EXPERIMENTAL INVESTIGATION OF AN EVACUATED TUBE HEAT PIPE SOLAR COLLECTOR EFFICIENCY

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Abstract: *Experimental investigation of the overall efficiency of solar collectors under local weather conditions of solar collectors evacuated tubes. Experimentation executes heat-pipe collector designs with the manufacturer's recommendation requirements, and some design improvements. An experimental set-up was built and used, involving full-scale collectors made of a row of 10 evacuated tubes and their tank, and a circulation device with measuring instruments. During the June period, in the summer, the experiments were performed on days when the sky was almost clear with some clouds scattered here and there. The result shows that when some amount of outlet hot water retransfers to the insulation tank which is connected to the inlet to the collector where mixing the hot and ambient temperature water and then transfer to the inlet of collector by using this method efficiency of collector almost 5 to 7 percent higher than before.*

Keywords: **Solar energy, Evacuated tube collectors, Insulating tank, Efficiency, Operating temperature, Comparison, Heat pipe, Thermosyphon, Temperature range.**

1. INTRODUCTION

Solar water heaters are increasingly being used around the world, and the evacuated tube models are the most common because of their flexibility and overall better performance over their flat-plate models, especially in poor weather conditions. Several evacuated tube designs have been developed and are being used among which, due to its low cost and easy manufacturing and installation procedures, the water-in-glass design is very common. The configuration uses an intermediate fluid heat-pipe system used to bring the heat from the heating elements to the tank. During this case, as it is being moved up and down, the working fluid undergoes a phase shift process.[1] Evacuated tube solar collector is a system used to supply heat at relatively high temperatures for various applications including water heating, air conditioning, etc. Due to the combined effects of highly selective surface coating and vacuum insulation, this collector can reach temperatures above 120 ^{0}C. [2] ETC uses phase changes in liquid-vapor materials to transfer heat at high efficiency. Such collectors feature a heat pipe that is a highly effective thermal conductor inside a tube that is sealed with a vacuum. The plug, which is a sealed copper plug, is then connected to a tube (absorber plate) filled black copper fin. A metal tip attached to the sealed pipe protrudes from the top of each drain. The heat pipe contains a small volume of fluid (e.g., methanol) undergoing a process of evaporation-condensation. Solar heat evaporates the liquid during this process, and the vapor travels to the region of the heat sink where it condenses and releases its latent heat. [4] The condensed fluid returns to the solar collector and repeats the cycle. Once such tubes are mounted the metal tips up to a heat exchanger (manifold). Water passes through the pipe, or glycol, and takes up heat from the tubes, Shows in figure 1

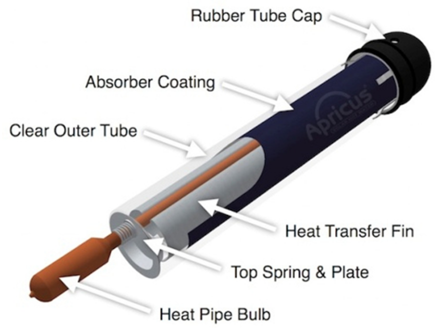


Figure 1 Evacuated tube with heat pipe [3]

Figure 2 displays the schematics of an evacuated U-tube solar collector; this consists of an external glass tube, an internal glass tube, a copper or aluminum fine, and a copper tube-shaped in U. The incident solar radiation is passed to the inner glass tube and is absorbed by the fin on the outer surface of the outer glass tube. The energy that the fin absorbs is transferred to the U-tube through conduction, and from there to the working fluid that flows by convection within the U-tube. [5]

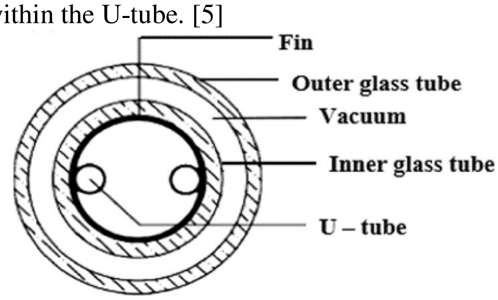


Figure 2 Schematic of evacuated U-tube solar collector. [5]

Evacuated tube collectors are usually made in standard sizes and placed at an angle. The angle to be calculated using the latitude of the position in question. Similar Parameters The overall output of collectors, including the angle of tilt, the weather conditions, the weather conditions, and the size of the collector, etc. When the sun rays strike, it is well admitted that the best performance is achieved Collector elements at right angles to optimize the function of absorption of energy. [6]

Nomenclature

A	Surface area of collector, m2
C_1,C_2	Coefficients
C_p	Specific heat at constant pressure, J/kg.°C
G	Irradiation, W/m2
$\dot{m}$	Mass flow rate, kg/s
Q	Heat rate, W
T_a	Ambient temperature, °C
T_{in}	Inlet temperature, °C
T_m	Mean temperature, °C
T_{out}	Outlet temperature, °C
η	Efficiency
η_0	coefficient

2. EXPERIMENTAL SETUP

An experimental setup was performed on the Jalgaon district on home terrace. Figure 3 shows the entire device with a regular evacuated tube solar collector with a heat pipe made of 10 evacuated tubes. A closed-loop circuit with the requisite components and measuring instruments is the experimental setup.

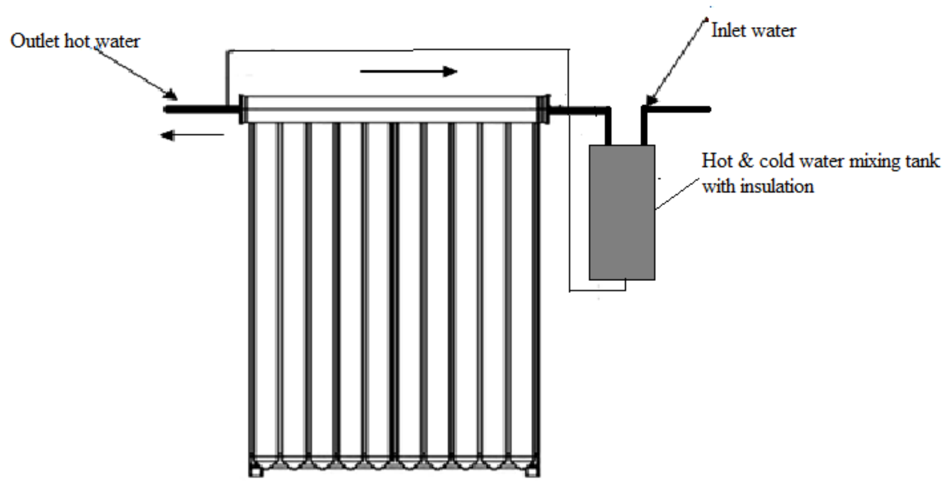


Figure 3 Experimentation setup of Evacuated tube with heat pipe collector

An insulated pipe is used to transfer outlet hot water in the inlet of the collector the diameter of that pipe is 1/6 of the outlet pipe diameter and it is connected to the insulated tax where the cold and hot water mix then transfer into the collector. A pyranometer, which was attached to a data logger, measured solar radiation. Readings were rendered by Taken manually at steady flow conditions, every 15 minutes. The temperature determinations were taken from the Controller and double-checked by reading the option for reading temperature difference in the Using Multifunctional Flow Meter. Figure 4 displays a representative collection of data gathered with the heat pipe collector tilted at 45 °. The various measured quantities are the time at which the measurement is taken, the irradiation, the flow rate, the collector's inlet, and outlet temperatures, and the ambient temperature. It should be remembered that in the early afternoon, at a time when solar irradiation tends to decline, the optimum temperature is reached.

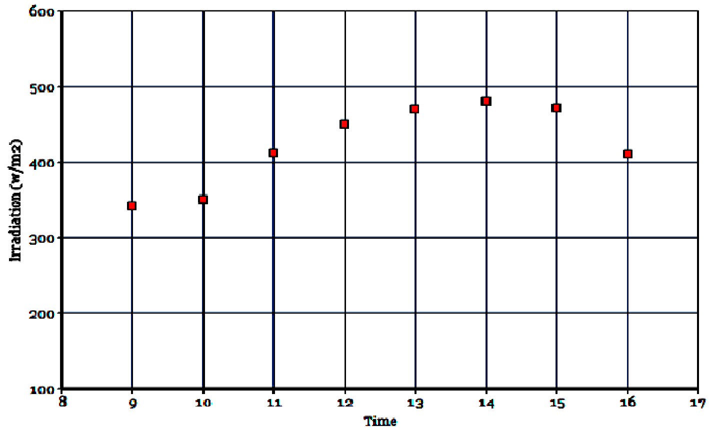


Figure 4 Solar Irradiation with time

3. THEORETICAL ANALYSIS

Two separate methods can be used to assess the efficiency parameters of solar thermal collectors: the steady-state test method and the quasi-dynamic test method. Both boundary conditions, such as solar irradiation, ambient temperature, and during the steady-state evaluation, the inlet temperature of the collector is kept constant. The collector effectiveness curve can be calculated through multi-linear The Methods of Regression. The boundary conditions are left free to differ throughout the quasi dynamic evaluation. Specific collector parameters are calculated based on a set of measurements, as well. With the process of quasi dynamic testing, In addition to the efficiency curve, additional parameters can be calculated, such as the heat capacity of the collector and the incident angle modifier coefficient. In both techniques, the basic principle is to expose the collector to solar radiation and calculate the working fluid's inlet and outlet temperatures at a known flow rate. It is observed that the solar collector's thermal efficiency depends on the intensity of the sunlight that strikes the surface of the collector, the temperature of the surrounding atmosphere and the absorbing layer, and the collector's optical and thermal efficiency, respectively, expressed by the values of (τα) and UL. The transmission of the absorber plate's glass cover and absorption (α) depends on the incidence angle of the collector and approximately 0.836 is the sum of the transmittance and absorption (τα) according to the literature.

$Q_U = \dot{m}C_P(T_{out} - T_{in})$

Efficiency; $\eta = Q_U / A_C\ G_n$ (1)

Therefore; $\eta = \dot{m}C_P(T_{out} - T_{in}) / A_C G$ (2)

It is possible to write the same net power output in terms of quantities representing the heat transfer Mechanism, or the input of heat minus the loss of heat, as

$Q = A_C\ F_R[G - U_L(T_m - T_a)]$ (3)

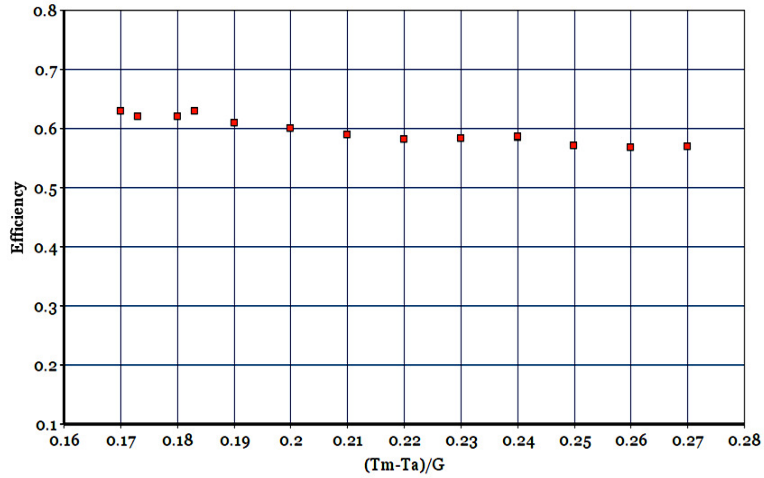
Where the collector heat removal factor is FR and the total coefficient of heat loss is UL. Tm is a mean temperature of the working fluid that flows within the collector, usually taken as the collector's average temperature between the inlet and outlet. Combining the heat rate given by equation (3) with the efficiency definition and noting that UL is typically a temperature function, leads to the following expression:

$\eta = \eta_0 - C_1(T_m - T_a)/G - C_2(T_m - T_a)^2/G$ (4)

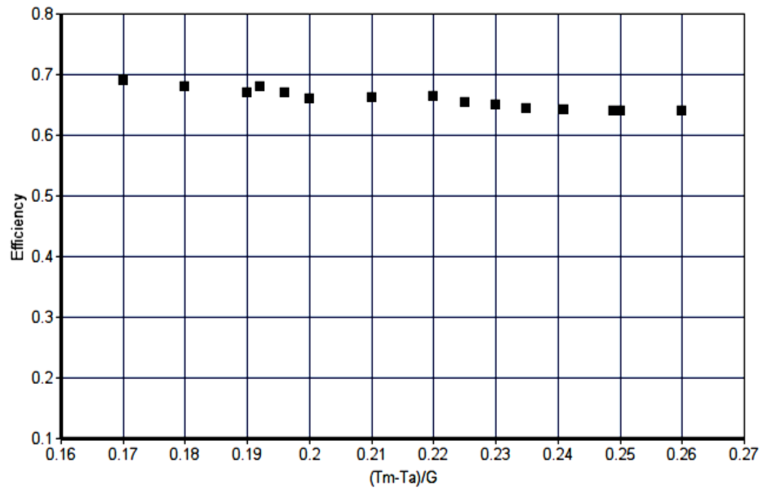
In which η_0, C_1 and C_2 are constants, either analytically or experimentally to be tested. The constants and efficiency are recommended by the manufacturer.

4. RESULTS & DISCUSSION

The experiments took place over 15 days duration, in the month of June. Figure 5 (a) and (b) demonstrates the results for both the heat-pipe collectors tilted at an angle of 45 ° relative to identical experimental results resulting from the manufacturer's guidelines and the results compared with the manufacturer's design adjustments and the result obtained.



(a)



(b)

Figure 5 (a) and (b) Experimental Result of Manufacturer Design (Left) after result change in Design (right)

Figure 5 shows the results for both the heat pipe before the design changes and after the design collector changes, tilted at an angle of Compared to comparable experimental results of both manufacturer recommendations collector and some improvements in the design, the result shows that the collector's efficiency was improved by connecting the certain amount of hot water transmitted to the insulated inlet tank that is given for mixing the hot and ambient temperature water, obviously increasing the collector's inlet water temperature. It is assumed that the tilt angle of the collector would have a non-negligible impact on the system's overall performance. It is well known that when sun rays reach the collector surface at the right angle, the best output is achieved.

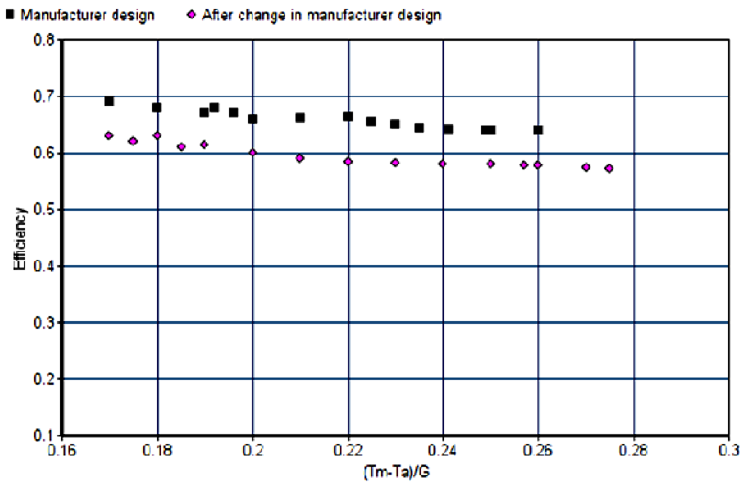


Figure 6 shows the comparison before and after the change in design

Figure 6 provides a comparison of the heat-pipe collector before and after the design adjustments. The overall performance of the heat-pipe collectors is approximately 5 to 7 percent higher than the collectors configuration recommended by the manufacturer.

5. CONCLUSIONS

Different tests were performed to characterize the overall performance of evacuated tube solar collectors as they were used on the local market. The findings are in good agreement with related reports published by producers and independent researchers in the field of science. The principal inference is that when some improvements are made in the design suggested by the solar collector manufacturer, then heat-pipe collectors have a much better performance.

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