ANALYSIS OF METEOROLOGICAL PARAMETERS FOR DEVELOPMENT OF SOLAR COLLECTORS

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Abstract. The article deals with measuring results of the solar radiation on stationary placed and tracking the sun surfaces, as well as air temperature and relative humidity from 01 April until 26 November 2005 in Ulbroka, Riga region. The measurements were carried out by the device of a special construction MD-4 developed at the Research Institute of Agricultural Machinery in 2004. For the data acquisition two thermo-batteries were used. The obtained data into computer memory were collected and after analyzed. It was stated that during the period of measuring (227 days) the thermo-battery tracking the sun has gathered by 1.4 times more heat energy than stationary located one. It means that in order to increase the heat yield solar collectors for domestic water heating have to track the sun.

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

Introduction

In order to diminish the dependence of imported energy resources first of all fossil ones, the development of the use of any local energy resources is of great importance in Latvia. We have enormous unused possibilities in utilization of our communal waste as raw material for production of new products as well as energy carriers like biogas, heat and electric energy. We have forests, peat, unused land for production of biomass as accumulated solar energy, that is possible to convert into other types of energy. We have big unused potential of wind, sea waves and solar energy.

In 2004 a group of researchers at the Research Institute of Agricultural Machinery in Ulbroka developed the device MD-4 for the acquisition of such meteorological parameters as air temperature, relative humidity and intensity of solar radiation both on the surface perpendicular to sun rays and on the surface located at any angle to the sun rays (Fig. 1). The device was envisaged for data acquisition (measuring and registration) about the air temperature, its relative humidity and intensity of solar radiation in different places, in order to state where it is more suitable to place the solar collector for domestic water heating. From 21 July until 3 August 2004 the above-mentioned data were measured, the acquired data collected into computer's memory and after analyzed [1]. The obtained results brought us to the conclusion that it could be valuable to state how the measured meteorological parameters are influencing the yearly heat yield of solar collectors. Therefore, the further investigation was aimed to collect similar data during the season of the next year.

Materials and methods

From 01 April until 26 November 2005 the measurements were continued. For acquisition of the corresponding data during 227 days of summer period the device MD-4 was placed and worked on the roof of a house at Ulbroka. The meteorological parameters were measured and their values fixed into the memory of a computer uninterruptedly every 15 minutes. For information registration, a four-channel module HOBO H08-007 and the BoxCar program have been used.

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 [2]:

$$\delta = \varphi - 15^{o}, \tag{1}$$

where φ – degree of latitude of the place.

At such a tilt angle it is possible to obtain maximum of heat energy during spring and autumn time, but for maximum of heat yield during a whole season it is recommended to figure this angle by coherence [2]:

$$\delta = \varphi - 27^{o}. \tag{2}$$

For Riga it means $\delta = 57^{o} - 27^{o} = 30^{o}$. In order to keep the solar collector's plane perpendicularly to the direct radiation of solar beams all the day round, it is necessary to provide the collector with a mechanism tracking the sun. The device MD-4 is equipped with such one.

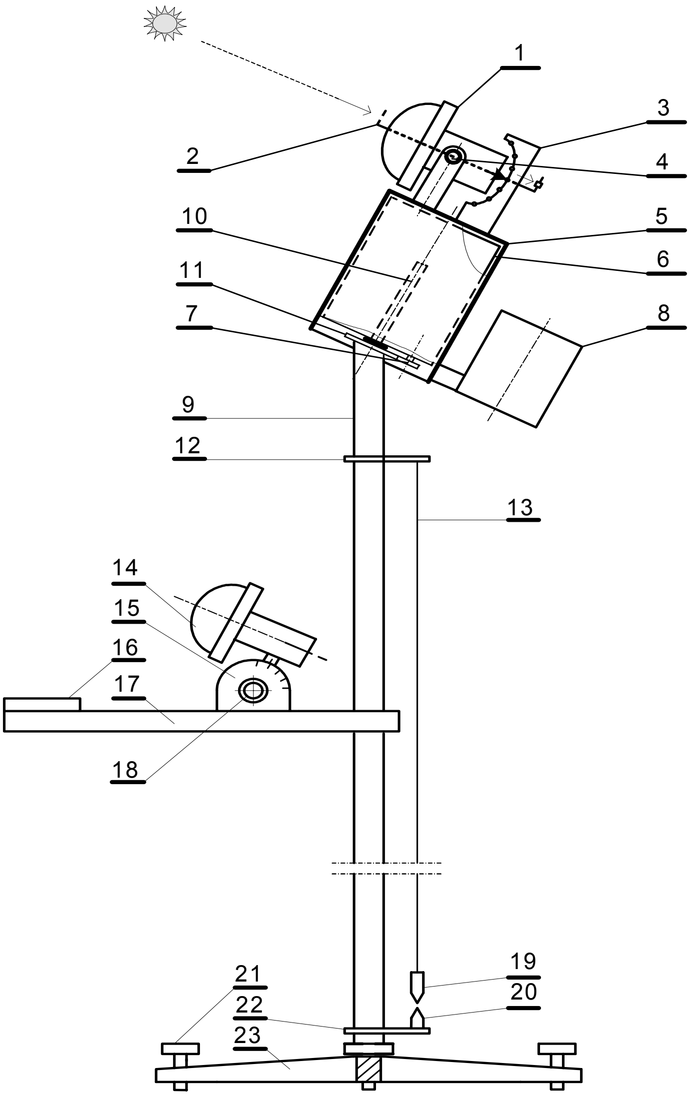

Fig. 1. **Construction of the device MP-4**:
1 – thermo-battery tracked the sun;
2 – back-sight;
3 – orientation limb;
4 – fixation button;
5 – protecting cylinder;
6 – driving drum;
7 – cog-wheel;
8 – conteiner for HOBO module;
9 – steel bar;
10 – slanting axle;
11 – immovable cog-wheel;
12 – holder of the plumb's thread;
13 – plumb's thread;
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.

Sunbeams in the atmosphere meet particles, which disperse and absorb the solar radiation. The intensity of direct solar radiation received by the earth surface depends on the angle of incidence of sunbeams α and atmospheric clearness rate p calculated as follows:

$$p = \frac{I}{I_o}, \quad (3)$$

where I – intensity of solar radiation falling perpendicularly to the earth surface, W/m^2;
I_o – the solar constant; 1.37 W/m^2.

If the angle of incidence α is less than 90^o, it is $m > 1$, where m – atmospheric mass, then intensity of direct solar radiation on rays perpendicular plane is calculated by formula [3]:

$$I = I_o \cdot p^m . \quad (4)$$

The smaller the angle of incidence α, the thicker is the atmospheric optical layer or atmospheric mass m, which sunbeams have to go through. Coherence between these two parameters is given in Table 1 [3].

Table 1

Connection between the angle of incidence of solar beams α and atmospheric mass m

α^o	90	60	50	40	30	20	15	10	5	3	0
m	1.0	1.15	1.3	1.55	2.0	2.9	3.82	5.6	10.4	15.4	35.4

For the ideal atmosphere (without steams of water and aerosols) the atmospheric clearness rate $p = 0.5 \div 0.85$. For the circumstances of Latvia, accepting that, $p = 0.8$ and $m = 1.2$, the intensity of direct solar radiation will be $I = 1.37 \cdot 0.8^{1.2} = 1.00$ kW/m^2.

Results and discussion

For the 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 of 227 days graphs were divided into three groups as following:

1) days with registered energy amount less then 25% of the possible to obtained during a clear sunny day;
2) days with registered energy amount from 25 to 75% of the possible;
3) days with registered energy amount more then 75% of maximum energy, possible to obtained in clear, sunny day.

The results are presented in Table 2. As it is seen from Table 2 during the time of measuring there have been 66 days with energetic value more then 75% of the maximum possible, but with energetic value less then 25% – 65 days. The rest 95 days have had the energetic value 26-74% of the maximum possible at that time. From the Table 2 it follows that in April, at the second half of August and at the end of September and beginning of October there have been several sunny days. Cloudy weather conditions have been from 26 July until 14 August, when only one day with Q > 75% has been and in autumn from November 6 – 26 there days with Q > 75% have not been.

During the measuring period the weather conditions in Ulbroka were rather changeable. Usually after 1 – 4 sunny days there were several cloudy and even rainy days with the diminished intensity of solar radiation. During these days the solar collector could receive not more than only 50% of solar radiation maximum on the same sunny day. In means that at installation of domestic solar water heating systems it is necessary to consider the volume of the hot water storage tank and surface area of the collector, in order to save the hot water for cloudy days or same kind of alternative water heating has to be envisaged.

Table 2

Distribution of days after maximal power values possible in the proper time at Ulbroka, 2005

Nr.	Period of time	Number of days	Number of days with solar radiation in % of possible		
			> 75%	25 – 75%	< 25%
1	April 01 – 06	6	4	2	-
2	April 16 – May 5	20	6	9	5
3	May 6 – 15	8	2	2	4
4	May 16 – 24	9	5	3	1
5	May 26 – June 14	19	5	8	5
6	June 14 – July 07	21	6	13	2
7	July 05 – 25	21	6	14	1
8	July 26 – August 14	20	1	12	7
9	August 15 – September 03	20	11	6	3
10	September 04 – 24	21	4	9	8
11	September 25 – October 14	20	10	7	3
12	October 15 – November 04	21	6	7	8
13	November 06 – 26	21	0	3	18
	Days total	**227**	**66**	**96**	**65**
	In %	**100**	**29**	**42**	**29**

From the *BoxCar* program the obtained information 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 3). From the table it follows that during 227 summer days the sun tracking thermo-battery has gathered 1387.1 kWh/m^2 of energy, but stationary located – only

994.19 kWh/m^2 or 1.4 times less (Q_{track}/Q_{st}). In comparison of both amounts of obtained energy it follows, that smaller difference has been at the start and at the end of measurements (about 1.2 times), but bigger difference (13.84 : 8.43) at the middle of the summer has occurred (1.64 times). It can be explained that in spring and autumn the angle of incidence of solar rays α is smaller and therefore the effect of tracking the sun is not so tangible. The biggest amount of energy is 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 have registered only 0.3 kWh/m^2. The intensity of solar radiation on that day has been 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 rather a big amount of heat energy. So on 1 November the thermo-battery tracking the sun has registered 5.7 kWh/m^2 but stationary placed one 4.7 kWh/m^2. If the solar collector tracking the sun is working with the rate of efficiency 30%, then during a day about 2 kWh of heat energy from each m^2 of collector area will have been obtained. On the second part of the measuring period the energy amount obtained by tracking the sun thermo-battery has diminished 13.84 : 5.7 = 2.43 times. After analyzing the every-day energy curves it is stated, that the decrease of obtained energy is mainly due to the fact that days in autumn are going to be shorter. It means that for domestic water heating in the weather conditions of Latvia tracking the sun solar collectors have to be used.

Table 3

Meteorological data obtained in Ulbroka from 01 April until 26 November 2005

Nr.	Period of time	Number of days	T_{aver}, °C	RH_{aver}, %	Q_{st}, kWh/m^2	Q_{track}, kWh/m^2	Q_{track}/Q_{st}
1	April 01 – 06	6	5.49	60.04	35.49	45.90	1.393
2	April 16 – May 5	20	7.11	57.66	113.54	139.43	1.228
3	May 6 – 15	8	8.72	70.01	14.70*	47.55	–
4	May 16 – 24	9	14.32	58.46	57.00	86.90	1.624
5	May 26 – June 14	19	14.86	63.93	98.27	134.43	1.368
6	June 14 – July 07	21	18.17	59.50	146,20	204.25	1.397
7	July 05 – 25	21	19.87	64.38	127.40	194.45	1.526
8	July 26 – August 14	20	17.44	78.23	68.03	90.48	1.330
9	August 15 – September 03	20	16.40	69.10	116.70	172.18	1.475
10	September 04 – 24	21	13.80	74.50	77.56	1204.12	1.342
11	September 25 – October 14	20	11.10	77.97	78.83	97.19	1.232
12	October 15 – November 04	21	4.97	65.47	53.08	61.97	1.167
13	November 06 – 26	21	2.71	83.27	7.39	8.31	1.120
	Total	227			994.19	1387.80	1.395

* *At this period some improvement and adjusting of the device was needed.*

Conclusions

1. During the summer time from April until November in Latvia it is possible to obtain about 1.4 times more heat energy if the solar collector is tracking the sun all day round.
2. Tracking the sun solar collector can successfully work from early spring until late autumn producing hot domestic water.

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