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Analysis of Passive Open Solar Pool Design and Energy Loss Calculation

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ABSTRACT. The article outlines the advantages of using locally available materials, particularly concrete, for constructing solar pools due to its high specific heat capacity. The work presents formulas for calculating heat losses caused by evaporation, radiation, and convection, using climatic conditions of Tashkent as a case study. The findings indicate that the majority of energy losses (67%) in such pools occur through evaporation, with smaller losses attributed to radiation and convection. A cost analysis of materials needed to build a pool with dimensions 3x3x0.5 m^3 shows that it can be economically constructed for $852 using local resources. The article advocates for solar energy utilization in pool heating to enhance energy efficiency and reduce reliance on conventional energy sources like gas and electricity. The results contribute to the growing body of research on renewable energy applications in pool construction, emphasizing environmental sustainability and cost-effectiveness.

KEY WORDS: Solar pool, operation, specific heat capacity, energy, temperature, radiation, evaporation, convection.

I.INTRODUCTION

Currently, one of the ways to improve public health is to develop physical and sports culture. In this regard, much attention is paid to the construction of swimming pools in health, medical and sports complexes. Heating a pool with solar energy allows saving 40-50% of natural energy sources [1]. Solar pools are available in many parts of the world, including: Brazil, Portugal, USA, Oman, Italy, Spain, India, Germany, England, Australia [2-9].

Today, in Uzbekistan, most of these pools are heated by natural gas or electricity and, in turn, consume a large amount of energy [10]. Thanks to the adopted resolutions of the President and the Cabinet of Ministers of the Republic of Uzbekistan such as "On the use of renewable energy sources" dated April 16, 2019, the Cabinet of Ministers of the Republic of Uzbekistan dated July 23, 2020 No. 452 "On measures to maintain state records of renewable energy installations and the energy generated by them" Resolution of the Cabinet of Ministers of the Republic of Uzbekistan dated March 24, 2022 No. 127 "On measures to organize the activities of the national research institute of renewable energy sources under the Ministry of Energy". The government is actively working to increase the share of solar energy in the energy balance of the republic.

Swimming pools are ubiquitous facilities located both outdoors and indoors. Pools are complex engineering and hydraulic structures [11]. Today, in our country and in the world, there are a number of regulations and acts on this matter [12-14]. According to statistics, pools built from concrete will require repairs every 5-7 years, although the operation of these pools should last at least 30 years. This may be due to the use of improper technology during pool construction or the wrong choice of material during operation [15].

The purpose of this work is to develop a scheme for creating an open solar children's pool for teaching children from 3 years old. This type of pool has small dimensions of any shape, attracts special attention to water purification, quality, temperature and depth, usually from 0.5-0.85 m; from 0.8 to 1.05 m; from 0.9 to 1.25 m [16].

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II.DESCRIPTION OF THE SYSTEM

Pools are classified by material: 1. Concrete. 2. Stainless steel. 3. Composite. 4. Frame (prefabricated) [12]. Of course, pools made of such materials have their advantages and disadvantages (Table 1).

Table1. Comparative characteristics of pools depending on the type of construction [13]

By type of pool bowl construction	Mobile	Any form	Complexity cost	Durability
Concrete	–	+	+++	++
Made of stainless steel	–	+	+++	+++
Composite	–	–	++	++
Frame	+	–	+	+

When building a solar pool, we need to use materials with the highest possible heat capacity. To keep more heat in itself during the summer period of the year. Since the source of heating of solar pools is considered to be solar radiation, it is advisable to use concrete as the main raw material for maintaining thermal energy in the pool (Table 2).

Table2. Specific heat capacity of materials used in the construction of swimming pools

By type of pool bowl construction	Specific heat capacity, kJ/(kg·K)
Concrete	1.13
Stainless steel	0.42-0.504
Composite (fiberglass and polyester resins, and also use a top layer - gelcoat, based on the same polyester resins.)	0.8-1.46

Outdoor solar pools are the most commonly used types, which are built in private yards or recreation areas, as well as in medical centers. For pools that will be built from concrete, the following materials will be required:

- Waterproof cement. Class B 25 concrete is used for this [17].
- The reinforcement should be 8-10 mm thick, depending on the design of the pool [17].
- Waterproofing materials should protect the concrete from the negative effects of moisture [17].
- Tiles for adding various decorations to pools [18] These are: natural stone, ceramic tiles, mosaics and three-layer polyethylene films [19].

To build the pool, methods of scientific analysis of design options and exploratory design were used [20-21].

Let us calculate the design of an open solar children's pool, which is planned to be built for conducting experiments (Fig. 1). For this purpose, the size of the children's pool 3x3x0.5 m^3 (4.5 m^3) was selected based on the requirements of sanitary norms of health [22].

Pools are built using cement because it has a higher specific heat capacity than other pool construction materials and is also cheaper. Reinforcement is used to ensure that the cement hardens well. The children's pool under construction differs

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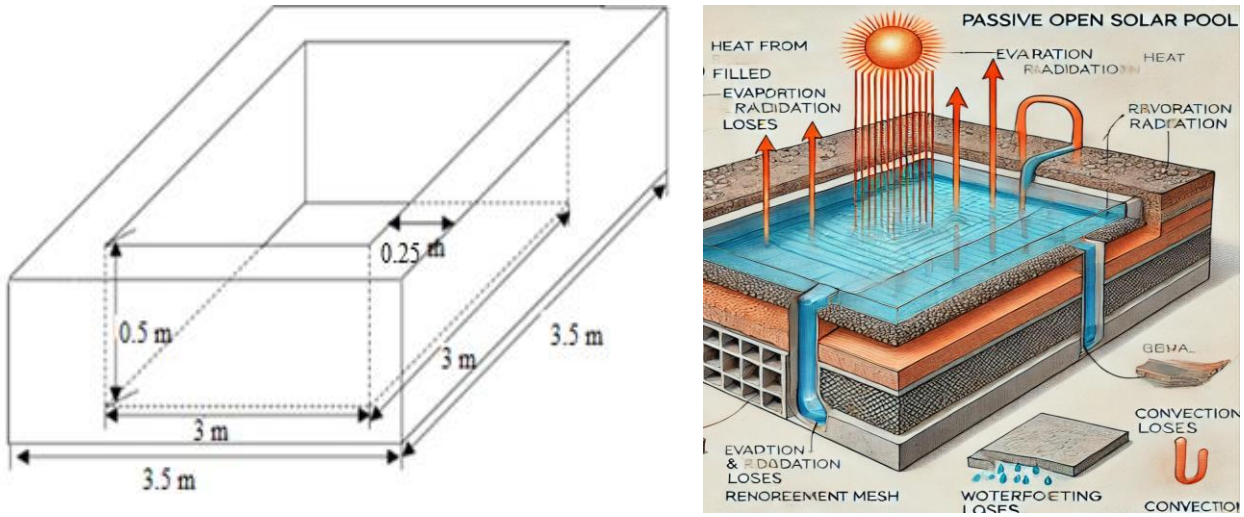
Vol. 11, Issue 9, September 2024

from its analogues in that it is relatively inexpensive, can be built in any shape (we chose a rectangular one), and will last



a **b**

Fig 1a, b. Scheme of an open children's pool

for many years.

Below are 5 steps to create a pool:

- The foundation is laid with gravel 15-30 cm thick, on top of which concrete 10 cm thick is laid.
- Reinforcement with a diameter of at least 8-10 mm is welded together in the form of a mesh measuring 15x15 cm^2.
- Concreting is carried out by creating a 25 cm thick wall and pouring cement.
- Waterproofing is carried out using acrylic or epoxy 4 mm layers.
- Decoration is carried out using special waterproof decorative materials [23].

Table3. Materials required for the construction of a children's pool with dimensions 3x3x0.5 m^3 and their cost (in the conditions of Uzbekistan) [24]

№	**Name and brand of material**	**Total quantity**	**Total cost (usd)**
To the base	Gravel 20 cm	2.5 m^3	21
To reinforcement	Iron diameter 8 mm	1200 m	455
Concrete	Cement M-450+ RECO	1500 kg	220
	Sand	3000 kg	120
For waterproofing	Akril Skrepa 2K	60 kg	13
For decoration	Mosaic for pools art 002	4.5 m^3	23
General			**852**

III.WORKING FORMULAS

Energy losses in passive open pools are calculated using the following formulas:

$$Q = Q_e + Q_r + Q_c \quad (1)$$

Heat loss due to evaporation [5]

$$Q_e = A(a + b \cdot w)(P_w - P_a) \quad (2)$$

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A - is the surface area of water in the pool (м^2), according to ASHRAE $a = 0.089\ \frac{W}{m^2 \cdot Pa}$, $b = 0.0782\ \frac{W}{m^3 \cdot Pa}$, w - is the wind speed at a height of 0.3 above the pool (м/с), P_w - is the saturated water vapor pressure at water temperature (кПа), P_a - is the partial pressure of water vapor in the air (кПа).

Radiation heat loss

$$Q_r = A\varepsilon_w\sigma(T_w^4 - T_a^4) \quad (3)$$

ε_w −is the emissivity, σ − is the Stefan-Boltzmann constant, T_w −is the water temperature, T_a - is the air temperature.

Convection heat loss

$$Q_c = A(3.1 + 4.1w)(T_w - T_a) \quad (4)$$

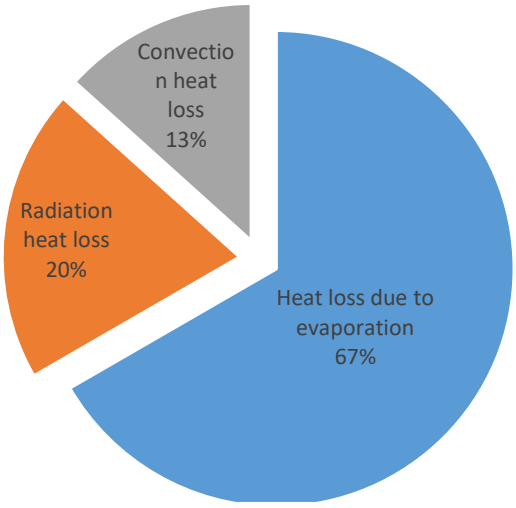

Fig 2. Diagram of energy losses in a passive outdoor pool is shown.

IV.CALCULATIONS

We find energy losses in a passive open children's pool according to the parameters shown in Fig. 1. The following parameters are appropriate for the pool:

$A = 9$ м^2, $w = 1.5$ м/с, $T_w = 305$ К, $T_a = 298$ К, P_w =*4246 Па*, $P_a = 3169$ Па, $\varepsilon_w = 0.9$, $\sigma = 5.67 \cdot 10^{-8}\ \frac{W}{м^2 \cdot К^4}$,

$Q_e = A(0.089 + 0.0782 \cdot w)(P_w - P_a) = 9 \cdot (0.089 + 0.0782 \cdot 1.5)(4246 - 3169) = 2$ кW,

$Q_r = A\varepsilon_w\sigma(T_w^4 - T_a^4) = 9 \cdot 0.9 \cdot 5.67 \cdot 10^{-8} \cdot (305^4 - 298^4) = 0.4$ кW,

$Q_c = A(3.1 + 4.1w)(T_w - T_a) = 9 \cdot (3.1 + 4.1 \cdot 1.5)(305 - 298) = 0.6$ кW.

V.CONCLUSION.

This paper analyzes the design and materials used in the construction of an open solar children's pool, and also considers the technology of its construction. Calculations of heat loss due to evaporation, radiation and convection in the pool were carried out, which made it possible to estimate energy losses in the summer climate of Tashkent. The results showed that a significant part of the energy is lost during evaporation of water, which indicates the need to use high-quality waterproofing materials and effective methods of heat conservation.

- Today, the construction of a 3x3x0.5 m^3 children's solar pool from locally available materials costs $852;
- It has been established that, in order to increase the temperature of a 3x3x0.5 m^3 children's solar pool, 3 kW of energy is lost as a result of external influences;
- 67% of energy is lost through evaporation, 20% of energy is lost through radiation, 13% of energy is lost through convection (Fig 2).

The calculations and comparison with literature data confirmed the efficiency of using locally available materials for pool construction. In particular, it was shown that concrete structures have the highest specific heat capacity, which makes them preferable for use in solar pools. It was found that the cost of building a solar pool from local materials makes this approach cost-effective.

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Thus, the developed scheme for creating an open solar children's pool using local materials and technologies allows not only to reduce construction costs, but also to ensure the efficient use of solar energy for heating the pool, which corresponds to modern trends in energy saving and environmental safety.

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