STEEL-TINPLATE ABSORBER INVESTIGATIONS IN AIR SOLAR COLLECTORS

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Abstract. In 2005 in the research laboratory 0.1x0.5x1.0 meters long equipment for experimental research into the materials of solar air collectors was built for research purposes. The construction of the equipment allows simultaneous comparative studies of cover and absorber materials. The experimental data were metered and recorded in the electronic equipment REG. The investigations are devoted the sun following collectors, which guarantee perpendicular location for all experimental time of the plane of absorber to the flow of the sun radiation. The collector covered material was a polystyrol plate, absorber – black colored steel-tinplate located at the bottom and middle of the collector. The solar collector with a steel shin plate absorber in the middle is 2 times more effective as a collector with a steel tinplate absorber at the bottom. Expressions for air temperature exchanging over and under the steel-tinplate absorber in the solar collector are obtained. The average temperature difference can reach 5 degrees at the exit between air temperature over and under the steel tinplate absorber. Comparing the coefficient β at different weather conditions in order to compare different absorbers and covering materials of solar collectors is offered. At favorable weather conditions the heating degree of the ambient air reaches more than 10 degrees at the exit with the absorber length 0.7 m and air velocity $v = 0.55$ m s^{-1}.

Key words: solar collector, air temperature, absorber.

Introduction

The sun, that alternative energy source more and more widely is used in practice. One of the simplest ways of usage is sun heating air collectors which are simple, cheap, ecologically friendly and widely used. One of the ways to use air collectors is agricultural production drying.

The investigations of air solar collectors were started by prof. E. Berzins [1, 2] at the Latvian Agricultural University. Power and located types of solar collectors at air velocity $v = 5 \div 6$ m s^{-1} were researched.

The efficiency of a solar collector depending on the collector covered materials (polyvinylchloride film, cell polycarbonate PC, translucent roofing slate), absorber (black colored wood, steel-tinplate), with different air velocities in the collector was investigated [3-6]. The main efficiency parameter of the solar collector is the air heating degree and it was choose as the criterion of efficiency.

The plane of absorber is perpendicular to the flow of the sun radiation at the sun following collector, therefore this type is more powerful than the stationary collector. The sun rays fall under the angle $0^{\circ}<\alpha<180^{\circ}$ to the stationary collector plane (it means it falls under the angle α to covered material) and it gives more reflection.

Materials and methods

The aim of our investigations was to state the air heating degree of solar collectors over and under the absorber steel-thin plate. We studied the length of the collector affect to the air heating degree. Our investigations are devoted the sun following collectors, which guarantee perpendicular location of the plane of absorber to the flow of the sun radiation

We researched in the situation when the absorber (black colored steel-tinplate) is put in the middle of the collector (Fig.1-2).

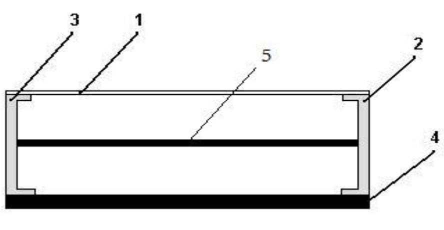

Fig. 1. **Schema of solar collector frontal view:** 1 – covered material; 2, 3 – side surface /plastic/; 4 – floor of collector; 5 – absorber (steel-tinplate)

In the experiments, the collector covered material was a polystyrol plate. This material has gained immense popularity due to such properties as safety, mechanical crashworthiness, translucence and high UV radiation stability.

In the laboratory a 0.1x0.5x1.0 meters long experimental solar collector was constructed for research into the properties of absorber materials. The air velocity at all experiments was v = 0.55 m s^{-1}. We tested the air temperature over and under the absorber correspondingly 30 cm from the inflow and outflow of the collector for the sun following collector (Fig. 2).

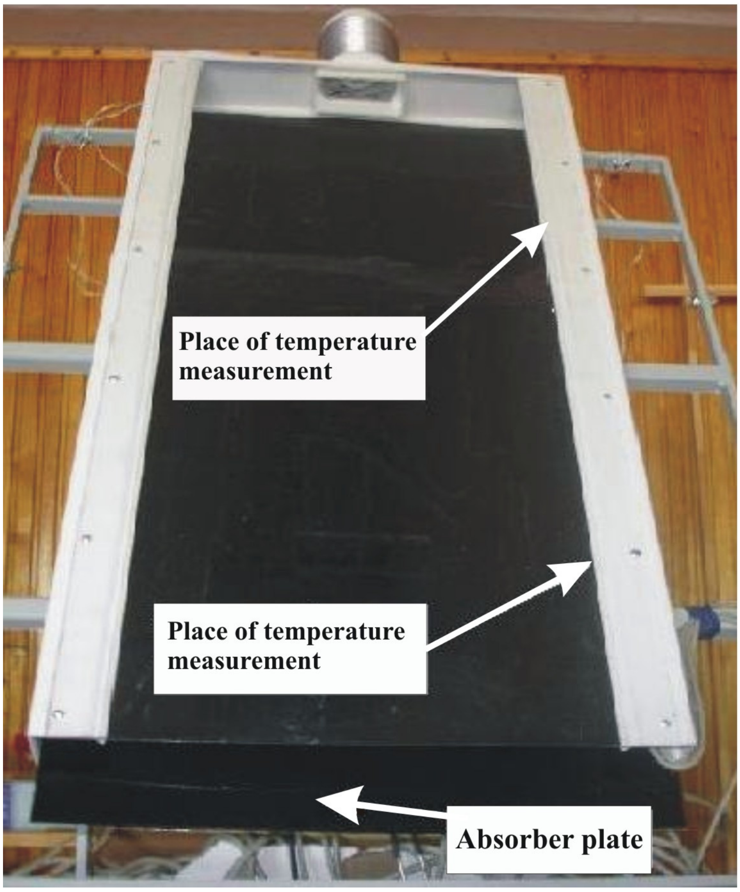

Fig. 2. **View of solar collector with steel-tinplate absorber in the middle**

The experimental data are recorded by means of an electronic metering and recording equipment of temperature, radiation and lighting REG [7]. It is equipped with 16 temperature transducers and metering sensors of solar radiation and lighting. The reading time of the data was one minute.

Results and discussion

This article continues the presented article [8]. Using the experimental results and statistical processing data we received a relation between the length of the collector, sun radiation to absorber plate and air temperature exchange in the collector. We got expressions for air temperature exchanging over and under the steel-thin plate absorber in the solar collector.

The temperature exchange ΔT **over** absorber can be expressed with the equation:

$$\Delta T = 18.34 \cdot x - 25.8 \cdot x^2 + 0.01 \cdot R - 7.6 \times 10^{-6} R^2 + 0.025 \cdot x \cdot R - 3.2 , \quad (1)$$

where x – length of collector (m);
R – sun radiation W m^{-2}.

The close connection of this expression shows the coefficient of determination η^2 = 0.98 in the temperature increase domain $\Delta T \in (0; 18)$. The graphical interpretation of this expression is shown in Fig. 3.

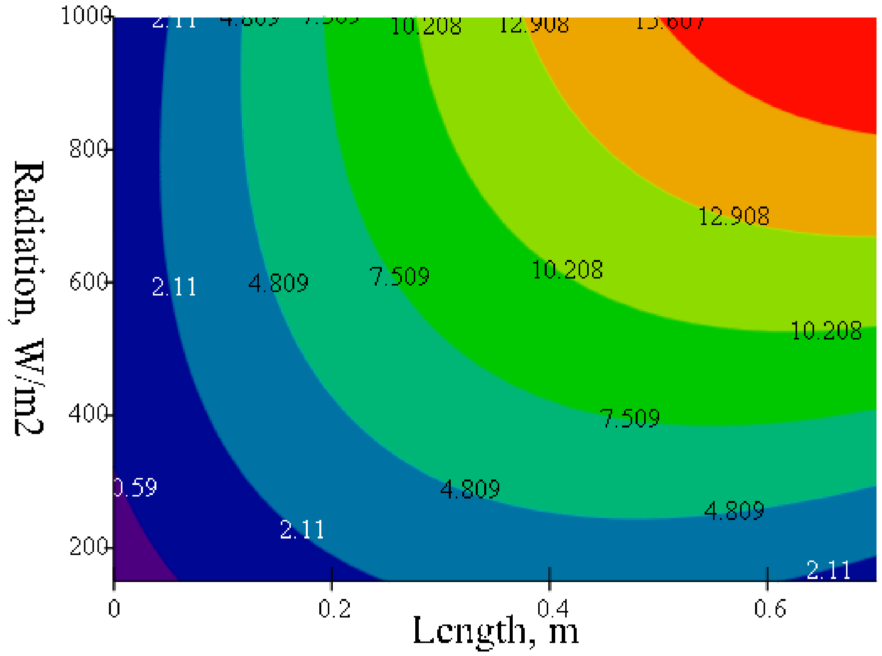

Fig. 3. **Contour plot of air temperature (over absorbent) increase dependence on length of collector and sun radiation**

The temperature exchange ΔT under absorber (steel-tinplate) can be expressed with the equation ($\Delta T \in (0; 10)$):

$$\Delta T = 4.96 \cdot x - 5.42 \cdot x^2 - 2.58 \times 10^{-3} R + 3.4 \times 10^{-6} R^2 + 0.012 \cdot x \cdot R + 0.11 , \quad (2)$$

with coefficient of determination $\eta^2 = 0.97$.

The visual interpretation of this expression (2) is shown in Fig. 4. as surface and as contour plot in Fig. 5. Every color corresponds to 2 degrees of temperature growth.

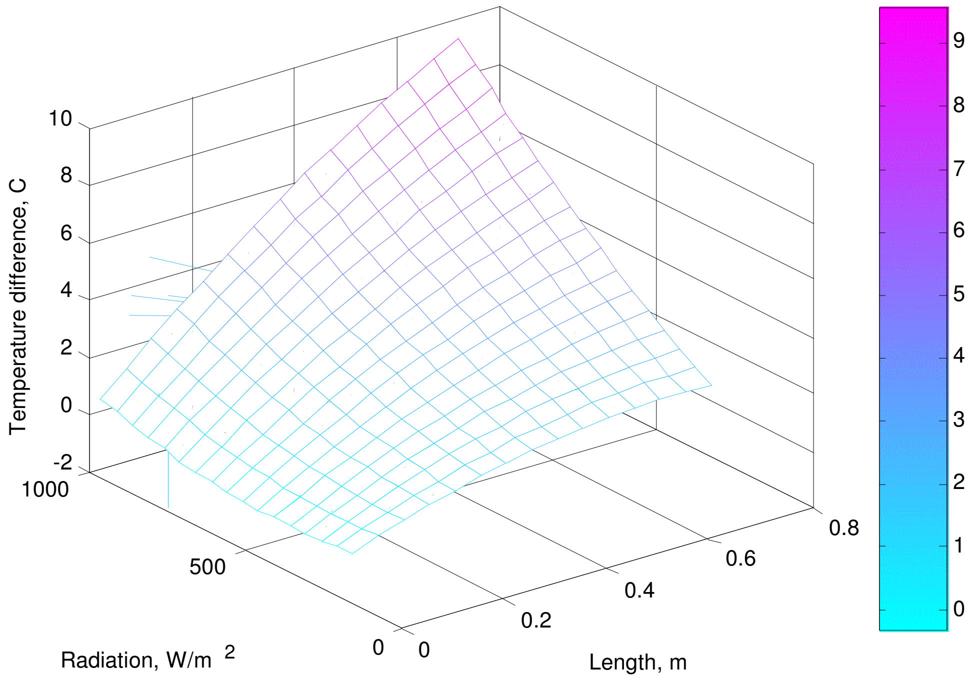

Fig. 4. **Surface plot of air temperature (under absorber) increase dependence on length of collector and radiation of sun**

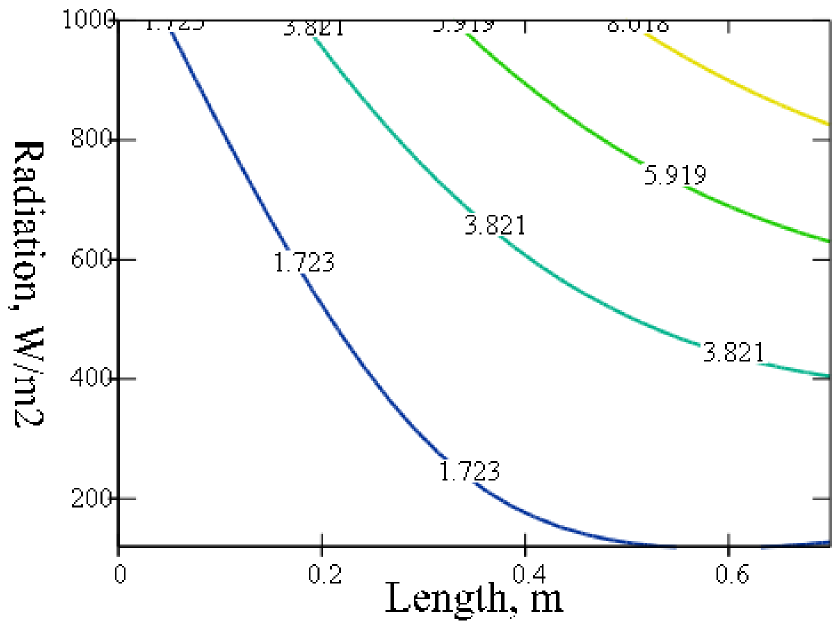

Fig. 5. **Contour lines of air temperature (under absorber) increase dependence on length of collector and radiation of sun**

The amount of heat *Q* which we receive from the sun can be calculated:

$$Q = c \cdot m \cdot \Delta T\ ; \tag{4}$$

where c – heat capacity of air, c = 1.009 ($kJ \cdot kg^{-1} \cdot K^{-1}$);
m – mass of heating air (kg),
ΔT – air heating degree (C°).

Let us assume that the solar collector works for 6 hours, the power of the fan 100 $m^3\ h^{-1}$ (in our case), then the heat amount with the average air temperature grows for 10 degrees $Q \approx 7810$ kJ.

The amount of heat which we get from different types of solar collectors is different. Larger amount of heat was obtained with absorber steel-tinplate at the middle by the sun following collector. The found amounts of heat at different types of collectors and absorbers are shown in Table 1.

The sun following collector approximately gives 1.4 times more energy than the stationary as shown in Table 1. The absorber of steel plate gives 2 times more amount of heat comparing with the absorber black colored wood.

Table 1

Obtained amount of heat in solar collectors

Type of collector	**Findings of amount of heat in 6 h (kJ)**
Stationary collector with black colored wood absorber	2655
Sun following collector with black colored wood absorber	3749
Stationary collector with steel-shin plate absorber	5467
Sun following collector with steel-shin plate absorber	7810

The weather conditions are not equal in the experiments. There are different ambient air temperature, wind with different velocity, clouds etc. it is known that the air heating degree depends on the sun radiation, therefore we introduce the comparing coefficient β which characterizes different types of collectors and absorbers in different weather conditions:

$$\beta = \Delta T / R_{vid} , \qquad (6)$$

where $\Delta T = \dfrac{\frac{1}{n}\sum_{i=1}^{n} \Delta T_i}{\frac{1}{m}\sum_{i=1}^{m} Ta_i}$ increase of average air temperature versus average ambient air temperature in experiment time;

R_{vid} – average sun radiation in experiment time.

The values of differences of the comparing coefficient β at different weather conditions did not exceed 9 %; at majority it did not exceed 5 %. The calculation results (in our case) are shown in Table 2.

Table 2

Values of comparing coefficient β

Type of collector	Comparing coefficient $\beta = \Delta T / R_{vid} \cdot 1000$
Sun following collector with black colored wood absorber	4.47
Stationary collector with steel-tinplate absorber (bottom)	4.55
Sun following collector with steel-tinplate absorber (bottom)	5.55
Stationary collector with steel-tinplate absorber (middle)	8.61
Sun following collector with steel-tinplate absorber (middle)	11.90

The sun following collector with steel-tinplate absorber is about 3 times more effective as the sun following collector with black colored wood absorber as shown in Table 2. The sun following collectors are approximately 30 % effective as stationary operated for 6 hours.

Conclusions

1. Sun following collectors are approximately 30 % effective as the same type of stationary collectors in operation time 6 hours.
2. The solar collector with tinplate absorber in the middle is 2 times more effective as the collector with tinplate absorber at the bottom.
3. The average temperature difference can reach 5 degrees at the exist between air temperature over and under the steel-tinplate absorber.
4. It is preferable to use the comparing coefficient β at different weather conditions in order to compare different absorbers and covering materials of solar collectors.
5. Air solar collectors due to their physical and mechanical properties are suitable to be used in Latvia for agricultural purposes. At favorable weather conditions the heating degree of ambient air reaches more than 10 degrees at the exit with the absorber length 0.7 m and air velocity $v = 0.55$ m/s.

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