International Journal of Education, Social Science & Humanities.
Finland Academic Research Science Publishers
ISSN: 2945-4492 (online) | (SJIF) = 7.502 Impact factor
Volume-11| Issue-12| 2023 Published: |22-12-2023|

CALCULATION OF THERMAL-TECHNICAL PARAMETERS OF THE SOLAR POND HEATING SYSTEM OF INDOOR SWIMMING POOLS

https://doi.org/10.5281/zenodo.10256786

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Abstract

In this article, the heat transfer parameters of a 2m³ experimental solar pond to an indoor swimming pool in the conditions of the city of Karshi were studied. During the experimental work, the coefficient of heat transfer of the solar pond to the indoor swimming pool, the hourly change of the temperature of the pool water leaving the LCZ of the pool were determined. The temperature of the water coming out of the solar pond rose to 41 °C in September. Taking into account the fact that the solar pond works only during the day, it is scientifically proven that it can heat a 5 m³ indoor swimming pool.

Key words

swimming pool, heat transfer coefficient, solar pond, heat exchanger, circulation pump.

Introduction

Ensuring the optimal temperature regime in swimming pools and saving traditional fuel energy resources in them are urgent issues in the world. Scientific research conducted by scientists and researchers from all over the world to reduce energy consumption and energy losses in swimming pool heating systems is important in the construction of swimming pools and the introduction of innovative energy-saving technologies [1-2].

The use of solar radiation for heating swimming pools has been proposed since the beginning of the 60s of the last century on this topic [3-4]. In the early and mid-1990s, field scientists used special software (TRNSYS) to study in detail the performance of active or passive solar systems used to heat swimming pools [5-6]. Solar collectors have been proposed by scientists in the field, primarily for heating swimming pools, mainly for countries with warm climate such as the Mediterranean basin or India [7-8]. In order to improve the performance of solar-heated swimming pools by reducing energy losses, scientists Chow, Bai, and Fong proposed the use of heat pump systems [9-27].

Scientific research and world experience in this direction show that indoor swimming pools require an additional alternative source of energy in the heating system in the winter mode, especially during the daytime in the winter months. Studies show that it is not possible to cover the heat load of the heating system of swimming pools in the winter mode completely by an alternative energy source (solar energy).

Therefore, improving the energy efficiency of swimming pools, developing heating systems combining the required energy mode with energy-efficient solar devices and traditional heating devices is one of the technical solutions for energy saving.

Materials and method

In order to solve the above problem only for the daytime, a solar pond heating system for an experimental swimming pool was developed (Fig. 1).

This heating system uses only the heat from the solar pond unit to heat the pool. In the heating system, the solar pond device also acts as a heat accumulator. The volume of the solar pond is $2m^3$, and 500 kg of salt (NaCl, MgCl2, KCl, etc.) is mixed with water to create a salt water mixture with a concentration of 25-30%. During experiments, it was found that it is possible to obtain heat energy from this device up to 60-65 ^oC from the lower heat storage zone [30-32].

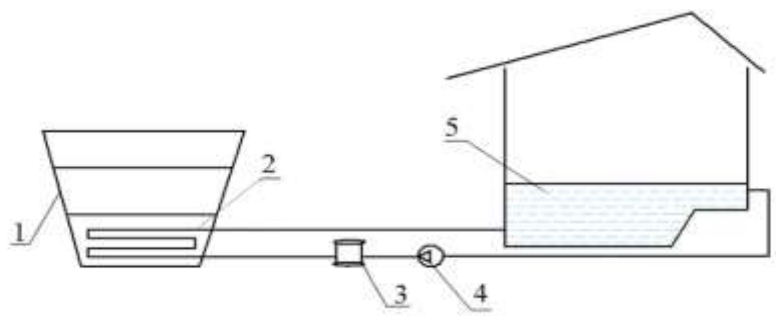

Figure 3.1. Swimming pool water heating system based on solar pond device

1- solar pond, 2- heat exchanger (coil pipe), 3- water filter, 4- circulation pump, 5- swimming pool.

In this system, the pool water is pumped through the water filter and enters the heat exchanger located in the LCZ of solar pond. The heated water passes through the heat exchanger and is pumped back into the swimming pool. A 100 W pump was used for water circulation. This pump circulates 0,45 m^3 of water per hour through the heat exchanger and injects water at the required temperature into the swimming pool.

The water coming out of the heat exchanger located in the lower zone of the solar pond serves to ensure that the temperature of the pool water does not change from the required values. In order to keep the swimming pool water at a constant temperature of 28-30 °C, the heat input will have to compensate for the thermal energy losses of the pool. to solve this problem, it is necessary to solve the heat balance equation.

So, the heat balance and heat transfer equation on the surface of the heat exchanger F_{he} in the time interval $d\tau$ will be in the following form.

$$dQ = k_w \cdot F_{he} \cdot \Delta t \, d\tau = G_w c_w (t_{out} - t_{in}) d\tau = m_p \cdot c_p \cdot dt_p \qquad (1)$$

Here, Δt - the average temperature difference at the moment of time τ of the heat carrier, °C; t_{in} - the temperature of the water entering the heat exchanger, °C; t_{out} - the temperature of the water leaving the heat exchanger, °C; t_{lcz} - the temperature of the lower convective zone of the solar pond, °C;

The average logarithmic value of Δt temperature change at the τ instant of time can be written as follows[31-33].

$$\Delta t = \frac{t_{out} - t_{in}}{\ln \dfrac{t_{lcz} - t_{in}}{t_{lcz} - t_{out}}} \qquad (2)$$

In the lower heat storage zone of the solar pond, there is a 20 m long stainless steel pipe with a diameter of 8 mm. The total external surface of this pipe is 0.5024 m², and water is used as a heat carrier. We calculate the heat transfer coefficient from the salt water of the lower heat storage zone of the solar pond to the heat exchanger device as follows.

Hence, t_{in}, t_{out}, and t_{lcz} are functions of time as the temperatures change over time. By inserting Δt into the expression (1), we get the following formula (3).

$$k = \frac{G_w \cdot c_w}{F_{he}} \ln \frac{t_{lcz} - t_{in}}{t_{lcz} - t_{out}} \qquad (3)$$

Results and discussion

In the autumn of 2023, experimental work on heat extraction from the solar pond was carried out. Average ambient temperature and temperature in the solar pond at the LCZ, incoming and outgoing heat transfer water temperatures, and

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Volume-11| Issue-12| 2023 Published: |22-12-2023|

daily average solar radiation of the beginning, middle, and last days of September, October, and November were determined.

The average values of ambient temperature, temperature of the lower layer of the solar pond, the average change of the inlet and outlet temperatures of the heat carrier over time, as well as solar radiation and the calculated heat transfer coefficient to the heat exchange device located in the LCZ of the solar pond in the climatic conditions of the city of Karshi the average change values over time are presented in the following 3 tables. The graphs of the quantities determined on the basis of these values are shown in Fig. 2 and Fig. 3.

Table 1

The results of the solar pond experiment (04.09.2023)

№	Time	solar radiation q_r, Vt/m²	Outside air temperature t_{out}, °C	Solar pond (LCZ) temperature t_{lcz}, °C	Inlet water temperature t_{in}, °C	Outlet water temperature t_{out}, °C	Heat transfer coefficient k, Vt/m² °C
1	9-00	954	26,2	32,1	19,5	25,1	612
2	10-00	963	27	35,9	19,8	27,7	700
3	11-00	980	29,5	37,4	20,2	29,8	852
4	12-00	992	31,3	41,6	23,3	34,3	970
5	13-00	973	33	45,2	24,5	37,4	1003
6	14-00	998	34,2	47,8	26,2	40	1079
7	15-00	1008	35,5	49,5	26,5	41	1050
8	16-00	978	34,8	50,1	26,8	40,5	952
9	17-00	909	33,1	47,2	25,2	37,7	878
10	18-00	788	31,4	45,1	24,3	35,1	751

Table 2

The results of the solar pond experiment (04.10.2023)

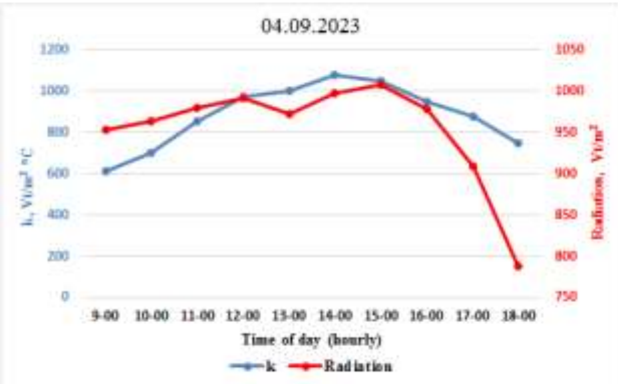
№	Time	solar radiation q_r, Vt/m²	Outside air temperature t_{out}, °C	Solar pond (LCZ) temperature t_{lcz}, °C	Inlet water temperature t_{in}, °C	Outlet water temperature t_{out}, °C	Heat transfer coefficient k, Vt/m² °C
1	9-00	785	22,6	29,3	19,5	23,9	623
2	10-00	897	24,2	32,2	19,6	25,8	712
3	11-00	922	26,4	33,9	20	27,6	829
4	12-00	945	27,6	36,8	21,1	30,4	920
5	13-00	963	28,3	39,3	23,6	32,8	995
6	14-00	970	28,4	42,2	24,2	35,3	998
7	15-00	996	27,8	44,8	25,6	37,2	968

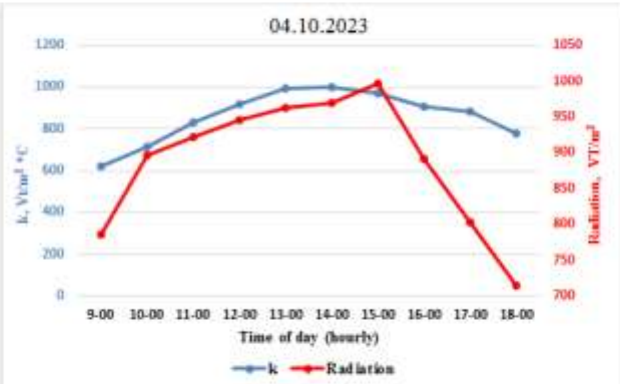
8	16-00	892	26,6	44,6	24,9	36,3	908
9	17-00	802	26,2	40,3	24,1	33,3	883
10	18-00	715	25,3	37,3	23,2	30,7	779

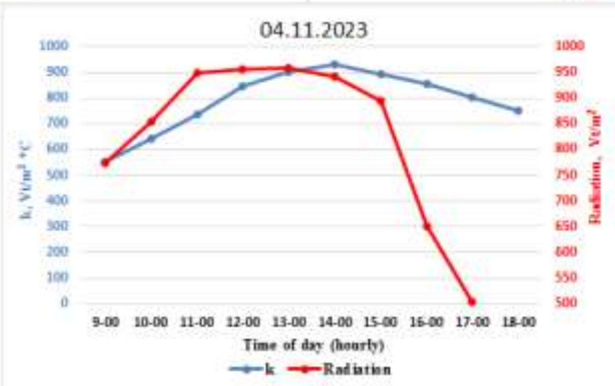
Table 3

The results of the solar pond experiment (04.11.2023)

№	Time	solar radiation q_r, Vt/m^2	Outside air temperature t_{out}, ^oC	Solar pond (LCZ) temperature t_{lcz}, ^oC	Inlet water temperature t_{in}, ^oC	Outlet water temperature t_{out}, ^oC	Heat transfer coefficient k, Vt/m^2 ^oC
1	9-00	774	18,1	25,9	17	21,9	551
2	10-00	854	19,2	27,8	18,3	23,2	644
3	11-00	950	20,4	30,4	19	24,1	735
4	12-00	955	21,6	32,5	19,9	25,6	845
5	13-00	958	22,3	34,9	21,8	28,1	902
6	14-00	943	23,4	36,9	23,9	31	932
7	15-00	895	22,8	38,5	23,5	32,4	895
8	16-00	650	21,2	37,3	21,8	30,9	853
9	17-00	503	19,8	35,8	20,8	28,8	805
10	18-00	0	19,3	32,6	19,6	26,4	750







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Volume-11| Issue-12| 2023 Published: |22-12-2023|

Figure 2. Graph of change of radiation and heat transfer coefficient over time

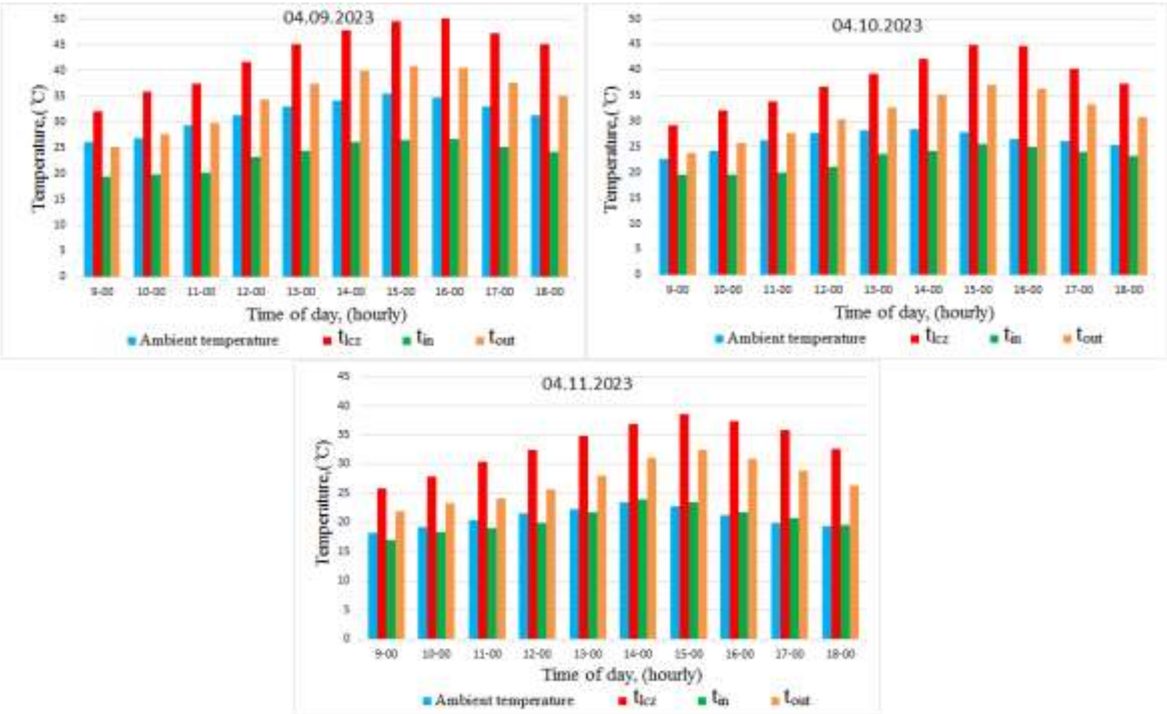

Figure 3. Graph of ambient temperature, solar pond bottom layer temperature, and heat exchanger inlet and outlet temperature over time

The water temperature in indoor swimming pools should not be lower than 28 °C for adults according to the requirements of SanPin 2.1.2.1188-03 [34-35]. Accordingly, calculations were made to determine the size of the experimental swimming pool at the required temperature according to the heat transfer capacity of the experimental solar pond. For this experiment, the temperature of the water entering the solar pond from the indoor swimming pool was determined. Taking into account that the temperature of the water of the swimming pool does not fall below the required value, it was determined that the temperature of the water entering the solar pond from the pool varies between 27-28 °C.

During the research (1), an empirical equation of the temperature change of the water coming out of the solar pond was developed using formula.

$$k \cdot F_{he} \cdot \frac{t_{out} - t_{in}}{\ln \frac{t_{lcz} - t_{in}}{t_{lcz} - t_{out}}} = G_w \cdot c_w (t_{out} - t_{in}) \qquad (4)$$

$$t_{out} = t_{lcz} - (t_{lcz} - t_{in}) e^{\frac{k\,F_{he}}{G_w\,c_w}} \qquad (5)$$

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Then, according to the hourly changes of ambient temperature and radiation values, the average hourly change of the temperature of the water leaving the solar pond in September, October and November was determined (Figure 4).

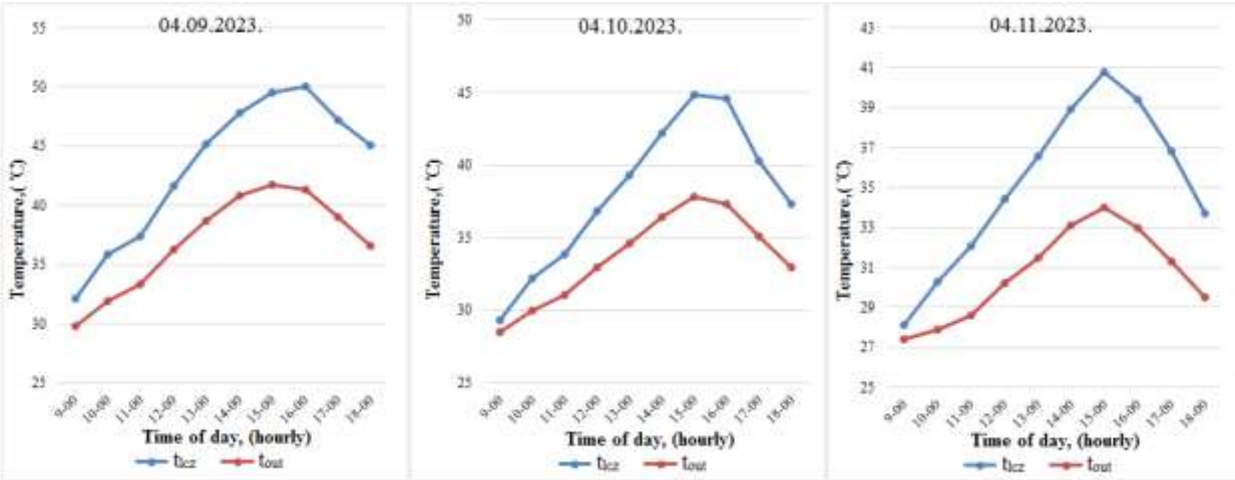

Figure 4. Graphs of the temperature change of the water leaving the solar pond when the temperature of the water entering the solar pond from the pool is constant at 27 °C.

Based on the developed empirical equation and the results of the conducted research, it was determined how much volume of warm water at the required temperature can be supplied to the indoor swimming pool in accordance with the heat transfer coefficient of the solar pond.

According to the pump power used in the experimental device, the amount of heat (Q_{sp}) removed from the solar pond through the heat exchanger device and the amount of heat (Q_p) used to heat the swimming pool were calculated according to the amount of heat energy supplied by the experimental solar pond to the swimming pool.

$$\begin{cases} Q_{sp} = G_w \cdot c_w (t_{out} - t_{in}) \\ Q_p = \rho_w \cdot V_p \cdot c_w (t_{in} - t_p) \end{cases} \Rightarrow \quad Q_{sp} = Q_p \qquad (6)$$

From the equality of these heat quantities, the size of the pool was calculated, taking into account the change of heat taken from the solar pond over time. In autumn, the energy collection time of the solar pond is 10 hours per day. During this time, the solar pond serves to supply the swimming pool with hot water at the required temperature.

$$V_p = \frac{G_w(t_{out} - t_{in})\tau}{\rho_w(t_{in} - t_p)} \quad (7)$$

In the course of research, it was estimated that a 2m^3 experimental solar pond and its heat exchanger located in the LCZ can supply a 5m^3 swimming pool with water of the required temperature for 1 day in the autumn season of Karshi.

Conclusion

- During the experiments, it was observed that the heat transfer coefficient of the solar pond decreases in parallel with the decrease in solar radiation and ambient temperature.

- The average temperatures of the pool water at the inlet and outlet of the solar pond were determined for September, October and November. The maximum temperature of the pool water at the exit from the solar pond was 41 ^oC.

- In the autumn season of Karshi city, it was found that a 2 m^3 solar pond heating system can supply a 5 m^3 swimming pool with water at the required temperature during the daytime.

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