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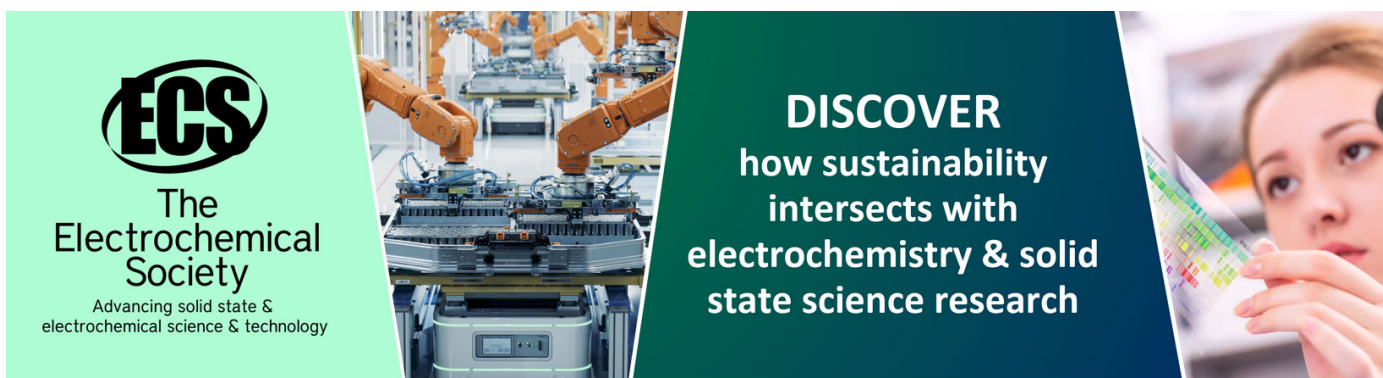
## Comparison of three systems of solar water heating by thermosiphon

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# Comparison of three systems of solar water heating by thermosiphon

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**Abstract.** The main purpose of this project was to elaborate a comparison between three water heating systems; using two plane water heating solar collector and another using a vacuum tube heater, all of them are on top of the cafeteria's roof on building of the "Universidad Pontificia Bolivariana" in Bucaramanga, Colombia. Through testing was determined each type of water heating systems' performance, where the Stainless Steel tube collector reached a maximum efficiency of 71.58%, the Copper Tubing Collector a maximum value of 76.31% and for the Vacuum Tube Heater Collector a maximum efficiency of 72.33%. The collector with copper coil was the system more efficient. So, taking into account the Performance and Temperature Curves, along with the weather conditions at the time of the testing we determined that the most efficient Solar Heating System is the one using a Vacuum Tube Heater Collector. Reaching a maximum efficiency of 72.33% and a maximum temperature of 62.6°C.

## 1. Introduction

Colombia emits 62 million tons of CO<sub>2</sub> per year and the United States about 5286, the latter, is one of the countries with the highest carbon footprint. A solution to these problems is the use of solar energy [1].

Use of the sun energy by the human being it is lost in the time. However, applying the knowledge gained from ancient times and the development of new materials, it has created applications for obtain welfare at home. The water tank exposed to sun in the past, has led to modern solar collectors to have domestic hot water (DHW), heating and similar services, with the same purpose as photovoltaic and wind systems [2].

This investigation is about study of testing three different types of solar water heaters. Two flat plate collectors with different material of the coil, one with stainless steel coil, the other with a copper coil and vacuum tubes are analysed. This in order to do a comparison of their performance curves and determine the optimal system. This project seeks to find a balance between environment and economy. Solar domestic hot water system by thermosyphon, where the liquid flows from the solar collector to the storage tank by buoyancy forces, has spread widely in the field of practice and research [3]. Numerous studies have investigated the performance of solar water heaters operating by thermosiphon [4-7]. Burbano et al. [4] they built a thermosyphon solar water heater with an interesting design process. Zerrouki A. et al. [5] found experimentally that the rate of mass flow increases in the hour of greatest radiation (11am - 2pm). Sakhrieh and Al-Ghandoor [6] presented an experimental study of the performance of different types of solar collectors and conclude that the vacuum tube collector is the top performer with respect to efficiency, with a maximum value of 72%. Gupta and Garg [7]



experimentally proved that the flow rate of a thermosyphon water heater can be increased if the relative height between the collector and the storage tank is increased, but the efficiency is not increased.

## 2. Theory

Energetic balance of a flat collector is:

$$Q_1 = Q + Q_2 \quad (1)$$

Where:

$Q_1$ : is the incident energy (direct+diffuse+albedo) in the unit time.

$Q$ : is useful energy, by collecting the heat transfer fluid.

$Q_2$ : is the energy lost by dissipation to the environment.

Given the definition of intensity of radiant energy,  $Q_1$  is the product of the intensity and the surface. Not all the incident energy  $Q_1$  will be absorbed in the absorber. First, if there is deck, you have to have the transmittance in a count, which will leave to flow part of this energy ( $\tau SI$ ). Moreover, the absorption coefficient  $\alpha$  or absorptance of the absorber plate never becomes equal to unity, so that the fraction of energy actually absorbed is:

$$Q_1 = \tau \alpha SI \quad (2)$$

As for the energy lost  $Q_2$ , detailed calculation is very complex because, must be taken into account simultaneously and in different proportions losses by radiation, convection and conduction. However, in order to be able to use a simple formulation, it has been agreed to include these influences in the overall loss coefficient called  $U$ , which is measured experimentally and is data supplied by the manufacturer. Experience has shown that supposing losses per unit of surface proportional to the difference between the average temperatures  $t_c$  of the absorber plate and the environment  $t_a$ , being the proportionality factor the coefficient  $U$ , is a good approximation. So that:

$$Q_2 = SU(t_c - t_a) \quad (3)$$

Substituting (2) and (3) in (1) is obtained:

$$Q = S[I(\tau \alpha) - U(t_c - t_a)] \quad (4)$$

Where:

$S$ : collector surface.

$I$ : radiant intensity ( $W/m^2$ ).

$\tau$ : transmittance of the transparent cover.

$\alpha$ : absorptance of the absorber plate.

$U$ : overall loss coefficient ( $W/(m^2 \cdot ^\circ C)$ ).

$t_c$ : average temperature of the absorbing plate ( $^\circ C$ ).

$t_a$ : environment temperature ( $^\circ C$ ).

The efficiency ratio of the collector,  $\eta$ , is defined by the relationship between energy captured and received at a given instant according to the Equation (5).

$$\eta = Q/(SI) \quad (5)$$

Substituting (4) in (5) is obtained (6)

$$\eta = F_R[(\tau\alpha) - U(t_m - t_a)/I] \quad (6)$$

Where  $t_m$  is the mean temperature of the collector according to the Equation (7).

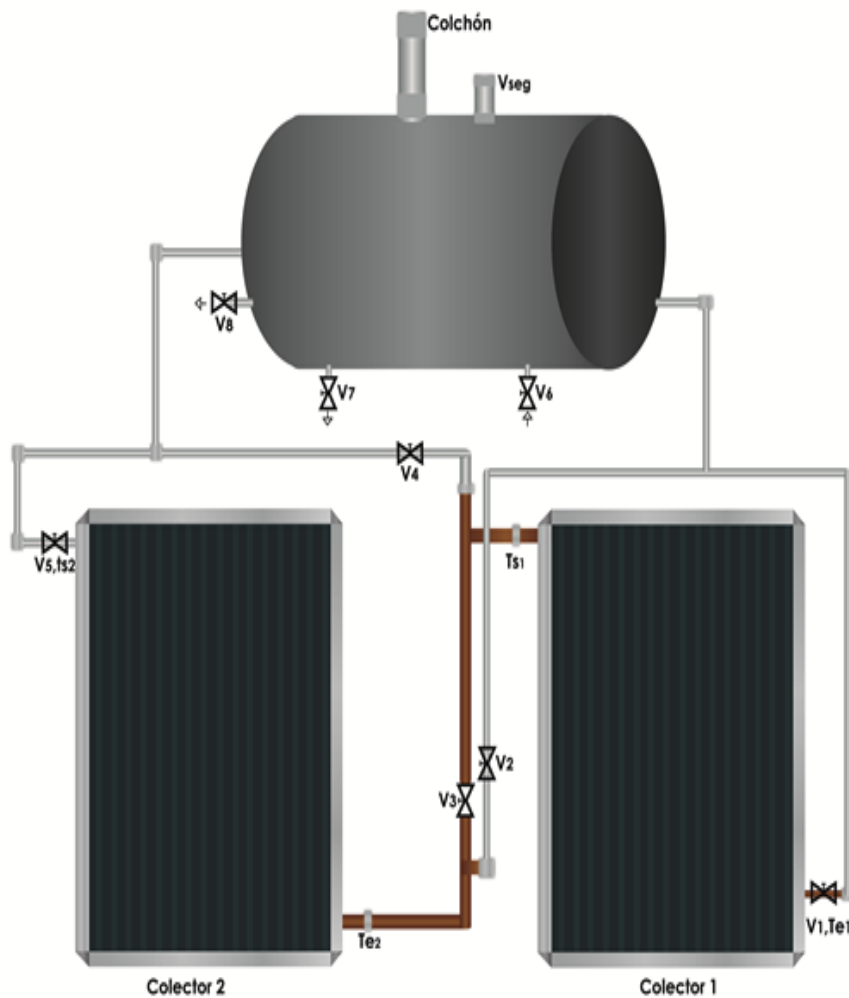
$$t_m = (t_e + t_s)/2 \quad (7)$$

For a flat plate collector the Equation (6) is approximate to the Equation (8).

$$\eta = 0.83 - 6.8(t_m - t_a)/I \quad (8)$$

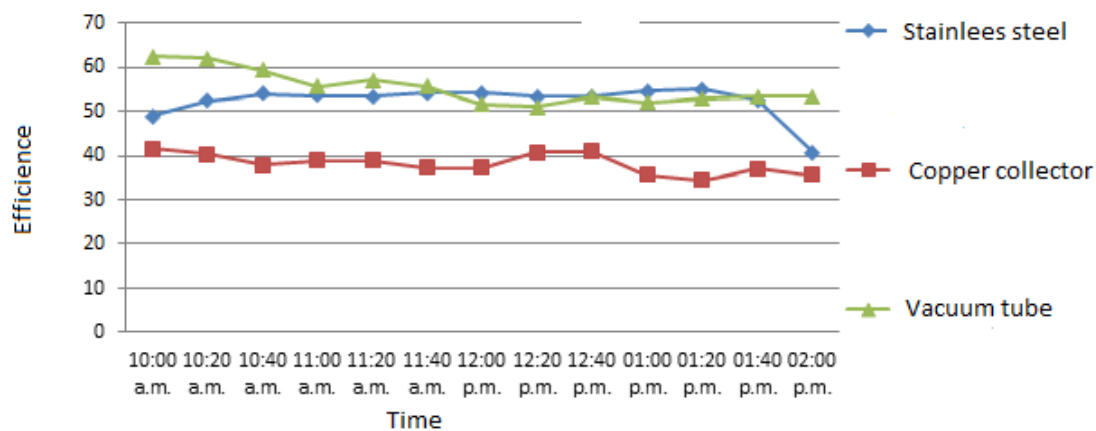
### 3. Methodology

The solar collector has the dimensions  $1.6m \times 0.8m \times 0.13m$  with stainless steel plates and copper according to Figure 1. Internally the collector has seven copper tubes  $1.5m$  long and 1.5 inches in diameter. The collector has a tempered glass dimensions  $1.6m \times 0.8m$ , which determines the catchment area of solar radiation.



**Figure 1.** Thermosiphon system.

Radiation  $I(W/m^2)$  was measured with a pyranometer Kipp & Zonen CM3 and temperatures with type K thermocouples located at the ends of the manifold, the results shown in Figure 2, are obtained.



**Figure 2.** Efficiency vs time for three systems.

#### 4. Conclusions

The system of solar water heating was implemented, two flat plate collectors, giving as a result of flat plate collectors with different material coil, one coil of copper and the other with stainless steel coil.

The maximum efficiency for the collector with stainless steel coil was 71.58% ( $\pm 0.0099\%$ ) of 76.31% ( $\pm 0.0003\%$ ) for the collector with copper coil and 72.33% ( $\pm 0.0063\%$ ) for the vacuum tube collector.

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