Design of a Wall-Heater-Solar Water

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ABSTRACT

In this article, two different conceptions of a wall solar water heater, one has the integrated storage and the other in thermosiphon with innovation consist on removing any connection by a thread and/ or internal welding of the sensor and the storage of hot water have been built and tested. The design of the new type of solar water heater integrated with facades is coming after a pre-required and previous studies, namely the knowledge of the Constitution of the solar water heater with its two components the sensor and the storage, the existence of the concept of the wall Trombe well-known as well as the heating by facade itself formed by the solar sensor in air. Our work leads to the innovation of wall solar water heater with integrated storage, where the sensor and the storage are an integral part of the general design of the building and a wall thermosiphon solar water heater, where the sensor is in the facade and the storage to the interior. The benefits of the integration of the solar water heater to the facades are the improvement of the architecture of the building "be more aesthetic", reduce the cost of the device and better intercept the solar rays in winter where the hot water needs are the most important. The prototypes built have been tested during three successive days in July 2017 under a clear sky without a cloud for a climate of South Tunisian "Gabes". The climate parameters (ambient temperature, solar flux) have been followed and it was determined the effectiveness of the devices. The performance obtained from solar heating system to the water is very encouraging and it outperforms the existing systems of solar sensors. In effect, the two configurations of the solar water heater wall, with integrated storage (IWSWH) and thermosiphon (ThWSWH) have leads to thermal performance of the order of 50% and the temperature values very satisfactory for the obtaining of the hot water (lukewarm) with a maximum value of 40°C for ThWSWH and 50°C for IWSWH.

INTRODUCTION

The energy is always a matter of concern of human societies. All activities and human behaviors are strongly related to its abundance or its shortage. To do this, researchers and scientists do not cease to develop energy alternatives effective to reduce dependence on fossil fuels. As well, the transition to other sources of energy that are renewable, clean and free constitutes an adequate solution. Among the resources of renewable energy, solar energy is a resource exploited since long seen its pervasiveness, its abundance and its sustainability. The solar energy is generally used to ensure the energy needs of buildings mainly electricity by photovoltaic panels, heating or cooling of premises and provision of the freshwater through the solar thermal collectors. Consequently, these solar systems and especially the solar water heaters of sanitary water are widely known, but some disability brakes their use. We cite their high cost even if the water heaters are subsidized and the need of the maintenance continues to cause of the leaks, they are non-functional. As well as some architects are opposed to the use of the solar water heater the fact that aesthetically the latter is regarded as a foreign body on the structure of the building. It is necessary therefore to find an adequate solution to all these problems to generalize the application of solar water heater even in the social layers the less affluent. The integration of the solar water heater to the building is a means to reduce the cost of the installation of this system which can be built locally by the mason even during construction and improve the aesthetics and the form of the architecture of

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the building while integrating in the envelope of its way to make the heating of the sanitary water by the solar thermal collectors more profitable. Indeed, the performance of the solar water heaters conventional, mounted on the roofs, is out of step with the needs because the hot water needs are more important in the winter as in the summer, the period where the sunlight is naturally more low and as well as the sensors are very often weakly angled according to the rule: Tilt equal latitude of the place (I=φ). While the solar rays are quite low in winter even at noon, so that the sensor receives very little of solar energy. In addition, the location of the solar sensors on the roofs especially for a residential building in several floors it has a large number of occupants have hot water needs, presents a problem of space since it must provide for each owner a separate surface to its sensor and its storage tank, adding the thermal losses primarily crucial for a building very high. From these findings, it was the idea to use the wall areas to integrate the solar water heaters on the facade of the buildings. In effect, the sensor plane will be installed in front of the brick of the regular wall so that it will be an element of the envelope of the building except that it adds an absorber and glazing in front with a good insulation. As well, the integration of the facade leads to the performance very satisfactory of solar water heaters if we are going to address the concept of different sides. The side aesthetic and architectural must be well studied to facilitate their acceptability by the users, as well as other technical rated and practices must be examined, such as the problem of overheating in the summer, as a result, the expenses of the cooling of the Interior of the building increased when this summer period which can be avoided by a proper isolation of the wall and the sealing to the water from the rain. The solar sensors installed vertically in front have already proven their effectiveness in two applications: the wal Trombe well known for the passive solar heating and solar air collectors for heating active. Various researchers have published in the concept of the wall Trombe. They have studied the place of flow of the air: between the window and the wall or between the wall and an Insulator Interior, the number of windows, with or without insulation, store and ports of air maneuverable or not [1-6]. In fact, in Trombe wall the sensor is a storekeeper, consisting of a concrete wall painted in black on the outside and a window to reduce the losses thermal and create the greenhouse effect. The movement of the air is done naturally through holes at the top and bottom of the wall under the effect of the difference in density. In effect, the warm air is lighter than cold air, then in limbering up; it shows to the top by causing a Low depression side which draws the air from the inside of local and the heating. To avoid the problem of overheating, several solutions are envisaged such as the overrun of the slab and the exhaust air to the outside of the upper side of the wall. This technique is useful because it allows us to eliminate the phase difference between the performance of the system and the needs of users. The vertical position of the sensor enables of well intercept and absorb solar rays in the winter, the period where the needs for heating are essential. On the other hand, the air solar sensors to air placed in existing facades are compact with good performance view the vertical position of the sensor and the fact that the solar rays are low in winter [7-10]. Hengstberger et al. have shown the influence of the heating by the vertical wall especially if it includes a phase change material [10]. In this innovation, we are going to build two solar water heater built into the vertical wall, in the manner of the Trombe wall and test their performance for a climate of the Tunisian south. Our prototypes of solar water heaters wall coverings have been tested in the summer period and they provide satisfactory results at the level of thermal performance and of the values of the temperatures achieved. As well these prototypes can only be efficient in winter.

Construction of Solar Water Heaters Integrated With the Facade of a Building

Units built are integrated to the facade of a building in such way that they will be a part of its envelope. As well, it has built two solar water heaters The Wall "embedded in the facade" according to two configurations: a sensor to integrated storage and the thermosiphon.

Solar water heater to wall integrated storage

This vertical design allows us to intercept the maximum solar radiation in winter, where the solar rays are low and the need for hot water is essential. However, this position of the sensor prevents the problem of overheating in the summer. The unit has been locked in a wooden frame of approximately 0.62 × 0.42 m and 220 mm thickness mounted on a wall of a vertical brick 100 mm of thickness. In the framework, an insulating layer of polystyrene with a thickness of 50 mm. Before the insulation, a layer of a concrete dyed black mate of 50 mm in thickness to operate as absorber solar irradiation and storage of heat and a copper tube of 14 mm diameter in the form of an emergent serpentine in the layer in concrete playing the role of a heat exchanger. Finally, the system was covered with a polycarbonate window with a thickness of 5 mm. The unit is placed on a metal support to facilitate the orientation of the sensor. The integration of the solar water heater to the facade of the building and the use of concrete as absorber and storage of heat allows to reduce its cost and generalize its application even in the social layers the less comfortable view its construction locally by the mason even at the time of the construction of the premises. **Figure 1** shows the prototype built the wall solar water heater to integrated storage.

Figure 1. Wall solar water heating to integrated storage according to two different views (IWSWH).

This sensor is very profitable and gives the hot water at high temperature on the day, yet the night cooling is important. Several solutions are envisaged to remedy this problem, such as the double glazing where well return to the classic storage with traffic in thermosiphon which will be discussed in the next part **(Figure 2)**.

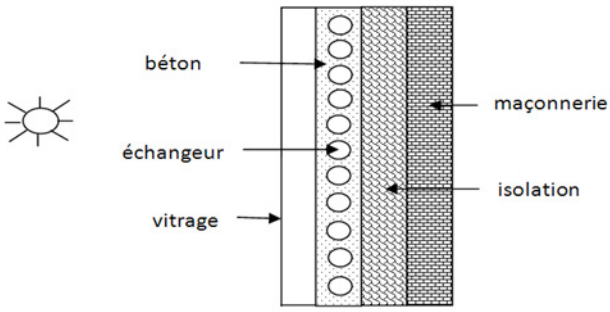

Figure 2. Block diagram of the wall solar water heater to integrated storage built in.

Solar water heater to wall thermosiphon

This configuration of the solar water heater guarantees as for the previous configuration "IWSWH" The uptake of maximum solar radiation view its vertical position. In addition, it allows reducing the night cooling while separating the flask of storage of the sensor that can be plastic instead of a metallic tank and it is possible to place it at the interior. As well, innovation is made with our prototype to reduce maintenance and extend the life of our system by avoiding any connection (solder and thread) to the inside of sensor and balloon. Our prototype is composed of a solar sensor and a balloon of storage. The solar sensor is mounted on a wall of a vertical brick of thickness 100 mm and consists mainly of a sheet- metal plate of copper in 1 mm thickness, painted in matt black playing the role of an absorber placed in front of a layer of polystyrene with a thickness of 50 mm. On which a copper tube of coiled tubing form and a diameter of 14 mm is fixed. The entire unit is surrounded by a wood frame, sized, 0.62 m × 0.42 m and thickness of 183 mm and is covered with a polycarbonate layer of 5 mm.

The sensor heats the clean water which rises by effect thermosiphon and flows to the flask of storage, which is a plastic tank. The connection of the conduct of the heat transfer fluid and even the intake lines and refinement of the sanitary water at the level of the storage are at the top of the ball. **Figures 3 and 4** explains the principle of operation of a solar water heater to wall thermosiphon "ThWSWH".

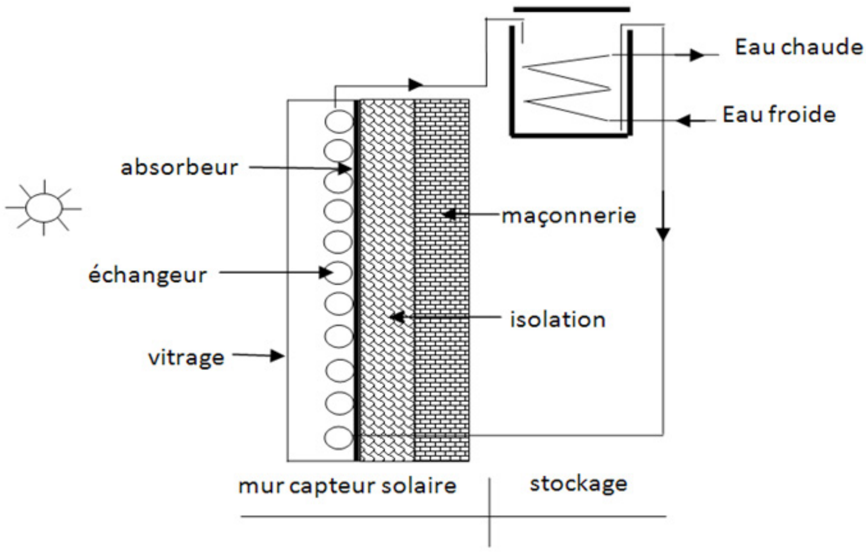

Figure 3. Block diagram of a wall solar water heater to thermosiphon.

Figure 4. Wall solar water heater to thermosiphon "ThWSWH" according to two different view.

Prediction of the Temperature of the Water to Achieve

To find the temperature reached by the water heated in function of the other parameters and characteristic of the system for a sensor placed on the front of South orientation, we are writing the energy balance of the water heater:

The absorptive surface of the sensor absorbs the fraction of solar radiation IN Transmitted by the window ($_v$: A fraction reflected by the glass of the radiation emitted by the black surface ($\tau_v.IN\ .\rho_a$) and radiation emitted by the cover of the fact of its temperature T_v Toward the black surface ($\tau_v.IN$). It emits by its black face ($\varepsilon_a.\ \sigma\ \left(T_a^{\,4}-T_v^{\,4}\right)$) In the direction of the glass. As well:

$$\Phi_s = \Phi_r + \Phi_{em} - \Phi_v \quad (1)$$

$$\tau_v.I_N = \tau_v.I_N\ .\rho_a + \varepsilon_a.\ \sigma\ \left(T_a^{\,4}-T_v^{\,4}\right) - \tau_v.I_N\ .\rho_a.\ \rho_v \quad (2)$$

Therefore:

$$\tau_v.I_N - \tau_v.I_N\ .\rho_a + \ \varepsilon_a.\ \sigma\ \left(T_a^{\ 4} - T_v^{\ 4}\right)\ -\ \tau_v.I_N\ .\rho_a.\ \rho_v = h.S.(T_a - T_{eau}) \tag{3}$$

$$T_{eau} = T_a - \frac{\tau_v.I_N.(1-\rho_a + \rho_a.\ \rho_v) - \varepsilon_a.\ \sigma\ \left(T_a^{\ 4} - T_v^{\ 4}\right)}{h.S} \tag{4}$$

Or even based on the actual measurements and the method of input-output which is to balance the heating energy of the water and the outcome of the sun to the calculation of energy efficiency:

$$\eta = \frac{m.cp.(T_{ef} - T_{ei})}{I_N.S} \tag{5}$$

$$T_{ef} = T_{ei} + \frac{\eta.I_N.S}{m.cp} \tag{6}$$

Where, m : Equivalent Mass in water to heat up; S : Incident solar flux on the sensor; S : Area of the surface for the Up-take of m², T_{ef} : Energy Efficiency of the sensor, T_{ef} : The temperature of the water measured at 19h, cp: The temperature of the water measured at 7h, cp : Mass heat of the water.

Evaluation of the Performance of Two Prototypes Built

Solar water heaters have been tested in South Tunisian "Gabes" during three successive days without cloud, under a clear sky (09-10-11/07/2017). The solar radiation incident on the sensors oriented to the south-east, the ambient temperature as well as the temperature at the outlet of the heat transfer fluid (water) is measured.

The performance of the prototype is estimated by the method input-output. It is defined as the quotient of the useful energy on the incident energy on the sensor.

Wall solar water heater to integrated storage

Figure 5 shows the evolution of the solar flux, ambient temperature and the temperature at the outlet of the water as a function of local time during the three days of the experimental test. The solar flux density presents the same pace during the three days of measurement. It increases at the beginning of the day and reaches its maximum of approximately 350 W/m² to 12h and decreases progressively toward the end of the day. As the sensor is a vertical wall, it is logical that the solar flux intercepted is reduced and weaker than in winter of the fact of the obliquity of solar rays vis-a-vis the vertical plane of the wall. The temperature of the outlet of the water increases at the beginning of the day in passing through a maximum at 13 h equal to 50°C and then it begins to decrease toward the end of the day slowly. It was found that the temperature of the water increases some degree for the 2nd and third day compared to 1 day [11-15]. As well as the ambient temperature presents the same pace than that of the water except that its maximum is reached toward 15 h instead of 13 h for the temperature of the water. In effect, the proposed prototype reaches a value of temperature very sufficient for the obtaining of the hot water and it stores the thermal energy for a long duration until the end of the day with a temperature value to the surrounding of 44°C to 17 h despite the vertical position of the sensor which is unfavorable for the summer period, period of measure. The performance of our unit built in function of the standardized gain is presented in **Figure 6**. The effectiveness of the IWSWH is acceptable given the thermal losses of the system as well as the measurement period and the position of the sensor that does not allow to intercept the maximum radiation and it reached 50%. According to **Figure 6**, one finds that for a standardized gain of 0.059 W°C/m², it has an increase in the temperature of 59°C for a solar flux from 1000 W/m², the sensor reaches a yield of 37%.

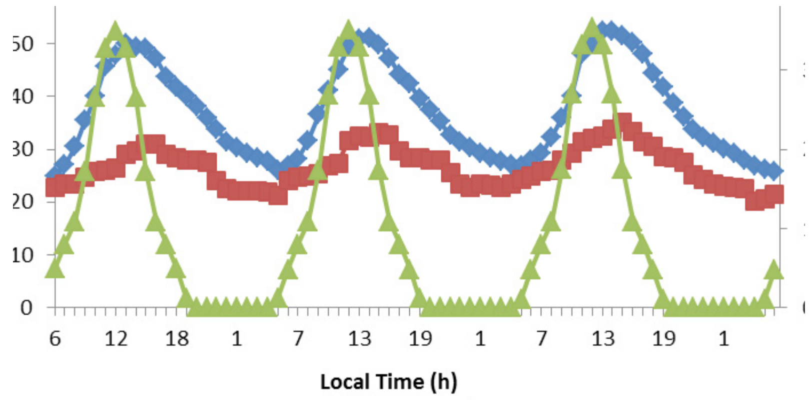

Figure 5. Variation of the incident solar flux, the ambient temperature and the temperature at the outlet of the water of the IWSWH according to the local time during three successive days (9-10-11/07/2017).

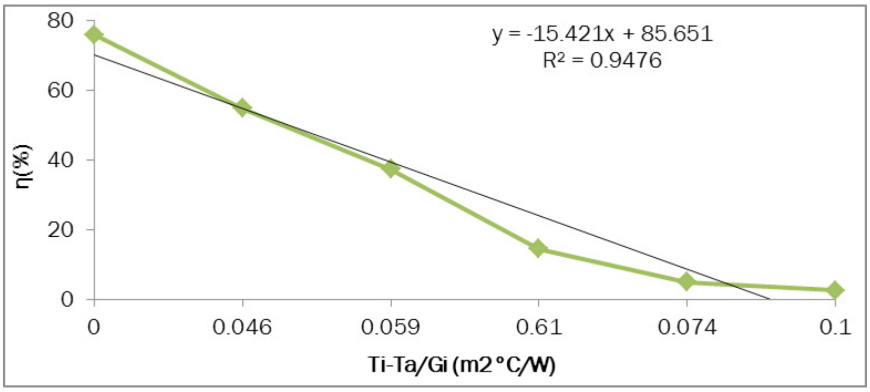

Figure 6. The effectiveness of the IWSWH according to standardized gain during the day of the test (9/07/2017).

Wall solar water heater to thermosiphon

We have measured the temperature of the water in the top and bottom of the storage reservoir and then calculated the average. According to **Figure 6**, the water temperature and the ambient temperature follows the same pace. The water of the storage heats up gradually at the beginning of the day to reach its maximum toward 15 h and then it begins to cool gently toward the end of the day. The value of temperature reached is not too high; it is around 40°C. This avoids the problem of overheating in summer and the higher the level of the temperature requested during this period is often not high enough. The experimental test shows that the Prototype tested is profitable. In effect, for measures in been "July 2017" and with a vertical sensor, the position that intercepts less of the solar radiation during this summer period or the warm water needs weaken, our water heaters built show this yields important thermal that exceed 50%. According to **Figure 7**, for a standardized gain of 0.059 it has an increase in temperature of 59°C for a stream of 1000 W/m², the ThWSWH shows a performance of 31% [16].

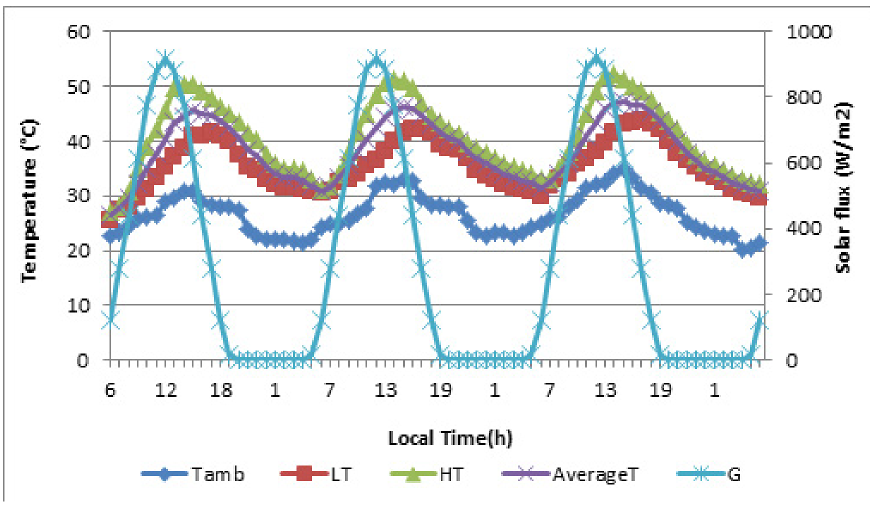

Figure 7. Variation of the incident solar flux, the ambient temperature, the temperature high, low temperature and the average temperature of the water in the storage tank in the ThWSWH according to the local time during three successive days (9-10-11/07/2017).

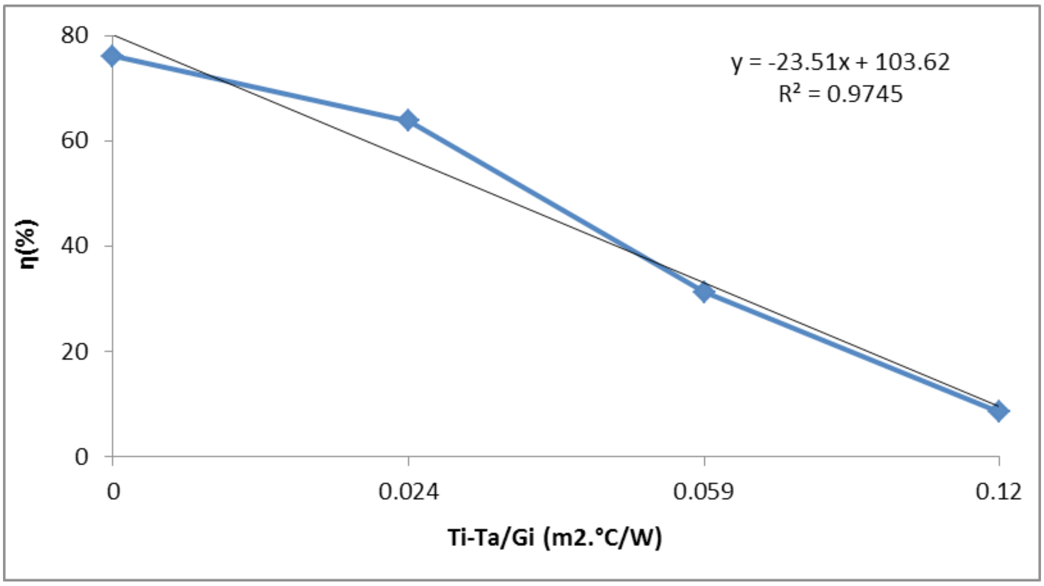

Figure 8. Effectiveness of the ThWSWH according to standardized gain during the day of the test (10/07/2017).

CONCLUSION

The objective of this work is the integration of heating of the sanitary water in front of the building in the same way that the Trombe wall or heating of the premises by the facade. In this framework, two prototypes of solar water heater built into the facade of two different configurations, integrated storage and thermosiphon have been built and tested. The experiments are carried out in the south of Tunisia in July 2017 for three successive days and under a clear sky **(Figure 8)**. Given the high solar radiation in the south of Tunisia and with a fraction of Sunshine has already reached in February 70% the system can only be efficient, which is confirmed by the experimental test. In effect, the system to thermosiphon presents a performance of approximately 60% and allows us to reach the temperature values acceptable passing by a maximum of 40°C [8]. As well as the solar water heater to integrated storage shows the efficiency of the order of 54% and the temperature values high of 50°C. By having a height of the sun high enough to its maximum during the period of Measurement " hot period of been" and for a wall sensor vertical, the perception of the solar radiation is therefore reduced. As well, the maximum efficiency calculated in our prototypes is favourable and acceptable for a summer period. In addition, in the summer the needs in a quantity of hot water are not important and the temperature level of the water requested is often not high then the returns achieved by our prototypes and the temperature of the water reached are sufficient for the obtaining of the hot water (lukewarm) in the summer especially that the climatic conditions are favourable. However, in winter the height of the sun low enough especially in January (the coldest month), the vertical wall is going so well the intercept and thus transmit the heat to the water to heat up. Therefore, the system performance will be improved and the temperature values will be very high in such a way to ensure the needs in hot water.

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