THERMAL DIFFERENCE BETWEEN A CLASSIC SOLAR COLLECTOR EVACUATED TUBE AND ONE WITH A THERMOSYPHON FLOW TUBE.

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1. Introduction

In order to diminish the environmental problems it is urgent to look for energy alternative sources that help to decreasing of pollutant agents, besides taking advantage of the renewable resources, as it is the solar energy case, especially in a country like Mexico, that receives a high solar radiation quantity, 25 MJ m^{-2} day^{-1}, but is even in an incipient development and use of this technology.

In Mexico the use of solar heating water technology is gradually growing. The design of flat plate finned tubes solar collector has dominated the market and has a great number of national manufacturers of this equipment. Nevertheless, in the last five years, the technology of solar collectors of evacuated tubes produced abroad, are becoming to dominate the national market and now exist a great amount of solar distributors of this equipment that begins to displace the solar manufacturers at the country.

However, the evacuated tubes solar collectors, by their own design, enormously low their yield by the amount of accumulated fouling in the tubes, especially when high content of hardness water (more than 250 mg L^{-1} like calcium carbonate) is used, what it is very common in our country.

With this problem occurring in the evacuated tubes of solar collectors, we have proposed to redesign a system of evacuated tubes in order to have a tube with an entrance and one exit emulating to a finned tube in a thermosyphon flow in opposition to the classical evacuated tube, in order to observe the differences in efficiency of both systems [Morrison, 2001] and [Budihardjo I].

The hypothesis of the present work was that the evacuated tube must be open on both sides, thus promoting a straightforward thermal circulation of the work fluid into the tube to the water thank, increasing the thermal efficiency in relation to the classical evacuated tube set-up, which has only one open side.

2. Experimental

In figure 1, a photograph of the experimental setup in operation it is depicted. The difference between both devices studied is that a system has an entrance and one exit emulating to a classical finned tube of a flat plate solar collector. The other device is constituted of a solar absorber tube, one side open and the other one closed. It is supposed, that the tube with an end closed, could diminish its thermal efficiency, because the flow may be move more slowly, extracting less heat, because the cold water entrance and the exit of the hot water towards the storage thank it is on the same tube edge; thus seems difficult the water movement.

Several experiments were performed for both evacuated tube designs. Each one was coupled to a storage tank. We tested several water volume in each system (10-30 L) performing simultaneously the experimental measurements in both set ups. We measured temperatures, using a K-type thermocouple along the tube and in the storage tank. We measured in a concurrent way the incident solar radiation using an Eppley pyranometer model PSP.

Fig. 1. Photo of the solar collector experimental set up, one system with a water storage and a solar absorber tube with a recirculation tube, one entrance and one water exit. The other system equivalent to the first one, but the solar absorber tube without a recirculation tube, one end closed.

3. Results

It was difficult to use the thermal data recorded along the tube, due to the complex variability of the measured temperatures. So, we proceed to evaluate the thermal efficiency using the water temperature data of the completely mixed thermotank.
Based on the experimental results and on the known thermal equation balances, we can determine the thermal efficiency of each system and we could establish that quite similar thermal efficiency is obtained for low water volume in both system. Increasing the water volume, a slight difference in thermal efficiency was observed.

The solar collector thermal efficiency is determined by the next factors as it is ascribed by Duffie and Beckmann.

a) Tube solar collector design (optical properties, material used)
b) Solar radiation incidence.
c) Environmental condition (Ambient temperature and wind speed)
d) Operation conditions. (Fluid flow speed, fluid temperature and thermal properties.

In this case, the thermal efficiency of the solar collector, η, was determined from equation 1.

$$\eta = \frac{Qu}{Qr} \quad \text{(eq 1)}$$

Where Qu is the useful heat output given by.

$$Qu = mCp(Tf - Ti) \quad \text{(eq 2)}$$

Where Tf=temperature of fluid on a thermal tank (completely mixed) at final time
Ti=temperature of fluid at the initial time.
M= total fluid mass in the thermal tank and the tube solar collector.
Also, Qr is the total solar energy received in a fixed interval time given by.

$$Qr = GA\Delta t \quad \text{(eq 3)}$$

Where G= total solar radiation (Wm^{-2})
A=collector area, (m^2)
Δt=fixed interval time, (s)

The efficiency of both solar collectors is supposed to depend only on the collector construction, that means, if the system is having one inlet and one exit to the thermal tank or if the tube solar collector is having one inlet, which is the same that the exit to the thermal tank, like the typical evacuated tube solar.

Figure 2, 3, 4 and 5, 6 and 7, represent the thermal profiles, the measured solar radiation and the calculated thermal efficiency, during the time of experimentation for two typical days measurement corresponding to two water volumes used. In general, small variations in the measured temperatures are observed as well as like in the calculation of the heat efficiency gained in the monitored thermotank, under a condition of full mixed fluid inside.

In general, and considering that the incident solar radiation levels and other physical parameters are quite similar on the tested devices, it is observed that the system with smaller mass water, seems to show higher efficiencies of heat collection that when the water mass is major. Nevertheless the thermal profiles and the thermal efficiencies of the system with recirculation respecting to the system with tubes closed by an end, do not seem to be significant, and the thermal efficiency variation seems to fall within the corresponding experimental errors associated to the measurements estimated in ± 3%.

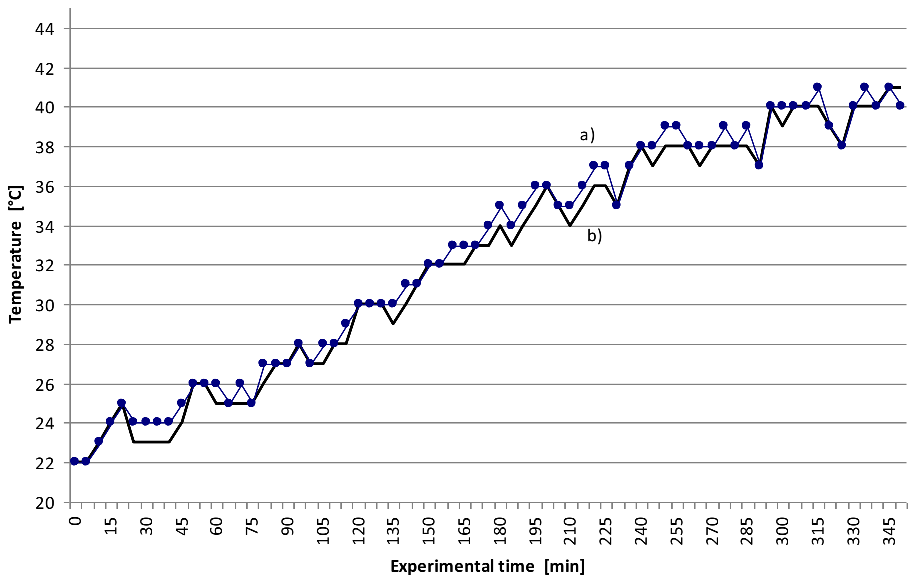

Fig. 2. Thermal profile for a tube with 20 L water in a storage tank with a) recirculation tube system and b)Without recirculation. The time 0 correspond to 9.55 AM initial measurement experiments, 2 may 2011.

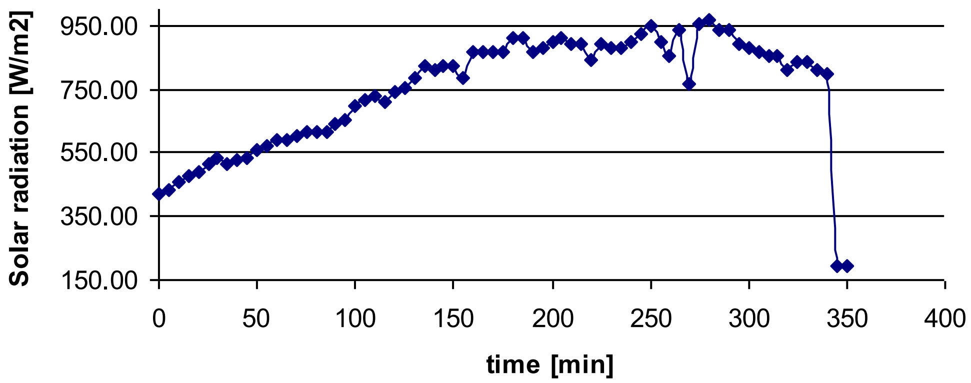

Fig. 3. Solar radiation as a function of the time. The time 0 correspond to 9.55 AM, 2 may 2011.

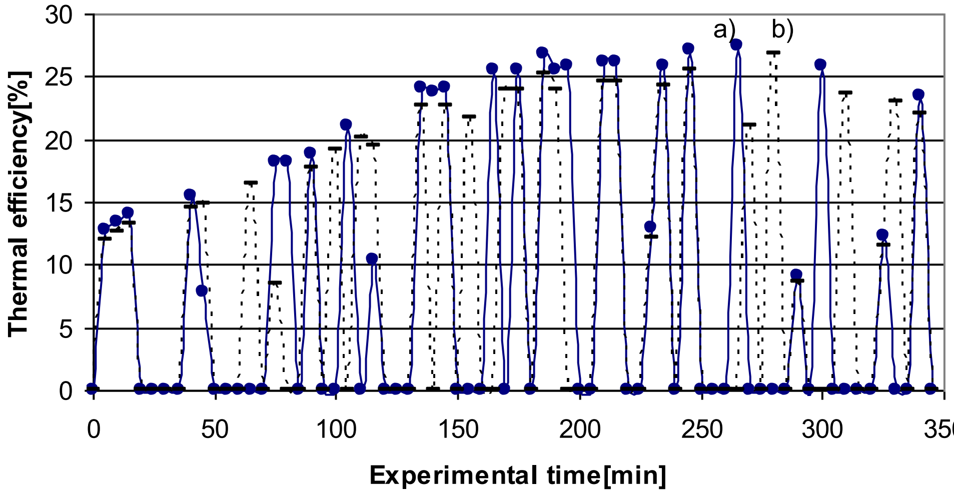

Fig. 4. Thermal efficiency as a function of the time of the day. a) recirculation tube system and b) Without recirculation. The time 0 correspond to 9.55 AM, 2 may 2011.

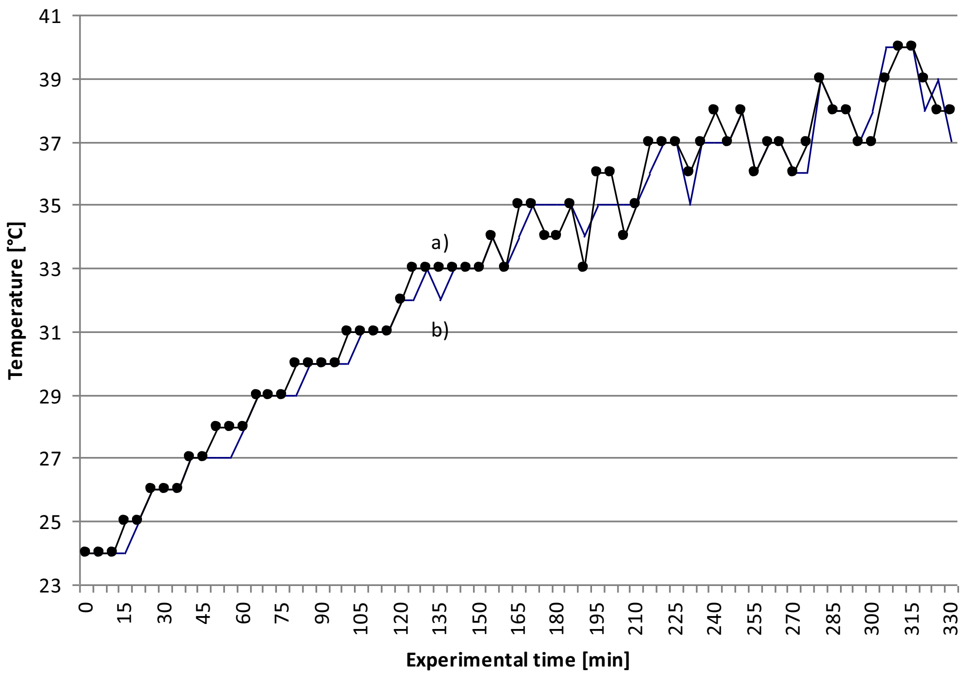

Fig. 5. Thermal profile for a tube with 25 L water in a storage tank with a) recirculation tube system and b) without recirculation. The time 0 correspond to 10.00 AM initial measurement experiments, 26 April 2011.

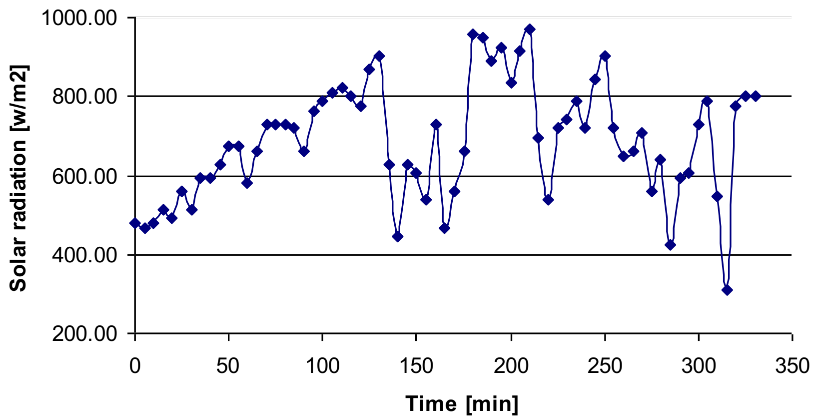

Fig. 6. Solar radiation as a function of time of the day. The time 0 correspond to 10.00 AM, 26 April 2011.

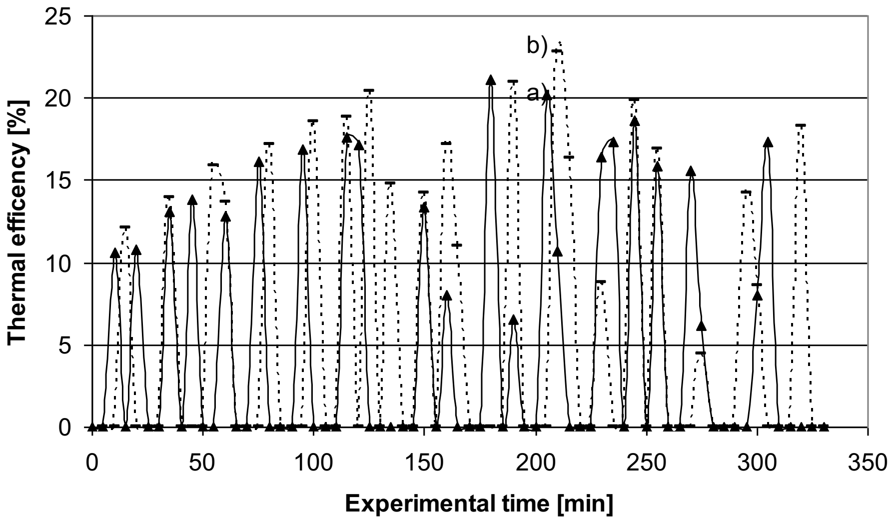

Fig. 7. Thermal efficiency as a function of the time of the day. a)recirculation tube system and b)Without recirculation. The time 0 correspond to 10.00 AM, 26 April 2011.

4. Conclusions and suggestions.

The thermal efficiency values calculated practically no differ according to set up design used. For large water volume on the storage tank, the efficiency of the tube having recirculation is slightly increased in relation to the conventional evacuated tube with only one open side, but in fact, a small difference in the thermal efficiency on both types of solar tube designs used in this study, practically fall within the experimental error of the measurements. That means that there is not any significant practical difference between both models used.

In spite of this surprising result, that shows that the design of the classic evacuated tubes, one closed end, is very efficient from the thermal point of view and it has an equivalent thermal efficiency to the termosyphonic flow with recirculation, we want to insist on proposing that the classic designs of evacuated tubes, must be modified with systems of both open sides, recirculation tubes.

The reason to support the previous comment, does not obey to thermodynamic questions, but rather practical reasons, that will help to extend the life period of the solar system, because it is a fact that such systems, at countries like Mexico that has very hard water to a large extent on the country, reaching more than 250 mg/L total water hardness, the system with open tubes will must be preferred that the classic system with one end closed.

The authors have observed in diverse solar collectors facilities, that there is a lot of evacuated tubes systems that in some years lose their efficiency because the tubes fill of fouling solids of the nonpermanent hardness. In some cases, it has been observed dramatically solar collectors fails, due the water solid hardness that precipitate and store in the tubes, flooding it with precipitated solid salts that sometimes cause catastrophic faults, in operation periods between 3 and 6 months. This happens, especially when it does not occur maintenance labor to these systems, as it is usual in the great majority of the systems in operation, by the lack of personal specialized in this matter.

We believe that if the system of open ends tube is adopted, it would not occurs the solid deposit in the tubes (decreasing the efficiency by fouling deposits) but in the tank of hot water, that it must be supplied of a drainage valve to eliminate solids after a certain time. Thus, improvements in the design, would generally extend the useful life of the solar collectors which by thousands already flood the Mexican market and the entire world.

Also, the redesigned evacuated tube could avoid the fouling accumulation inside the tubes, therefore eliminating or diminishing the more frequent maintenance labors as is required for the conventional solar evacuated tubes.

5. References

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