SYSTEM OF HEATING OF SWIMMING POOL FOR SOLAR ENERGY

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Abstract *A swimming pool heating system is presented, composed of two alternative collectors with serial PVC absorber tubes that work in regimen of forced stream that is gotten through a bomb. A 500 liters reservoir was used, simulating the swimming pool, being raised some data that show the viability of the considered system. The chosen outflow was corresponding to 100 l/h. In function of the low outflow it was necessary the use of a not popular bomb, choosing the use of a low outflow alternative pumping system, using an air conditioner engine with three different rotations for the desired end. The thermal data related to each collector and their developed system will be presented. The UV and thermal degradations of the PVC exposed to solar radiation will be also boarded, demonstrating the viability of using tubes of this material as absorber elements of radiation in water heating solar collectors.*

Key-words: solar energy, solar swimming pool, water heating, PVC tubes, alternative system.

1. INTRODUCTION

The swimming pools water heating, either for therapeutical use or comfort, constitutes one of the more viable applications of the solar energy, because of the economy advantages and efficiency that it presents in relation to other systems that use conventional energies. In our region, mainly in Natal, that presents three hundred sunny days in a year, the use of swimming pools heating is mainly for the nocturnal period because of the propitiated comfort. So, solar heating represents a sufficiently viable option of this energy source.

The collectors generally used for this purpose will have to be capable of keeping the swimming pool to a temperature around 30.0^{o}C, being generally used collecting polypropylene tubes, disposed in parallel, without covering or box. Such collectors present the problem of the fast consuming, generated for the levels of temperature that it reaches, once the propylene presents a great susceptibility to the UV and thermal consuming.

Another disadvantage of such systems is the necessity of great areas of collectors, about half of the swimming pool area. These collectors without covering directly receive the water from the swimming pool and it returns in the same outflow, with a temperature increase of more or less 2.0^{o}C. After some days of functioning it reaches the temperature of balance that is around 30.0^{o}C (Censolar, 2001).

This work presents an alternative system for swimming pools heating, using two alternative solar collectors with PVC absorber tubes, disposed in series in regimen of forced stream obtained through a bomb. The will be demonstrated thermal, economic and of materials viabilities of the considered heating system through parameters measured in the carried through tests. Also the thermal and for UV degradations of the tubes will be focused relative aspects to absorption of the solar energy of PVC tubes.

2. LITERATURE REVISION
2.1. ALTERNATIVE COLLECTORS

Alternative collectors are those that differ in constituent geometry, materials and elements in relation to the used ones in the confection of the conventional collectors. The main objective of the study of alternative collectors is the reduction of the manufacture cost a time that it represents 50.0% of the total cost of investment for the acquisition of a water heating solar system.

Exactly having long useful life, the heating solar systems require high initial investment, this explain the low tax of growth in the use of water heating solar systems in the world. The development of research is essential and has as bigger objective the attainment of systems of lesser cost with good thermal performance (Cristofari, C., 2002). With these purposes, some works have been developed, demonstrating that the plastic solar collectors of low cost present ample viability of use.

Souza (2002) showed the viabilities thermal, economic and of materials of a heating solar system composed of alternative collectors, also analyzing the inherent degradations to the use of the PVC when submitted the atmospheric variations.

2.2. The Thermal and Radiation UV Degradations Inherent to the PVC tubes

In a solar collector that it uses as absorber elements PVC tubes, the first raised question is about the inherent degradations by its exposition to the ultraviolet radiation and the heat. Literature shows that the susceptibilities to the thermal consuming of the PVC increases when they reach levels of temperature above of 60.0°C in its external surface. The degradation for UV also represents a restriction to the use of solar collectors with PVC absorber tubes, once those radiations with this wave length affect the mechanical integrity of this material tubes. (Souza, 2004).

3. MATERIALS AND MÉTHODS

The considered system presents the following components:

- Two alternative collectors using PVC tubes as absorber elements;
- A pumping alternative system;
- Box of 500 liters, simulating a swimming pool;
- Linking elements (Tubes, curves, registers);

The collectors with PVC tubes with diameter of 0.020 m and thickness of 0.0015 m, propitiate a bigger resistance to the levels of temperatures reached in the system. Some generations of alternative collectors that use PVC tubes as absorption elements had been constructed and tested and it was demonstrated the viability of use of collectors that use tubes of this material, also studying and quantifying the levels of degradation of these tubes when submitted to UV radiation and to the heat.

In the specific case, they are formed by a a wooden box box of 1.5 m x 1.0 m x 0.10 m, coated internally with woolen glass thermal isolation of 0.050 m, having as cover a transparent flat glass blade of 0.003 m of thickness. The geometry of the absorber coils that constitute an innovative element in relation to the collectors conventionally used are shown in Fig. (1). Two types of collectors, differentiated for the geometry of the coils used in both: wing and in labyrinth.

a) Wing geometry **b) Labyrinth geometry**

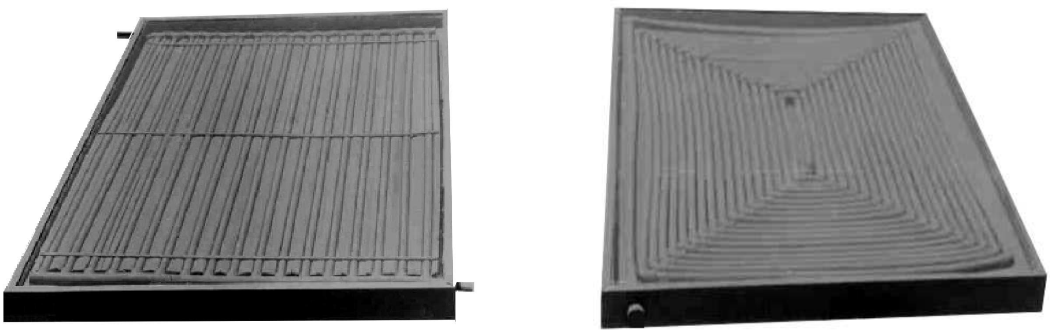

Figure 1. Collectors of the proposed system.

The pumping system consisted of a centrifugal pump model used for didactic ends, set in motion for an engine machine used in conditional air devices of corresponding power 1/15CV, and three levels of rotation. The chosen level of outflow was of 100.0 liters/hour in agreement recommends the Manual of Aplicaciones Practicas Censolar for the swimming pools heating system. A reservoir of 500.0liters was used to simulate a swimming pool, volume that if understood appropriate to demonstrate the thermal viability of the system of considered heating. For the regulation of the adequate outflow was used a register a time that the lesser produced outflow, for the lesser rotation, about 900 RPM, was around 0.7 m³/h.

The system in study, consisting of the two collectors in series, with the collector in labyrinth being the first one of them, was tested during eight hours, from 8am to 4pm, being raised the following parameters: global solar radiation, input temperature of the collector in labyrinth, output temperature of the collector in labyrinth, input temperature of the wing collector, output temperature of the wing collector, inside temperature of the swimming pool and ambient temperature. The measurements had been made to each 30 minutes. The system in screen meets shown in Fig. (2).

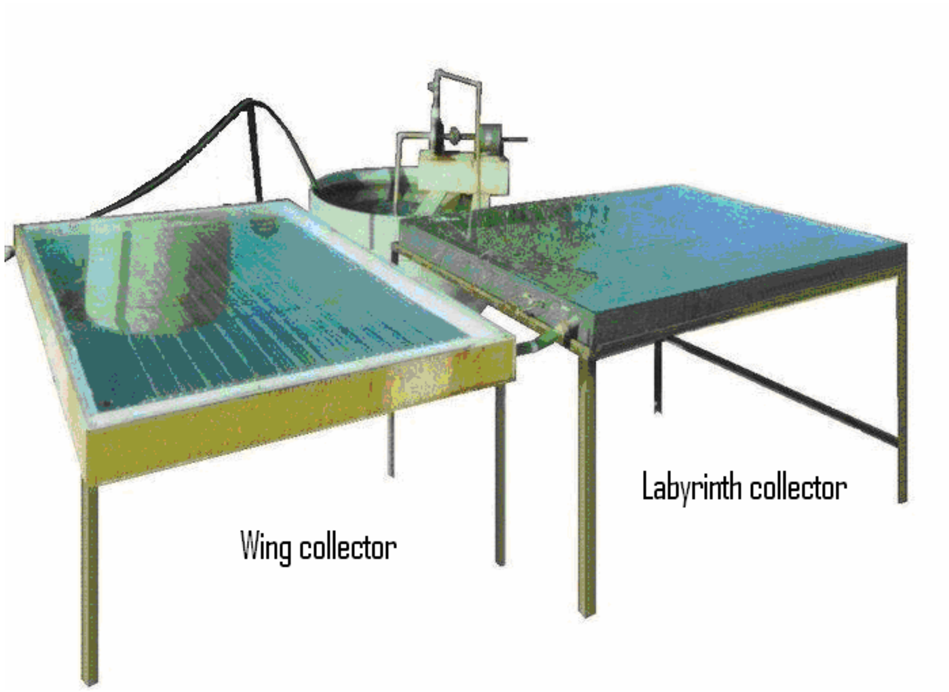

Figure 2. Swimming pool heating system in study.

The temperatures had been measured with the use of chrome-aluminum thermocouples coupled to a digital thermometer and global solar radiation was measured using an alternative low cost radiometer, constructed in the LES/UFRN (Souza, 2002). For the measure of the outflow an indirect method was chosen. It consisted of measuring the filling time of a container of known volume, corresponding to 1000 ml. Is standed out that the day chosen for test was practically without cloudiness.

The parameters that characterize the thermal efficiency of a solar collector are the thermal efficiency and the loss global coefficient. For the determination of the loss global coefficient was used Eq.(1). It also had been determined the absorbed heat (Q_{abs}) by the system, the useful heat transferred to fluid (Q_{useful}) and the system lost heat (Q_{loss}), determined by the equations (2), (3) e (4), shown to follow. Eqs.(5) will be used for the determination of the thermal efficiency (Duffie&Beckman, 1991, Souza, 2006, Gil, 2001).

$$U_{loss} = \frac{(\tau_v.\alpha_p - \eta_t)I}{(T_{pm} - T_a)} \tag{1}$$

Where:

τ_v = glass transmissivity (%)

α_p = plate absortivity (%).
η_t = thermal efficiency (%).
T_{pm} = plate average temperature (°C).
T_a = environment temperature (°C).

$$Q_{abs} = \tau_v.\alpha_p.\text{I.A} \tag{2}$$

$$Q_u = \dot{m}.c_p.\Delta\text{T} \tag{3}$$

where:

$\dot{m} = \rho.Q$ = mass outflow;

c_p = specific heat the constant pressure

ΔT = gradient of temperature of the fluid in the collector

$$Q_p = Q_{abs} - Q_u \quad (4)$$

$$\eta_t = \frac{Q_u}{A.I} \quad (5)$$

Where:

Q_u = useful total energy transferred to the work fluid, in kW.
I = global solar radiation, in kW/m^2.
A = = collector area, in m^2.
$\dot{m}$ = mass outflow, in kg/s.
c_p = specific heat of the water, in KJ/kg ^oC.
ΔT = temperature gradient between entrance and exit water, in °C.

The related equation will be used for the determination of the thermal efficiency of the collectors and the system for the period of 8:00 h to the 16:00 h, being represented by the Eqs. (6) and (7) respectively.

$$\eta_t = \frac{0.0774.\Delta T}{I} \quad (6)$$

$$\eta_t = \frac{0.0387.\Delta T}{I} \quad (7)$$

4. RESULTS AND DISCUSSIONS

The temperature data measured in test it was shown in the Tab. (1). The Tab. (2) shows the thermal performances of the collectors and of the system together with the levels of radiation, temperature in the interior of the swimming pool and hourly thermal efficiency. The behavior of these parameters can be seen through the graphs contained in the Figs. (1), (2), (3)

Table 1. Temperature data of the collectors and of the heating swimming pool system.

TIME (hour)	$T_{entrance}L$ (^oC)	$T_{exit}L$ (^oC)	ΔT_L (^oC)	$T_{exit}W$ (^oC)	ΔT_W (^oC)	ΔT_{SYSTEM} (^oC)	T_{SP} (^oC)
8:00-9:00	28.6	33.4	4.8	37.0	3.6	8.4	28.0
9:00-10:00	30.2	36.2	6.0	40.0	3.8	9.8	30.0
10:00-11:00	32.5	38.0	5.5	43.0	5.0	10.5	32.0
11:00-12:00	34.9	40.0	5.1	46.0	6.0	11.1	34,5
12:00 -13:00	36.9	42.5	5.6	48.0	5.5	11.1	36.5
13:00-14:00	38.4	43.0	4.6	47.0	4.0	8.6	38.0
14:00-15:00	39.3	42.0	2.7	45.0	3.0	5.7	39.0
15:00-16:00	38.5	39.5	1.0	41.0	1.5	2,5	38
Average	34.9	39.3	4.4	43.4	4.1	8,5	34,5

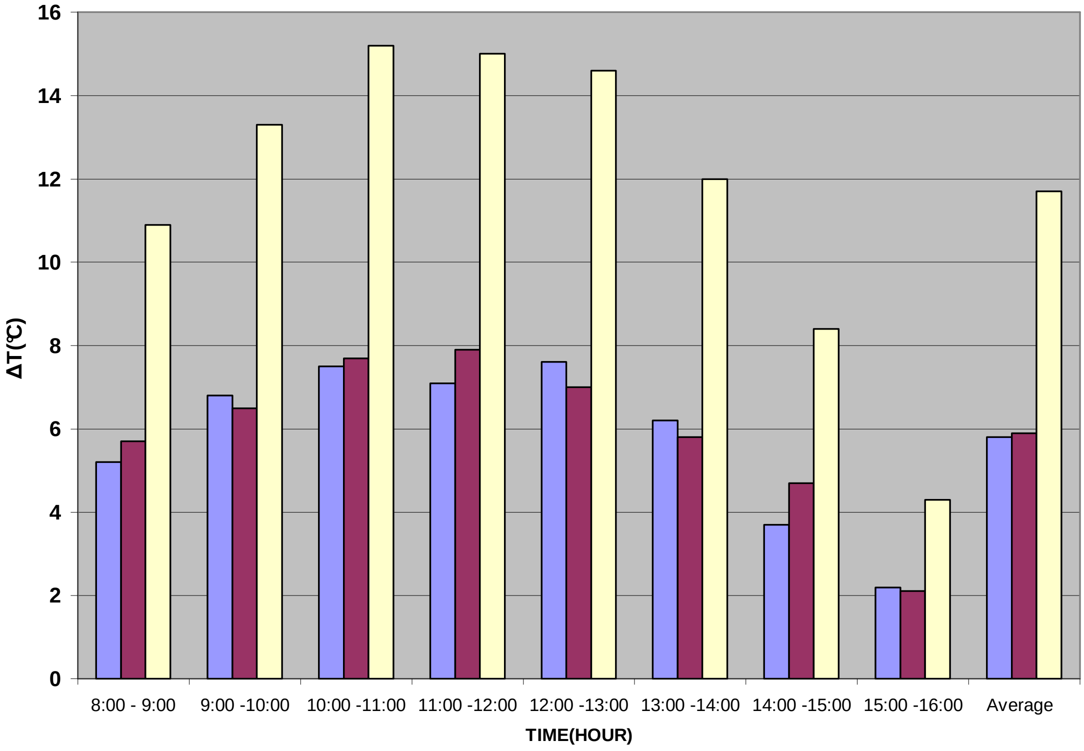

Figure 1. Behavior of the temperatures gotten in the collectors and the system.

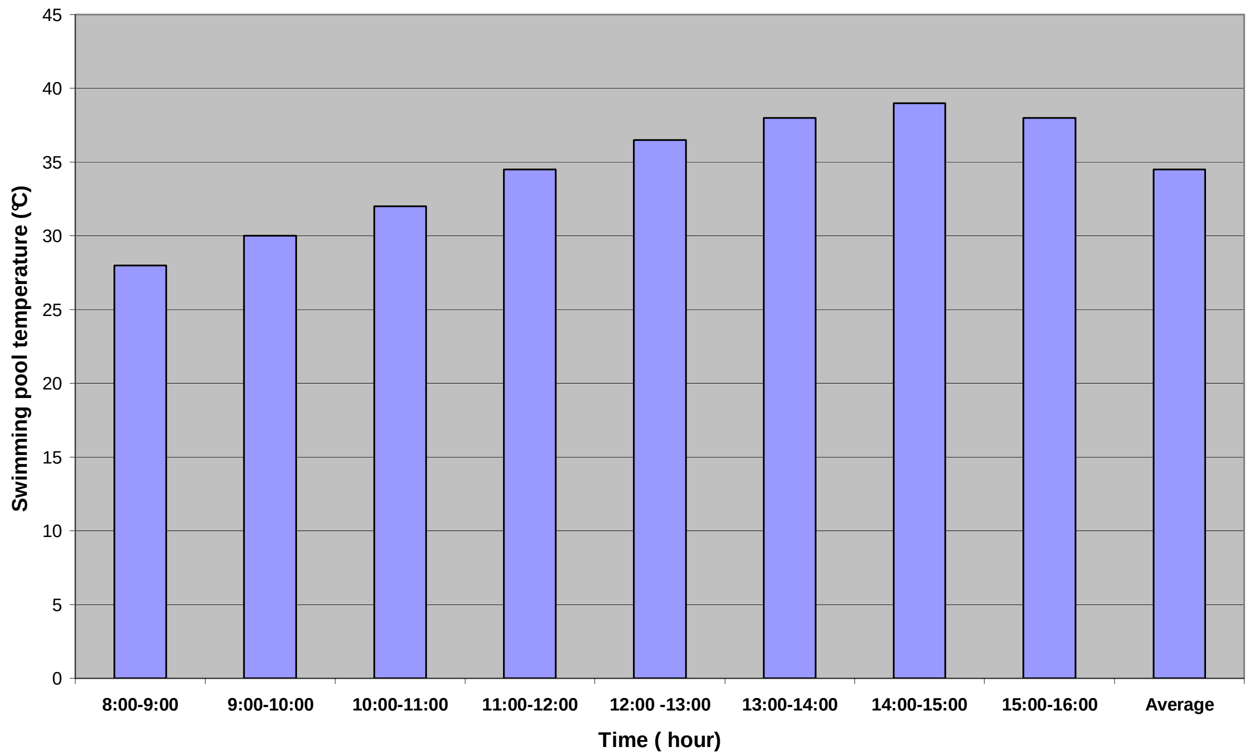

Figure 2. Levels of temperature in the inside of the swimming pool

Table2. Thermal efficiencies and global solar radiation.

TIME (hour)	$\eta_t L$ (%)	$\eta_t W$ (%)	$\eta_t S$ (%)	I (KW/m^2)
8:00-9:00	0.56	0.42	0.48	0.66
9:00-10:00	0.63	0.40	0.51	0.73
10:00-11:00	0.56	0.51	0.53	0.76
11:00-12:00	0.50	0.59	0.54	0.78
12:00-13:00	0.55	0.54	0.54	0.78
13:00-14:00	0.47	0.41	0.44	0.75
14:00-15:00	0.32	0.36	0.33	0.65
15:00-16:00	0.14	0.21	0.17	0.55
AVERAGE	0.48	0.44	0.45	0.71

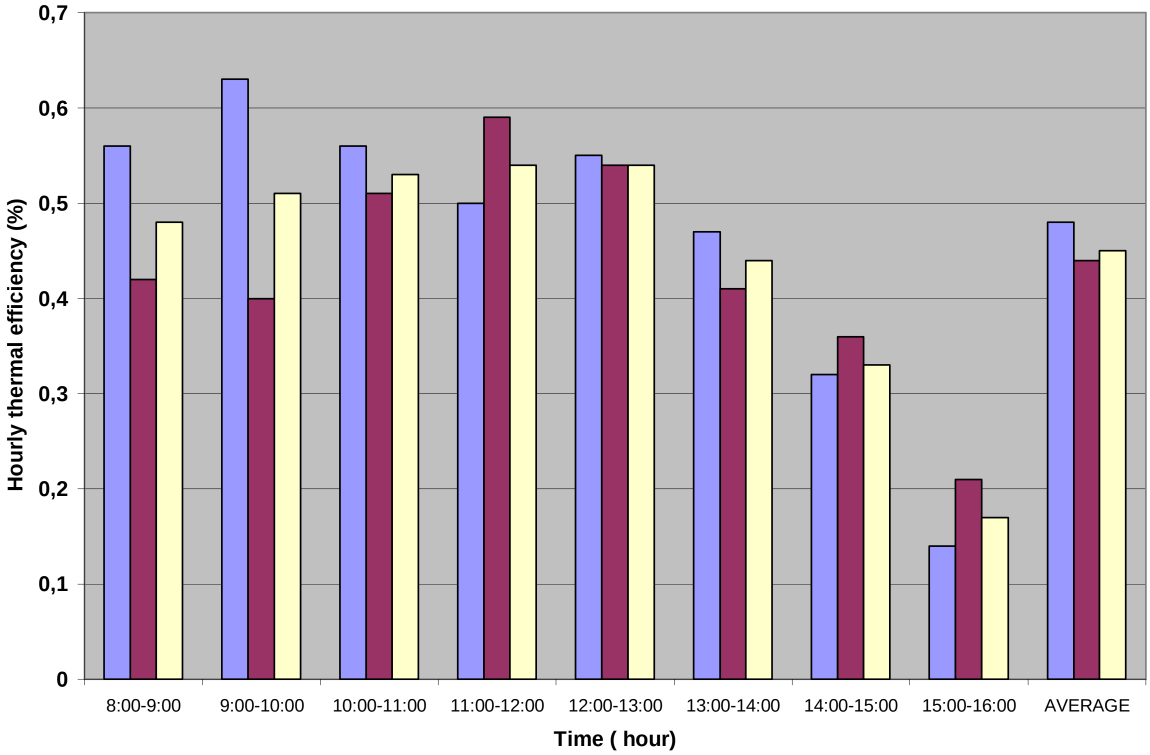

Figure 3. Hourly thermal efficiency of the collectors and of the system.

By the analysis of the data measured is perceived that both collectors had shown themselves viable for the considered use, having almost identical and sufficiently significant gradients of temperature for a 100 liters/h outflow. The maximum reached gradient was 5.6 ^oC for the collector in labyrinth and 5.5^oC for the wing one. In respect to the system the maximum reached gradient was 11.1 ^oC. The maximum temperature reached by the system, with the two collectors in series, was of 48.0 ^oC. With regard to internal temperature of the swimming pool the reached maximum value was 39.0^oC, sufficiently above of the described ideal temperature for literature around 30^o C.

In respect to the thermal performance the collectors had presented practically the same levels, 48.0% for labyrinth and 44.0% for the wing one, being wing a little more efficient. The performance of the system was also sufficiently next to these values reaching an average value to 45.0%. The average global solar radiation was of the order of 700 W/m^2, in accord with the literature (Bezerra, 2001), that points the Brazilian Northeast annual average global radiation in the band of 500.0 – 700.0 KW/m^2. Standing out that the test of the system occurred in one privileged month in relation the reception of the solar energy in our city, in October**.**

Table 3 shows to the levels of temperature of the external surface of the absorber tubes for the tested levels of outflow. The shown values had been measured in some points of the absorber grid of the collectors that constitute the system. Figure 4 shows the comportment of this parameter.

Table 3. Minimum, average and maximum temperature in the external surface of the PVC absorber tubes

SYSTEM	Q (l/h)	$T_{min.}$ (°C)	$T_{max.}$ (°C)	T_{ave} (°C)
(Labyrinth +Wing)	100	42.5	48.1	45.0

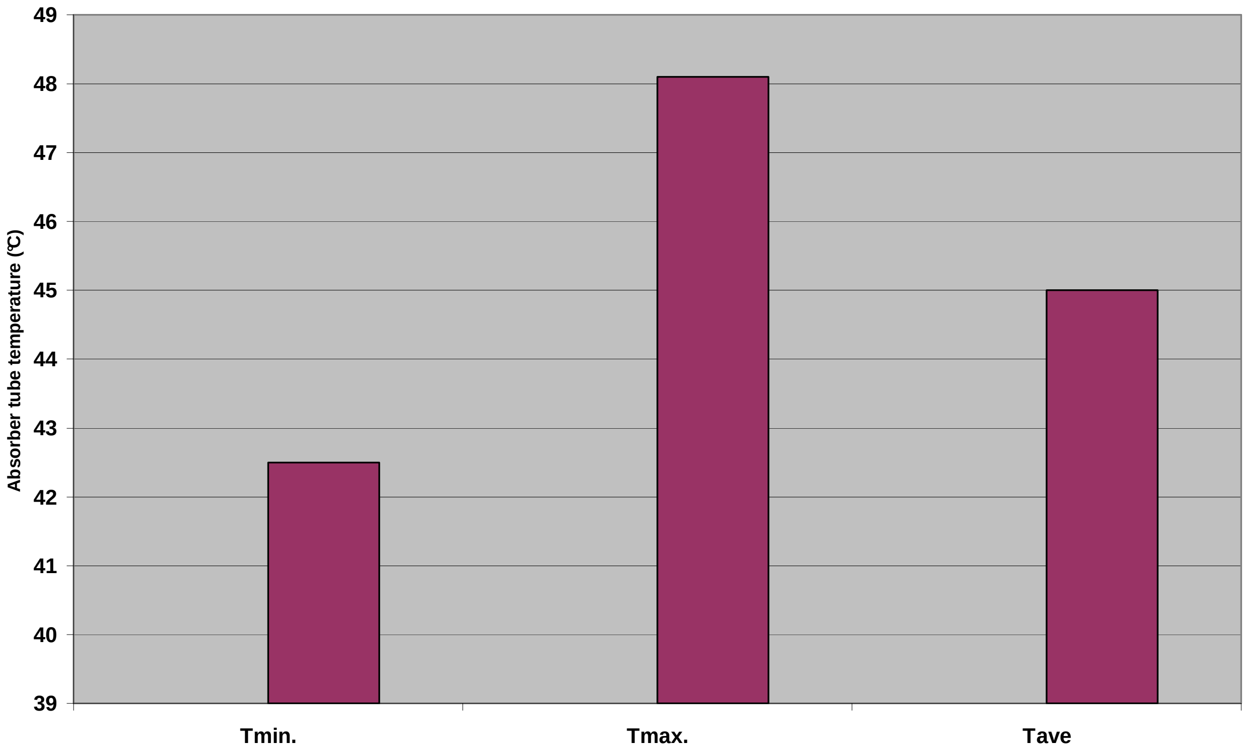

Figure 4. Maximum, average and minimum temperatures of the external surface of the absorber tubes.

The temperature levels of the external surface of the absorber tubes had always been below the criticize temperature for the beginning of the thermal degradation, which is above of 60.0°C. It is standed out that the reached maximum values, 48.0ºC, are very lesser that the PVC deflection temperature, above of 75.0°C. Therefore, the PVC tubes do not reach critical temperatures being able to be used as absorber and conductors of heat, what it demonstrates the thermal viability of the considered system.

The cost of each collectors that compose the proposed heating system is around R$150.00, for an area of 1.5m², that it is inferior at the cost of conventional collectors that use copper absorber surfaces and is also inferior at the cost of conventional systems of swimming pool heating that use polypropylene tubes. This certifies the economic viability of the developed system.

To evaluate thermal loss of the system, some parameters had been calculated, which values are shown in the table 4.

Table 4. Thermal loss parameters of the heating system, where Q is the outflow; Q_a is the heat absorbed by the system; Q_u is the heat transferred to the fluid; Q_{loss} is the system lost heat; T_{pm} is the average temperature of the absorber plate, T_a is the ambient temperature, U_{loss} is the loss global coefficient and η_t is the thermal efficiency

Type	Q (l/h)	Q_a (W)	Q_u (W)	Q_{loss} (W)	T_{pm} (^oC)	T_a (^oC)	U_{loss} ($W/m^2.K$)	η_t (%)	Q_u/Q_a (%)	Q_p/Q_a (%)
System (L+W)	100.0	1790.1	1288.8	501.2	45.0	32.0	12.48	54.00	0.72	0.28

The thermal losses global coefficient was above of the conventional collectors that are situated in the band between 6.0 and 12.0W/m^2.K, (Duffie & Beckman, 1991), however in function of its inferior cost, it presents thermal viability when compared to the conventional systems of market.

5. CONCLUSIONS AND SUGGESTIONS

1. The system was viable for the considered use;
2. The used collectors had presented a significant thermal performance for the chosen outflow;
3. It didn’t have visible deteriorations in the absorption grids formed by PVC tubes. The temperatures of the external tubes surfaces had been less than the critical values for the occurrence of degradation (60^{o}C). Therefore, PVC tubes present a sufficiently significant viability for the substitution of the absorber grid in collectors destined to swimming polls heating, using polypropylene tubes, because they are more weather resistant;
4. For this level of outflow the temperatures reached for the system are above of those reached by used conventional polypropylene collectors for the considered end;
5. The system of considered heating propitiated the attainment of internal temperature levels for the swimming pool above of the required ones in few hours of functioning;
6. It can be perceived that the effect of the thermal and UV degradation, so inherent to the use of the PVC displayed to the heat and the sun, really can be fought with the painting of the tubes, that reduces considerably its susceptibility to the UV degradation, while the thermal degradation is fought with the use of the regimen of forced stream with some passes of the work fluid, and with the choice of an appropriate outflow. For the swimming pool heating the used level of outflow eliminates the risk of the collector absorption tubes to reach temperatures above of 60^{o}C, considered critical for the thermal degradation. This demonstrates the thermal and materials viability of the collectors in study.
7. Conventionally used systems present the advantage of not having glass blade covering nor box to lodge the absorber tubes, however its level of heating is well lower and the time necessary to reach the thermal balance is bigger. It is standed out that its cost is sufficiently low once the collectors of PVC they use present a low cost of construction (around R$ 150.00/m^2) and that the tubes of plugging between the swimming pool and the collectors can be manufactured with a very lower cost that the traditional tubes of CPVC, universally used;
8. The system must be tested for other levels of outflow and greater volumes of water to be heated;
9. The temperatures of the external surface of the absorber tubes and the temperatures of the fluid of work in some points of the absorber grid must be measured to evaluate the occurrence or not of saturation of the system

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