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Improving Efficiency of Solar Heating Systems with Flat Solar Collectors: Key Reserves and Possible Ways of Their Implementation

Karshiev,Sharif,Sherkulovich

PhD doctorate**,** Tashkent institute of architecture and civil engineering
Tashkent institute of architecture and civil engineering
Tashkent institute of architecture and civil engineering

ABSTRACT: . Improving efficiency of using solar thermal energy in SHS is usually achieved in two main ways cumulative efficiency of its individual elements and improving circuit design, as well as operating parameters of SHS, aimed at reducing temperature losses during heat transfer from the SC to the heat accumulator and further to the consumer thermal energy.

KEYWORDS: Solar heating systems, solar collectors, Improving efficiency, thermal energy.

I. INTRODUCTION

Solar heating systems (SHS) are one of the areas in which large-scale practical use of solar energy has actually been achieved. From 2000 to 2017, the total area of installed solar collectors (SC) as part of various SSTs increased 7.6 times and amounted to 675 million m2 in the world [1], of which solar water heating installations (WHI) accounted for 93.5%. Recently, however, the growth rate has been decreasing [2], and the production of ICs in China, Australia and the Middle East has been falling for the fourth year in a row. The European IC market has been stagnant for a number of years already: the volume of SC commissioning has been falling since 2009. From this point in time, the main task of European solar science is to find ways to reduce the cost of IC and systems as a whole [2].

In the current situation, the identification and assessment of the main reserves for increasing the efficiency of using solar thermal energy in heating systems in order to simplify them, increase reliability and reduce the cost is currently a very urgent task.

SHS differ from traditional systems by the presence of SC, which, compared to fuel or electric heat generators, is very sensitive to the temperature conditions of the system. If in fuel generators, due to the high temperature of fuel combustion (more than 1000 ° C), the final temperature of the heated water has almost no effect on their efficiency, then for WHI, in the first approximation, we can assume that an increase in the working temperature of water heating by each degree leads to a decrease in the efficiency of the flat collector by 1-2% [3]. Therefore, the loss of temperature potential in the processes of generation of thermal energy in the SC, its accumulation in the heat accumulator, transfer to the consumer and collaboration with the backup source is the main criterion for evaluating the effectiveness of the VCA.

The purpose of this study is to identify and assess the main reserves and identify promising areas and rational ways to implement increasing the efficiency of solar heating systems with flat SCs, based on minimizing the loss of temperature potential during the transfer of thermal energy from the solar collector to the heat accumulator and further to the consumer.

II. RESEARCH OF METHOD

The identification and assessment of key reserves and the identification of promising areas and rational ways to increase the efficiency of CCT were carried out by the method of critical analysis of domestic and foreign experience in increasing the efficiency of solar energy use in heating systems based on available literature data. At the same time, it

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was believed that an increase in the operating temperature of the heating SC for each degree in the first approximation leads to a decrease in its efficiency by 1-2% [3].

III. RESULTS AND EXPERIMENTAL INFORMATION

Increasing the efficiency of using solar thermal energy in SHS is usually achieved in two main ways [4]: increasing the efficiency of its individual elements and improving circuit design, as well as operating parameters of SHS, aimed at reducing temperature losses during heat transfer from the SC to the heat accumulator and further to the consumer thermal energy.

In world practice, each of these approaches has been applied [4].

SK is a key and most valuable element of the FTA.

Issues relating to the review of the world market and improving the efficiency of the IC are discussed in [2, 3]. In the work [2] it is noted that over the past 15 years, the weight and size characteristics and parameters of thermal engineering perfection of flat solar collectors have practically not changed, are quite well developed in world practice and have reached the parameters close to the limit.

Therefore, it seems promising the second approach to improving the CCT - aimed at creating new circuit solutions and operating parameters of the SC, ensuring maximum efficiency of already existing structures of the SC.

It should be noted [2] that in recent years there has been a tendency towards an increase in the number of large centralized solar heating systems. There are 300 installations in the world with an SC area of more than 500 m2, the total area of collectors in them is 1648 thousand m2. The leader of this direction is Denmark, where 110 installations (1318 thousand m2) were built [1]. For large FTAs, the issues of thermal-hydraulic self-regulation are still insufficiently studied, although they can significantly improve their efficiency and cost-effectiveness by reducing the specific flow rates of the heat carrier in the solar circuit while maintaining the required uniform distribution of the heat carrier at low flow rates. Ultimately, this means reducing the diameters of the interconnecting pipelines of the SK Heliopolis network, reducing the cost of electricity for circulating coolant, simplifying automation requirements, reducing the cost of CCT, etc. All this is a reserve for increasing the efficiency of the use of solar thermal energy in large FTAs, which are not yet sufficiently studied and require their own scientific substantiation.

When designing pumping CCTs, an important point is also the determination of the optimal specific coolant flow rate through the SC [4]. The coolant flow through the SC is one of the main operational parameters affecting its efficiency and operational readiness of the solar hot water system, which is determined by the time when the heat begins to be supplied to the consumer with the required temperature without additional heating.

It is known [3] that before 1980, in the pumping systems of solar hot water supply, the coolant flow rate was chosen at the level of 0.015 kg / (m2 • s) or 54 kg / (m2 • h). Then it was justified by the need to ensure a high value of the coefficient of heat removal FR from the SC [3]. In recent years, plants with significantly lower specific consumption have been used, providing the best temperature stratification of water in the storage tank and high availability of the system, which after 1 ÷ 1.5 hours after the circulation of the coolant in the solar circuit starts, allows the hot water to be supplied to the consumer with the required temperature. For example, in Sweden typical unit costs range from 0.002 to 0.006 kg / (m2 • s) or from 7.2 to 21.6 kg / (m2 • hour) [3].

The practice of designing CCTs of the German company Viessmann assumes three main modes of circulation of the coolant through the SC: mode with a flow rate of up to 30 l / (m2 • hour); a mode with a flow rate of more than 30 l / (m2 • h) and a mode with an adjustable flow rate of the coolant. The optimal value for solar systems with flat collectors is 25 l / (m^2 • h) at full pump power. With the development of solar technology, the optimal value of the coolant flow rate changed, for example, 10 years ago for flat collectors the value of 40 l / (m^2 · h) was considered optimal.

It is interesting to note that over the course of almost 40 years of world experience in the design and implementation of CCTs with flat VAC, the value of the optimum specific coolant flow through the SC was periodically adjusted and decreased from 54 kg / (m2 • hour) to 25 l / (m^2 • hour), tons. e. more than twice, and in Sweden - 2.5 ÷ 7.5 times. This indicates that until now there is no sufficient scientific justification for determining the value of the optimum specific coolant flow through the SC for various CCT circuit solutions (single-loop, double-loop, without a backup heat source, from a backup heat source, etc.) taking into account the climatic conditions of the construction area.

Designing SSTs is carried out mainly by the traditional approach used in conventional heat supply systems, when thermal and hydraulic processes occurring in the system are considered separately for stationary mode to simplify.

Thermo hydraulic dynamic effects arising in CCT and its elements (in solar circuit, heat accumulator, etc.)

during non-stationary post are not taken into account. Solar energy, which, when creating certain conditions, may be accompanied by synergistic effects of self-organization and self-regulation [4].

The idea of improving the FTA by effectively using self-regulating thermal hydraulic processes and self-regulating devices based on them was proposed in 1982, studied and put into practice standard (14 projects) and experimental (20 projects) design with reference to the construction of 1200 sets of project documentation, with the actual implementation in Uzbekistan in the amount of more than 20 thousand m2 operated by the IC [4]. It has not lost its relevance and should receive its further development in the new conditions of the IC market stagnation [2], when such qualities as simplicity, reliability and low cost of technical solutions become in demand to ensure the competitiveness of the FTA.

A distinctive feature of this approach [4] is that the creation and design of SST is carried out taking into account the application of the simplest self-regulating active elements (SRAE) in the form of a Ventura tube 3 (Fig. 1, a), perforated tubes 1 ÷ 4 (Fig. 1, b), solar collector.

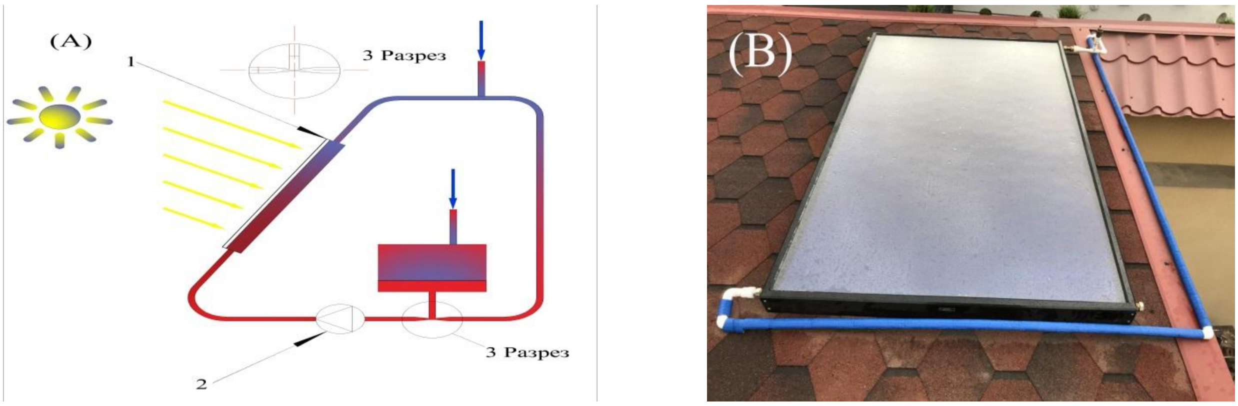

Fig.1. Schematic diagram of the self-draining heliocontour (a), the stratification accumulator (b) solar collector

As can be seen from the above diagrams, the use of the EPSs makes it much easier and more economical to solve a number of specific solar-related tasks related to the protection from freezing of the IC, with highly efficient stratification of heat accumulation, with the stabilization of the water heating temperature, etc. due to the creation of optimal modes for the operation of the IC [4]. However, the use of the EPS in the FTA requires consideration and a more thorough calculation of the non-isothermal fluid movement in these devices with some critical parameters, due to which the effects of self-regulation occur in the conditions of unsteady solar energy.

IV. CONCLUSION

Based on the studies performed, the following conclusions can be drawn:

1. In modern conditions, when SC designs are well developed and the reserves for reducing their cost are almost exhausted, identifying the main ways to increase the efficiency of using solar thermal energy in heat supply systems is a very urgent task. One of these ways is the improvement of circuit solutions and operating parameters of the SST and their equipment using the simplest self-regulating active elements.

2. Used in world practice, CCT circuit solutions are constantly being improved in terms of improving their energy efficiency and reliability, and their operating parameters have not yet been brought to optimum values. This creates a certain reserve for increasing the efficiency of the use of solar energy in heating systems.

3. The planned ways of further research to improve the efficiency of solar thermal energy in heating systems with minimal loss of temperature potential in their elements can be used to improve the CCT with the EPS.

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