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AIR HEATING SOLAR COLLECTORS AND ITS APPLICABILITY FOR ROOM VENTILA TION AND HEATING

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Abstract

This paper describes the results of the investigation the aim of which was to find new air heating solar collector constructions and easily to accessible materials which it is possible to use as absorbers. We tested the inflatable air heating solar collector construction. Inflatable solar collector gives good correlation with air heating degree and radiation (r=0.93). This type of collectors very sensitive to radiation changes, response time is only about 1 minute. Given type of air heating solar collectors is a good efficiency, the efficiency coefficient is η =0.63. Absorber materials (seed boxes made by polypropylene, black colored energy drink cans situated on steel-tinplate) are tested for room heating and ventilating. Stationary air heating solar collectors for room heating are using in case, when sun radiation exceed 300 W/m^2 , otherwise it is not effective or ambient air temperature is cooling room air. Collectors is recommended for room ventilation to reduce heat lost in cold weather. The collectors should be well insulated, especially if they are to be used in early spring, when ambient temperatures are low. These researches show air heating solar collectors applicability in room heating and ventilating, agricultural production drying at Latvia weather conditions

Key words: *solar collector, air heating, temperature, absorber*

1. INTRODUCTION

Sun, that alternative energy source more and more widely is used in national economics. 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. So if more people used solar energy to heat the air and water in their homes, our environment would be cleaner. Over the past century, fossil fuels provided most of our energy, because its were much cheaper and more convenient than energy from alternative energy sources. The limited reserves of fossil fuels cause situation in which the price of fuels will accelerate as the reserves are decreased.

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.

We can use solar energy to heat and cool buildings (both actively and passively), drying production, heat water for domestic and industry use, heat swimming pools, generate electricity, for chemistry applications and many more operations.

The application of solar energy is completely dependent on solar radiation. 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 air heaters are flat-plate collectors (FPCs), consisting of an absorber, a transparent cover, and backward insulation. The performance of solar air heaters is mainly influenced by meteorological parameters (direct and diffuse radiation, ambient temperature and wind speed), design parameters (type of collector, collector materials) and flow parameters (air flow rate, mode of flow). The principal requirements of these designs are a large contact area between the absorbing surface and air (S. Kalogirou, 2009).

The efficiency of air heating solar collector depending from collector covered materials (polyvinylchloride film, cell polycarbonate PC, translucent roofing slate), absorber (black colored wood, steel-thin plate etc.) and insulation of collector body with different air velocities in collector was investigated (A. Aboltins et al. (2009, 2010, 2011), G. Ruskis et al. 2011).

The air heating collectors can be used in two main directions for production drying and room heating (ventilation). Production issues through drying in the sun-warmed air are discussed a lot in works (H. Andoh et al. 2010, A. Aboltins, Upītis 2010). We are exploring a variety of coating and absorbent materials to increase the air warm-up stage

In case, if you are using FPCs for room air heating, then they mostly are stationary it efficiency is not only dependence from sun radiation, but also from sun rays angle against collector surface. The sun rays fall under angle to collector plane (it means its fall under angle to covered material) and it gives more reflection.

We want to look at and to study same created inflatable solar air heating collector usage of production drying and room heating questions using different material absorbent stationary air-heating solar collectors.

2. MATERIALS AND METHODS

An aim of the experiment was to made inflatable solar collector (Patent LV-14452). Inflatable solar collector had simple constructions, easily usable and transported. This type of collector based on the inflated carcass with a good insulator of absorbent. As a coating material has been used polyethylene film.

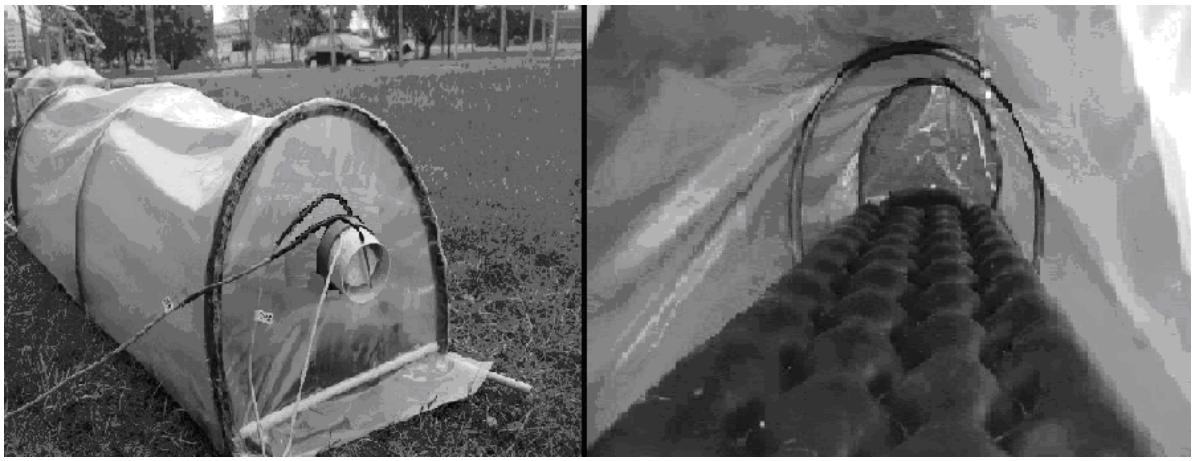


Fig. 1. Inflatable air heating solar collector (overview, inside).

For experiments we used inflatable air heating solar collector with dimensions: length 1.5 m, width 0.7 m and height 0.6 m (Fig.1). We used fan with power 100 m^3/h for air ventilation in collector.

The another part of our investigations devoted to the flat-plate collectors situated at wall in southward direction. The aim of our investigations was to compare different absorber materials use and to make out their usability in air heating solar collectors for room heating and ventilation.

The *0.1x0.5x1.0* meters long experimental solar collector was constructed for research. As a absorbers was used- steel tinplate with cylinders of black coloured energy drink cans (Fig.2) and black seed boxes which was made out of polypropylene (Fig.3). Air velocity at the experiments in collector was v=0.9 m/s. In collector we used fan with power 100 m^3/h and room space was approximately 80 m^3.



Fig. 2. View of solar collector with cylinders of black coloured energy drink cans situated on steel-tinplate absorber.



Fig. 3. View of solar collector with black polypropylene seed boxes absorber.

In the experiments, the collector covered material was polystyrol plate. This material has gained immense popularity due to such properties as safety, mechanical crashworthiness, translucence and high UV radiation stability. Covered material - polystyrol plate reduced sun radiation by 12-15 %. Solar radiation measuring instrument was the pyranometer which is used to measure total radiation.

Our task was to investigate air heating solar collector possibility to use it for room heating. For this task we used the collector built-in window. Through this window collector we ventilated room air. We measured room air, ambient air, and ventilated air temperature inlet and outlet of collector.

Experimental data is recorded by means of an electronic metering and recording equipment of temperature, radiation and lighting REG (REG, 2004). Solar radiation measuring instrument was the pyranometer.

The aim of our experiment was to compare and analyze different type air heating solar collectors use for Latvian climatic conditions.

Experiments were made in year 2011 from spring to autumn in different weather conditions at different ambient air temperatures and wind speed.

3. RESULTS AND DISCUSSION

The data of inflatable solar collector (Patent LV-14452) shown in Figure 4. The experiment took place in the 6. May 2011. Results show a very strong correlation between solar radiation and air warm-up stage. It should be noted that the air warm up in the collector quickly react to changes in radiation (clouds, shadows). Response delay time inflatable collector is approximately 1 minute, compared to the classic it accounted for 5-7 minutes (A. Aboltins et al. ,2011, G. Ruskis et al., 2011).

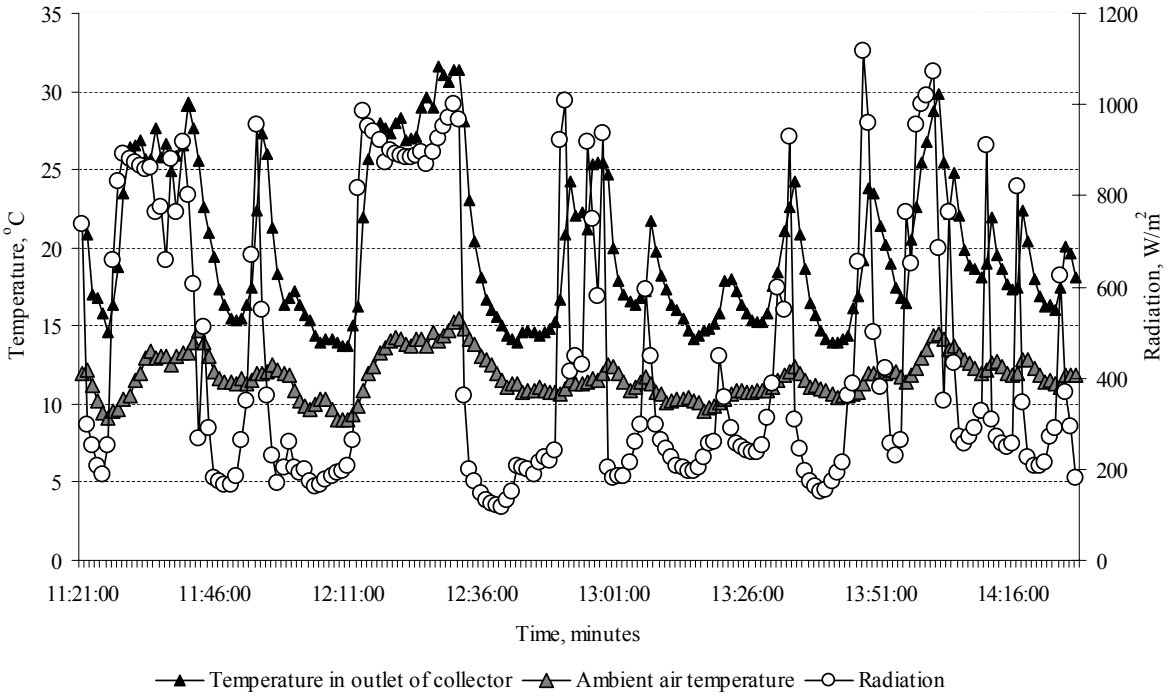


Fig. 4. Inflatable solar collector heated and ambient air temperatures comparing with sun irradiance in time.

Using the obtained data and taking into account the warm-up delay time (1 minute) obtained the relationship, which is characterized by atmospheric air warm-up degree in inflatable air heating solar collector, depending on solar radiation (Fig.5).

It should be noted the high correlation coefficient ($r = 0.93$) with such a rapidly changing sun radiation conditions.

We determined the efficiency of the solar collector, as prescribed in ASHRAE Standard 93 2003. The efficiency of the solar collector can be calculated by the following equation (Clearinghouse, 1994):

$$\eta = \frac{m \cdot c_p \cdot (T_{fo} - T_{fi})}{S \cdot R_T} \quad (1)$$

where η - efficiency coefficient of solar radiation converted into heat;

m - mass flow rate of air, kg·s^{-1};

c_p - specific heat, J·kg°C^{-1};

S - area of solar collector, m²;

R_T - global solar irradiance incident upon the aperture plane of collector, W·m⁻²

T_{fo} , T_{fi} - outlet and inlet working air temperatures, °C

With the equation (1) were defined effectiveness coefficient over the all experimental time using average working air temperatures and radiation. In our case inflatable air heating solar collector efficiency coefficient η =0.63

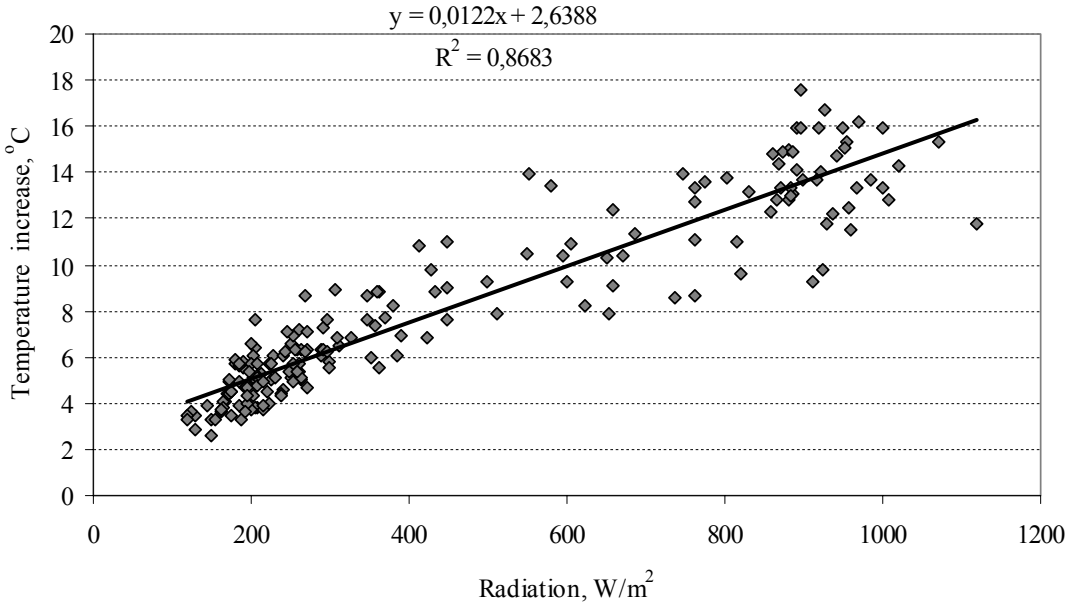


Fig. 5. Temperature increase in outlet of inflatable air heating solar collector comparing with sun radiation.

An issue, how to use the air heating solar collectors for room heating at Latvian climatic conditions. Experiments were performed with two types of absorbent materials (cylinders of black colored energy drink cans and with black polypropylene seed boxes).

As can be seen from the experimental 1 March 2011, solar radiation significantly affected by passing room air temperature warm-up stage (Fig 6). Experimental data show that, near little sun radiation are not visible constitutive air heating, but increasing sun radiation is growing air heating level (Fig. 6).

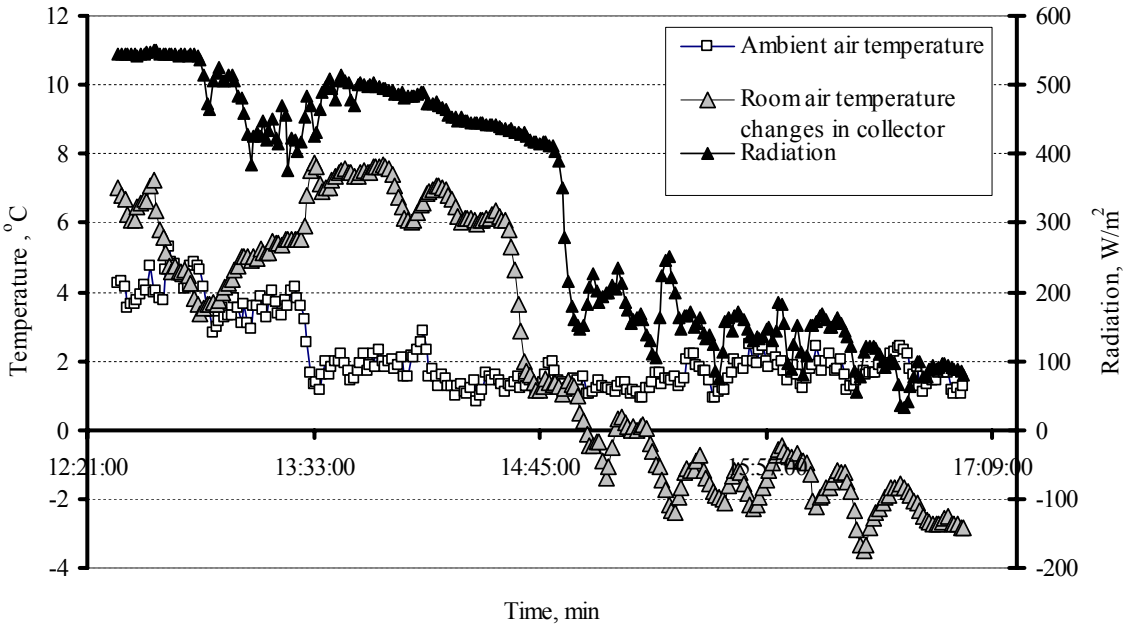


Fig. 6. Room air temperature changes in outlet of collector (cylinders of black colored cans) and ambient air temperatures comparing with sun radiation in time.

When radiation is smaller than 300 W/m^2 collector is not heating room air, because absorbent can not compensate heat loses in atmospheric temperature influence. Air heating level is not highly dependent on ambient temperature, much more it is influenced by solar radiation and horizontal irradiance angle of sun to collector surface.

We can see that the solar radiation changes significantly affect the passing air temperature. This effect does not happen instantly, but with a delay of 4-7 minutes. It should be noted that the un-insulated collector efficiency is highly influenced by wind speed, which cools the surface of the collector body.

Experimental data, which took place on 14 April 2011. with black polypropylene seed boxes absorber shown in the Fig. 7. The room air passing through the collector heats up to 10 degrees up radiation greater than 600 Wm^{-2}.

We are interested in room air temperature increasing in outlet of collector. We would like to know how sun radiation influence air heating level for stationary collector. Experimental data from 14 September 2010 shows sun radiation and air temperature increasing dependence in Fig. 8 (collector with absorber steel tinplate with cylinders of black colored cans). Large data dispersion shows that horizontal irradiance angle of sun to collector surface is giving influence to temperature increasing witch we ignored. Sun's rays angle influence to collector effectiveness is shown at (A.Aboltiņš et al. CIOSTA 2011).

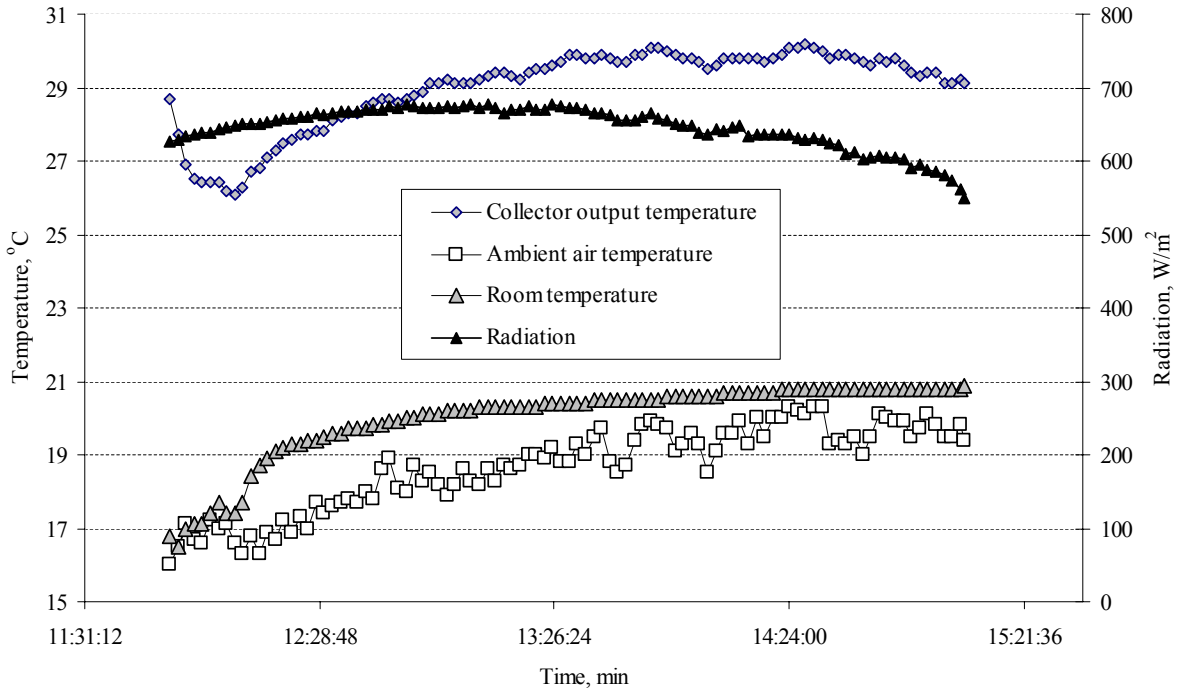


Fig. 7. Room air, ambient air and collector outlet air temperatures (absorber material - black polypropylene seed boxes) comparing with sun radiation and time.

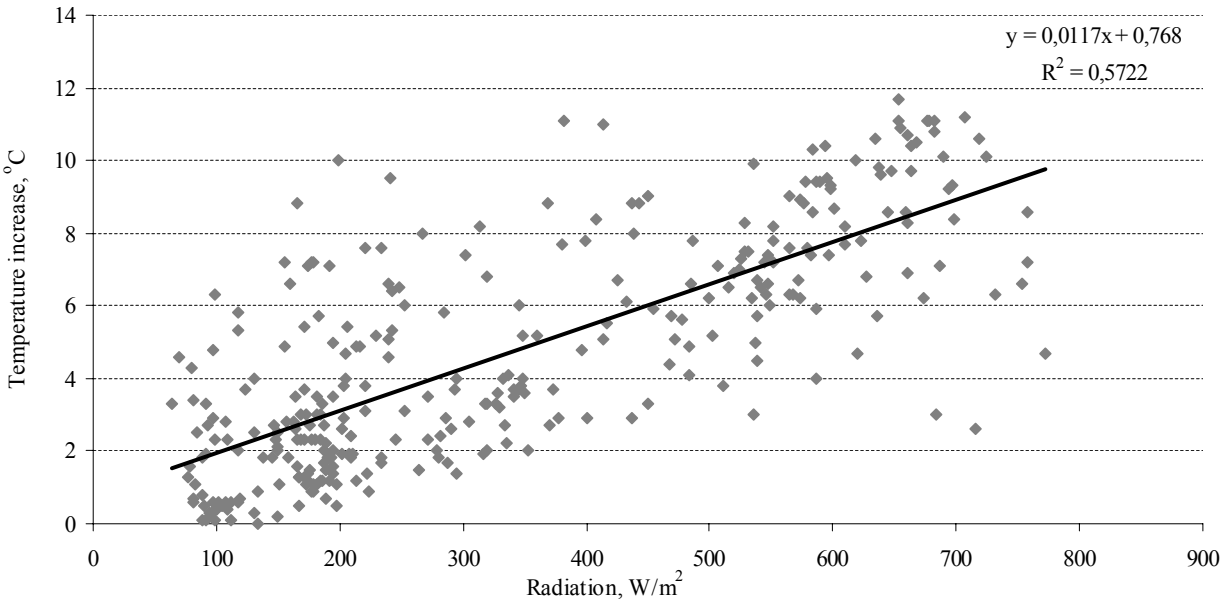


Fig. 8. Temperature increase in outlet of collector (absorber steel-tinplate with cylinders of black colored cans) comparing with sun radiation.

Air-heating solar collectors have a wide range of use possibilities of ventilation, using atmospheric air, especially in spring and autumn. Atmospheric air passes through a collector, it is heated and thus reducing heat loss in room during ventilation.

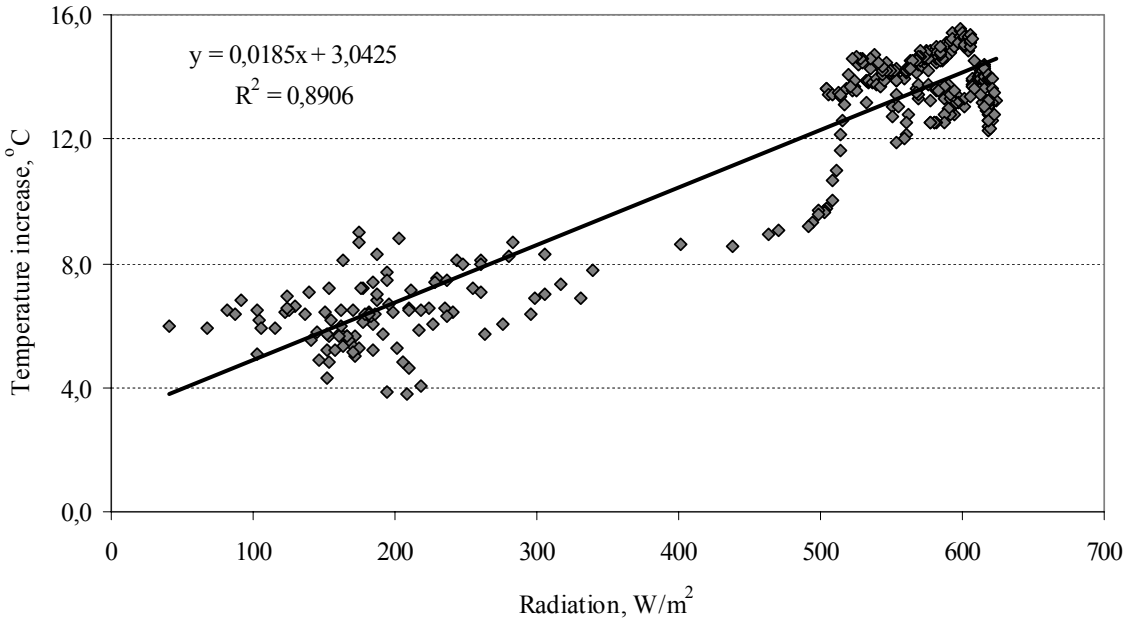


Fig. 9. Atmospheric air temperature increase in outlet of collector (absorber steel-tinplate with cylinders of black colored cans) comparing with sun radiation.

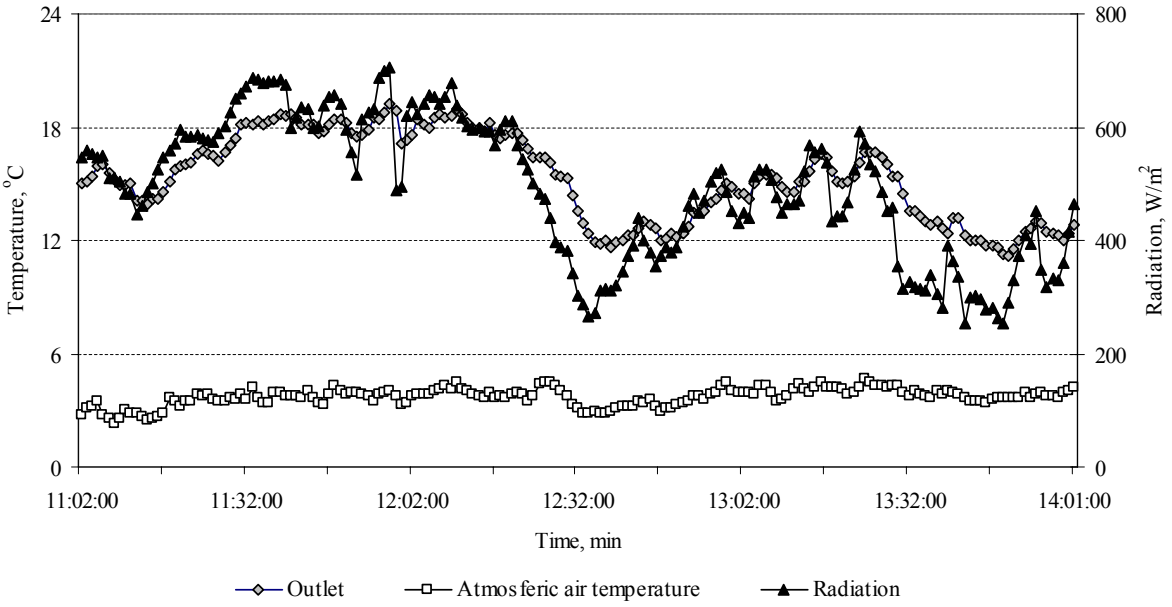


Fig. 10. Atmospheric air temperature, collector outlet air temperature (absorber material - black polypropylene seed boxes) comparing with sun radiation and time.

By using atmospheric air ventilation (mean temperature during the experiment was 4.2 ^{o}C), it is heated by an average of 11.6 degrees to the average radiation R = 461 Wm^{-2}. Experimental data (experiment took place in the 3rd March 2011 from 10.30 hours to 16.30) show close sun radiation and atmospheric air temperature increasing dependence (collector with absorber steel tinplate with cylinders of black colored cans) (Fig. 9). The ambient air temperature, air temperature at outlet of collector (absorber- black polypropylene seed boxes) and sun irradiance data (17.03.2011) show , that air with average temperature 3.7 ^{o}C heated up to 15.3 ^{o}C with sun radiation 492 Wm^{-2} (Fig. 10).

4. CONCLUSIONS

1. Inflatable solar collector is giving good results, average ambient air temperature increase in experiments is 10,2C° and max increase is up to 16 C°. This collector gives good correlation with air heating degree and radiation (r=0.93). This type of collectors very sensitive to radiation changes, response time is only about 1 minute. Given type of air heating solar collectors is a good efficiency, the efficiency coefficient is η =0.63.
2. Inflatable solar air heating collector is easy to make, operate and to derange construction. It works well in Latvian climatic conditions.
3. Stationary air heating solar collectors for room heating are using in case, when sun radiation exceed 300 W/m^2 , otherwise it is not effective or ambient air temperature is cooling room air. It should be noted that the collectors should be well insulated, especially if they are to be used in early spring, when ambient temperatures are low.

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