

Investigation of Solar Collector Irradiated from Both Sides

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Abstract. The ordinary flat plate solar collector receives solar radiation only from one side of its surface. Another side is covered with a heat barrier. The solar collector with reflectors has been developed and examined to track the sun. The absorber of this type of a collector was irradiated from both sides. The experimentally obtained energetic parameters of the collector tracking the sun have been compared to those of the ordinary flat plate solar collector. In order to complete the experiment, a special stand has been developed. The experimental investigation has been carried out at the intensity of radiation 2,000, 1,000 and 500 W m⁻² in different combinations. The temperature has been measured in certain points of different parts of the collector by several thermocouples. With the aid of a multi-meter, the obtained results were collected to the memory of a computer, and later processed and analyzed. When a collector surface is tracking the sun, the heat energy produced by the collector is 1.4 to 1.5 times higher in comparison with a stationary solar collector of the same size. A solar collector tracking the sun and irradiated from both sides depending on the reflection quality of the reflector's material is able produce about 2.5 times more heat energy than a stationary flat plate solar collector irradiated only from one side.

Key words: Sun, solar collectors, efficiency

INTRODUCTION

The amount of heat energy produced by a solar collector depends on the type of collector, its working surface direction towards the sun, meteorological conditions of the location and many other factors. There are different collectors: The so-called flat plate solar collectors, parabolic collectors or those concentrating sun beams, spherical collectors, stationary and sun tracking collectors, and others.

It has been stated that in order to produce as much heat energy as possible, the surface of the receiver of solar radiation has to be directed perpendicularly towards the sun beams. In this case the efficiency of a solar device will be at its maximum. The ordinary flat plate solar collector receives solar radiation only from one side of its surface. Another side is covered by a heat barrier. The efficiency of these collectors is in practice no higher than 40–60%, depending on the atmosphere's mass, nebulosity and lucidity, the intensity of solar radiation, the time and day of the year, etc. In order to increase the efficiency of solar collectors, several original constructions, such as a spherical collector, a collector with canal absorbers, a flat plate solar collector with polycarbonate cell absorber, a solar collector with two-plate absorber, and a sun tracking solar collector with reflectors (Ziemelis et al., 2007; Iljins et al., 2007; Ziemelis et al., 2008; Putans et al., 2008; Putans et al.,

2008) have been developed and examined both in laboratory and outside conditions on a house roof.

The absorber of a solar collector with reflectors has to be tracking the sun all day round, because the sun beams striking the reflectors are reflected from them on the rear side of the absorber, only if the collector is in a perpendicular position towards the sun beams. Thus the absorber of the collector is irradiated from both sides simultaneously with direct and reflected radiation. The experimentally obtained energetic parameters of a sun tracking collector with those of an ordinary flat plate solar collector have been compared and analyzed. Our experimental investigation has shown that such a system makes the solar collector device more expensive. At the same time the collector receives more solar radiation energy and produces more heat energy (Putans et al., 2005).

The main objective of the research is to determine the thermo-energetic parameters of a solar collector, the absorber of which is irradiated from both sides, and compare these results with the corresponding data of an ordinary flat plate solar collector.

MATERIALS AND METHODS

In order to investigate the properties of a sun tracking solar collector with reflectors, we developed such a collector (Fig. 1). In the experimental examination of the collector it was stated that at irradiation of the rear surface of the absorber with two glass mirrors of collector size (glass thickness 4 mm), the radiation intensity received by the collector rear side is 1-1.2 of the frontal radiation striking the collector.



Fig. 1. A sun tracking solar collector with reflectors.

To clear out the energetic parameters of the collector irradiated from both sides, experimental investigation has been carried out both in laboratory and field conditions. For that a special stand (Fig. 2) has been developed, containing a collector 1; an absorber 2; a heat accumulation basin (0.72 liters) 3; a circulation pump 4; a heat carrier flow meter 5; two glass covers 6; a funnel 7; a heater 8

(infrared lamp); thermocouples for measuring the heat carrier temperature at the out flow from the absorber 9 (T_{out}), inflowing into the absorber 10 (T_{in}), and surrounding air 11, respectively; a thermometer for air temperature T_0 measuring; multi-meters (micro-voltmeters) 12 and 13. The collector consists of a box-type absorber placed into a wooden box, and covered from both sides with glass covers. The absorber area is 0.1m^2 ($240 \times 430 \text{ mm}$), its capacity is 0.3 liters. The system capacity is 1.2 liters. The laboratory equipment has been presented in Fig. 3.

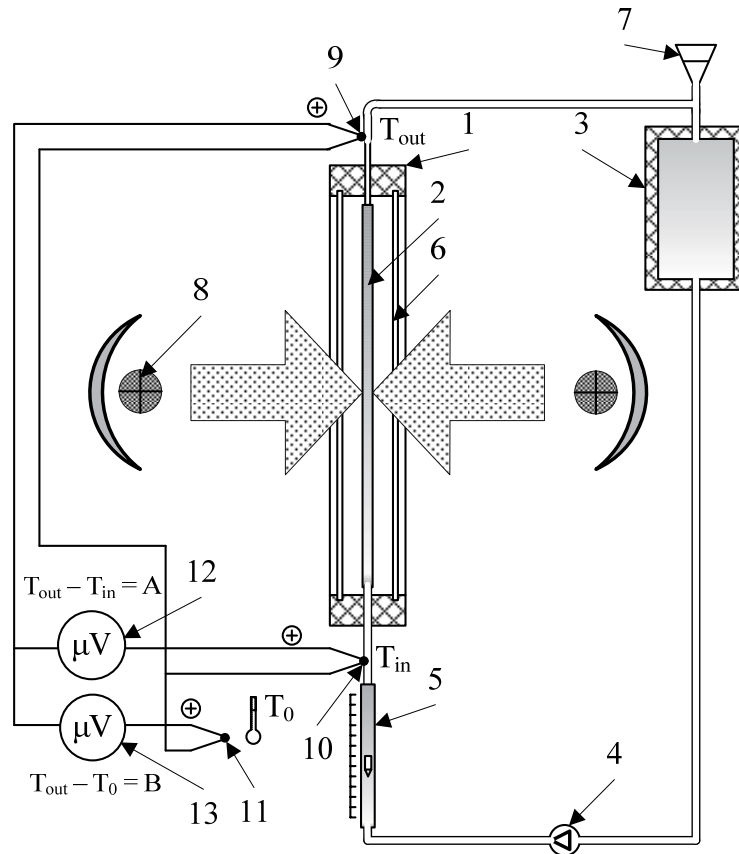


Fig. 2. A stand for the experimental investigation of solar collectors: 1 – collector; 2 – absorber; 3 – heat accumulation basin; 4 – circulation pump; 5 – heat carrier flow meter; 6 – glass cover; 7 – funnel; 8 – heater; 9, 10, 11 – thermocouples for temperature measuring; T_0 – thermometer; 12, 13 – multi-meters.

As it has been mentioned above, the absorber received global solar radiation from its front side and reflected solar radiation from its rear side reflectors (mirrors), which were of the same size as the absorber (Fig. 1). The intensity of reflected radiation on the rear side of the absorber was 1–1.2 from the intensity on the front surface. It means that the intensity of solar radiation which the absorber received was about two times higher than the one an ordinary solar collector receives, when irradiated only from the front surface. The irradiation intensity of the collector was measured with a device consisting of a pyranometer thermo battery and a multi-meter (Fig. 4). The device was graduated this way that $1,000 \text{ W m}^{-2}$ radiation power corresponded to the voltage of 10 mV. The necessary

intensity of the surface irradiation was installed by the use of the device, changing the distance between the lamp and the absorber.



Fig. 3. A stand for investigating the absorber of the solar collector with reflectors.

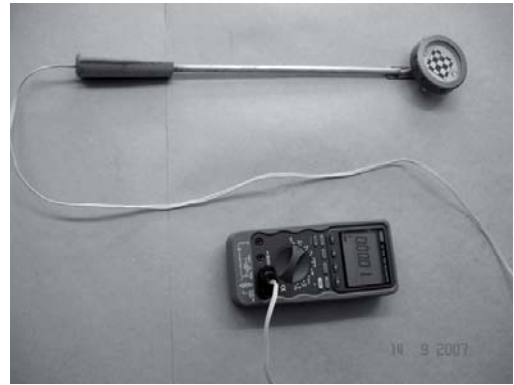


Fig. 4. A device for measuring radiation intensity.

RESULTS AND DISCUSSION

In order to determine what part of solar radiation, received from both surfaces of a flat plate, the solar collector is able to convert into heat energy, an experimental stand (Fig. 2) has been used. The absorber of the collector has been irradiated from both surfaces (Fig. 5) and from one side (Fig. 6).

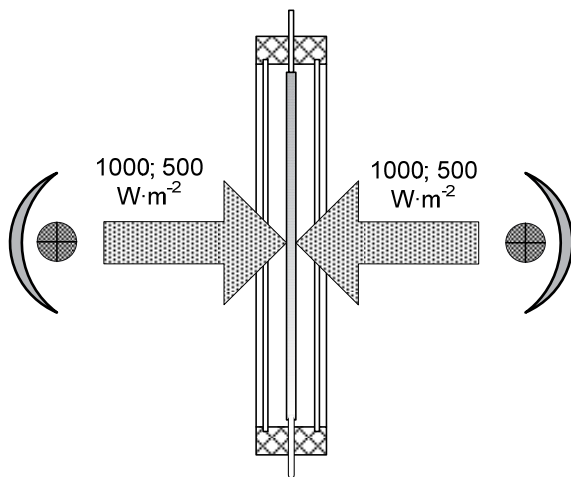


Fig. 5. Cross section of the collector irradiated from both sides.

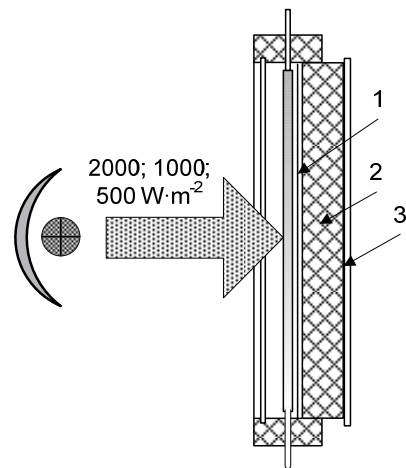


Fig. 6. Cross section of the collector irradiated from one side: 1 - plastic film; 2 - rock wool; 3 - cover.

When both surfaces of the absorber are irradiated with $1,000 \text{ W m}^{-2}$ intensity ($1,000 + 1,000 = 2,000 \text{ W m}^{-2}$), the double $T_{in}-T_o$ increase is not obtained in comparison with irradiation of one absorber side with $1,000 \text{ W m}^{-2}$ intensity. When

one side of the absorber surface is irradiated with $2,000 \text{ W m}^{-2}$ intensity, the increase in obtained heat power has doubled (Fig. 7). The same regards to the curves in Fig. 8.

In Tables 1 and 2 the numerical values of the examined collectors are given: Maximum temperature of the produced and consumed energy amount, efficiency of different types and power of radiation during 75 and 120 minutes of heating.

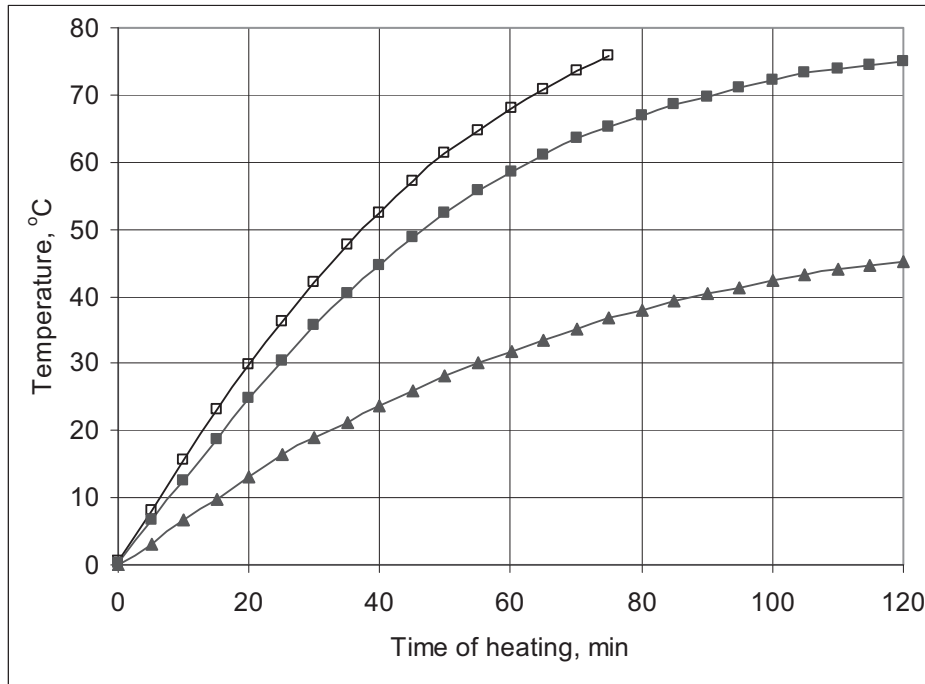


Fig. 7. Temperature $T_{in} - T_o$ increase at different regimes of irradiation: \square $2,000 \text{ W m}^{-2}$; \blacksquare $1,000 + 1,000 \text{ W m}^{-2}$; \blacktriangle $1,000 \text{ W m}^{-2}$.

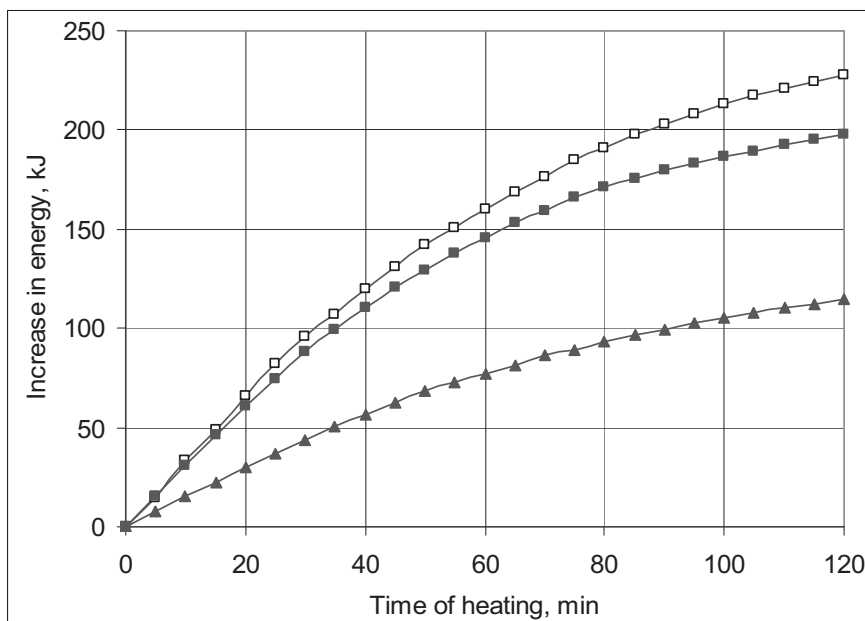


Fig. 8. Heat energy increase at different regimes of irradiation: \square $1,000 \text{ W m}^{-2}$; \blacksquare $(500 + 500) \text{ W m}^{-2}$; \blacktriangle 500 W m^{-2} .

In order to evaluate the produced amount of heat energy, Tables 1 and 2 present irradiation of the absorber only from one side with power 500 W and 1,000 W, respectively, as a reference point. In this case the other absorber surface is covered with a heat barrier (Fig. 4). It follows from Tables 1 and 2 that if both surfaces of the absorber with power equal to the reference power are irradiated, 1.73 and 1.77 times more heat energy is produced. If only one surface of the absorber with two times higher power is irradiated, 1.99 and 2 times higher amount of heat energy is produced.

Table 1. Energetic parameters at irradiation of the absorber surface with power 500 and 1,000 W m⁻²

No.	Parameters	Absorber irradiated by power, W m ⁻²		
		500		1,000
		one surface irradiated, another insulated	both surfaces irradiated	one surface irradiated, another insulated
1.	Time of heating, min.	120	120	120
2.	T _{in} -T _{o max} , °C	22.7	39.2	45.2
3.	Power consumed, kJ	360	720	720
4.	Power produced, kJ	114.4	197.4	227.3
5.	Efficiency average	0.32	0.27	0.31
6.	Gain	1	1.77	2

Table 2. Energetic parameters at irradiation of the absorber surface with power 1,000 and 2,000 W m⁻²

No.	Parameters	Absorber irradiated by power, W m ⁻²		
		1,000		2,000
		one surface irradiated, another insulated	oth surfaces irradiated	one surface irradiated, another insulated
1.	Time of heating, min.	75	75	75
2.	T _{in} -T _{o max} , °C	22.7	39.2	45.2
3.	Power consumed, kJ	450	900	900
4.	Power produced, kJ	114.4	197.4	227.3
5.	Efficiency average	0.32	0.27	0.31
6.	Gain	1	1.77	2

It follows on the basis of these and abovementioned data that while using selective tracking and a solar collector with two reflectors of collector size, the produced heat energy in comparison with a stationary collector irradiated only from

one side is $1.43 \times 1.77 = 2.5$ times higher. Solar collector area for a family of 4 people is usually about 4.5 m^2 . If a selective and sun tracking collector with reflector is used, its working surface area can be decreased up to 1.8 m^2 .

CONCLUSIONS

1. A sun tracking solar collector without reflectors produces 1.4–1.5 times more heat energy in comparison with a stationary operating flat plate solar collector of the same size.

2. A sun tracking solar collector with reflectors and a selective absorber produces 2.5 times more heat energy in comparison with a stationary flat plate solar collector of the same size placed under optimal angle and irradiated only from one side.

3. If the absorber of an ordinary flat plate solar collector is irradiated with twice as high radiation intensity, it produces almost twice as much heat energy.

4. When the absorber of a collector is irradiated from both sides with equal radiation intensity, it produces 1.75 times more heat energy than in case it is irradiated only from one side, the other one having a heat barrier.

5. The design of a sun tracking solar collector with reflectors is simpler, if the absorber is irradiated from both sides; therefore, this variant is advisable for practice.

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