# USAGE OF DIFFERENT MATERIALS IN AIR HEATED SOLAR COLLECTORS

**Aivars Aboltins, Janis Palabinskis, Guntis Ruskis**
Latvia University of Agriculture, Faculty of Engineering, Institute of Agriculture Machinery
aivars.aboltins@inbox.lv, janis.palabinskis@llu.lv, guntisruskis@inbox.lv

**Abstract.** The paper describes the results of the investigation the aim of which was to find new easily to accessible materials which are possible to be used as absorbers in air heating sun collectors. Different size seed boxes made of polypropylene were used as such materials and each box value efficiency in air heating was defined. The experimental results of the sun following collector by air movement 0.9 $m \cdot s^{-1}$, show that in air heating cylindrical type boxes absorber with the size $R$=2.5 cm and $H$=7 cm (7 boxes in line) is more effective, which is warming up air on average by 1.6 ˚C on 100 $W \cdot m^{-2}$ at the collector size 0.1x0.5x1.0 m it is air heating level by 1000 $W \cdot m^{-2}$ is reaching 16 ˚C. Using such kind absorber material (different size seed boxes) it is possible to heat air more than 10 ˚C by sun radiation 1000 $W \cdot m^{-2}$. The air heating level is dependent on the box size it is out of the available absorbent surface. Very good weather conditions can be a cause for such absorber material damage (smelting), especially, if the material is thin.

**Keywords:** solar energy, absorber, air heating.

## Introduction

The greatest advantage of solar energy as compared with other forms of energy is that it is clean and can be supplied without environmental pollution. Over the past century, fossil fuels provided most of our energy, because they were much cheaper and more convenient than energy from alternative energy sources, and until recently, environmental pollution has been of little concern. The limited reserves of fossil fuels cause a situation in which the price of fuels will accelerate as the reserves have decreased.

Under Kyoto targets, the European Commission member states and stakeholders identified and developed a range of cost-effective measures to reduce emissions. The new package sets a range of ambitious targets to be met by 2020, including improvement of energy efficiency by 20 %, increasing the market share of renewable to 20 %. In a renewable energy-intensive scenario, global consumption of renewable resources reaches a level equivalent to $318 \cdot 10^{18}$ J per annum of fossil fuels by 2050, but it is less than 0.01 % of solar energy reaching the earth surface each year [1].

Solar energy is used to heat and cool buildings (both actively and passively), for drying products, heat water for domestic and industry use, heat swimming pools, to generate electricity, for chemistry applications and many more operations [1].

The application of solar energy is completely dependent on solar radiation, a low-grade and fluctuating energy source. An intrinsic difficulty in using solar energy is given by the wide variation in the solar radiation intensity. The availability of solar radiation depends not only on the location, but also on the season. Extreme differences are experienced between summer and winter, and from day to day.

In general, solar water and solar air heaters are flat-plate collectors (FPCs), consisting of an absorber, a transparent cover, and backward insulation. Despite the similarity in designs, the different modes of operations and different properties of the heat transfer medium greatly affect the thermal performance and electric energy consumption for forcing the heat transfer medium though the collector. Solar water heaters are operated as a closed-loop system whereas, in most cases, solar air heaters are operated in the open-loop mode.

The performance of solar air heaters is mainly influenced by meteorological parameters (direct and diffuse radiation, ambient temperature, wind speed), design parameters (type of collector, collector materials) and flow parameters (air flow rate, mode of flow). The principal requirement of these designs is a large contact area between the absorbing surface and air.

The efficiency of solar collectors depending on the collector covered materials (polyvinylchloride film, cell polycarbonate PC, translucent roofing slate), the absorber (black colored wood, steel-thin plate etc.), with different air velocities in the collector was investigated [2-6]. The main efficiency parameter of the solar collector is the air heating degree and it was chosen as the criterion of efficiency.

The plane of the FPC absorber is perpendicular to the flow of sun radiation at the sun following collector, therefore this type is more powerful as the stationary collector. The sun rays fall under an angle to the collector plane (it means they fall under an angle to the covered material) and it gives more reflection.

## Materials and methods

The aim of the investigations was to compare usage of new absorber materials and to make out their usability in sun air heating collectors.

The solar radiation measuring instrument was the pyranometer which is used to measure total radiation within its hemispherical field of view. As an absorber different size black seed boxes were used which were made of polypropylene (Figures 1-3). In the laboratory a 0.1 x 0.5 x 1.0 meters long experimental solar collector was constructed for research into the properties of absorber materials (Figure 3). The air velocity in the experiments was $v = 0.9\ m \cdot s^{-1}$. Our investigations are devoted to the sun following collectors, which guarantee perpendicular location of the plane of the absorber from the flow of sun radiation.

In the experiments, the collector covered material was a polystyrene plate. This material has gained immense popularity due to such properties as safety, mechanical crashworthiness, translucence and high UV radiation stability. The covered material - polystyrene plate reduced the sun radiation by 12-15 %.

The situation when the absorber (different size seeds boxes) is put at the bottom of the collector is investigated (Figures 1, 2).

Fig. 1. **Sun heated collector with 22 seed box absorber**

Fig. 2. **Sun heated collector with 12 seed box absorber**

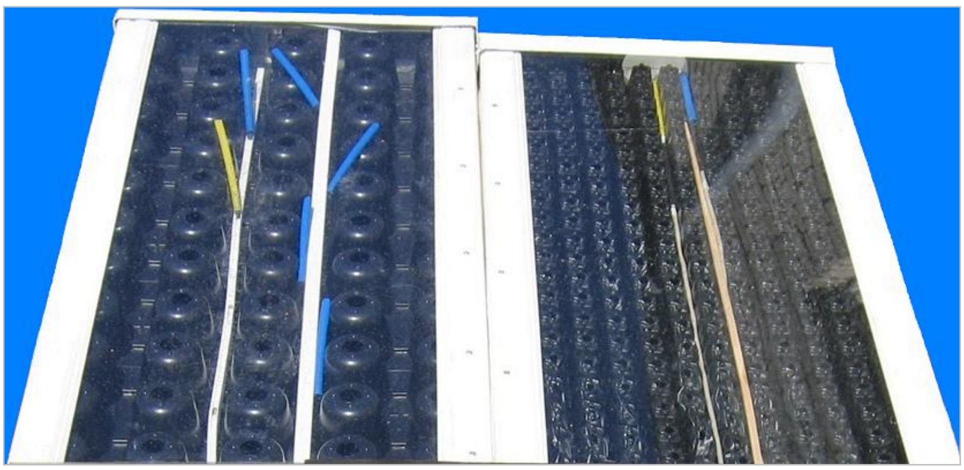

Fig. 3. **Sun collector comparative research in the experiment**

The experimental data are recorded by means of an electronic metering and recording equipment of temperature, radiation and lighting REG [8]. It is equipped with 16 temperature transducers and metering sensors of solar radiation and lighting. The reading time of the data can be programmed from 1 to 99 minutes (1 and 2 minutes in our case).

The recorded data are stored in the REG memory (there is room 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. The information is stored in the form of a table and in case of need it is depicted as a graph.

## Results and discussion

The experiments were made in 2009, in May-September months in different weather conditions at different atmospheric air temperatures. To assess different absorbers influence comparative research was performed in similar weather conditions.

As it can be seen in Figure 4 near small sun radiation are not visible constitutive air heating, but increasing sun radiation is growing air heating level and we can see that the collector with 12 elements in line is more powerful than the collector with 22 elements in line. The air heating level is not independent on the ambient air temperature, only on radiation.

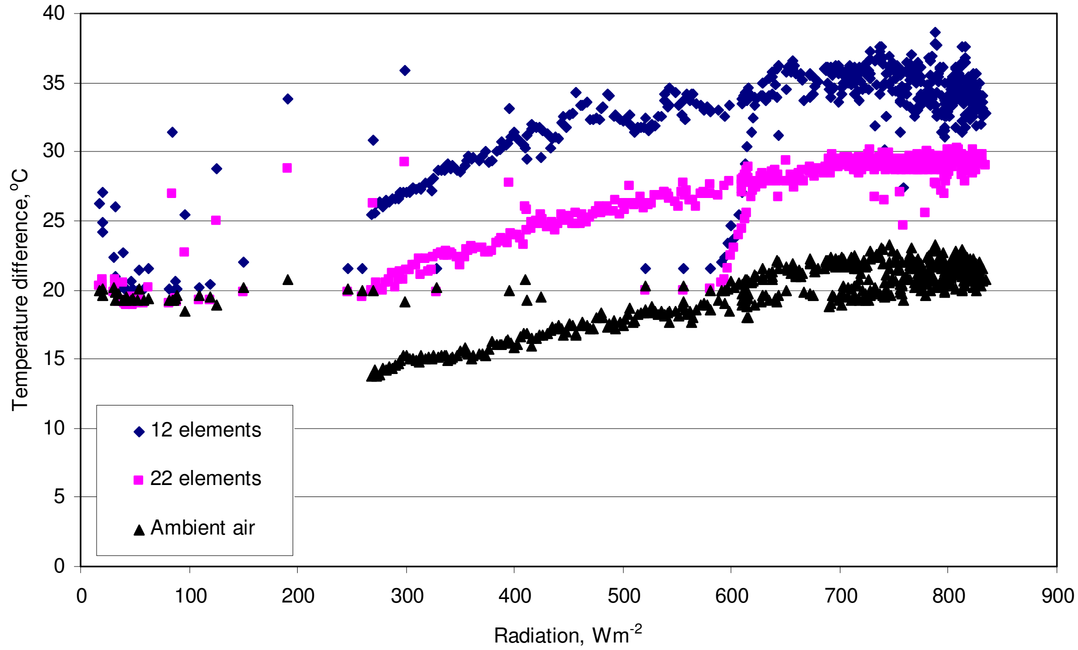


Fig. 4. **Heated air temperature in outlet of seed boxes with 12 and 22 elements in line comparing with ambient air in dependency of sun radiation**

To compare absorbers with 12 elements and 7 elements in line we can see that at the same weather conditions for 7 elements collector is warming up air to 2 degree up (at radiation 800 $W \cdot m^{-2}$) than collector with 12 elements. We can see tight connectedness in-between the air heating level and the radiation, correlation coefficient $r$>0.92 (Figure 5)

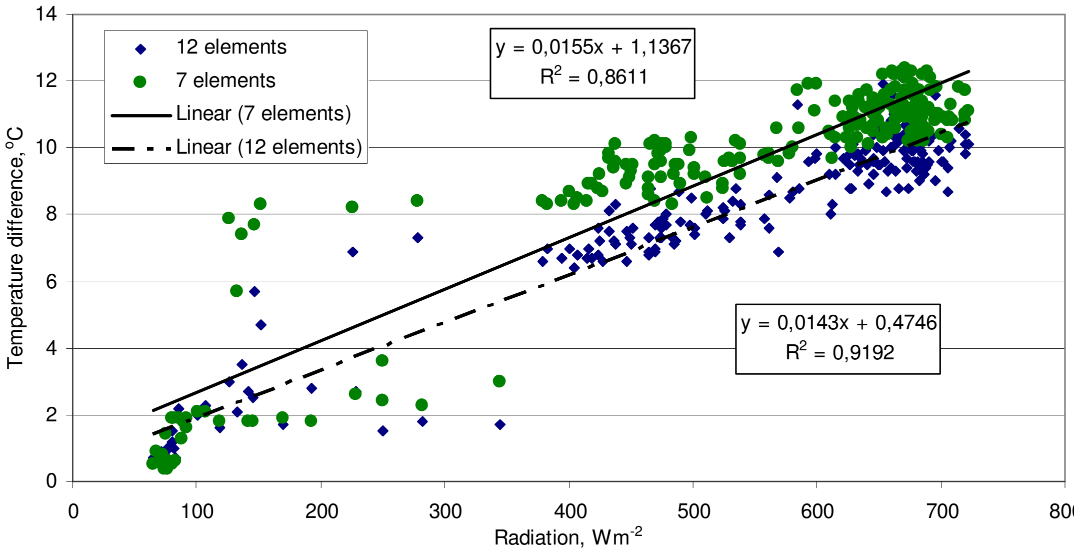


Fig. 5. **Temperature difference in outlet of seed boxes (with 12 and 7 elements in line) comparing with sun radiation**

The collectors with 7 and 5 elements in line are compared (Figure 6). It is visible, that collectors with 7 elements have worked more effectively.

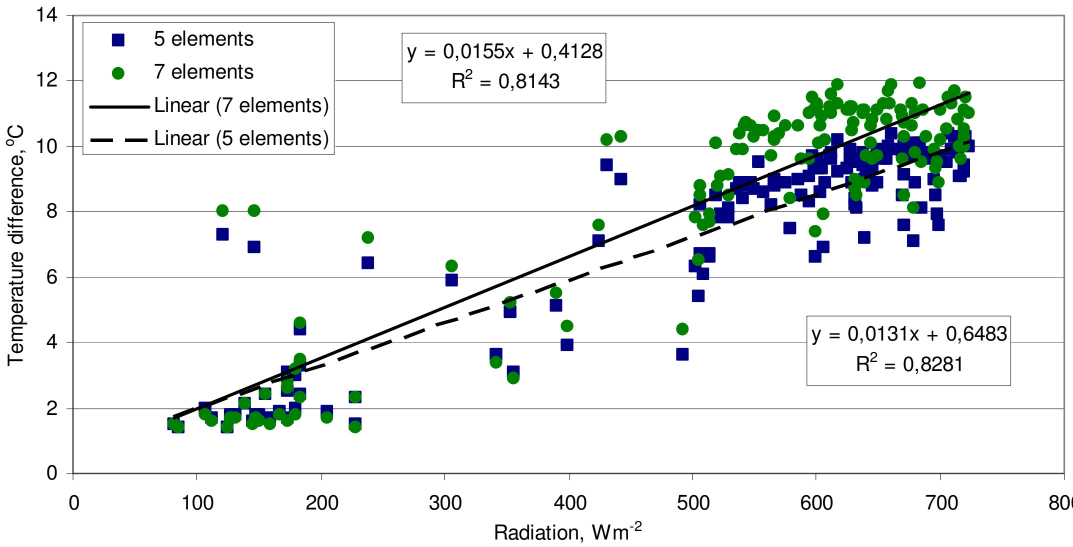


Fig. 6. **Temperature difference in outlet of seed boxes (with 12 and 7 elements in line) comparing with sun radiation**

In order to assess the absorber efficiency $\Delta T$ each absorber heating level for 100 W·m$^{-2}$ radiant energy has to be defined

$$\Delta T = \frac{k \cdot \sum_{i=1}^{n} \left( T_{out}^{i} - T_{amb}^{i} \right)}{n \cdot \sum_{j=1}^{k} W_j} \cdot 100, \qquad (1)$$

where $T_{out}^{i}$, $T_{amb}^{i}$ – air temperature at outlet of the collector and the corresponding ambient air temperature,

$W_j$ – sun radiation at the time step *j*;

*n*, *k* – number of air and radiation measurements accordingly.

In all experiments (in different weather conditions) the experiment time (from 6 to 10 hours) of the air heat up average outlet temperature in the collector and the average radiation value was calculated in order to calculate $\Delta T$. After it the average efficiency $\Delta\overline{T}$ of each box type was recalculated and the results of operations generalized in Table 1.

Table 1

**Usable absorber material (different size seed boxes) efficiency $\Delta\overline{T}$ (degree on 100 W radiation) comparison**

| Number in line | Type of seed boxes absorber | | | |
|---|---|---|---|---|
| | 5 | 7 | 12 | 22 |
| **Absorber efficiency average coefficient** $\Delta\overline{T}$ | 1.27 | 1.59 | 1.28 | 1.14 |

The isolated experimental measurements $\Delta T$ deviation of the calculated average (Table 1) values $\Delta\overline{T}$ are not greater 10 %.

The best air heating level is reached with 7 elements in line absorber (one box size $R$ = 2.5 cm, $H$ = 7 cm.). The 7 elements collector by radiation 1000 $W \cdot m^{-2}$ is warming up air on average about 4.5 degrees higher than the collector with 22 elements in line. The 5 and 12 elements in line collector efficiency is similar though it is on average 3 degrees lower than of the collector with 7 elements in line at 1000 $W \cdot m^{-2}$ radiation. It can be because of the ventilate absorber surface size and air flow profile.

Note, that in very good weather conditions (hot, sunny weather) in the collector the heated air can cause absorber (seed boxes) damage (smelting) (Figures 3 and 7).

Fig. 7 **Absorber defect in air heating sun collector in very good weather conditions**

## Conclusions

1. In Latvian climatic conditions it is possible to use seed boxes (made of polypropylene) as air heating sun collectors absorbers.
2. The best air heating level is reached with a 7 elements in line absorber (one box size $R$ = 2.5 cm, $H$ = 7 cm). The 7 elements collector by radiation 1000 $W \cdot m^{-2}$ is warming up air on average by 4.5 ˚C higher than the collector with 22 elements in line.
3. The 5 and 12 elements (in line) collector efficiency is similar even if it is on average 3 degrees lower then of the collector with 7 elements by 1000 $W \cdot m^{-2}$.
4. The sun following collector is showing more closer correlation in-between the air heating level and sun radiation than stationary.
5. Using seed boxes as collector absorbers we must pay attention to heat resistance of this material, that it by high sun radiation temperature increasing does not cause absorbent degradation.

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