THE MATERIAL INVESTIGATIONS OF SOLAR COLLECTOR

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Abstract. The princes of energy resources used for grain drying are increasing year by year. In order to reduce grain drying costs, in the Research Laboratory of Grain Drying and Storing of the Faculty of Engineering, the LUA research into methods of energy – saving grain drying is in progress. In 2005 in the research laboratory equipment for experimental research into the materials of solar collectors was built for research purposes. The construction of the equipment allows simultaneous comparative studies of two materials. Experimental data is metered and recorded in the electronic equipment REG. Cell polycarbonate PC (bronze) (henceforth referred to as polycarbonate) with absorbers steel-tinplate and black coloured wood was researched in relation to the polyvinylchloride film (henceforth referred to as a film). The researches were made with different air velocities. For theoretical investigation of the air heating power in solar system we use mathematical model which solution we can use for estimation of different materials /absorbents/ and its heat source.

Key words: radiation, sun, air, material, temperature, polycarbonate, film.

Introduction

Grain drying as well as all costs of its first treatment and storage depend upon equipment, the balance cost of buildings, power supply systems, the amount of the drying material and its moisture content, the level of cleanness and energy carrier's prices, which are continuously rising.

Fuel is getting more expensive year by year but grain has to be dried in order that it can be stored. Nowadays more attention has been paid to environmental protection thus ways how to use alternative energy more widely are being explored. Therefore, research into usage of solar energy for grain drying is going on and extending. The sun is the most powerful heat generator, which neither of the heat sources created by mankind can compete with. Yearly the earth is reached by the solar energy 15000 times more than the power industry of the whole world can produce. It means that only a tiny part of solar energy is being used for the sake of mankind.

Increase in the utilization of solar energy is closely connected with research into solar collectors. The necessary amount of heat for grain drying with active ventilation from July to September can be obtained by making use of solar radiation. In Latvia at midday in this period of time the average solar radiation power on a horizontal surface is more than 600 W/m^2 [1]. The air heated this way is not toxic and electrically neutral. Solar collector efficiency is not high but it has simple construction and is cheap to make and operate.

Materials and methods

The aim of the research is to find the optimal technical solutions, utilized materials, operation parameters and power possibilities for a solar collector. In the laboratory a 1.5 meters long experimental solar collector was constructed for research into the properties of roof materials. The keynote of the equipment is to conduct comparative studies of the utilized materials for solar collector. Building materials industry offers new materials whose applicability to solar collectors has not been studied. The collector has been built so that it can be easy to use in a laboratory setting. The box-like frame of the collector is divided into two parts (Fig. 1). One part is covered with a traditional material for solar collectors, i.e. a polyvinylchloride film, henceforth referred to as a film. The other part is used for the placement of the researched material. The researched material is compared to the polyvinylchloride film. In the two channels experimental equipment equal conditions for the experiment are ensured.

Experimental data is recorded by means of an electronic metering and recording equipment of temperature, radiation and lighting REG [2]. It is equipped with 16 temperature transducers and metering sensors of solar radiation and lighting. Reading time of data can be programmed from 1 to 99 minutes. The recorded data is stored in the REG memory (there is place for 16,384 records) and in case of need it is transferred to a computer for archiving with further processing. For evaluation and analysis of the results software REG – 01 has been developed, which is meant for transfer to the computer and processing of the recorded data. Information is stored in the form of a table and in case of need it is depicted as a graph.

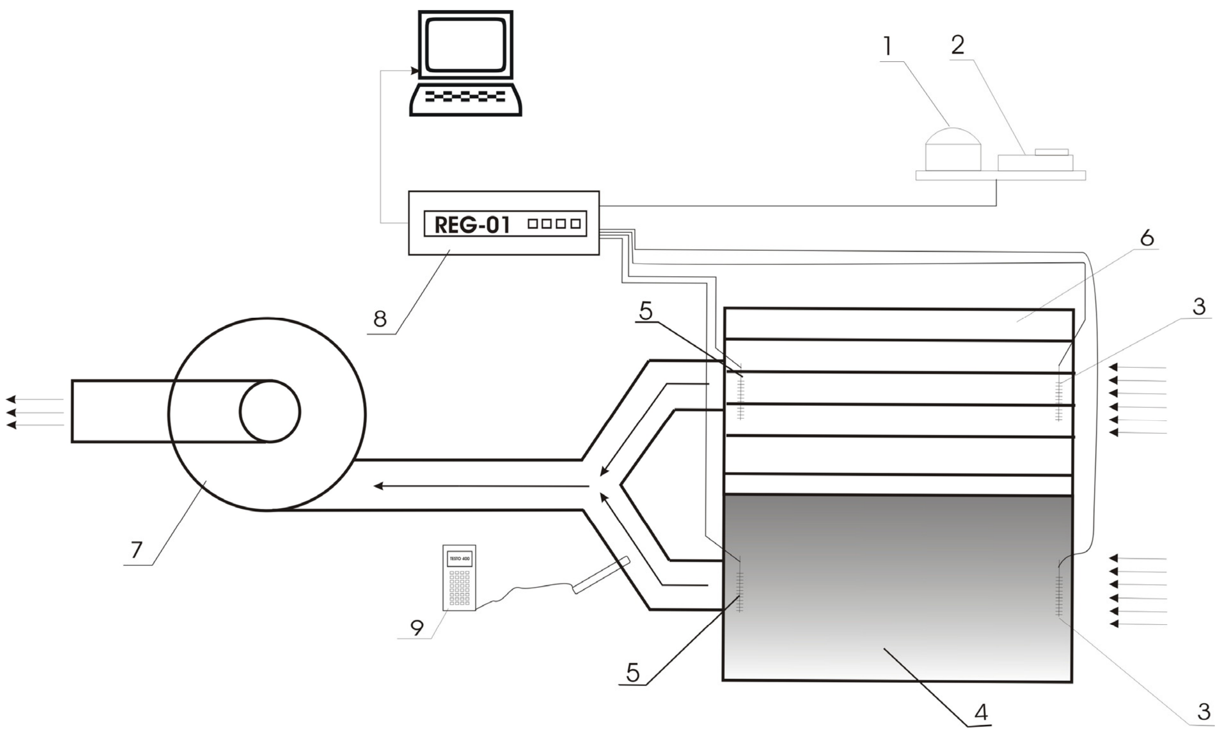

Fig. 1. **Experimental equipment for research into the properties of solar collector materials**:
1 – solar radiation meter (pyranometer); 2 – solar lighting meter; 3 – temperature transducers of incoming air; 4 – polyvinylchloride film; 5 – temperature transducers of outgoing air;
6 – researched material; 7 – fan; 8 – metering and recording equipment REG, 9 – TESTO 400.

For theoretical investigation of the air heating power in solar system we use mathematical model why describe heat-mass transfer in 1 dimension case (x – direction)

$$c\rho \frac{\partial T}{\partial t} + v\frac{\partial T}{\partial x} = \lambda \frac{\partial^2 T}{\partial x^2} + q\,, \tag{1}$$

where $T(x,t)$ – air temperature function;
v – air flow velocity;
λ – rate of thermal conductivity;
q – heat source /absorbent/;
c – specific heat of air;
ρ – density of air.

In the simplest case when heat exchange process in solar system is constant $\frac{\partial T}{\partial t} = 0$, equation (1) becomes in simple form:

$$\frac{\partial^2 T}{\partial x^2} - a\frac{\partial T}{\partial x} + Q = 0, \text{ where } a = \frac{v}{\lambda},\ Q = \frac{q}{\lambda}. \tag{2}$$

Function T becomes that one dimension function, depending only from distance of air flow x and equation (2) can be solve that linear differential equation of second part. We use two boundary conditions for solving:

$$T\Big|_{x=o} = T_0, \tag{3}$$

$$\left.\frac{\partial T}{\partial x}\right|_{x=l} = 0. \tag{4}$$

Condition (3) shows temperature T_0 of air going into collector (x = 0), (4) shows that does not happen heat exchange of air at the end of sun collector (x = l).

Solving equation (2) with boundary conditions (3-4) we obtain air temperature changes in solar system for stationary case:

$$T = T_o + \frac{Q}{a^2} e^{-(l-x)a} + \frac{Q}{a} x.$$

Using theoretical and experimental results we can estimate different materials /absorbents/ and its heat source.

Results and discussion

In the experiment, the researched material was compared to the polyvinylchloride film, which in most cases is used as a solar collector material. Cell polycarbonate PC (bronze) [3] was used as the researched material. This material has gained immense popularity due to such properties as fir safety, mechanical crashworthiness, translucence and high UV radiation stability. It is easy to bend polycarbonate PC plates and they do not need previous treatment. The research results of this material we showed [4]. This results we obtain with absorber – black coloured wood. The results of investigations of PC with absorber steel-tinplate are as follows (Fig. 2 and 3).

As the experiments demonstrate, no important difference of temperature heating degree of solar collector covered by polycarbonate and film (Fig. 2). Heating degree ΔT grows, growing radiation of sun. Experiments show that absorber steel-tinplate works more effectively that black coloured wood with polycarbonate plate cover of collector (Fig. 2 and 3).

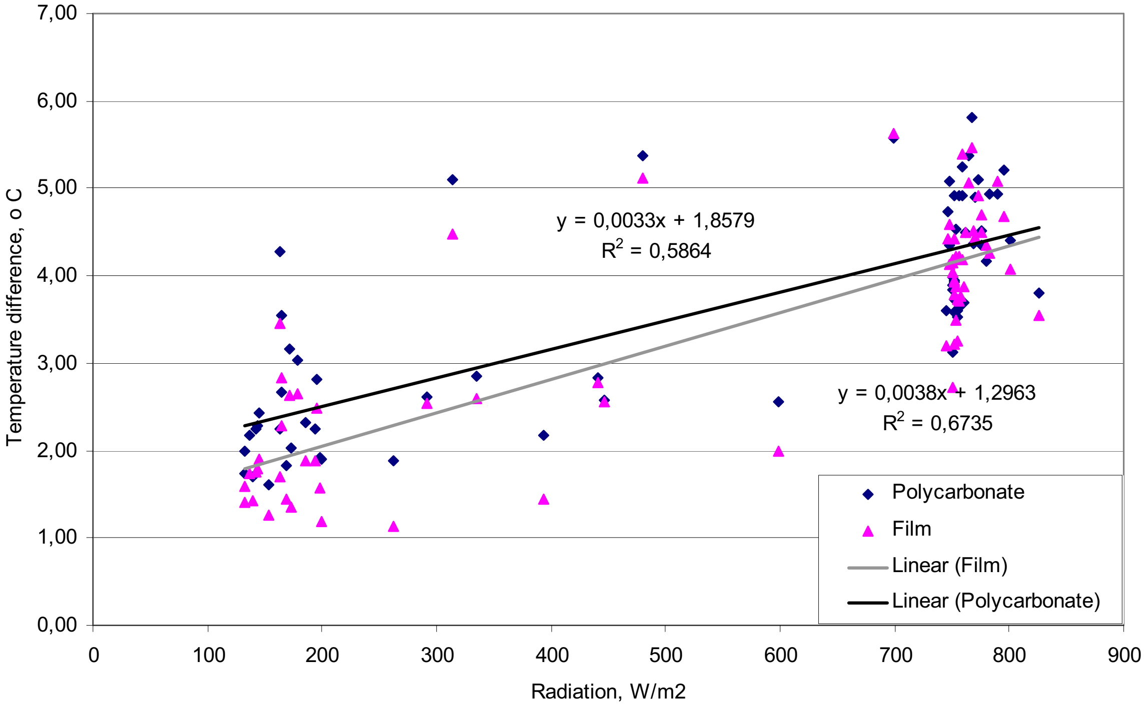

Fig. 2. **Air heating temperature difference ΔT of film and polycarbonate with black coloured wood absorber depending upon solar radiation I at air velocity v = 0.5 m/s**

The researchers tried to find a correlation between the heated air temperature difference ΔT of the collector and two kinds of material – the polyvinylchloride film and the polycarbonate plate with different absorbers (Fig. 2 – 3).

The difference of temperature reaches up to 2 ^{o}C.

By comparing the effectiveness of usage, it is obvious that the air heating degree does not change substantially at low air velocities v and it is directly dependant on solar radiation I volume. The heating degree ΔT (^{o}C) is directly proportional to the radiation level I with sufficiently high correlation factors.

We compare temperatures of ambient air, temperatures of the end of collector covered by film and translucent roofing slate depending of sun radiation with different air velocities (Fig. 3 – 7).

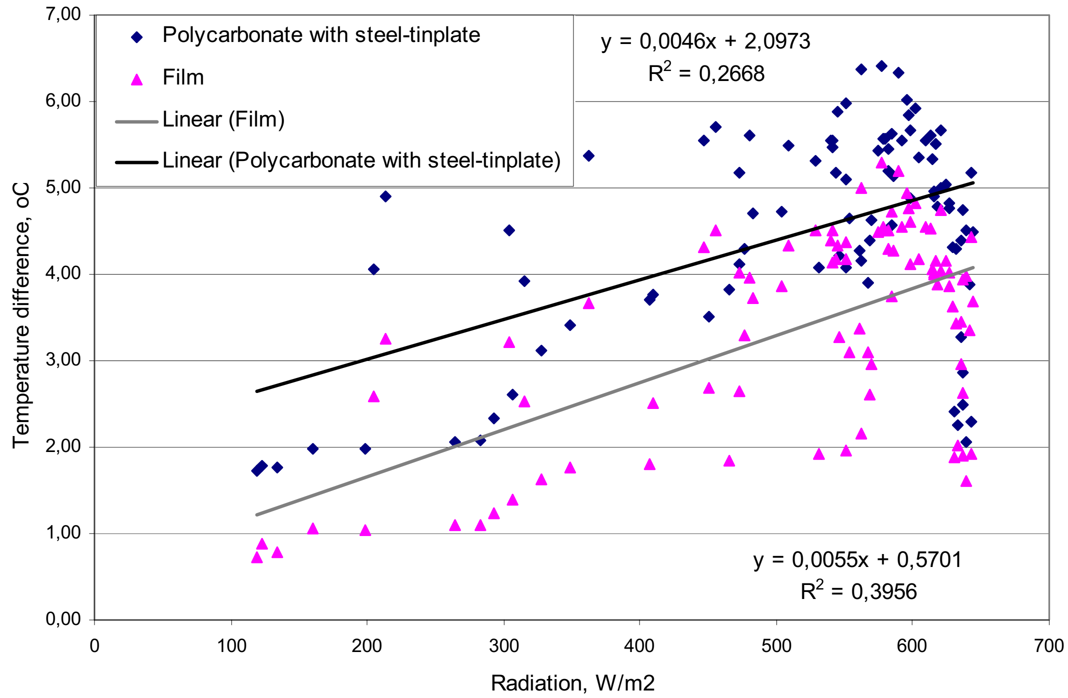

Fig. 3. **Air heating temperature difference Δ*T* of film with black coloured wood absorber and polycarbonate with steel-tinplate absorber depending upon solar radiation *I* at air velocity *v* = 0.5 m/s**

We can see that the effectiveness of translucent roofing slate is higher that using film. With small velocities the effectiveness is higher that with large velocities. The correlation of dependents (from experimental data) is high $r \in (0{,}65;\ 0{,}85)$.

At lower air velocities $v = 0{,}75;\ 0{,}95$ m/s correlation is lower. Experiment results show that heating degree of solar collector depending from air velocity and it's is higher with less velocities.

One can conclude from the heating degree of the collector that the translucent roofing slate as a sun collector material is more effective than the polyvinylchloride film.

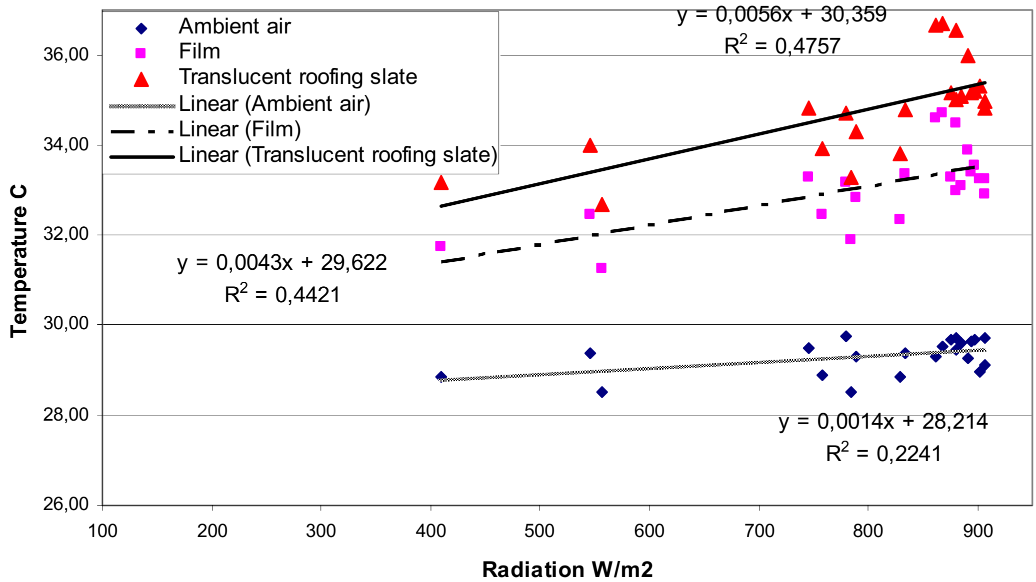

Fig. 4. **Ambient air temperature, colector heating temperature covered by film and translucent roofing slate dependence from solar radiation *I* at air velocity *v* = 0,75m/s**

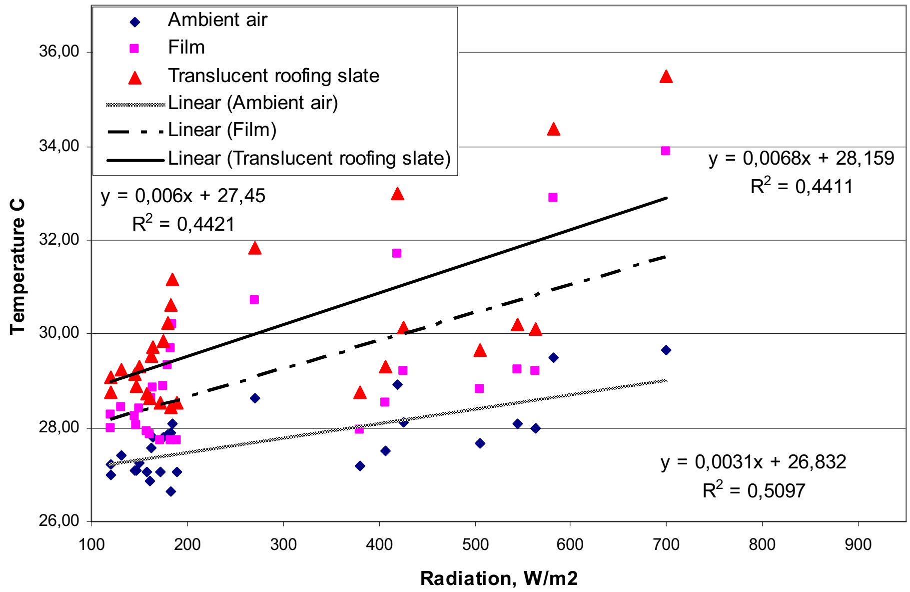

Fig. 5. **Ambient air temperature, colector heating temperature covered by film and translucent roofing slate dependence from solar radiation *I* at air velocity *v* = 0,95 m/s**

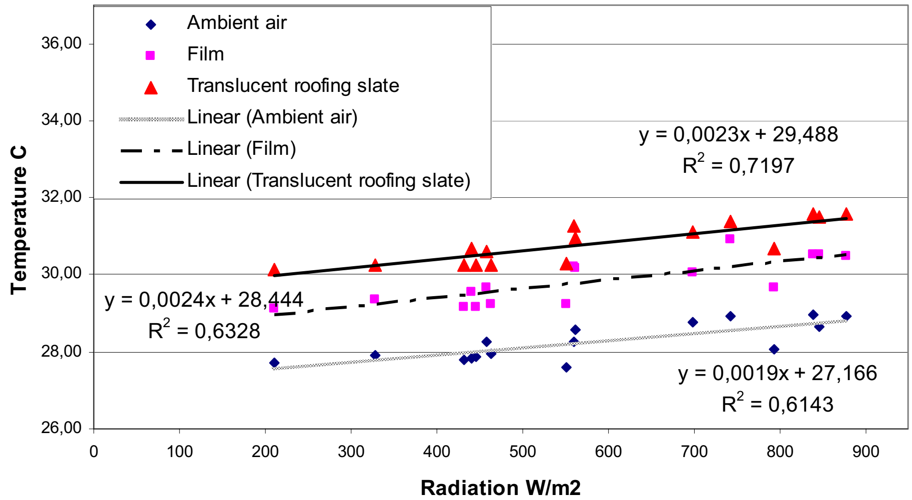

Fig. 6. **Ambient air temperature, colector heating temperature covered by film and translucent roofing slate dependence from solar radiation *I* at air velocity *v* = 1,2 m/s**

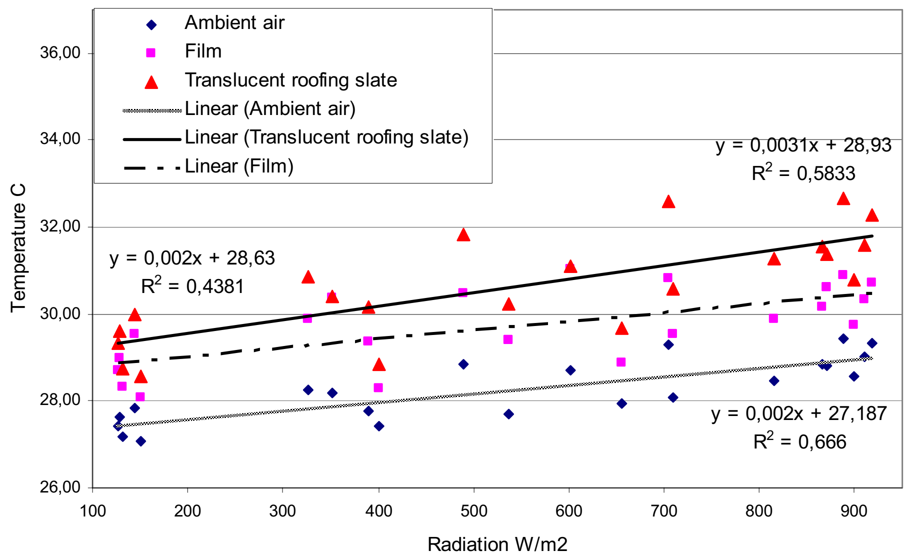

Fig. 7. **Ambient air temperature, colector heating temperature covered by film and translucent roofing slate dependence from solar radiation *I* at air velocity *v* = 1.34 m/s**

Conclusions

1. The air heating degree ΔT in the solar collector is dependent on solar radiation I and air velocity v in the solar collector. In the experimental equipment, the length of which is 1.5 meters, the air got hot to ΔT = 6 °C at the velocity v = 0.5 m/s.
2. The air heating degree ΔT in the polycarbonate collector did not significantly differ from the film collector by black colored wood absorbent, but it is significantly higher using absorbers of steel-tinplate
3. The translucent roofing slate as a sun collector material is more effective than the polyvinyl-chloride film.
4. The research results demonstrate a close correlation between the air heating degree ΔT and solar radiation I at various velocities of air v in the collector.
5. Polycarbonate PC and translucent roofing slate due to its physical and mechanical properties is a suitable material to use in solar collector construction for agricultural purposes.

References

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