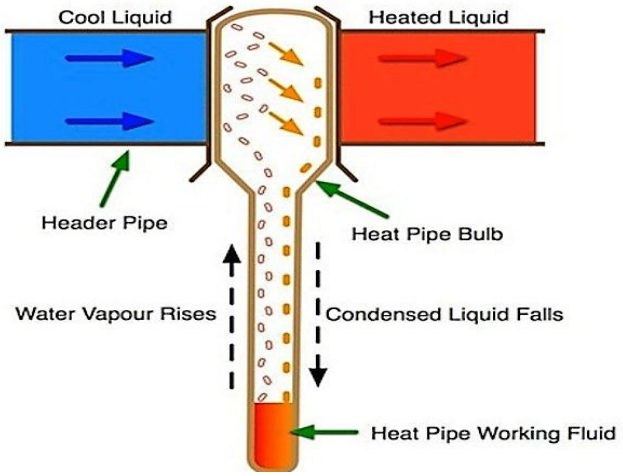

Fig.1 Working Principle of Heat Pipe.

The Heat Pipe is generally made of hollow copper tube enclose with a very small amount of working fluid. When the evaporator section of Heat Pipe is heated then the fluid inside the tube is rises and transmits heat to the water flowing into the header of the collector storage tank. After heat transfer vapor is converted into liquid and flow back to the evaporator section. Heat Pipe based Evacuated Tube collector is very efficient for water heating. The connection between Evacuated Tube and Heat Pipe is flexible, means Evacuated Tubes and Heat Pipe replaced individually without any interference in the system operation.

1.4 Heat Transfer Fluid: Heat transfer fluid used in Heat Pipe is depends upon properties of the fluid. The following parameters are considered for the selection of working fluid:

- Low toxicity
- High latent heat
- High Thermal conductivity
- High Heat transfer capacity
- Low flammability
- Excellent Thermal stability

Ethylene Glycol and a mixture of ethylene glycol and water solution are most commonly used in heat transfer application.

II. EXPERIMENTAL SETUP & METHODOLOGY

The experimental setup is situated 29° 58' N and 76° 53' E in NIT Kurukshetra. The Heat Pipe based Evacuated Tube collector is shown in Fig. 2 and photograph of the experimental setup are shown in Fig. 3. The main components of the experimental setup are:

- Evacuated tube solar collector (ETC)
- Heat pipe
- Connecting Pipes
- Storage Tank

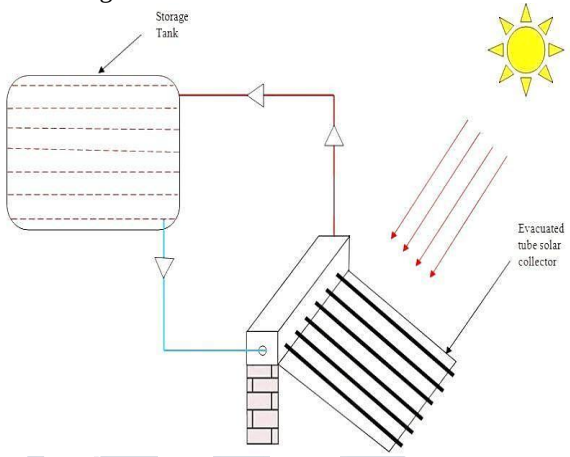

Figure 2. Evacuated Tube collector

Figure 3. Photograph of Experimental Setup.

2.1 Working Principle of Experimental Setup: Heat Pipe based Evacuated Tube collector use series of borosilicate glass tube to harness the solar energy then transfer energy to the Heat Pipe, when Heat Pipe collects heat from Evacuated Tubes then fluid inside the tube ethylene glycol is vaporize and rise up to the top of Heat Pipe and transfer heat to water flowing inside the header of the collector storage tank and then return to bottom of heat pipe. This cycle is repeated again & again.

2.2 Specification of Experimental Setup: The design parameters and specification of experimental set up are shown in Table 1:

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Table 1: Design parameters and specification of experimental setup

Sr. No.	Design Parameters	Value
1	Length of Evacuated Tube	1800 mm
2	Evacuated Tube Outer Diameter	58 mm
3	Outside Diameter of Inner Tube	49 mm
4	Inside Diameter Inner Tube	47 mm
5	Glass Thickness	16 mm
6	Number of Tubes	10 mm
7	Outer Diameter of Heat pipe	12 mm
8	Inner Diameter Heat pipe	10 mm
9	Heat Transfer Fluid (Ethylene Glycol)	0.0002 m^3

2.3 Measuring Instruments & Devices: Different parameter was measured during the experiment by using various instruments as shown in Table 2.

Table 2: Measuring device specification

Sr. No.	Measurement	Device	Operational Range
1	Temperature	RTD PT 100	0°C to 300°C
2	Intensity of Solar radiation	Pyrano-meter	0 to 2000 W/m^2
3	Air flow rate	Anemo-meter	0 to 40 m/s

III. RESULTS AND DISCUSSIONS

In this research, aim was to study the efficiency of Heat Pipe based Evacuated Tube Collector throughout the year.

3.1 Collector Efficiency: Heat Pipe based Evacuated Tube collector tested throughout the year and obtained results are shown in fig. 4. The results show that Efficiency of ETC is higher in November due to the increase in solar insolation than other months. The ETC efficiency is calculated by:

Ŋcollector =

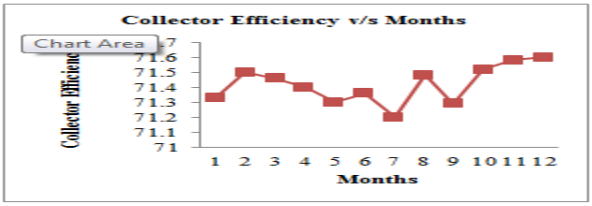

Figure 4. Collector Efficiency for Heat Pipe based Evacuated Tube Collector.

3.2 Water Outlet Temperature: The outlet temperature of the water is recorded throughout the year. The result shows that water outlet temperature is 64°C in summer and 52°C in winter seasons. Monthly obtained results are shown in Figure 5.The hot water outlet temperature is calculated by:

$Q_{thermal} = m_w C_p (T_o - T_i)$

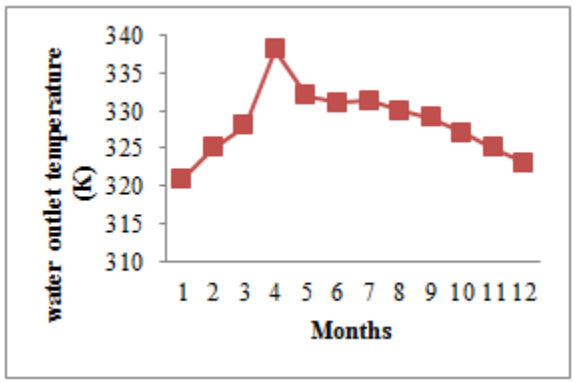

Figure 5. Water outlet temperature of Heat Pipe based ETC

IV. CONCLUSION

In this paper, the performance of Heat Pipe based Evacuated Tube collector has been experimentally investigated throughout the year. The following conclusion has been investigated from the results.

1. Hot water produces by Heat Pipe based Evacuated Tube collector with an average of 64°C in summer and 52°C in winter seasons respectively.
2. The efficiency of Heat Pipe based Evacuated Tube collector reaches up to 72 %.
3. Water outlet temperature also depends upon the number of Evacuated tubes, solar radiation and environment conditions.
4. The hot water outlet temperature is 52° C in winter season which is sufficient for domestic usage.
5. Heat Pipe based Evacuated Tube collector has a high efficiency, low cost and low thermal loss than the Flat Plate collector.
6. The Heat Pipe based Evacuated Tube Solar collector is low heat loss at high temperature.

V. FUTURE SCOPE

In the present study Heat Pipe based Evacuated Tube collector uses conventional fluids such as water, ethylene glycol and a mixture of water and ethylene glycol has poor thermal conductivity than nanofluid. Hence, it is necessary to carry an experimental work on the different nanofluid to increase the

efficiency and performance of the Heat Pipe based Evacuated Tube collector. Nomenclature

Cp	Specific heat (kJ/kg K)
Irad	Intensity of Solar radiation (W/m2)
T	Temperature (°C)
Asa	Solar Selective Absorber Area (m2)
Nt	Number of tubes

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