Accumulation of Thermal Energy in the Thermal Tank Storage with the Help of the Sun

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Abstract. The propose of study is a convert the capture of solar energy into thermal energy as one of the renewable energies. Surface-selective hot water collectors with an area of 225 m^2 are used to collect solar energy. This energy captured by the collectors is transferred by technologically modified water, which transfers the heat in the technical room with the help of an exchanger. On the other side of the exchanger is water in which energy is stored. Water with a volume of 160 m^3 is stored in three different sizes of thermal tank storage. The smallest thermal tank storage with a volume of 24 m^3. This thermal tank storage was measuring during 2 years which charging and discharging cycles took place. In the first year, there were large heat losses through evaporation from the water surface. And in the second year of research, the water surface was covered, which helped to eliminate heat losses and extend the accumulation period.

Keywords: Thermal tank storage · Renewable energy · Solar energy · Long-term accumulation · Thermal energy

1 Introduction

In Slovakia and similarly situated countries, the demand for heat in the heating season is 10 times higher than in the non-heating season. Paradoxically, at the same time when solar radiation reaches its maximum, the need for heat for heating is the lowest. From May to August, solar radiation in our country is most intense [1]. In this summer season, there is no need to use another fossil source, but you can heat and heat hot drinking water directly. However, during the non-heating period, there is a minimal demand for heat, which is also a problem, Fig. 1. This heat captured during the summer needs to be accumulated in order to reduce energy consumption in the heating season [2].

2 Thermal Energy Tank Storage

2.1 Thermal Energy Tank Storage Measured

Surface-selective hot water collectors with an area of 225 m^2 are used to collect solar energy. This energy captured by the collectors is transferred by technologically modified water, which transfers the heat in the technical room with the help of an exchanger. On

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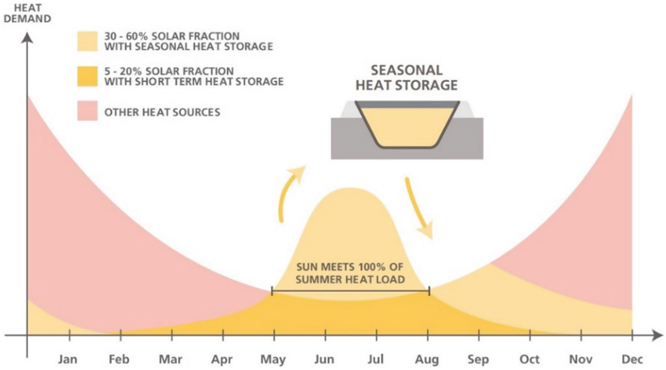

Fig. 1. Energy production and energy demand in year [2].

the other side of the exchanger is water in which energy is stored. Water with a volume of 160 m^3 is stored in three different sizes of thermal tank storage, Fig. 2. Different sizes of thermal tanks allow them to be used for different purposes and at different times. The structure of the thermal tank storage is made of reinforced concrete with thermal insulation and they are stored under the floor of the hall. Collectors are also installed on the roof of the hall.

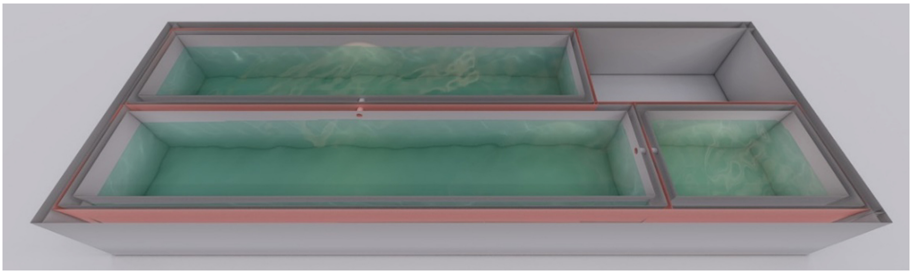

Fig. 2. Three sizes on thermal energy storage

2.2 Thermal Energy Tanks Storage in Different Types

We can divide the thermal tank storage according to the media in which the energy is accumulated into sensible heat and latent heat. Performance, efficiency and other parameters can be divided according to media, method of accumulation and use. But we basically divide them into thermal and chemical accumulation, Fig. 3 [3].

We will not discuss chemical energy that comes from fossil fuels because it is not a renewable resource. Thermal storage tanks are used today. These thermal tanks storage can be divided into sensible heat and latent heat storage tanks. Latent heat is generated when the state changes. E.g. when switching from ice to water, just as much energy is needed as heating the water to 80 °C. Sensible heat represents the behavior of the

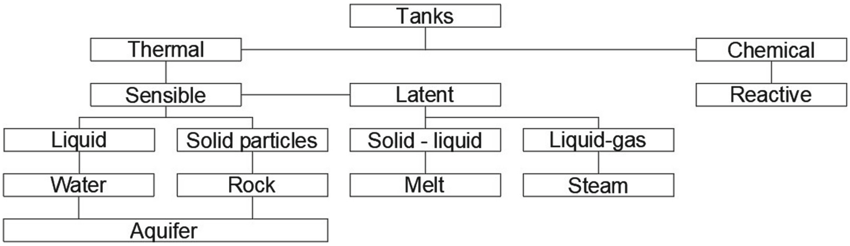

Fig. 3. Types of tanks [3].

temperature during the supply and consumption of energy. Sensible heat is derived according to the Eq. (1) [4] (Table 1)

$$Q_{sp} = m.c.(\varnothing_2 - \varnothing_1). \quad (1)$$

Table 1. Specific and volumetric heat capacity of materials for heat accumulation at 20 °C [4]

Medium	Temperature range (°C)	Specific heat capacity (Wh/kg K)	Volume heat capacity (Wh/m^3 K)	Density (kg/m^3)
Water	0–100	1.16	1160	998
Air	−273 -> 1000	0.28	0.31	1.1
Oil	0–400	0.44–0.5	350–450	800–900
Gravel sand	0–800	0.2	360–390	1800–2000
Granite	0–800	0.21	570	2750
Concrete	0–500	0.24	460–560	1900–2300
Brick	0–1000	0.23	330–440	1400–1900
Iron	0–800	0.13	1000	7860
Gravel backfill (37% water)	0–100	0.37	810	2200
Mix of salts ($53KNO_3$ + $4NaNO_2$ + $7NaNO_3$)	150–450	0.36	480–550	2561–2243

The heat in the Q_{Sp} storage tank depends on the weight of the medium (m), the heat capacity (c) and the temperature difference. If we have a 200 L tank and needed to heat it from 10 °C to 60 °C, the energy needed would be:

$$Q_{sp} = 200 \cdot 1.16(60 - 10) = 11600 \text{ Wh} = 11.6 \text{ kWh}. \quad (2)$$

According to these values, water availability and specific heat were selected as the medium [5].

3 Measuring

Were collected data took place for 2 years. During these 2 years, the water temperatures in the thermal tank storage and in the ground near the reservoirs were recorded to find out if there is heat loss to the environment, Fig. 4.

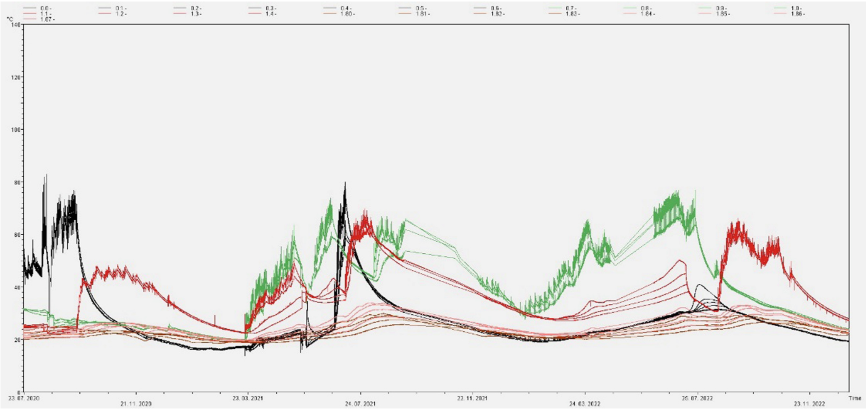

Fig. 4. Graph of 2-year temperature measuremets in tanks

A total of 27 temperature sensors are located in all 3 thermal tank storage and the ground. These sensors recorded temperatures for two years, which gave us the graphic representation in Fig. 4. In Fig. 4, the color-coded temperature curves according to location correspond to the colors according to Fig. 5.

4 Comparison AN1 Tank Between Seasons

So far, the thermal tank storage AN1 with a volume of 24 m^3, which is the smallest of them, has been investigated. This tank showed heat losses caused by evaporation. This graphic representation is the course of measurement over two years, Fig. 6.

4.1 Accumulation Tank Without Cover

Evaporation through the water surface caused large heat losses in the first year, which are graphically shown in Fig. 7.

The real measurement data shows us how quickly the energy was discharged from the reservoir. The discharge process is quadratic without energy consumption, Fig. 7.

The graphic percentage representation is from the maximum medium temperature of 67 °C to the initial temperature of 18 °C, which corresponds to the ambient temperature. The discharge took place in 85 days. The effectiveness of such discharge is very low, as it would only be enough for a short time, Fig. 8.

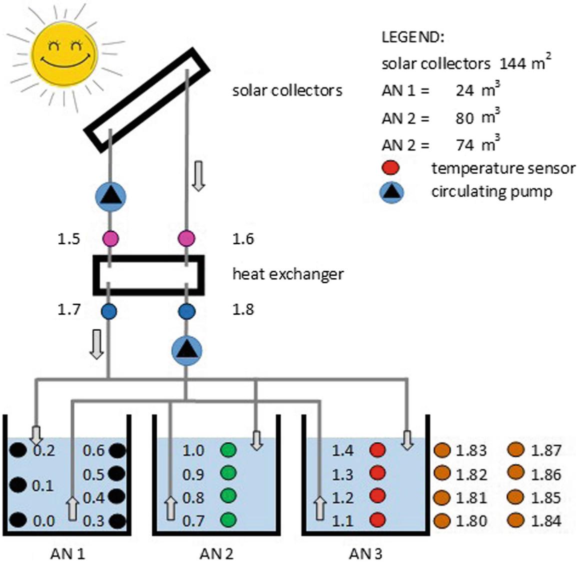

Fig. 5. Placement of temperature sensors

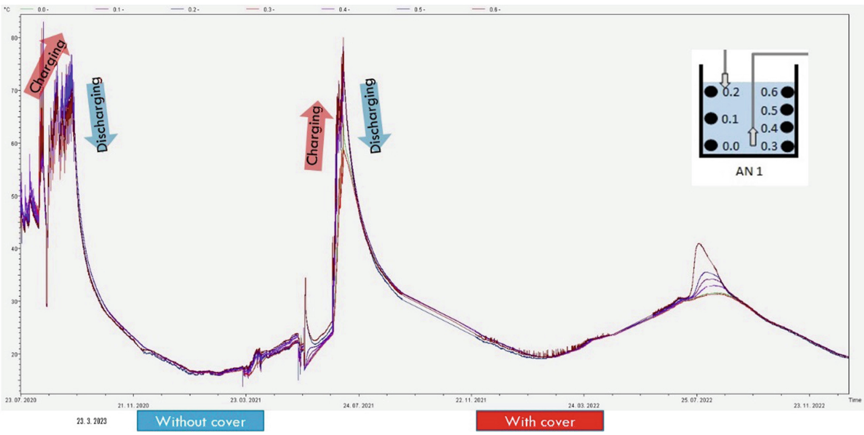

Fig. 6. Graphs of 2-year temperature measurements in AN1-tank

4.2 Accumulation Tank with Cover

In the second year, we improved the AN1 research thermal tank storage by covering the water surface. The covering consisted of thermal insulation made of polystyrene with a thickness of 20 mm. It can be proven from the collected temperature values that the discharge is not so fast. This discharge passes at a certain temperature from quadratic to linear discharge, Fig. 9.

In the second year, the tank was charged up to a temperature of 73 °C, but 100% of the temperature value for comparison between the first and second year was set to

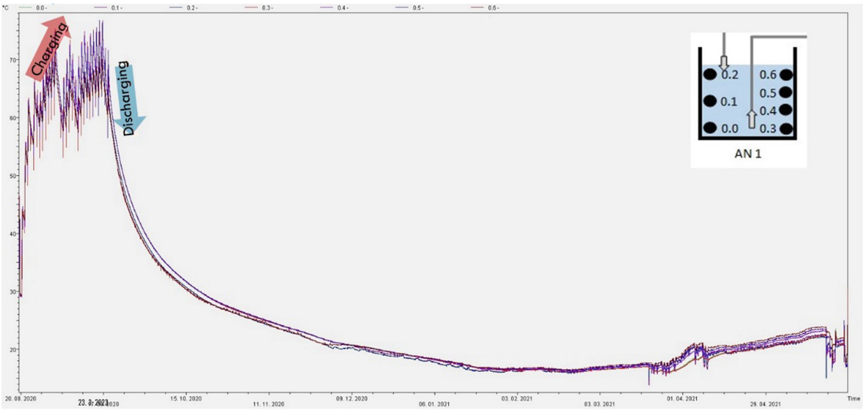

Fig. 7. First year of temperature measurements in tank without the cover

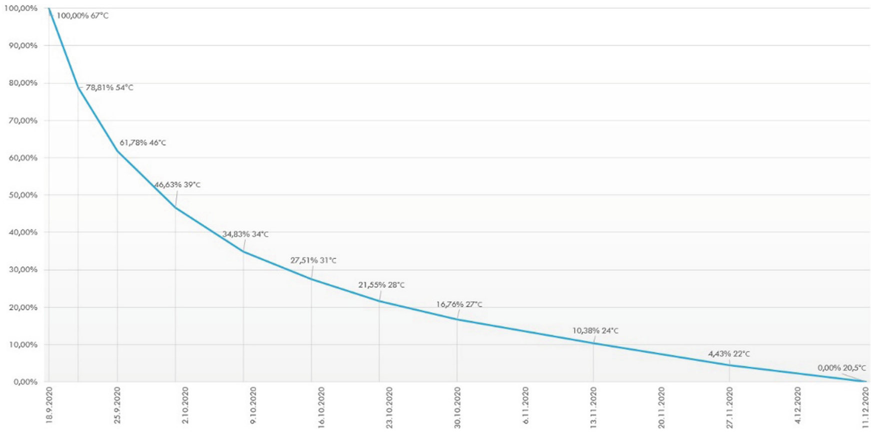

Fig. 8. Percentage graph showing tank discharging energy in the first year, vertical column - 0%–100%. Horizontal column - time data in days.

67 °C from the first year. So 100% is 67 °C and 73 °C is 108,11%. For the second year, therefore, the covered water surface shows a more effective solution for long-term energy accumulation. Comparing the first and second years, in the third week the temperature before covering was 34 °C, and after covering it was 46 °C. In the second year, the tank was discharged to the original temperature of 18 °C, which was 183 days, Fig. 10.

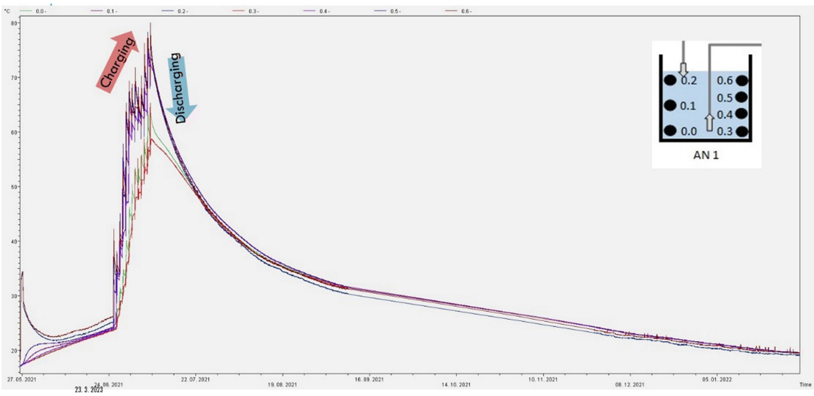

Fig. 9. Second year of temperature measurements in tank with the cover

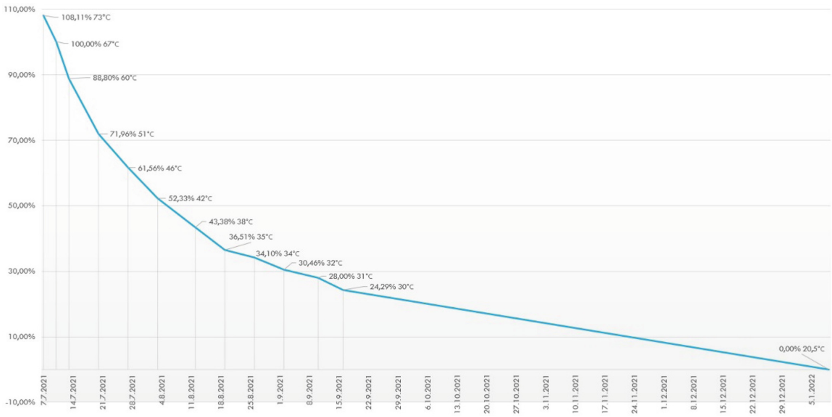

Fig. 10. Percentage graph showing tank discharging energy in the second year, vertical column - 0%–100%. Horizontal column - time data in days.

5 Conclusion

This research pointed out how to prevent heat losses, eliminate them and thereby increase the efficiency of the accumulation. In the future, we will focus on examining physical processes such as heat loss, stratification, etc.

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