TECHNICAL AND ECONOMICAL ASSESSMENT OF INTEGRATED COLLECTOR STORAGE SOLAR WATER HEATERS

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Solar water heating implementation has as effect greenhouse gas emission reduction. Romanian solar collector market and solar technologies implementation are not yet developed because the market is dominated by high cost equipments. Due to this, the author deduces that the use of simpler technologies, with lower technical performances, but inferior capital cost, will induce higher solar energy penetration into the market. One of the cheapest solutions for solar water heating is Integrated Collector Storage Solar Water Heaters technology. The author purpose an analytical method for technical and economical solar collector's performance assessment. Technical performances of the solar collectors will be compared for different types of ICSSWH's.

Systems calculation will be done analytically. The starting point of the estimation is the heat balance on solar collector's boundary. Using heat transfer equation, energy fluxes and equipment efficiencies during collection and store time can be calculated. Technical performances for market existing solar collectors will be reminded. The paper conclusions are valuable for solar hot water design.

Key words: Compact Solar Collector, Technical Calculation, Economic Performance.

1. Introduction.

In the last period we put more and more the accent on sustainable development and the use of renewable energy sources. The use of solar energy for hot water production is one of the simpler solutions for the green house gas emission reduction. Unfortunately, Romanian solar thermal market is dominated by imported expensive technologies as evacuated tubes. Most times those are used for hot water production and in the summer period. In these conditions the development of solar energy use can be achieved by the utilization of other types of solar energy thermal collectors.

One of the simplest solutions is Integrated Collector Storage Solar Water Heaters technology.

This paper purpose a mathematical method for technical performance of ICSSWH assessments.

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2. Mathematical model.

Efficiency calculus for solar collector begins from heat balances for installation boundary. For this the following stages are needed:

I. Establishment of collector's geometry;
II. Establishment of energy fluxes around the collector;
III. Writing the heat balance equation;
IV. Collector efficiency calculus.

First stage. Establishment of collector's geometry;

The collector has a triangular shape with tow separated surfaces, presented in figure 1:

- S_2 is the active surface;
- S_1 is the insulated surface.

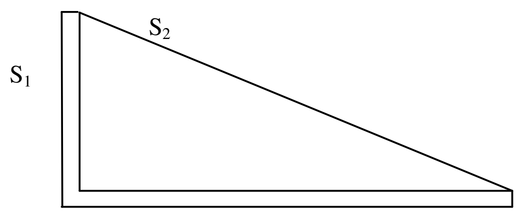

Fig. 1. Solar collector shape.

The main geometrical parameters are presented in table 1.

Table 1

Main geometrical parameters of the solar collector

	Parameter	Value
1	High, m	0.5
2	Length, m	2
3	Tilt angle	30 º
4	Base, m	0,866025
5	Active length, m	1
6	Collector's volume, m^3	0,433013
7	Active surface, m^2	2
8	Insulated surface, m^2	3.5

Second stage. Establishment of energy fluxes around the collector;

We can find the next type of energy fluxes between the collector and the environment:

- ♦ Optical fluxes:
  - o Solar incident energy;

- Optical looses (occurs on the active face of the collector and represents the difference between the solar incident radiation and energy absorbed by the collector).

♦ Utile and losses fluxes:

- Convection fluxes (occurs on all surfaces of the collector and are greatly influenced by the wind speed);
- Radiation fluxes (on the active surface and is the thermal radiation emitted by the absorbent surface);
- Conduction fluxes (occurs only on insulated surfaces and are greatly influenced by the thickness of the insulating material);
- Useful energy.

Figure 2 represent the Sankey diagram for the solar collector

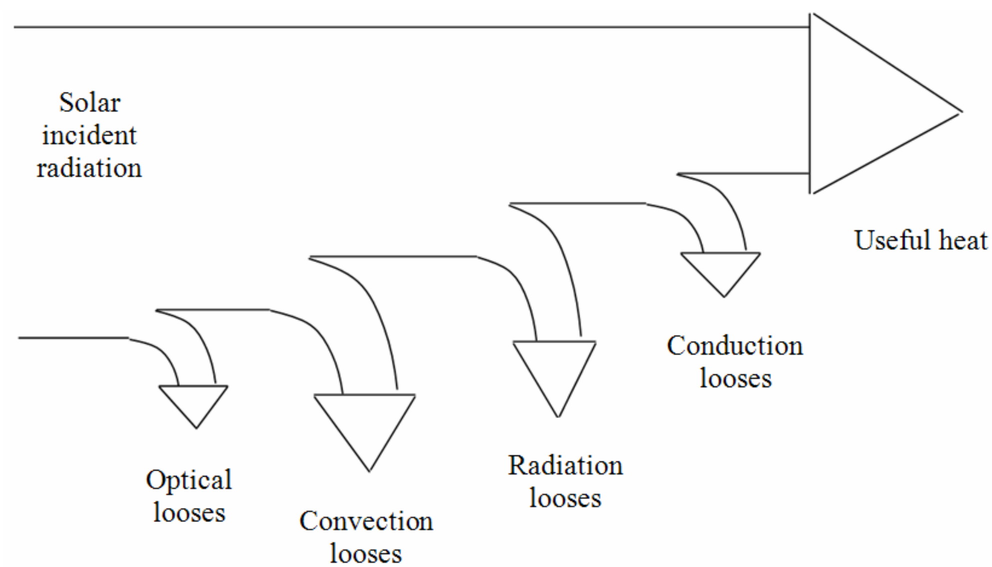

Fig. 2. Sankey diagram for the solar collector.

Third stage. Writing the heat balance equation;

The paper presents the balance equation for transitory regimes. The first is for the active surface [1]:

$$\rho_g \delta_g C_g \frac{dT_g}{dt} = G\alpha_g + (h_{wind} + h_{r,g-a})(T_a - T_g) + (h_{c-g} + h_{r,c-g})(T_c - T_g) \quad (1)$$

,where ρ_g glass density;

δ_g thickness of the glass;
C_g specific heat value of the glass;
T_g temperature of the glass;
t time variable;
G incident solar radiation;
α_g glass absorbance;
h_{wind} exterior convective heat transfer coefficient;
$h_{r,g-a}$ external radiativ heat transfer coefficient;
T_a ambient temperature;
h_{c-g} internal convective heat transfer coefficient;
$h_{r,c-g}$ internal radiativ heat transfer coefficient;
T_c absorbent surface temperature.

For the absorbent surface the equation are:

$$\rho_c \delta_c C_c \frac{dT_c}{dt} = G\alpha_g \alpha_c + (h_{c-g} + h_{r,c-g})(T_g - T_c) + h_{c-f}(T_f - T_c) \qquad (2)$$

,where ρ_c density of the absorbent surface;
δ_g thickness of the absorbent surface;
C_g specific heat value of the absorbent surface;
α_c absorbent surface absorbance;
h_{c-f} heat transfer coefficient between the absorbent surface and the working fluent;
R_{in} is;

If the radiation influence on the insulating surfaces is small the thermal resistance for those surfaces is:

$$R_{in} = \frac{\delta_{in}}{k_{in}} + \frac{1}{h_{wind}} \qquad (3)$$

The heat transfer coefficients are:

- $h_{wind} = 2{,}8 + 3{,}0 u_{wind}$, for the wind convection coefficient (where u_{wind} is the wind speed);
- $h_{r,g-a} = \varepsilon_g \sigma (T_g^2 + T_a^2)(T_g + T_a)$, the radiation heat transfer coefficient between the glass and the atmosphere (ε_g is the glass emissivity and σ is Stefan-Boltzmann constant);

- $h_{r,c-g} = \dfrac{\sigma(T_g^2 + T_a^2)(T_g + T_a)}{\dfrac{1}{\varepsilon_g} + \dfrac{1}{\varepsilon_c} - 1}$ is the radiation heat transfer coefficient between the glass and the absorbent surface;

For a mixed stock, the transitory regime temperature can be established with the following equation:

$$\left(m \cdot C_p\right)_s \frac{dT_s}{dt} = Q_u - L_s - (UA)_s\left(T_s - T_a\right) \tag{4}$$

,where Q_u the useful heat extracted for the stock;
L_s the heat entered the stock (from the active surface);
$(UA)_s$ is the heat transfer coefficient between the stock and the ambient;

Forth stage. Collector efficiency calculus.

The solar collector efficiency can be calculated as a division between the useful produced heat and the incident solar radiation. Three types of active surfaces will be evaluated:

- Black unglazed surface;
- Black glazed surfaces;
- Selective absorption surface.

3. Results.

In figure 3, ηI represent the characteristic for the unglazed black collector, ηII for glazed black paint collector, and ηIII for selective absorbent collector.

For simple efficiency calculus and stationary conditions the following equation can be used [3]:

$$P_{out} = F'(\tau\alpha)_{en} G - c_1(t_m - t_a) - c_2(t_m - t_a)^2 \tag{5}$$

,where P_{out} useful heat for 1 m^2 of solar collector;
$F'(\tau\alpha)_{en}$ is the optical looses coefficient;
c_1 and c_2 are the parameters that describes the heat losses fluxes.
t_m is the average temperature between the inlet and outlet of collector;

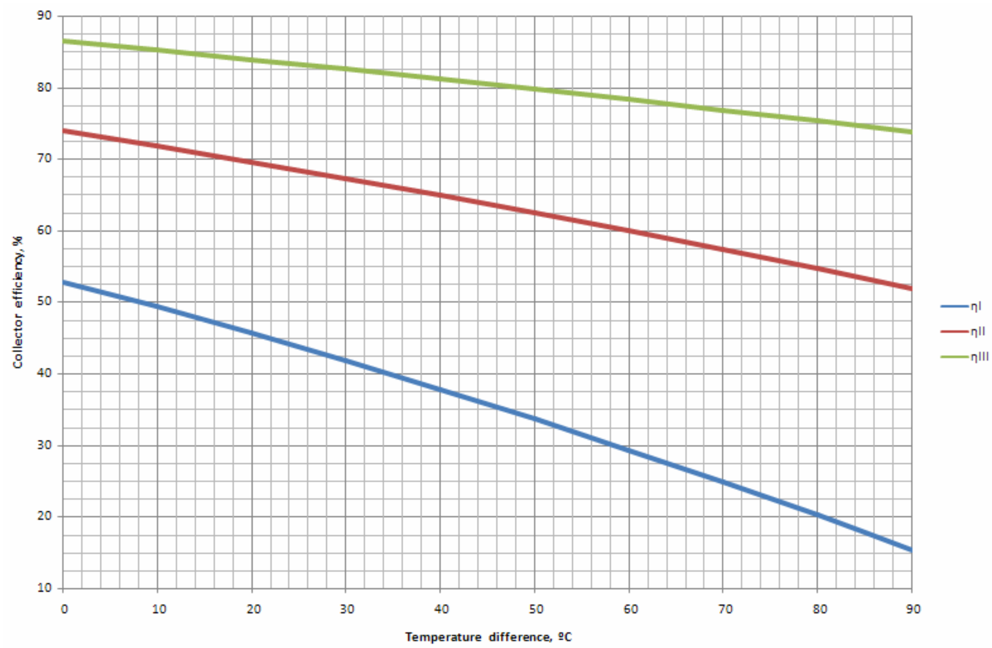

Fig. 3. Efficiency characteristic of the solar collector

4. Conclusions

As seen in figure 3 overall of efficiencies of ICSSWH are smaller then the flat solar collectors ones. But, the market prices of the solar flat collectors are in the interval of 150 EURO / m^2 (for selective surface collectors) to 500 EURO / m^2 [4] (for evacuated tubes collectors), and storage tanks are not included (1000 EURO / 0,4 m^3 storage). This will give at least 1300 EURO for one equivalent system to the described one. The cost of the ICSSWH is less then 300 EURO.

Using of the ICSSWH technologies can greatly improve the solar energy captor technologies on Romanian market.

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