Experimental Testing and Numerical Simulation of a Single-Circuit Solar Water Heater with a Thermosiphon

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Abstract: - In this article, a single-circuit solar water heater with a thermosiphon was built, tested and numerically modeled in Kazakhstan, Almaty. To heat cold water in the south-eastern region of Kazakhstan, a flat solar collector was developed and studied, as well as a mathematical model of a single-circuit solar installation with a thermosiphon. In this mathematical model, the Bernoulli equation was used to solve the water flow in the dispenser tank and in the collector itself. Numerical modeling in MatLab was developed using a mathematical model. The dependences of the temperature inside the solar collector, which is usually distributed inside the collector in accordance with the law of thermodynamics, were obtained, and the maximum relative humidity, which was 75%, was also solved. In the course of the study, the annual change in the efficiency of the system was decided.

Keywords: Flat solar collector, thermosiphon, numerical simulation

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1 Introduction

When using traditional energy, which requires production, leads to pollution and harms the environment. In [1,2], a water heating system with a thermosiphon effect was developed. In [3], a system was developed to compare conventional and spiral models to improve thermal performance using a spiral standing pipe, which increases productivity. In the article [4], a process with a ribbed tube was developed and investigated, which showed an increase. In [5], a water heater made of an absorption pipe was developed. It has been recorded that the absorption pipes absorb another pipe in which the pipe has increased. In [6], a system was developed that was experimentally analyzed. In [7], flat plate solar collectors with heat pipes without a wick were developed, having different pipe cross-sectional geometry and filling factor. In [8], heat absorption by the solar collector was improved. In [9], the characteristics of an energy harvesting device modeling CFD are studied. In the article [10], an effect using improved transmission of solar energy is developed and investigated. In the article [11], and an efficiency comparison was carried out. In [12], the thermal efficiency of collectors was evaluated. In the article [13], experimental work was carried out to increase the heat transfer of the device. In [14], the thermal characteristics of the solar heat supply system, as well as fossil fuels, were experimentally tested [15]. While compared to a solar heating system with forced circulation [16].

Fig. 1: Single-circuit solar water heater with thermosiphon

Figure 1 shows a single-circuit solar water heater with a thermosiphon on the campus of Yunnan University. Each consists of 18 tubes (inner tube/lid diameter 47/58 mm, length 1.8 m) (Fig. 2).

Collector slope: inclined 22° 46°. The following were developed: the first was intended to study the operation at night of a single-circuit solar water heater with a thermosiphon and reverse, and the second was a loss analysis for reverse control of ambient air temperature, a PT100 sensor located nearby was used [17].

Fig. 2: Single-circuit solar water heaters

Theoretical flow forecasts in thermosiphon forecasts are proposed studies of forecasts [18]. In [19], experimental comparisons were made between two sets of single-circuit thermosiphons in a tank, but for another system, the storage tank was located horizontally with a vertical distance of 0.35 m between the connections of the collector circuit in the tank.

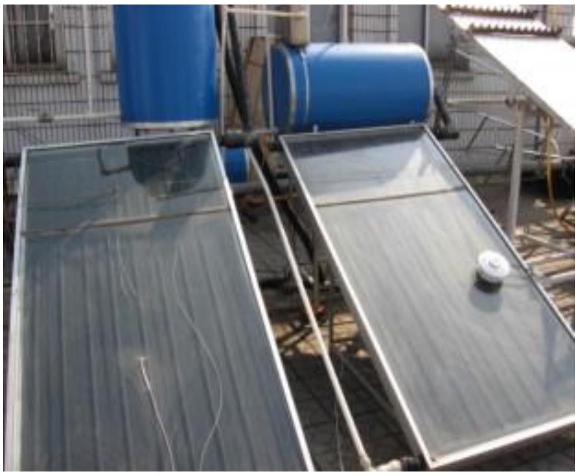

Fig. 3: Single-circuit solar water heaters

Figure 3 shows a single-circuit solar water heater. In Fig. 4, the work is chosen as a horizontal solar collector with a vacuum tube "water in a glass", since it is used largely depending on the speed of the natural circulation flow [20].

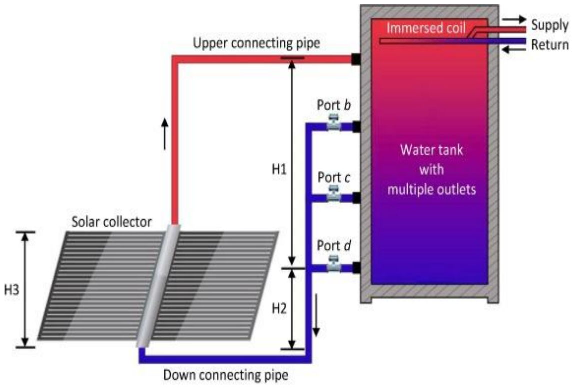

Fig. 4: Single-circuit solar heating systems with thermosiphon

In the article [21], bioenergy is being developed, which makes it possible to reduce hydraulic exploration. This article [22] discusses the resources for biogas production in the Republic of Kazakhstan. As a result, it was found that when using the technology of anaerobic digestion of manure, the output of biogas from solid household waste and sewage sludge was calculated.

2 Research Method

A single-circuit solar water heater with a thermosiphon was designed and installed in Almaty, Kazakhstan (Fig. 1 and 2).

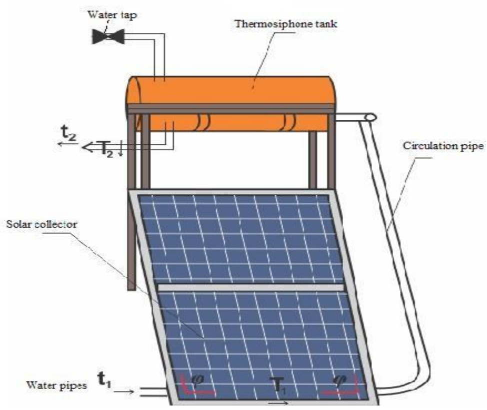

Fig. 5: Collector diagram

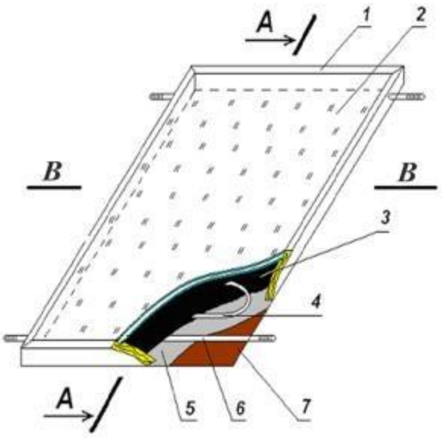

Fig. 6: Collector

Fig. 7: Single-circuit solar water heater with thermosiphon

3 Mathematical Model of the System

3.1 Thermosiphon Solar Water Heater

A single-circuit solar water heater with a thermosiphon multilayer stationary reverse flow circuit, which is separated by several perpendiculars, is solved using the Bernoulli equation applied to the power circuit

$$\Delta P_i = \rho_i * g * \Delta h_i + \rho_i * g * h_{Li} \quad (1)$$

This model includes a velocity that satisfies the calculated friction pressure of the fluid in the collector, and a separate insignificant throughput

$$T_{po} = T_a + (T_{pi} - T_a)\exp[-\frac{(UA)_p}{mC_p}] \ (2)$$

The friction pressure loss in the pipe is defined as

$$H_p = \frac{f*L*v^2}{2d} + \frac{Kv^2}{2} \quad (3)$$

$$T_{ck} = T_a + \frac{I_T F_R(\tau\alpha)}{F_R U_L} + (-T_a - \frac{I_T F_R(\tau\alpha)}{F_R U_L})*\exp[\frac{F' U_L}{G*C_p} * \frac{(k-\frac{1}{2})}{N_x}]$$
(4)

The amount of heat in the system is:

$$Q_u = r_c A(F_R(\tau\alpha) I_T - F_R U_L(T_{CI} - T_a) \quad (5)$$

were

$$r_c = \frac{F_{R,use}}{F_{R,test}} = \frac{G(1-\exp(\frac{U_L \dot{F}}{GC_p})}{G_{test}(1-\exp(\frac{U_L F}{G_{test} C_p})} \quad (6)$$

3.2 The Battery Tank

The average temperature supplied for loading is:

$$T_d = \frac{V_h T_h + (V_L - V_h) T_1}{V \quad L} \quad (7)$$

Calculated conductivity of the storage tank

$$\rho C_p V_i \frac{dT_i}{dt} = -(UA)_i (T_i - T_{env}) + (k_s A)_{i-1} \frac{(T_{i-1} - T_i)}{\Delta h_{i-1}} - (k_s A)_i \frac{(T_i - T_{i+1})}{\Delta h_{i+1}}$$
(8)

$$Q_{in} = m_h C_p (T_h - T_R) \quad (9)$$

The amount of the substance is

$$Q_{sup} = m_L C_p (T_D - T_L) \quad (10)$$

4 Results and Discussion

Using a mathematical model and the MatLab program, a numerical analysis was obtained for a single-circuit solar water heater with a thermosiphon.

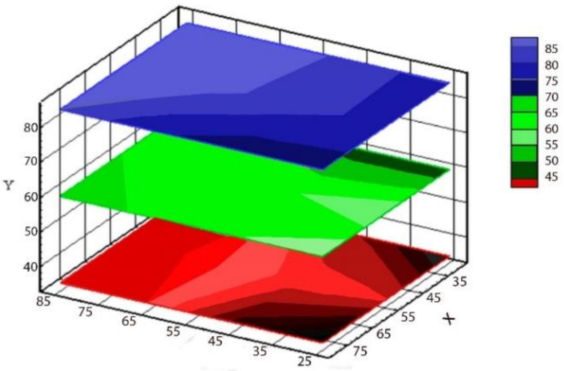

Fig. 8:. Temperature distribution at heating temperature

Figure 8 shows the distribution of the solar collector at a constant heating temperature. As can be seen from the figure, this is due to the fact that

the temperature is well distributed inside the collector.
Thus, in Figure 9, the accounting of the quantity provided by the collector remains unchanged.

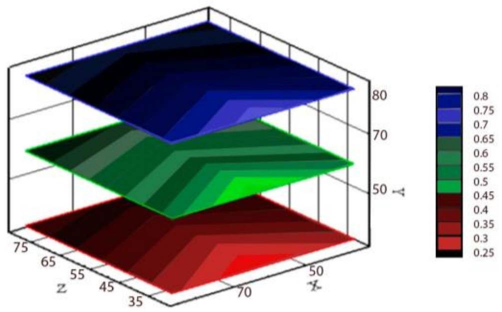

Fig. 9: Relative humidity distribution system with constant heating temperature

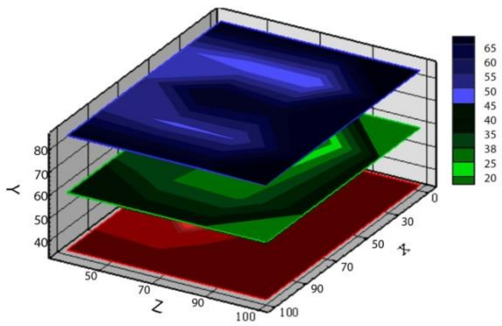

Fig. 10: Distribution of the upper level temperature

Figure 10 shows the upper level of the distribution. As you can see from the picture, the distribution is also present in the system, which allows you to improve performance.
Figure 11 shows the annual change in efficiency, which varies, does not have a definite value, does not lead to a significant improvement in performance and does not have much significance for system performance.

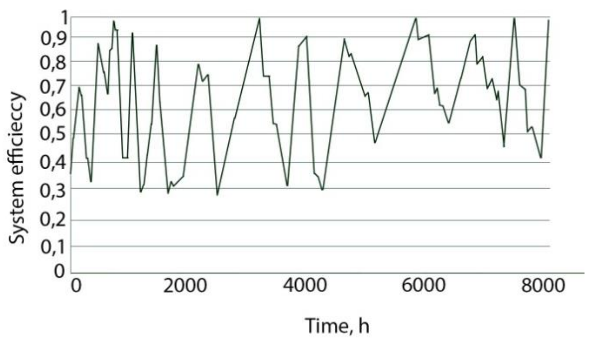

Fig. 11: Annual change in system efficiency

5 Conclusion

A single-circuit solar heat supply system has been developed, installed and tested in Kazakhstan, which is used as a heat source. The system can work continuously. As a result of testing the system, it was found that the use of a thermosiphon circulation system increases the efficiency and economy of the system and ensures good condensation.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

-Taganova Guldana, Murat Kunelbayev carried out the simulation and the optimization.

-Abdildayeva Assel, Zhadyra Zhumasheva has implemented the Algorithm in MatLab.

-Tletay Sholpan, Kurmanali Meiramgul has organized and executed the experiments of Section 4.

-Duissembayeva Laura, and Kurbanaliyeva Aimanwas responsible for the Statistics.