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ACQUISITION OF SOME METEOROLOGICAL PARAMETERS FOR THE DEVELOPMENT OF SOLAR COLLECTORS

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Abstract

In order to get maximum economic effect, when setting a solar collector in a peasant yard, it is important to choose the correct place. The yield of obtained heat energy will be at its maximum, if the temperature of surrounding air and solar radiation are higher but the relative humidity of the air – lower. To define these parameters, a special device 'Meteorological Device' (MD-4) was developed. The device was supplied with a mechanism which tracks the sun all day round. So the direct solar radiation on the surface perpendicular to the sun beams was measured. The second measuring of the solar radiation was made in relation to the surface, which was perpendicular to the sun beams only at the middle of a day time. For the measuring of the air temperature and relative humidity, corresponding sensors were used. In every 15 minutes the data of these four meteorological parameters were automatically measured and the results were saved into a logger – the device for data accumulation. After a certain period of time the information was brought into the memory of a computer and analysed.

Key words: solar collector, air temperature, relative humidity, solar radiation.

Introduction

For the transformation of solar radiation into heat energy, the so called flat - plate solar collectors are widely used. They are simpler by construction and therefore cheaper in comparison with other kinds of solar collectors. In Latvia, more than three hundred m^2 of such collectors are installed. A flat - plate solar collector consists of a wooden, plastic, or metal collector box (3), into which a layer of heat insulation (4) and a metal (steel, copper) sheet with a heat exchanger (bended metal tube) (2) are placed. From the front side, the box is covered with a pane of glass (1) but from rare side the box is covered with a sheet of veneer (5) (Fig.1).

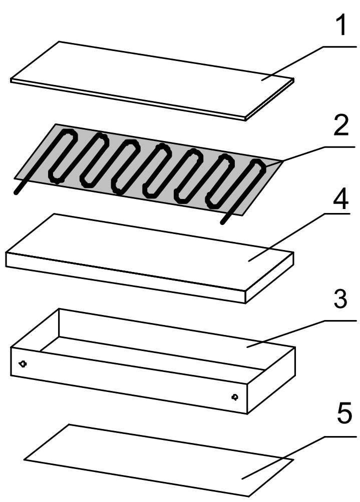

Figure 1. A flat - plate solar collector: 1 – pane of glass; 2 – absorber with heat exchanger; 3 – collector box; 4 – heat insulation; 5 – rare cover (a sheet of veneer).

A flat - plate solar collectors usually are placed on the sloping roof of a house. The maximum of solar energy can be obtained, when the solar collector is oriented in the South direction and direct solar rays are striking the collector plane perpendicularly. For this the optimal tilt angle δ between horizontal line and collector's plane has to be calculated by formula (Шукстерис et al., 1989);

$$\delta = \varphi - 15°, \qquad (1)$$

where

φ – degree of latitude of the place.

At such a tilt angle it is possible to obtain maximum heat energy during spring and autumn, but for maximum heat yield during the whole season it is recommended to figure this angle by coherence (Шукстерис et al., 1989);

$$\delta = \varphi - 27°. \qquad (2)$$

For Riga it means $\delta = 57° - 27° = 30°$. In order to keep the solar collector's plane perpendicularly to the direct radiation of solar beams all day round, it is necessary to provide the collector with a mechanism for tracking the sun.

For the experimental investigation of difference between the heat energy obtained by a solar collector focused to the sun and solar collector placed at every angle to the horizon, by means of the device MD-4 during the period of time from 21 July till 3 August, 2004, and registered the power of solar radiation, air temperature and

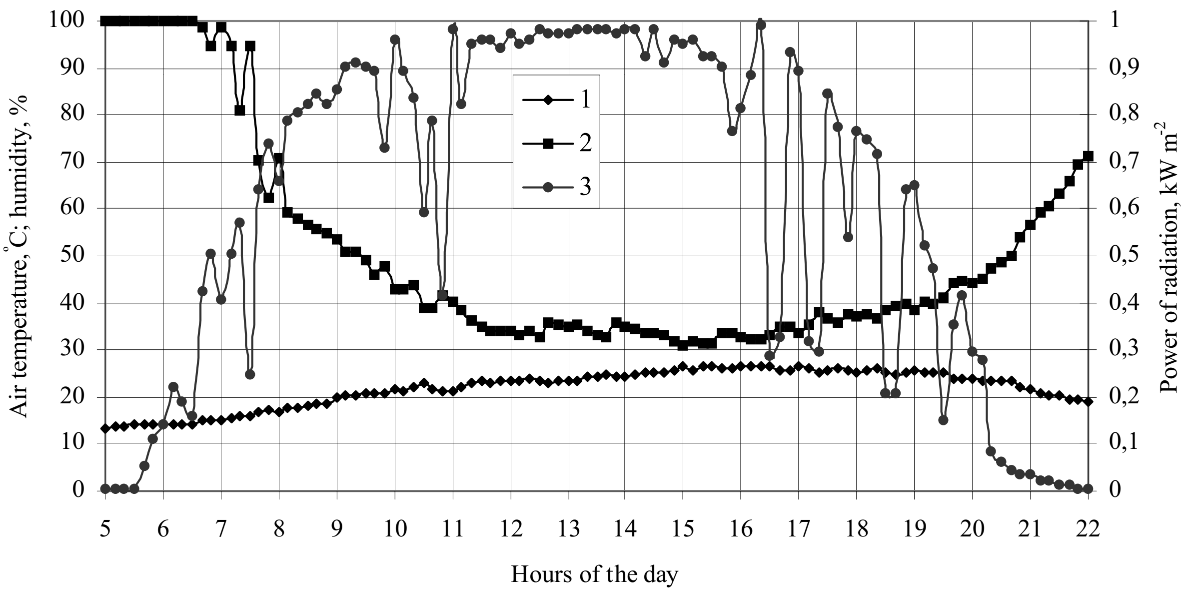

Figure 2. Air temperature, humidity and power of solar radiation on July 26, 2004:
1 – air temperature; 2 – humidity; 3 – power of radiation.

relative humidity continuously were measured. The obtained data were recorded into four measuring channel module HOBO H08, then stored into the computer program 'BoxCar', after wards transported to 'Excel' program, processed and analyzed. The results were positive. It was stated that the solar collector tracking the sun is able to produce by 34% more heat energy in comparison with the stationary located one (Putans et al., 2005). The obtained data testifies the value of air temperature, relative humidity, and the power of solar radiation (Figs.2).

The goal of the investigation was to clarity heat energy additionally gained from using the solar collector, which follows the sun, for a longer period of time – during summer and autumn months from April till November.

Materials and Methods

To orientate the solar collector in a direction perpendicular to the sun beams, it is possible to turn the collector's plane:

- only in a vertical plane, that is, to change the angle of the slope of a collector in relation to the horizon;
- in two planes – horizontal and vertical – in order to follow the collector's working surface to the sun.

If the solar collector is not built into the roof of a house but is put on the flat roof of a building, it is technically and economically simply with small additional payments to realise the first variant. In this case, the solar collector has to be mounted on a special pad and placed on the ground or flat roof with easy access for service. When the second type of collector installation is used, the collector should be provided with a mechanism turning the collector along the sun in its orbit. The implementation of this principle makes the collector more expensive, but increased additional amount of heat energy obtained by such a collector will soon cover the additional investments.

In order to determine the additional gain of heat energy by the solar collector, which tracks the sun, a special device MD-4 was developed in 2004 (Fig.3).

The data acquisition device MD-4 consists of the base (23) into which the steel bar (9) is fixed. At the upper part of the bar, a slanting axle (10) with a fixed cog-wheel (11) is attached. On the axle, a driving drum (6) having a clock drive and cog-wheel (7) is put on. The cog-wheel (7) has an engagement with a cog-wheel (11). The cog-wheel (7) turns the drum (6) with protecting cylinder (5), on which a thermo-battery (1) with back-sight (2) and fixation button (4) are fastened. When the protecting cylinder is put on the driving drum, they are jointed immovably. The cog-wheel (7) has a fixation coupling, therefore for orientation the thermo-battery to the sun, the driving drum is turned around the axle (10). At the upper part of the driving drum, the thermo-battery operational voltage amplifier plate, the amplifier's feeding battery and a handle for winding up the clock spring are placed. The stationary thermo-battery (14) is fixed on the holder (17), which is immovably linked with the bar (9). This thermo-battery has a scale (15) and position fixation button (18). On the holder (17), the compass (16) is fastened. A plumb (19) (details 12, 13, 20, and 22) and four screws (21) are envisaged for adjustment of the device in vertical position (Putans et al., 2005).

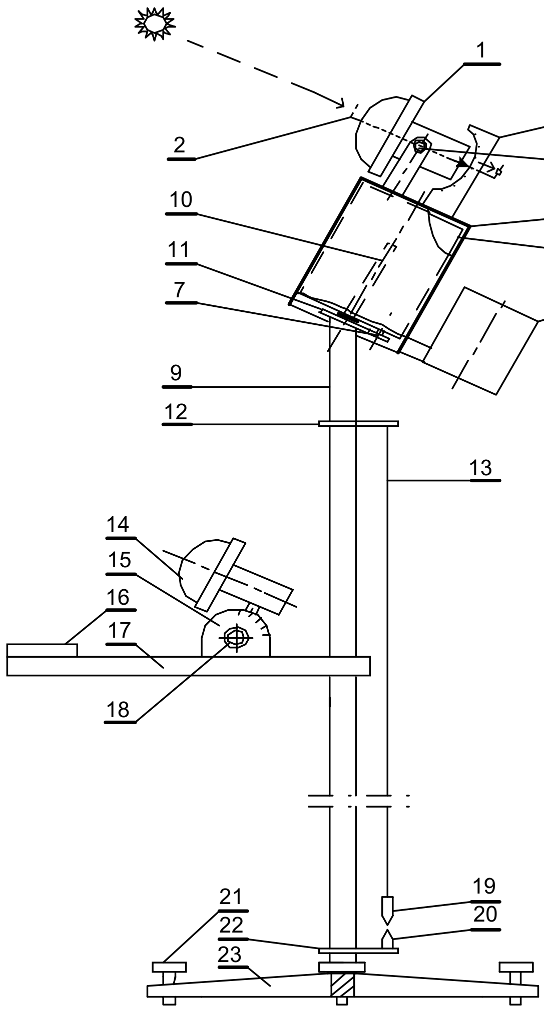

Figure 3. Construction of the device MD-4: 1 – thermo-battery tracing the sun; 2 – back-sight; 3 – orientation limb; 4 – fixation button; 5 – protecting cylinder; 6 – driving drum; 7 – cog-wheel; 8 – container for HOBO module; 9 – steel bar; 10 – slanting axle; 11 – immovable cog-wheel; 12 – holder of the thread plumb; 13 – thread plumb; 14 – stationary thermo-battery; 15 – limb of the stationary thermo-battery; 16 – compass; 17 – holder; 18 – fixation button of the stationary thermo-battery; 19 – plumb; 20 – cone of the plumb; 21 – screws; 22 – holder of the cone; 23 – base.

In 2005, from April 1 to November 26, using meteorological data acquisition device MD-4, the intensity of solar radiation on the surface tracking the sun and stationary placed one, air temperature, and relative humidity were measured. The obtained results were registered into the data saving device HOBO H08 module 007 and the 'BoxCar' computer program. For measuring of temperature and relative humidity, corresponding sensors were used, but for acquisition of the intensity of solar radiation – two thermo-batteries. One of the batteries followed the movement of the sun but the other was kept stationary in a position that sunbeams were striking it perpendicularly in the middle of the day.

Results and Discussion

The solar radiation on both planes, registered by thermo-batteries, was compared to the data given in the literature.

For every series of measuring by the use of 'Excel' program the mean temperature, relatives humidity and amount of energy registered by tracking the sun and stationary placed thermo-batteries is calculated. The energy obtained by thermo-batteries with values of global radiation given in literature is compared (Fig.4). Fig.5 illustrates the power of solar radiation, amount of energy registered by thermo-batteries, the air temperature, and relative humidity on 20 June, 2005.

The obtained results are generalized in Table 1. During the 227 days of measurement, thermal-battery tracking the sun registered 1387.1 kWh$\cdot$m^{-2} of energy, but the stationary located battery – 994.19 kWh$\cdot$m^{-2}. It means that tracking the sun thermobattery gathered 1.395 times more heat energy in comparison with the stationary placed one.

From the 'BoxCar' program the obtained information

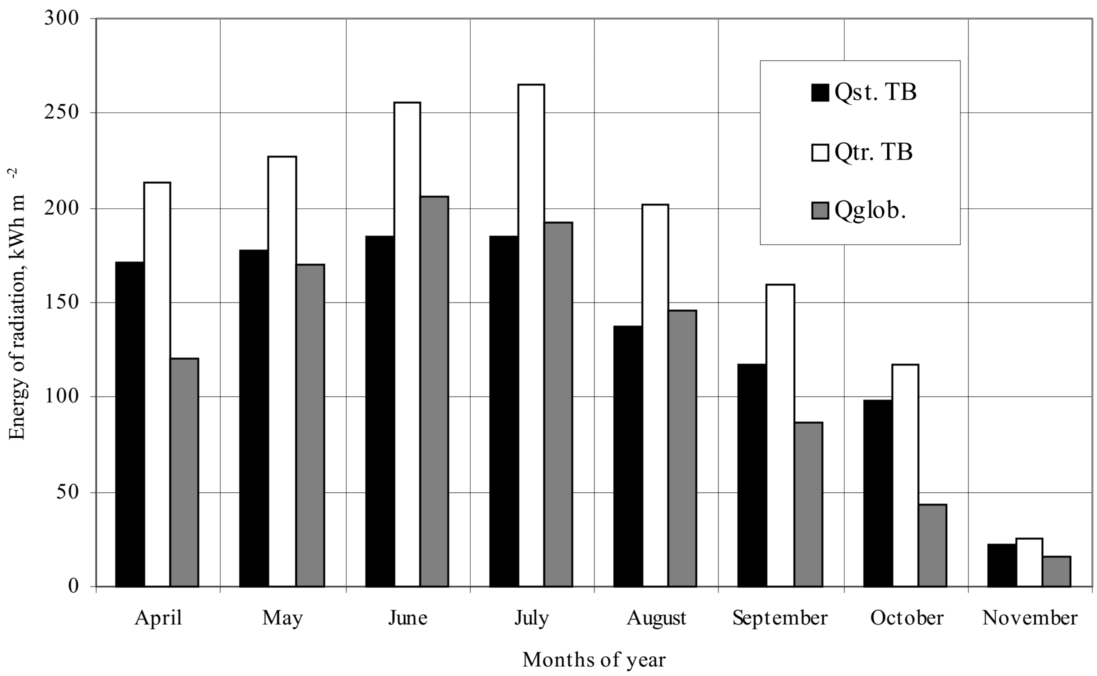

Figure 4. Energy of the sun radiation by months in 2005: $Q_{st.}$ – registered by a stationary placed thermo-battery; $Q_{tr.}$ – registered by tracking the sun thermo-battery; $Q_{glob.}$ – global radiation, given in literature (Kaškarova, 2003).

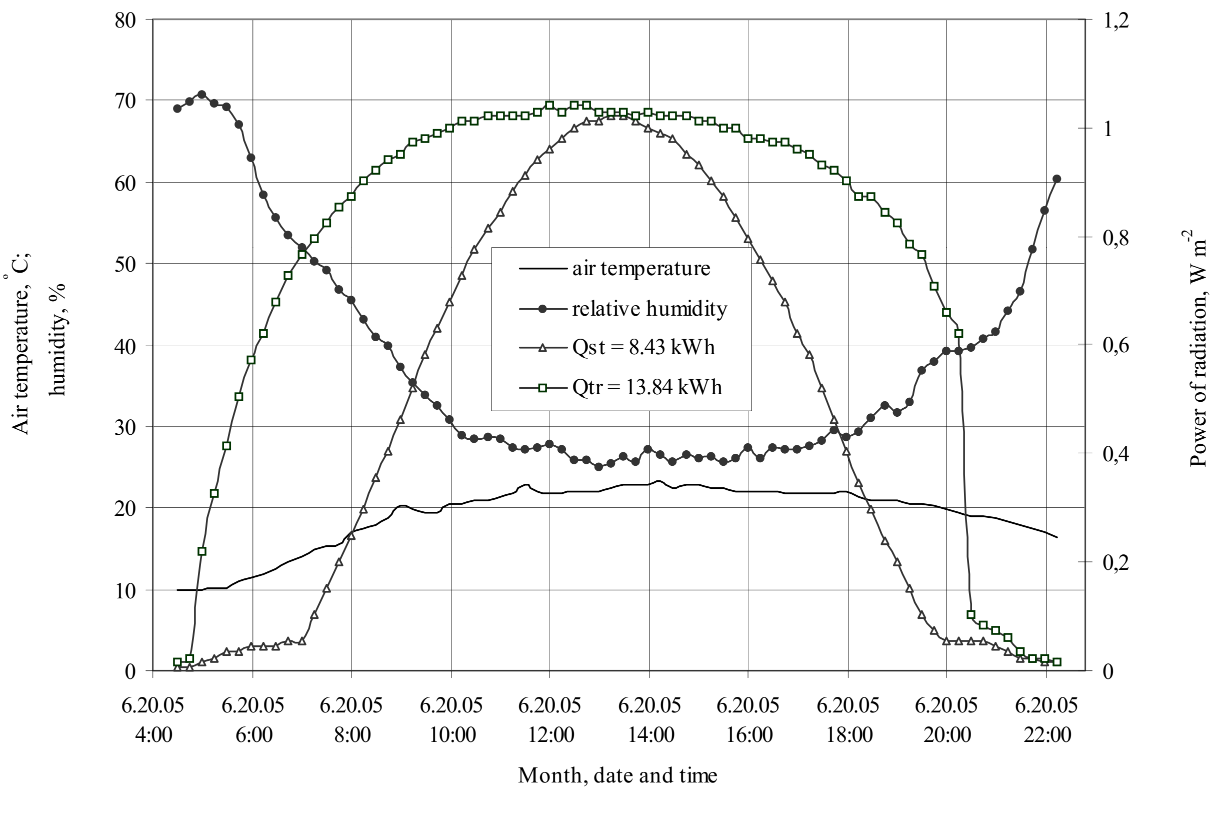

Figure 5. Power of solar radiation, amount of energy registered by thermo-batteries, air temperature, and relative humidity on 20 June, 2005.

Table 1

Distribution of days after maximal power values at Ulbroka, 2005

Period of time	Number of days	Number of days with solar radiation %		
		>75%	25-75%	< 25%
April 1 – 6	6	4	2	-
April 16 – May 5	20	6	9	5
May 6 – 15	8	2	2	4
May 16 – 24	9	5	3	1
May 26 – June 14	19	5	8	5
June 14 – July 7	21	6	13	2
July 5 – 25	21	6	14	1
July 26 – August 14	20	1	12	7
August 15 – September 3	20	11	6	3
September 4 – 24	21	4	9	8
September 25 – October 14	20	10	7	3
October 15 – November 4	21	6	7	8
November 6 – 26	21	0	3	18
Days total	227	66	96	65
In %	100	29	42	29

was brought into the 'Excel' program by means of which for every of series (number of days) the average values of the air temperature (T_{aver}), relative humidity (RH_{aver}) and intensity of solar radiation on the surface tracking the sun (Q_{tr}) and stationary placed (Q_{st}) were calculated (Table 2). From the table 2 it follows that during 227 summer days the sun tracking thermo-battery gathered 1387.1 kWh·m^{-2} of energy, but the stationary located – only 994.19 kWh·m^{-2} or 1.4 times less (Q_{track}/Q_{st}). Comparison of both amounts of the obtained energy shows that smaller difference was at the start and at the end of measurements (about 1.2 times), but bigger difference (13.84/8.43) – in the middle of the summer (1.64 times). It can be explained by the part that in spring and autumn the angle of incidence of solar rays is smaller and therefore the effect of tracking the sun is not so tangible. The bigger amount of energy was registered on 20 July (13.84 kWh) by the thermo-battery tracking the sun, but the smallest amount – on November 17 when both thermo-batteries registered only 0.3 kWh·m^{-2}. The intensity of solar radiation on that day was only 0.07 kW·m^{-2}. If the weather conditions are good and days are sunny, even in late autumn it is possible to obtain a rather big amount of heat energy. So on 1 November, the thermo-battery tracking the sun registered 5.7 kWh·m^{-2} by energy, but the stationary placed one – 4.7 kWh·m^{-2}. If the solar collector tracking the sun is working at 30% efficiency rate, then during a day about 2 kW h of heat energy will be obtained from each m^2 of the collector's area. In the second part of the measuring period, the energy amount obtained by tracking the sun thermo-battery diminished by 13.84/5.7 i.e. 2.43 times. Analysis of every-day energy curves demonstrated that the decrease of obtained energy was mainly due to the fact that days in autumn are becoming shorter. It means that under the weather conditions of Latvia, tracking the sun solar collectors should be used for heating of domestic water.

For processing of measuring data, the 'BoxCar' and 'Excel' programs were used. First of all, in the 'BoxCar' program the visual review of the obtained graphs was done. According to the power cost, all 227 days, graphs were parted into three groups as follows:

1) days with registered energy amount less than 25% of the possible obtained during a clear sunny day;

2) days with registered energy amount from 25 to 75 % of the possible obtained;

3) days with registered energy amount more than 75%

Table 2

Meteorological data obtained in Ulbroka from 1 April till 26 November, 2005

Period of time	Number of days	T_{aver}, °C	RH_{aver}, %	Q_{st}, kWh m^{-2}	Q_{trac}, kWh m^{-2}	Q_{track}/Q_{st}
April 1 – 6	6	5.49	60.04	35.49	45.90	1.393
April 16 – May 5	20	7.11	57.66	113.54	139.43	1.228
May 6 – 15	8	8.72	70.01	14.70*	47.55	–
May 16 – 24	9	14.32	58.46	57.00	86.90	1.624
May 26 – June 14	19	14.86	63.93	98.27	134.43	1.368
June 14 – July 7	21	18.17	59.50	146,20	204.25	1.397
July 5 – 25	21	19.87	64.38	127.40	194.45	1.526
July 26 – August 14	20	17.44	78.23	68.03	90.48	1.330
August 15 – September 3	20	16.40	69.10	116.70	172.18	1.475
September 4 – 24	21	13.80	74.50	77.56	1204.12	1.342
September 25 – October 14	20	11.10	77.97	78.83	97.19	1.232
October 15 – November 4	21	4.97	65.47	53.08	61.97	1.167
November 6 – 26	21	2.71	83.27	7.39	8.31	1.120
Total	227			994.19	1387.80	1.395

*In this period some improvement and adjustment of the device was needed.

of the maximum energy possible to obtain in a clear sunny day.

As it is seen from Table 2 during the time of measuring 66 days with energetic value more then 75% of maximum possible were, but with energetic value less then 25% were 65 days. The rest 95 days were with the energetic value 26–74% of maximum possible at that time. In April, at the second half of August, at the end of September, and at the start of October there were several sunny days. Cloudy days were from 26 July till 14 August, when there was only one day with Q>75%, and from 6–26 November, when there were no days with Q>75%.

Conclusions

1. Meteorological information about solar radiation, air temperature and relative humidity was acquired during 227 days – from 1 April to 26 November has been carried out – in Ulbroka, Riga region.
2. Power of solar radiation was measured with two thermo-batteries, one of which followed the motion of the sun and its surface was constantly kept perpendicular to the direction of falling sunbeams, but the second was placed stationary and periodically turned only in a vertical plane.
3. During the period of investigation, the stationary thermo-battery registered 994.19 kWh·m^{-2} of energy but tracking the sun battery – 1387.1 kWh·m^{-2}, which is 1.395 times more.
4. The greatest amount of energy on a clear sunny day like 20 June registered by the thermo-battery tracking the sun was 13.84 kWh·m^{-2}, but amount of energy registered by a stationary placed thermo-battery – 8.4 kWh·m^{-2}.

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