ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 7, July 2024

Experimental Research of Combined Solar Pond-Heat Pump Heating System

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ABSTRACT: In this research work, the energy efficiency of the introduction of heat pumps into the water heating systems of swimming pools in the conditions of Karshi city was evaluated based on the thermodynamic cycle of the heat pump operating on the basis of a low-temperature source and the experimental study of its parameters. During the experiments, the transformation coefficient of the steam compressor heat pump was determined at four temperatures of 5, 10, 15 and 20 °C of the low-temperature source coming from the solar pond. It was observed that the coefficient of performance of the heat pump increased with the increase in the temperature of the low-temperature source. During the research, it was found that the value of the It was observed that the coefficient of performance of the heat pump increased with the increase in the temperature of the low-temperature source. Of the heat pump changed from 2.1 to 3.5 at different temperatures of the low-temperature source. Also, a transformation coefficient of 3.5 was achieved using a heat source with a temperature of 20 °C.

KEY WORDS: *solar pond, swimming pool, compressor, evaporator, condenser, throttle.*

I. INTRODUCTION

The development of green technologies and environmentally safe energy technologies in the world serves as the basis of sustainable development of energy, green economy and the state[1-2]. For this purpose, it is possible to increase the energy efficiency of heating systems based on the heat pump system and objects that need to be heated using secondary energy sources and renewable energy sources. According to the research of scientists, the use of heat pump devices in many heating systems is predicted to reach 12% [3-5]. It can be seen that the introduction of environmentally friendly energy sources in heating systems to reduce the impact of CO_2 emissions on the environment will lead to the increase of heat pumps.

A. Moreno-Rodriguez conducted theoretical and experimental studies with the heat pump working in a solar energy directly to determine the operating parameters and consumption of a domestic hot water system. Water with a temperature of 51 °C was obtained through this system [6-7]. E Kinab, D Marchio and others have studied the seasonal performance of the heat pump[8]. Japanese scientists Y. Shiba, R. Ooka and K. Sekine researched the working mode of the water-to-water heat pump using underground energy. During the study, it was determined that the cooling efficiency (COP) of the heat pump reached 5.5[9].

To date, many researchers have conducted research on improving the efficiency of solar energy collection and combining solar energy with other auxiliary energy. However, sufficient research has not been conducted on the application of solar ponds working based on the solar energy with heat pumps to swimming pool heating systems

II. MATERIALS AND METHODS

Therefore, a heat pump system based on solar pond energy was developed and its energy efficiency was studied. In this research work, increasing the energy efficiency of swimming pools by using a combined solar pond-heat pump heating system and heat exchange processes of the heat pump were experimentally studied. The role of the heat pump in increasing the efficiency of the heating system was calculated based on the experimental results.

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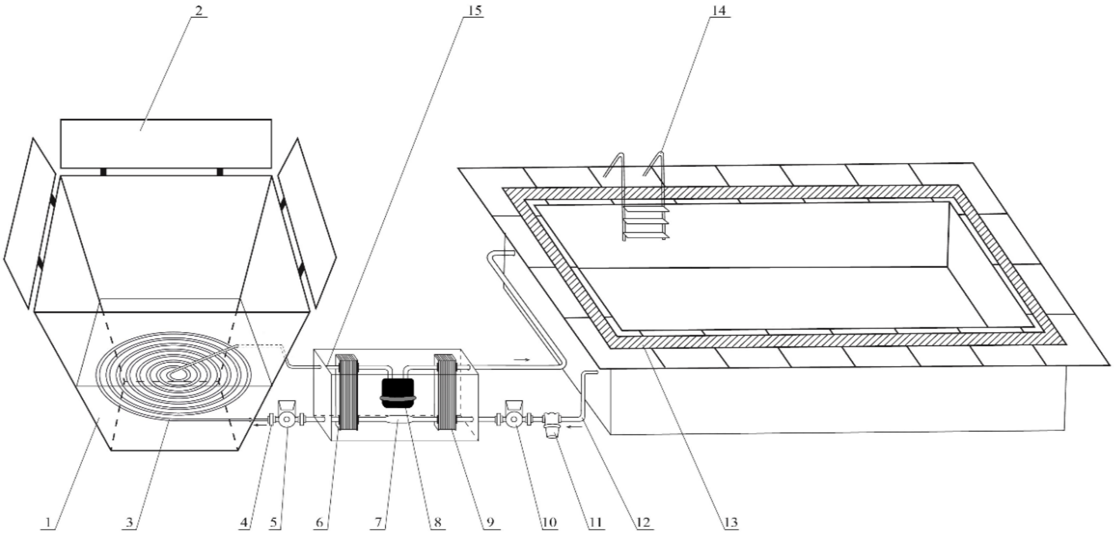

Figure 1. “Solar pond heat pump” heating system of swimming pools

1-solar pond, 2-reflector, 3-heat exchanger , 4-nut for connecting pipes, 5,10 - circulation pump, 6-evaporator, 7-throttle, 8-compressor, 9-condenser, 11 -water filter, 12- connecting pipe pool and heat pump, 13- excess water drainage tray, 14- pool ladder, 15- solar pond and heat pump connecting pipe.

Based on the specified heating capacity of the water-to-water heat pump and the working coefficient of the heating system, the capacity of the swimming pool and solar pond circulation pumps is selected.

During the researches, the energetically optimal operating conditions of the combined solar pond-heat pump heating system were studied. The optimal operating conditions of this heating system during the heating season were determined during the experiments. The considered heating system consists of solar pond, heat pump, solar pond and swimming pool circulation pumps.

The physical model of the heating system consists of 3 circuits: water circulation circuit through the solar pond, cooling agent circuit, and hot water circuit.

It is important to determine and analyze the efficiency of each circuit in determining the efficiency of the system. Through this, it is possible to determine the efficiency of the heat pump and the entire heating system. Therefore, research work was carried out in order to determine the heating capacity and efficiency of the heat pump in the heating system.

The efficiency of the heat pump in the heating mode (COP) is determined by the ratio between the heating power of the heat pump and the compressor power [10-11].

$$COP = \frac{Q_{con}}{N_{comp}} \quad (1)$$

The heating power of the heat pump is equal to the heat given by the heated vapor of the refrigerant to the hot water in the condenser. The heat transferred to the condenser is equal to the sum of the power of the evaporator of the heat pump and the power of the compressor:

$$Q_{con} = Q_{eva} + N_{comp} \quad \text{ю } (2)$$

Substituting formula (2) into formula (1), we get the following equation:

$$COP = \frac{Q_{eva} + N_{comp}}{N_{comp}} = \frac{Q_{eva}}{N_{comp}} + 1 \quad (3)$$

As can be seen from the equations, when determining the efficiency of the heat pump, the power consumed by the circulation pumps is not taken into account. In addition to the compressor capacity, the capacity of the circulation pumps placed in the solar pond heating circuit and the swimming pool heating circuit must also be taken into account when determining the efficiency of the heating system. The overall efficiency of the heating system was determined during the experiments by dividing the total heat power by the sum of the electric power consumed by all consumers [12].

$$N_{el.p} = N_{comp} + N_{pond} + N_{pool} \quad (4)$$

The thermal power of the heating system includes the heat flow transferred in the condenser and the power of the circulation pump of the swimming pool.

$$\eta = \frac{Q_{h.p}}{N_{el.p}} \quad (5)$$

The electricity consumption includes the power of the compressor and both circulation pumps.

$$Q_{h.p} = Q_{con} + N_{pool} = Q_{eva} + N_{comp} + N_{pool} \quad (6)$$

The following expression is obtained for the overall efficiency of the heating system based on the given equations.

$$\eta = \frac{Q_{con} + N_{pool}}{N_{comp} + N_{pond} + N_{pool}} \quad (7)$$

To increase the efficiency of the heating system, it is necessary to ensure that the efficiency of the heat pump and circulation pumps reaches the maximum value. For this, it is important to correctly choose the power of the pumps and calculate the optimal option of their mass consumption.

The efficiency of the heat pump can be increased by choosing the correct water consumption of the circulation pumps placed in the solar pond heating circuit and the swimming pool heating circuit. Through this, the efficiency of the entire heating system can be increased. The increased efficiency allows you to provide the swimming pool with hot water at the required temperature, using less energy.

Accordingly, calculation of heat exchange processes in the heat pump evaporator and condenser, heat energy transfer processes from a low-potential heat source to a high-temperature consumer were studied at the heat pump test stand. During the research, the method and order of the experiment was determined. During the calculation and processing of the measurement results, the transformation coefficient of the heat pump was determined.

Figure 2. Overall view of the heat pump experimental device

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The experimental device consists of a vertical stand 1 (Fig. 2) installed on a table. The stand has 4 pressure manometer gauges and 6 temperature gauges. The compressor is bolted to the table through 5 rubbers. The compressor is single-stage, and R134a Freon (refrigerant) is used to raise the heat to a high level.

The heat pump unit is a closed hermetic system consisting of a motor-compressor 5, two copper tube heat exchangers i.e. evaporator 4, condenser 6, filter drier 7, pressure gauges 8, temperature thermometers 9, copper pipes 10 and also includes unloading and protection automatic equipment. Copper tube heat exchangers were placed in water tanks where convective heat exchange was observed. Filter drier 7 cleans freon from mechanical impurities and moisture. Pressure measuring manometers allow measuring high and low pressure at four points of the hydropneumatic system of 8 heat pumps.

In the process of conducting research work, first of all, the following dimensions of the system were determined based on the measurement results.

During the experiment, the electricity consumed by the compressor was calculated:

$$N_{comp} = I \cdot U \cdot \tau \tag{8}$$

Here *I*-current strength (A), *U* - voltage (V), τ - time (sec).

$$Q_{con} = c \cdot m(t_{in} - t_{fin}) \tag{9}$$

The amount of energy used to heat water in the condenser was calculated.

Here *c* - is the specific heat capacity of water (*c*=4,19 kJ/(kg K)); *m*-mass of water in container (kg); t_{in}, t_{fin} initial and final temperature of water in the condenser.

The transformation coefficient of the heat pump was calculated based on the results of the experiment.

In order to perform the above calculations, experimental work was carried out on the experimental heat pump stand. During the experiments, the temperatures of the refrigerant at the inlet and outlet of the evaporator and condenser were determined using a TPM-10 mini digital thermometer. Temperatures of water in the evaporator and condenser were measured using an electronic thermometer. Low pressures of the refrigerant at 2 points at the inlet to the compressor and high pressures at 2 points at the outlet were measured using a manometer. A V040EU type digital measuring device was used to determine the heat pump's power consumption, voltage and AC power. During the experiment, the process time was calculated and the measured time of each value was recorded.

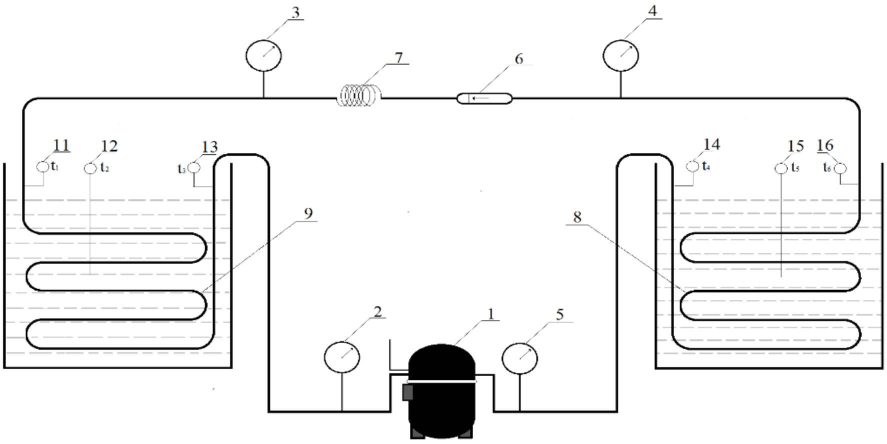

Figure 3. Scheme of the heat pump experimental device

1-compressor; 2-3-low pressure manometer; 4-5 high pressure manometer; 6-filter; 7-throttle; 8- heat exchanger (condenser); 9- heat exchanger (evaporator); 11- temperature thermometer at the entrance to the evaporator (t_1); 12- water temperature thermometer on the side of the evaporator (t_2); 13- temperature thermometer at the outlet of the evaporator (t_3); 14- temperature thermometer at the entrance to the condenser (t_4); 15- water temperature thermometer on the condenser side (t_5); 16- temperature thermometer at the outlet of the condenser (t_6);

Experiments were carried out for different initial water temperatures of 5, 10, 15 and 20 ^{o}C. At these different initial temperatures, experimental measurement work was carried out for each experimental process in heating the water to the

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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required temperature. During the experiment, the temperature, high and low pressures of the refrigerant at the inlet and outlet of the evaporator and condenser, and temperature changes of the water in the condenser and evaporator were measured. Based on the measurement results, efficiency (transformation) coefficients for each experimental process of the steam-compressor heat pump device were determined. The scheme of the experimental device is presented in Fig. 3.

III. RESULTS AND DISCUSSIONS

Determining the efficiency of the heat pump in the heating system requires the implementation of many thermodynamic calculations based on the temperature differences determined in the pump cycles, freon and heat exchangers. Diagrams of working fluids (freon) are also used for calculating heat pumps.

The graphs of changes of the following quantities with respect to time were obtained on the basis of the experimental results of the conducted research processes.

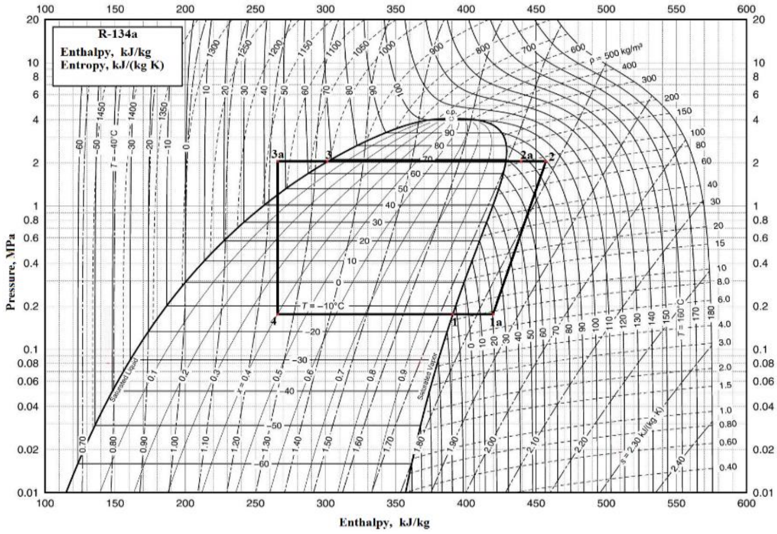

Figure 8. p-h diagram of a freon cycle of a heat pump with an experiment steam compressor

The p-h diagram of this experimental device was used to determine the efficiency (COP) coefficient of the experimental steam compressor heat pump and compare it with the experimentally determined values (Fig. 8).

Figure 9. Energy characteristics of the experimental HP device

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International Journal of AdvancedResearch in Science, Engineering and Technology
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The change in the amount of electrical energy taken from the low-temperature source in the evaporator, transferred to the high-heat source in the condenser, and consumed in relation to time was calculated (Fig. 9).

IV.CONCLUSION

The working principle of the combined solar pond-heat pump heating system was studied on the basis of thermodynamic laws, equations and experiments. During the analysis of the research results, the following conclusions were made:

Based on the results of experimental measurements, it was determined that the temperature of the low-temperature source water in the evaporator of the heat pump varied from 2 ^oC to 20 ^oC. The temperature of the water supplied to the consumer in the condenser increased from 15 ^oC to 53.5 ^oC.

During the experiments, the energy efficiency coefficient of the steam compressor heat pump reached a high value when the evaporator water was 20 ^oC, and it was scientifically proven that the transformation coefficient $\varphi = 3{,}5$ was equal.

During the research, it was found that the energy conversion coefficient of the heat pump at different temperatures of the low-temperature source changed from 2.1 to 3.5.

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