PECULIARITIES OF DOMESTIC WATER HEATING BY SOLAR COLLECTORS

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Abstract. A lot of various types and modifications of solar collectors are known. Aimed to evaluate the possibilities of the use of solar collectors for warm water production in meteorological conditions of Latvia all over the year in the agency of the Latvia University of Agriculture (LLU), Research Institute of Agricultural Machinery (LTZI) in collaboration with Department of Physics of the Information Technologies Faculty in Germany produced vacuum tube type solar collector Vitosol 200 SD system with the collector area 3 m^2 was set up. Researches about efficiency of the solar collector (placed on the roof of the building) during December 2008 and in the first 11 months in 2009 were made in conditions of production in Ulbroka.

Key words: collector of solar energy, temperature, warm water.

Introduction

To evaluate the possibilities of the use of solar collectors for warm water production in meteorological conditions of Latvia all over the year in LTZI in Germany produced vacuum tube type solar collector Vitosol 200 SD system with the collector area 3 m^2 was set up and operated. The system is not equipped with warm water registration meters, therefore HOBO H08 logger was used to estimate the warm water supply system completely, which registered water temperature inside the accumulation tank of warm water of the solar collector during the year. For this purpose HOBO temperature sensor is placed in the existing nest of the temperature sensor located inside the accumulation tank of warm water of the solar collector. The temperature values were registered with 15 minutes interval for each month separately. Making the data analysis of the diagrams (Figure 1) we can judge about the duration of operation of the solar collector during the corresponding period of time, warm water temperature variations inside the accumulation tank of the solar collector and increase of warm water temperature during the operation of the solar collector. Making the data analysis in the Excel program, i.e., getting empirical distribution of temperatures into the groups by the range of temperature values it is possible to get durations of warm water provision during a range of different temperature values. In the same way (if we know the amount of water in the accumulation tank and increase of the temperature value) it is possible to calculate the amount of heat energy produced by the heat collector during a definite period of time [1]. Using the data from the tables of the diagrams it is possible to calculate heat losses of the accumulation tank of the solar collector.

In the course of the year power of global irradiance and charging power of the electric accumulator produced by the solar collector are registered as well. If we join global irradiance or the power of produced by the solar collector diagrams with the diagram of temperatures of warm water in the accumulation tank we can judge about the production capability of the solar collector in dependence on the power of solar irradiance.

The aim of the research is to get a characteristic diagram of produced by the solar energy collector warm water temperature and distribution of days (amount) into the groups by the range of temperature values for separate months and for the whole year.

Materials and Methods

The most important element of the solar energy collector system is the warm water accumulation tank to which two loops are connected: the loop of the collector and the warm water loop. The elements of the loop of the solar collector are interconnected with copper tubes, through them heat carrier is circulating – conducting the heat gained in the solar collector to the accumulation tank. The elements of the warm water loop are interconnected with steel or plastic tubes (warm water is supplied to the users from the accumulation tank).

The loop of the solar energy collector starting from the collector and going in the direction of the flow of the heat carrier is shown in the Figure 1. The loop of the solar energy collector consists of the solar collector 1 where in the output of the heat carrier temperature sensor 7 and air valve 18 are placed; the meter system 3 where the thermometer 4 is built in; heat exchangers 25 and 26; the system of the filling valve of the heat carrier 18, one-way valve (retention valve) with the indicator of the intensity of flow 7, the circulation pump of the heat carrier 6 and the thermometer 5. As it was mentioned before all these elements are interconnected with copper tubes, into them using the filling valve system 18 and the air valve 9 under the pressure heat carrier (glycol) is being filled in. The heat carrier is circulating through the loop when the circulating pump is operating.

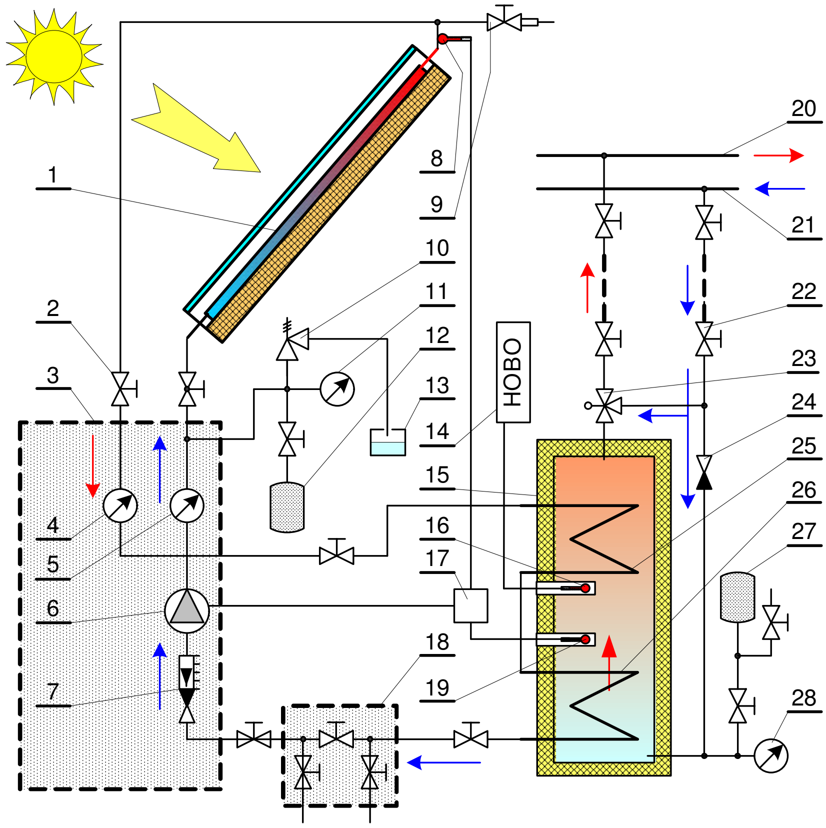

Fig. 1. **Functional scheme of the solar energy collector Vitosol 200 SD:**
1 – solar energy collector Vitosol 200 SD; 2 –valves; 3 – metering system PS10; 4 – thermometer of preheated heat carrier; 5 – thermometer of cold heat carrier; 6 – circulation pump of heat carrier; 7 – one-way valve (retention valve) with indicator of intensity of the flow; 8 – temperature sensor of the collector; 9 – air valve; 10 – safety valve; 11 – manometer; 12 – expansion compensation vessel; 13 – passage vessel; 14 – data registration system; 15 – warm water accumulation tank Vitocell-B 100 CVB (300 l); 16 – temperature sensor of the registration system; 17 – programmed control unit of operation of the solar collector; 18 – filling valve system; 19 – temperature sensor of the heat accumulating tank; 20 – distribution canal of warm water; 21 – lead of cold water; 22 – valves; 23 – mixing valve of cold and warm water (is not set up); 24 – one way valve; 25 – first heat exchanger; 26 – second heat exchanger; 27 – expansion compensation vessel; 28 – manometer

To the collector loop controller and safety appliances are connected: the safety valve 10, the manometer 11, the expansion compensation vessel 12 and the passage vessel 23. The collector system is equipped with disjunctive valves in case if it is necessary to replace or repair a system element, for example, the circulation pump is equipped with a disjunctive valve to make replacement of the pump possible without discharge of the heat carrier.

The loop of warm water consists of the one way valve 24, the expansion compensation vessel 27, and the manometer 28, the warm water accumulation tank 15 and the mixing valve of cold and warm water 23 (is not set up), the tubes and valves 22 connect the warm water accumulation tank with lead of the cold water 21 and the distribution canal of the warm water 20. If we open one of the taps of the warm water distribution canal (in Figure 1 are not shown), cold water through the valves 22 and 24 flows in the warm water accumulation tank and through the warm and cold water mixing valve presses out warm water through the opened tap. The control unit 17 of the solar collector serves for the system operation in automatic regime.

The system in automatic regime is operating as follows. When the sun warmed up in the absorber existent heat carrier (glycol) and the set up temperature at the temperature sensor 8 is greater for some degrees, for example, for 6 ˚C (factory setup), comparing to the setup at the temperature sensor 19 temperature value, the control unit switches on the circulation pump. The circulation pump is pumping the warmed up heat carrier through the heat exchangers 25 and 26, where the heat carrier becomes cold giving heat energy to water of the accumulation tank. While the circulation pump is being operated the temperature of the heat carrier decreases. When the temperature difference between 8 and 19 becomes less than 4 ˚C (factory setup) the pump switches off. If the heat carrier becomes wormier the operation process of the system repeats. We can change the switching on and switching off temperature difference by programming the control unit. Thereby the sensor 8 is located a little bit further from the collector, when the pump starts operation, the temperature of the collector loop which is measured with the thermometer 4 firstly increases and when it achieves the biggest value (for example 90 ˚C) starts decreasing till the pump is being switched off. Such location of the sensor 8 guarantees periodical operational regime of the system.

The setup values of the operational parameters:

- maximal temperature value of warm water in the accumulation tank: 60 ˚C;
- minimal rev of the pump, % out of nominal value, rev per minute: 30 %;
- temperature difference for switching on the pump $T_s - T_w$: 6 ˚C;
- temperature difference for switching off the pump $T_s - T_w$: 4 ˚C;

where T_s – setup temperature at the sensor 8;
T_w – temperature in the warm water accumulation tank (sensor 19).

Fig. 2. **Solar energy collector Vitosol 200 SD 3 m^2 on the roof of the building in Ulbroka**

The solar energy collector Vitosol 200 SD system is located on the roof of the four storey building of the LTZI, where 7 sinks and 1 shower stall are connected. 40 persons are using warm water. The biggest part of the warm water piping is heat insulated. On the roof of the building (Figure 2) the solar energy collector is located, but in one of the cabinets on the 3rd floor all other equipment of the collector system is located (Figure 3).

As the system is not equipped with the produced and consumed heat energy metering system, than, to judge about the operational efficiency of the system, it was equipped with the produced warm water temperature registering appliance (logger) HOBO H08, the temperature sensor 16 (see Figure 1) was placed in the second (not used) temperature sensor nest of the warm water accumulation tank. HOBO H08 makes data registration and storing without any assistance, that is, without connection to the computer. The computer is required only for setup of the registration data parameters and for data load to the computer, where they can be stored, processed and presented in the necessary way.

To achieve the aim of the research it was planned to register two temperatures – water temperature (T_w) in the accumulation tank (temperature in the second, upper sensor nest of the accumulation tank) and indoor air temperature (T_i), where the accumulation tank is located (it is necessary in case if we need to use the data more widely). If we register two parameters, it is 2 parameters with 15 min interval, the HOBO memory is enough for 33 days. That means that is needed to load the data to the computer monthly, obtaining the monthly temperature diagram (table form) for T_w and T_i temperatures. It is clear, that in dependence on the water consumption, weather and seasonal conditions the warm water temperature T_w is variable and it is difficult to predict the value of it. To judge about the characteristics of the produced warm water in the accumulation tank per time period it is assumed that the temperature range 15-65 ˚C is divided into groups by 5 ˚C. For each temperature range it is required to define the duration of cases when water achieves a definite value for each month and the whole year as well. From the mathematical point of view [2, 3] that means, that it is necessary to find temperature empirical distribution into the groups by the value range.

Fig. 3. **Main elements of the system of the solar energy collector:**
3 – metering system *PS10*; 12 – expansion compensation vessel of the heat carrier (40 l); 16 – warm water accumulation tank *Vitocell-B 100 CVB* (300 l); 17 – programmed control unit of the solar collector system, *Vitosolic 100*; 18 – filling valve system of the heat carrier; 27 – expansion compensation vessel of the warm water loop

Results and discussion

Making the data analysis gained from HOBO H08, diagrams of produced warm water in the solar collector accumulation tank T_w and indoor air temperature T_i for 11 months 2009 and December 2008 were obtained. Distribution into the groups of the number of days (weather) by the temperature range is calculated (see Table 1).

If we consider warmed up water by solar energy at temperature 40 ˚C as warm (standard 55±5 ˚C), then we can assume that water heating starts in the third decade of February (Figure 5), when in two days water in the accumulation tank warmed up till 40 ˚C and the increase of water temperature in the warm water accumulation tank was 27 ˚C. More favourable heating conditions are in March, when water in the accumulation tank warmed up to 50 ˚C (Figure 4).

Making the analysis of the spring/summer season we can affirm that qualitative water heating appears only in April and ends in September (Figure 5). It means that it is possible to use the solar energy collector as the main energy source for water heating during 6 months. During the mentioned before period warm water temperature in the accumulation tank achieves the setup value of control – 60 ˚C when water heating is interrupted, the power of solar irradiance is sufficient to continue water heating yet. Therefore, equipping the system with a water mixing valve (23, Figure 1), in a sunny day, it is possible to store up in the accumulation tank more heat energy and to reduce durations of the temperature drops during unfriendly weather conditions. In September temperature of the warm water in the accumulation tank achieves 60 ˚C as well (Figure 5).

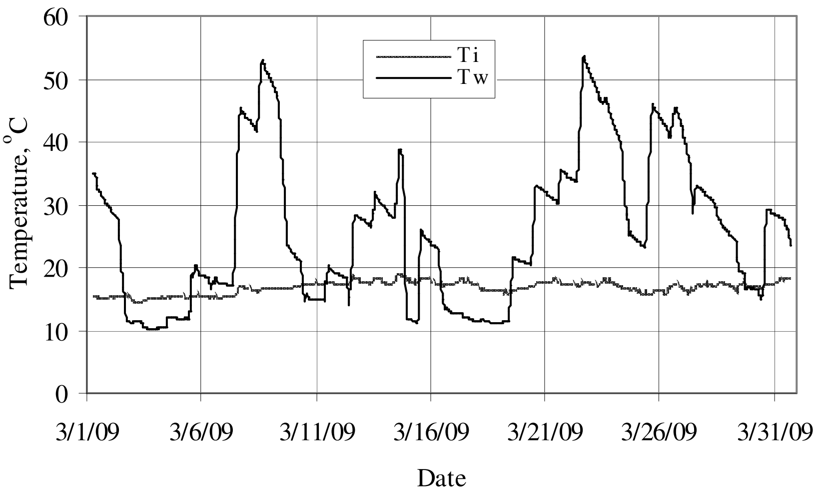

Fig. 4. **Indoor air temperature T_i and water temperature in the accumulation tank T_w during March 2009**

In October power of solar irradiance considerably decreases and therefore the water temperature value in the accumulation tank does not become warmer than 40 ˚C. As from November and till the end of February stand-by time of the solar collector operation appears, when the power and duration of solar irradiance is too insignificant to warm up water in the accumulation tank.

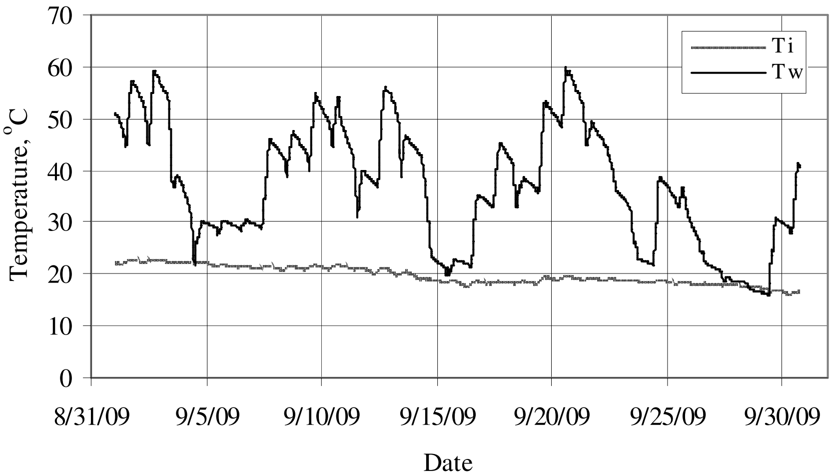

Fig. 5. **Indoor air temperature T_i and water temperature in the accumulation tank T_w during September 2009**

In Table 1 data about warm water temperatures in the accumulation tank per temperature range by 5 ˚C are presented (within 15 till 65 ˚C). From the table it follows, that during the year warm water in the solar energy collector Vitosol 200 SD accumulation tank was at 30-35 ˚C during 176.6 days (48.4 % from 365 days); at 40-45 ˚C during 125.4 days (34.4 %); at 50-55 ˚C during 72.4 days (19.8 %).

Table 1

Distribution of number of days by temperature value in the solar collector Vitosol 200 SD accumulation tank

Months 2009	Number of days with the warm water temperature value in the accumulation tank greater than, ˚C									
	15	20	25	30	35	40	45	50	55	60
January	7.4	3.1	-	-	-	-	-	-	-	-
February	16.0	9.6	4.0	1.9	0.8	0.2	-	-	-	-
March	23.4	18.6	15.0	10.4	6.2	5.0	2.4	0.9	-	-
April	-	27.9	26.7	25.5	24.7	23.1	18.6	14.0	6.2	0.8
May	-	30.5	30.4	30.0	28.1	22.0	17.4	14.0	7.7	0.8
June	-	29.8	27.0	24.1	19.8	14.2	11.0	8.8	6.5	1.0
July	-	31.0	30.8	30.2	27.9	24.9	21.0	17.3	10.7	1.3
August	-	31.0	30.8	28.7	25.9	23.6	18.2	12.5	5,8	0.1
September	29.8	27.6	23.9	19.9	16.6	12.2	8.3	4.8	1.7	-
October	17.8	9.9	4.9	3.3	2.1	0.0	-	-	-	-
November	12.4	6.3	5.5	2.6	1.2	0.1	-	-	-	-
December	2.2	1.9	0.8	-	-	-	-	-	-	-
Total	-	227.2	199.7	176.6	153.2	125.4	96.9	72.4	38.6	4.0
% out of 365 days	-	62.0	54.7	48.4	42.0	34.4	26.5	19.8	10.6	1.1

Conclusions

1. During the year warm water in the solar energy collector Vitosol 200 SD accumulation tank was at 30-35 ˚C during 176.6 days (48.4 % from 365 days); at 40-45 ˚C during 125.4 days (34.4 %); at 50-55 ˚C during 72.4 days (19.8 %).
2. During the period of time from April till October it is possible to use the solar energy collector as the main energy source for water heating.
3. If warm water at a higher temperature value than 40 ˚C is required without interruptions, than use of an additional energy source is required, such as an electric water heater.
4. From November and till the end of February stand-by time of the solar collector operation appears, when power and duration of solar irradiance is too insignificant to warm up water in the accumulation tank.
5. During March and October the solar energy collector can serve as an additional energy source for water heating.

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