N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 6, Number 438 (2019), 54 – 63 **https://doi.org/10.32014/2019.2518-170X.155**

UDC 621.38

Y. Amirgaliyev[1,2], W. Wójcik[3], M. Kunelbayev[1,2], T. Merembayev[1], D. Yedilkhan[1], A. Kozbakova[1,2], O. Auelbekov[1], N. Kataev[1]

[1]Institute Information and Computational Technologies CS MES RK, Almaty, Kazakhstan,
[2]Al-Farabi Kazakh National University, Almaty, Kazakhstan,
[3]Lublin University of Technology, Poland.
E-mail: amir_ed@mail.ru, waldemar.wojcik@pollub.pl, murat7508@yandex.kz, merembaevt@gmail.com, yedilkhan@gmail.com, ainur79@mail.ru, omirlan@mail.ru, k_nazbek@mail.ru

THEORETICAL PREREQUISITES OF ELECTRIC WATER HEATING IN SOLAR COLLECTOR-ACCUMULATOR

Abstract. In the article herein, we consider the theoretical prerequisites of the solar collector accumulator energy saving sources One of the solar collector-accumulator main peculiarities is in the fact that it works under cold temperatures or in the dull days due to design features. There was proposed a new method of the flat solar collector using modern materials, thanks to which the collector's performance upgrades and its cost reduces. Collector's efficiency is reached owing to the proposed construction, which consists of transparent thermally insulated body, semitransparent color, absorber's capacity, thermoelectrical heater. Thermoelectrical heater is a main feature, which is used for water heating. Proposed new method of thermoelectric heating is theoretically substantiated and consists in adjusting the thermoelectric power to changing the stress in appropriate range, as well, to changing the resistance of thermoelectric heating elements through switching from sequential circuit to parallel one. The new electric scheme has been offered as a controlled thermoelectric heater inside the collector. Solar collector-accumulator researches and workings in the mode of electric heating show, that the computation of water heater average value from 5 до 9% confirms the suggestion about the theoretical outcomes of the solar collector accumulator work. There have been selected thermoelectric capacities values as 1,5, 3,0 and 4,5 kW, liquid optimal temperature (60 °C) has been reached for 3 hours at capacities 3,0 and 4,5 kW, it is a good result for a cold season or dull days. Economic analysis of using the proposed thermoelectric capacity inside the solar collector is not considered in the work herein and remained for further studying.
Key words: solar collector-accumulator, solar energy, thermoelectric heating element, electrical energy.

Introduction. Fossil fuel and nuclear energetics for energy resources sustainable development at present shall be promptly changed with renewable energy resources. Renewable energy resources are stable and able to satisfy the current and future projected global needs in energy without any impact on the environment. For sustainable meeting of the world demands in energy renewable energy resources such as the solar energy, wind, hydro energetics, and biogas are proper alternatives. The best alternative for meeting the growing demand in energy is the solar one. Solar radiation transformation into the heat is one of the simplest and direct means of using its power. Flat solar collector is a device, used for transforming the solar energy into the thermal one. Flat solar collectors nowadays are most widely used all over the world in water heating commercial and domestic systems Therefore, the domestic sector can reduce its impact on the environment by installing the flat solar collectors for water heating. Flat plates, vacuum-processed tubes or concentrated collectors are solar collectors for domestic hot water. The most frequently used type for the low temperature medium is a single-layer flat plate.

The main component of the solar water heater is a flat plate collector. An absorber plate serves as a central element of the collector. Solar collector thermal specifications depend on optical and thermal properties, as well, on absorber's design. A standard flat collector consists of an absorber in the insulated box together with transparent covers (glazing). An absorber usually consists of a metal sheet (as copper, aluminum) with high thermal conductivity with the built-in or connected tubes. Its surface is covered with special selective material to maximize the beam energy absorption along with the beam energy radiation minimization. Insulated box reduces the heat losses in the collector from its backward and lateral sides [1]. The most commonly and widely used collector is a thermosyphon or naturally circulation system of solar water heating system (SWHS). It consists of a plate collector, accumulating tank and connecting tubes. Collector contains an absorber plate, water riser and collecting pipes, glass cover, body and insulation. Water in water risers is heated and flows to a reservoir for storage due to difference in density. Its flow depends on thermosyphon head, related to buoyancy effect, corelated with water density change, caused by water temperature rising in the solar collector. The solar energy is used in various areas for many applications. In the works [2, 3] there were carried out sufficient quantities of experiences on transforming the solar energy into heat. There were many works using a single phase heat transfer technology. In this article [4], there has been developed a microprocessor control system that provides synchronous operation of a solar power station with an electric grid. It is shown that, in practice, the voltage in the mains does not correspond to a pure sinusoid and has distortions to which the output voltage of the inverter must be adapted. In the researches [5-9] the experiments have been conducted in the solar collector with flat plates using a single phase heat exchange process, with application of non-insulated reservoir for water and uninsulated collecting tube, as well insulated reservoir for water and an insulated tube. For that purpose, a flat solar collector operates as a heater and a reservoir for water maintains the heat water. There is a possibility to cut huge heat losses, as well from a collecting tube. Final result is water temperature rise and that of flat collector performance, which will happen.

A flat solar collector is usually used for the solar energy transformation into an effective thermal energy. A collector in the heating and water supply systems is designed for moderate temperature. Thanks to absence of electric energy expenditures comparing to conventional electric heaters, usage of solar water heaters plays an important role [10].

The solar collector output reduces due to a bigger factor of heat transfer due to upper capacity loss and, as a consequence, owing to lower thermal characteristics [11]. It has been defined, overall heat loss, i.e., 75%, occurs from the upper collector [11]. In the work hereby there has been specified the influence of the surface radiating and absorbing ability at the different temperatures characteristics [12].

In our article the researchers study theoretical prerequisites of the energy saving electric water heating in the solar collector-accumulator.

To perform theoretical prerequisites the developers investigated a new flat solar collector accumulator, as well, performed experimental investigations and substantiation of the parameters of the electric heating energy savings means, applying a thermoelectrical heater, inbuilt into a flat solar collector.

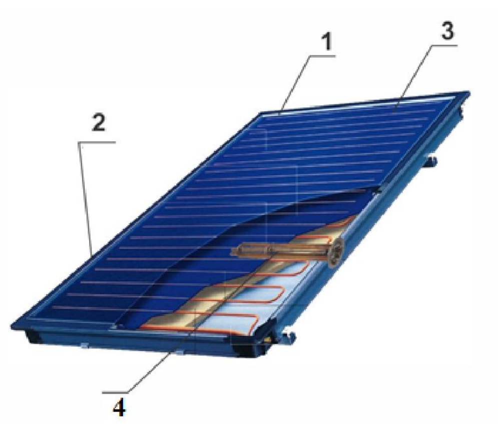


Figure 1 –
Principal diagram of a flat solar collector-accumulator:
1 – thermally insulated body; 2 – translucent cover;
3 – absorber tank; 4 – thermoelectric heater

To achieve the prescribed goal it is offered to implement a new approach to designing the flat solar collectors accumulators using model materials, at the expense of which we can get sufficient reduction (2-3 times) of the solar installation cost. The offered method essence and novelty is in the fact, that, in distinction from the known designing principle, the collector contains 1 – transparent thermally insulated body; 2 – translucent cover; 3 – absorber tank; 4 – thermoelectric heater.

In the gap between a double glass and frame bottom there is laid a flexible thin wall stainless corrugated tube 4∅16 mm in the coil form. The pipe edges are fixed to the input and output protruding tubes. Thermoelectric heater mounted inside between a double glass and frame bottom. Thermoelectric heater is the principle component for electric water heating.

Figure 2 –
A full scale model (mockup)
of a flar solar collector -accumulator

Figure 2 demonstrates a mockup of a solar collector-accumulator. Solar collector is the main heat generating unit, the energetic and operating indices of which directly depend on the solar installation parameters. To achieve our set goal we have elaborated a brand new flat solar collector-accumulator based on which there will be constructed the standard series of solar collectors for water heating.

Table 1– Technical specifications of a flat solar-collector accumulator

Transparent insulations layers number	2
One collector square, m^2	Up to 2
Water heating average temperature	60-80
Flowing capacity regarding the solar radiation upon falling the sunbeams normally onto the surface	0,89
Specific volume for heat transfer medium, l/m^2	2,0
Absorbing capacity with regard to solar radiation	0,99
Operational pressure, MPa	0,7
Overall dimensions, micron	1x2
Product of optical factor Thermal Efficiency and the panel absorber performance rate	0,8
Multiplication of collector thermal loss factor by the panel absorber performance rate	0,75
Ratio of heat absorbing surface square	0,95
Collector mass, kg	60
Life cycle, years	15

Research method. One of the solar collector-accumulator's functions is electric water heating in the cold season or in dull days upon solar radiation absence. The researches have shown that the traditional means based on heating at thermoelectric heater constant power tolerates sufficient energy losses, which can lower controlling the heating regularities from the initial (t_o) to final (t_k) temperature.

$$E_{EH} = c \cdot m \cdot (t_k - t_o) + k_a \cdot F_a \int_{t_o}^{t_k} (t - t_m) \cdot d\tau, \tag{1}$$

where $c{\cdot}m$ – specific heat capacity and water mass; $k_a{\cdot}F_a$ – specific heat losses and solar collector surface square; t, t_o, t_k – current, initial, final temperatures of water being heated; $t_м$ – environmental temperature.

In this connection there were offered the new techniques of water heating:

– regulating the thermoelectric heating capacity by means of stress changing from initial (U_o) to final ($U_н$) ($U_o< U< U_н$);

– changing the thermoelectric heating resistance, for instance by means of switching it from series to parallel scheme.

We have drawn up the equations of heating techniques energy balances [13]:

conventional $P_{тэн}=const$

$$k_a \cdot F_a(t-t_m)+cm\frac{dt}{d\tau}=P_{TEH}=\frac{U_h^2}{R} \tag{2}$$

regulating the thermoelectric heating stress

$$k_a \cdot F_a(t-t_m)+cm\frac{dt}{d\tau}=\frac{dQ_{TEH}}{d\tau}, \quad U_o< U< U_н . \tag{3}$$

By the solution (3) there were set the formulae of:

current temperature (t):

$$(t-t_m)=\frac{U_H^2}{R\cdot k_a \cdot F_a}\left[1-exp\left(-\frac{k_a \cdot F_a}{cm}\cdot\tau\right)\right]+(t_o-t_m)\cdot exp\left(-\frac{k_a \cdot F_a}{cm}\cdot\tau\right) \tag{4}$$

heating time from t_o to $t_к$

$$\tau_к=-\frac{cm}{k_a \cdot F_a}\ln\frac{U_н^2-R\cdot k_a \cdot F_a(t_k-t_m)}{U_н^2-R\cdot k_a \cdot F_a(t_o-t_m)}, \tag{5}$$

heating energy capacity [13]

$$P=cm(t-t_o)+\frac{U_h^2\cdot\tau}{R\cdot k_a \cdot F_a}-\left[\frac{U_H^2}{R\cdot k_a \cdot F_a}-t_o+t_m\right]\cdot\frac{\tau^2}{\tau_н}\cdot exp\left(-\frac{\tau}{\tau_н}\right). \tag{6}$$

Under the decision (6), there were set the formulae of:

stress provided the temperature linear changing [14]

$$U^2=U_0^2+k_a \cdot F_a \cdot R\left(\frac{t_к-t_o}{\tau_к}\cdot\tau+t_o\right)+\frac{cm\cdot R}{\tau}(t_к-t_o), \tag{7}$$

thermoelectric heating initial stress [14], provided that at $\tau_к$, $U=U_н$

$$U_0^2=U_н^2-k_a \cdot F_a \cdot R\cdot t_к+\frac{cm\cdot R}{\tau}(t_к-t_o), \tag{8}$$

heating energy capacity

$$E=cm(t-t_o)+k_a \cdot F_a \cdot\left[\frac{t_к-t_o}{2\tau_к}\cdot\tau^2+(t_o-t_m)\tau\right] \tag{9}$$

thermoelectric heating average integral capacity [14]:

$$P_{average}=\frac{cm}{\tau_к}\cdot(t_к-t_o)+k_a \cdot F_a \cdot\left(\frac{t_к+t_m}{2}\right). \tag{10}$$

There have been fulfilled experimental researches in order to confirm the convergence of theoretical (designed) and experimental outcomes.

The article developed a microprocessor control system that ensures the synchronous operation of a solar power station with a power grid. It has been shown that in practice in the power supply network the voltage does not correspond to a pure sine wave and has distortions to which it is necessary to adapt the inverter output voltage [15].

In article [16], the authors proposed a physical and mathematical description of a process of converting solar energy, research of a physical and mathematical model of an energy converter and description of a model of low – power solar thermal power plant (STPP) designed to maximize using of solar energy. In developing design of low – power STPP will allow using a coefficient of solar energy efficiency (SEE) until 50%. STPP will solve problems with a shortage of power systems due to high cost energy resources and a lack of energy in remote areas of the country also it will not have a negative impact on environment which is relevant at the moment.

In article [17] a heat loss of flat solar collectors is considered. It is proposed that if water heated to 60 °C (in some cases to 80 °C) it will be necessary to divert water. In static state, the same heat flow passes through an air between heat receiver and glass, meets thermal resistance during a transition to atmospheric air. The thermal resistance in direction of the glass consists of the following values: the thermal resistance of the air gap between the beam and the absorbing surface of the heat receiver and the glass surface facing it.

Electric heating energy saving method's experimental studies and parameters substantiation have been fulfilled on the stand, the scheme of which is given on the figure 3.

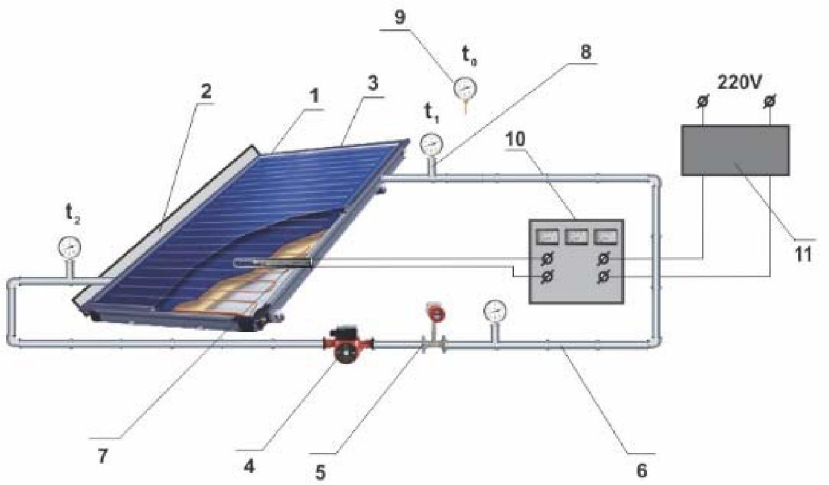


Figure 3 – Scheme of the stand for studying regularities of the solar collector-accumulator electric heating:
1 – thermally insulated body of the solar collector; 2 – translucent cover; 3 – c; 4 – circulating pump; 5 – flowmeter; 6 – pipeline; 7 – tubular electric heater; 8, 9 – thermometers for measuring water temperature at absorber's tank input and output and the environment; 10 – set of electric measuring devices К 501; 11 – autotransformer.

Stand scheme consists of thermally insulated body of the solar collector 1, translucent cover 2, absorber tank 3, circulating pump 4, flowmeter 5, pipelines 6, thermal electric heater with a thermal regulator 7, thermometers 8, 9, for measuring water temperature at absorber's tank (t_1) output and input (t_2) and the environment (t_m), measuring device К 501 and an autotransformer 11 for regulating the thermal electric heater capacity.

Water heating is fulfilled by switching on the thermal electric heater to the network through autotransformer, which allows regulating its capacity smoothly from 0 to nominal value. Circulating pump serves for mixing and aligning water temperature between lower and upper layers.

Measurements metrological maintenance:

– mercury thermometer, with division value 0,1ºC, for measuring water temperature at the input (t_1) and output (t_2). They are placed at 10cm distance from the collector (position 8);

– mercury thermometer, with division value 0,2ºC for measuring the environment temperature (t_m) (position 9).

The process energy capacity for the sought time interval is defined by the capacity multiplying measured with a wattmeter by the interval duration, for every hour interval, and total energy capacity by summing the intervals energy capacity.

Electric heating in temperature linear rising mode from t_o to $t_к$ is executed by means of the stress regulation from initial U_o to final $U_к$=220 V according to a certain designed regularity, where the stress interval values are computed according to a formula:

$$U = \sqrt{cm \cdot (t_i - t_{i-1}) + k \cdot (t_i - t_{i-1}) \cdot \tau \cdot R_n},$$

where R_n – thermal electric heater resistance; t_i, t_{i-1} – water temperature in *i*-м and *i – 1^st^* interval, *k*=0,029 kW·h/degree – coefficient of the solar collector-accumulator total heat losses (defined experimentally), $k=U_i \cdot S_{ГКА}$, $S_{ГКА}$ – square of the flat solar collector-accumulator surface.

The stress change is performed manually, stepwise, in hours interval, and experiment with the stress regulation is repeated for thermal electric heater's each nominal capacity $P_н$ = 1,5; 3,0 and 4,5 kW.

Results and discussions. Results of experimental measurements and rated values of the uncontrolled (at thermoelectrical heater's constant temperature) electric heating dynamics of solar collector-accumulator electric heating, dependent on time, with different capacity thermoelectrical heaters ($P_{ТЭН}$ = 1,5, 3,0 and 4,5 kW) are given on the figure 2. Analysis shows, that divergence between the experiments and computations outcomes is, in average from 5 to 9%, which confirms the convergence of theoretical conclusions.

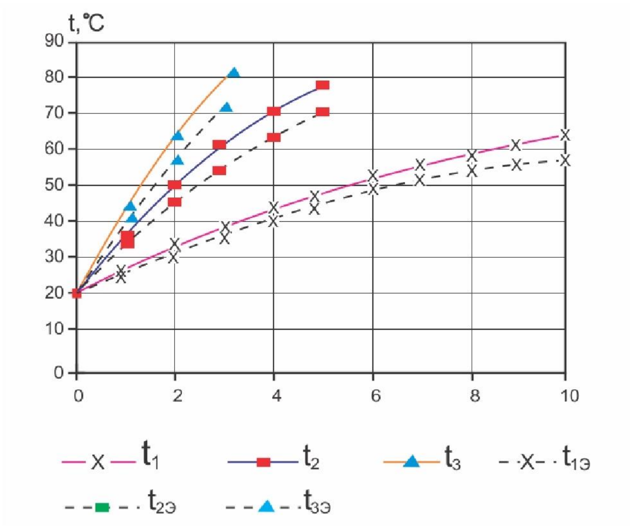
Diagrams have exponential regularity, connected with heat losses growth due to the heat temperature increase, and in the working range – from 20 to 60^{0}C, the solar collector-accumulator heating at the thermal electric heaters capacity at 1,5 kW achieved for 1…10 hours. As it is seen from the figure 4 in the winter period at experimental research and computation the solar collector-accumulator at the thermal electric heating at 1.5 kW the heating time at the temperature from 20 to 60^{0}C has changed from 1 hour to 10 hours. It confirms, that the solar collector-accumulator has worked in the dynamic regime at the constant capacity.

With increasing the thermoelectric heating capacity 2 times up to3,0 kW, the temperature 60ºC achieved for 3 hours, and at the capacity 4,5 for 1,6…1,8 h. At that the temperature regularity through time changed practically linearly.

We have defined rated and experimental energy intensities of uncontrolled (at thermoelectric heater's constant capacity) water heating in the solar collector-accumulator. Results comparability has been provided with observing the experiments and computation similar conditions. Experimental measurements outcomes are given on the figure 4 in denominator, and rated values - in numeratorв (upper numbers).

It was specified, with capacity increasing the process's energy intensity decreases. For example, at the capacity 1,5 kW the energy intensity (experimental) of electric heating has amounted to 14,8 kW·h, including heat losses of 7,8 kW·h or 52,7%. With the heating capacity increase 2 times (3,0 kW) the

Figure 4 –
Dynamics of uncontrolled
water electric heating
in the solar collector-accumulator
the thermoelectric heaters
are of different capacity
(1 – 1,5 kW; 2 – 3,0 kW; 3 – 4,5 kW)



heating energy intensity decreased to 9,8 kW·h, and heat losses down to 2,8 kW, i.e., to 28%, at the capacity 4,5 kW energy intensity reached 9,2 kW·h, and heat losses 2,2 kW·h, i.e., decreased to 24%.

We have studied the regularities of control electric heating.

The figure 5 shows experimental and rated outcomes of processes energy intensities at th heating capacity 1,5, 3,0 and 4,5 kW.

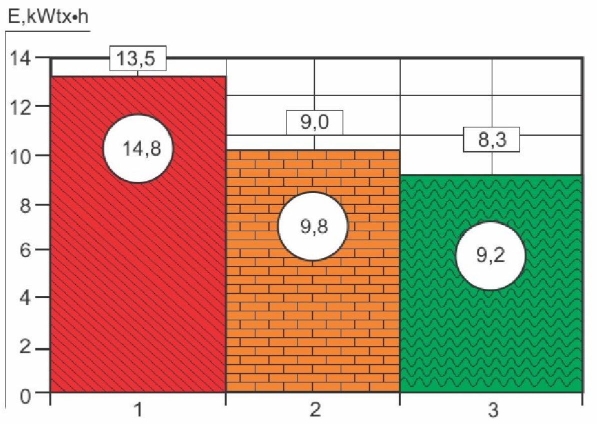


Figure 5 –
Rated (numerator) and experimental (denominator) energy capacity at electric heating from 20 to 60ºC under the heating element's constant capacity:
1 – 1,5 kW; 2 – 3,0 kW; 3 – 4,5 kW

As it is seen from the figure 6 in the process of controlled heating, there has been maintained the temperature linear growth from 20 to 60ºC, through regulation the thermoelectric heater stress with a capacity of 1,5 kW от U_o = 165V до $U_н$ = 220V. At that process energy capacity has amounted to 13,1 kW, that is, it is less *1,7* kW·*h* or for 11,5%, comparing to the controlled heating.

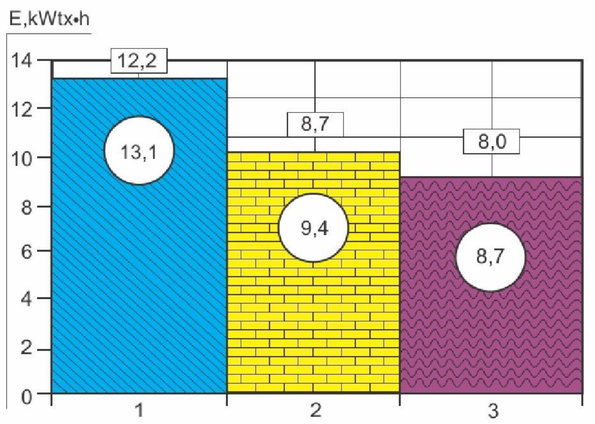


Figure 6 –
Rated and experimental energy intensity of the controlled electric heating, regulating the heating element's deformation
(1 – P = 1,5 kW, U = 165 ÷ 220 V;
2 – P = 3,0 kW, U = 200 ÷ 220 V;
3 – P = 4,5 kW, U = 210 ÷ 220 V)

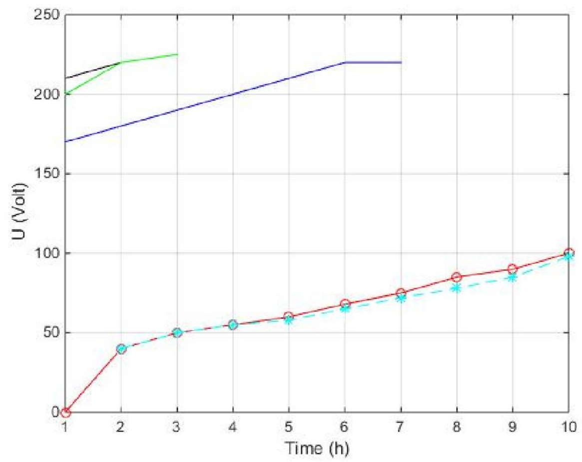


Figure 7 –
Controlled patterns during heating with a 1.5 thermoelectric heaters; 3.0 and 4.5 kW
(respectively, graphs 1, 2 and 3) and the linear heating temperature of the 1.5 kW heater

The same regularity has been observed at other capacities as well. Energy intensity of the controlled heating at the capacity 3,0 kW has been 9,4 kW·h, and upon uncontrolled 9,8 kW. At the power 4,5 kW those indices have amounted to 8,7 and 9,2 kW·h, accordingly. That is, there is achieved the energy intensity decrease for only 4% as regards to the noncontrolled heating.

The figure 7 demonstrates the regularities of stress change (diagrams 1, 2, and3) at which there has been maintained heating temperature linear growth and the graphs 4 and 5, as an example, accordingly, rated and experimental (dashed curve) regularities of thermoelectric heater linear heating with a capacity 1,5 kW at stress regulation from U_o=165V to $U_н$=220V, where maximum rated and experimental temperatures haven's exceeded 5C^o.

Conclusion. In the work herein there were given the theoretical prerequisites of energy-saving electric water heating in the solar collector-accumulator. There were specified designed and experimental energy intensities and dynamics of controlled and uncontrolled electric water heating in the solar collector-accumulator with thermoelectric heaters of various capacities.

In the controlled heating process there was the temperature linear growth from 20 to 60°C, through the stress regulation by thermoelectric heater with a capacity of 1,5 kW from U_o=165V to $U_н$=220V. Process energy intensity constituted 13,1 kW·h, that is, it was less for 1,7 kW·h.

In the uncontrolled heating process there took place practically the temperature linear rise 20 to 60°C, through the stress regulation by thermoelectric heater with a capacity 1,5 kW from U_o = 165V to $U_н$ = 220V. Electric heating energy intensity (experimental) amounted to 14,8 kW·h, i.e., it was higher than at uncontrolled heating.

Thus according to the outcomes of experimental measurements and rated values of uncontrolled and controlled electric heating of the solar collector-accumulator, dependent on the time, by means of thermoelectric heater shows, that at different capacity (P_{TEH} = 1,5, 3,0 and 4,5 kW) there is divergency between experiments and computation outcomes which is , in average, from 5 to 9%, which proves the theoretical conclusions convergence.

Acknowledgements. This work is supported by grant from the Ministry of Education and Science of the Republic of Kazakhstan within the framework of the Project «BR05236693 "Mathematical and computer models, hardware and software tools and experimental development on creation of network combined effective dual-circuit solar collectors with thermosiphon circulation and monitoring of their functioning».

Е. Амиргалиев[1,2], В. Вуйцик[3], М. Кунелбаев[1,2], Т. Мерембаев[1], Д. Едилхан[1], А. Козбакова[1,2], О. Ауелбеков[1], Н. Қатаев[1]

[1]ҚР БҒМ ҒК Ақпараттық және есептеуіш технологиялар институты, Алматы, Қазақстан,
[2]Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
[3]Люблин технологиялық университеті, Польша

ГЕЛИОКОЛЛЕКТОР-АККУМУЛЯТОРДАҒЫ СУДЫ ЭНЕРГИЯ ҮНЕМДЕЙ ЭЛЕКТРЛІК ҚЫЗДЫРУДЫҢ ТЕОРИЯЛЫҚ НЕГІЗДЕМЕЛЕРІ

Аннотация. Мақалада күн коллектор-аккумуляторының энергия үнемдеуіш көздерінің теориялық негіздемелері қарастырылады. Күн коллектор-аккумуляторының басты ерекшеліктерінің бірі – ол құрылымдық ерекшеліктерінен жылдың суық уақытында да немесе бұлтты күндері де жұмыс жасайды. Коллектордың құнын төмендетуге және тиімділігін арттыруға әсер ететін заманауи материалдарды қолданумен жазық күн коллекторының дизайнының жаңа тәсілі ұсынылды. Коллектордың тиімділігін арттыру термоэлектрлік жылытқыш, абсорбер сиымдылығы, жартылай мөлдір жабын, мөлдір жылу оқшаулауыш корпустан тұратын құрылымның арқасында қол жеткізіледі. Термоэлектрлік жылытқыш – суды жылыту үшін пайдаланылатын басты ерекшелік.

Термоэлектрлік қыздырудың ұсынылатын жаңа әдісі теориялық тұрғыдан негізделген және рұқсат етілген шектеуде кернеуді өзгерте отырып алынған термоэлектрлік қуаттылықтың баптауынан, сонымен қатар тізбектіден параллелдік сызбаға ауыстыру жолымен термоэлектрлік жылыту элементтерінің кедергісінің өзгертулерінен тұрады.

Коллектор ішіндегі бақыланатын термоэлектрлік жылытқыш ретінде жаңа электр сызбасы ұсынылған. Электрлік жылыту режиміндегі күн коллектр-аккумуляторын жасау мен зерттеу суды 5-тен 9 %-ға дейінге жылытудың орташа мәнін есептеудің күн коллектор-аккумуляторының теориялық нәтижесі туралы болжамын растайтындығын көрсетеді. Термоэлектрлік 1,5, 3,0 және 4,5 кВт қуаттылық мәні таңдап алынды, 3,0 және 4,5 кВт қуаттылықты қолдануда 3 сағатта сұйықтықтың тиімді температурасына жетті (60 °С), суық мезгілдер мен бұлтты күндер үшін бұл жақсы нәтиже. Күн коллекторы ішіндегі ұсынылған термоэлектрлік қуаттылықты қолданудың экономикалық түрдегі талдауы мақалада қарастырылмайды және ары қарай зерттеуге қалтырылады.

Түйін сөздер: күн коллектор-аккумуляторы, күн энергиясы, термоэлектрлік жылыту элементі, электрлік энергия.

Е. Амиргалиев[1,2], В. Вуйцик[3] , М. Кунелбаев[1,2], Т. Мерембаев[1], Д. Едилхан[1], А. Козбакова[1,2], О. Ауелбеков[1], Н. Катаев[1]

[1]Институт информационных и вычислительных технологий КН МОН РК, Казахстан
[2]Казахский национальный университет им. аль-Фараби, Алматы, Казахстан
[3]Люблинский технологический университет, Польша

ТЕОРЕТИЧЕСКИЕ ПРЕДПОСЫЛКИ ЭНЕРГОСБЕРЕГАЮЩЕГО ЭЛЕКТРИЧЕСКОГО НАГРЕВА ВОДЫ В ГЕЛИОКОЛЛЕКТОРЕ-АККУМУЛЯТОРЕ

Аннотация. В статье рассматриваются теоретические предпосылки энергосберегающих источников солнечного коллектора-аккумулятора. Одной из главных особенностей солнечного коллектора-аккумулятора является то, что он работает в холодное время года или в пасмурные дни из-за конструктивных особенностей. Предложен новый способ дизайна плоского солнечного коллектора с использованием современных материалов, благодаря чему повышается эффективность и снижается стоимость коллектора. Эффективность коллектора достигнута благодаря предложенной конструкции, которая содержит прозрачный теплоизолированный корпус, полупрозрачное покрытие, емкость абсорбера, термоэлектрический нагреватель. Термоэлектрический нагреватель – это главная особенность, которая используется для нагрева воды. Предложенный новый способ термоэлектрического нагрева является теоретически обоснованным и состоит из настройки термоэлектрической мощности с изменением напряжения в приемлемых пределах, а также с изменением сопротивления термоэлектрических нагревательных элементов путем переключения с последовательной схемы на параллельную. Новая электрическая схема была предложена в качестве управляемого термоэлектрического нагревателя внутри коллектора. Исследования и разработки солнечного коллектора-аккумулятора в режиме электрообогрева показывают, что расчет среднего значения нагрева воды от 5 до 9% подтверждает предположение о теоретических результатах работы солнечного коллектора-аккумулятора. Были выбраны значения термоэлектрической мощности 1,5, 3,0 и 4,5 кВт, оптимальная температура жидкости (60 °C) достигнута за 3 часа при использовании мощностей 3,0 и 4,5 кВт, это хороший результат для холодного сезона или в пасмурные дни. Экономический анализ использования предлагаемой термоэлектрической мощности внутри солнечного коллектора в статье не рассматривается и остается для дальнейшего исследования.

Ключевые слова: солнечный коллектор-аккумулятор, солнечная энергия, термоэлектрический нагревательный элемент, электрическая энергия.

Information about authors:

Amirgaliyev Yedilkhan, doctor of technical sciences, professor, Institute Information and Computational Technologies CS MES RK, Almaty, Kazakhstan; amir_ed@mail.ru; http://orcid.org/0000-0002-6528-0619

Wójcik Waldemar, doctor of technical sciences, professor, Lublin University of Technology, Poland; waldemar.wojcik@pollub.pl; https://orcid.org/0000-0002-0843-8053

Kunelbayev Murat, senior researcher, Institute Information and Computational Technologies CS MES RK, Almaty, Kazakhstan; murat7508@yandex.kz; http://orcid.org/0000-0002-5648-4476

Merembayev Timur, software engineer, Institute Information and Computational Technologies CS MES RK, Almaty, Kazakhstan; merembaevt@gmail.com

Yedilkhan Didar, PhD, senior researcher, Institute Information and Computational Technologies CS MES RK, Almaty, Kazakhstan; yedilkhan@gmail.com

Kozbakova Ainur, PhD, senior researcher, Institute Information and Computational Technologies CS MES RK, Almaty, Kazakhstan; ainur79@mail.ru; http://orcid.org/0000-0002-5213-4882

Auelbekov Omirlan, candidate of physical and mathematical sciences, senior Researche, Institute Information and Computational Technologies CS MES RK, Almaty, Kazakhstan; omirlan@mail.ru

Kataev Nazbek, candidate of pedagogical sciences, senior researcher, Institute Information and Computational Technologies CS MES RK, Almaty, Kazakhstan; k_nazbek@mail.ru; http://orcid.org/0000-0003-0501-3719

REFERENCES

[1] Duffie J.A., Beckman W.A. Solar Engineering of Thermal Processes. John Wiley and Sons. New York, 2013. doi:10.1002/9781118671603

[2] Chuawittayawuth K., Kumar S. Experimental investigation of temperature and flow distribution in a thermosyphon solar water heating system // Renewable Energy. 26 (2002) 431-448. doi:10.1016/s0960-1481(01)00085-4

[3] Taherian H., Rezania A., Sadeghi S., Ganji D.D. Experimental validation of dynamic simulation of the flat plate collector in a closed thermosyphon solar water heater // Energy Conversion and Management. 52 (2011) 301-307. doi:10.1016/j.enconman.2010.06.063

[4] Isembergenov N., Taissariyeva K., Seidalieva U., Danilchenko V. Microprocessor Control System For Solar Power Station // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. ISSN 2224-5278. Vol. 1, N 433 (2019). P. 107-111. https://doi.org/10.32014/2019.2518-170X.13

[5] Zerrouki A., Boume dien A., Bouhadef K. The natural circulation solar water heater model with linear temperature distribution // Renewable Energy. 26 (2002) 549-559. doi:10.1016/s0960-1481(01)00146-x

[6] Samuel Luna Abreu, Sergio Colle. An experimental study of two-phase closed thermosyphons for compact solar domestic hot-water system // Solar Energy. 76 (2004). P. 141-145. doi:10.1016/j.solener.2003.02.001

[7] Alireza Hobbi, Kamran Siddiqui. Experimental study on the effect of heat transfer enhancement devices in flat-plate solar collectors // International Journal of Heat and Mass Transfer. 52 (2009). P. 4650-4658. doi:10.1016/j.ijheatmasstransfer.2009.03.018

[8] Ogueke N.V., Anyanwu E.E., Ekechukwu O.V. A review of solar water heating systems // Journal of Renewable and Sustainable Energy. 1, 043106, 2009. doi:10.1063/1.3167285

[9] Amirgaliyev Ye.N., Kunelbayev M., Wójcik W., Kalizhanova A.U., Auelbekov O.A., Kataev N.S., Kozbakova A.Kh., Irzhanova A.A. Solar-Driven Resources Of The Republic Of Kazakhstan // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. ISSN 2224-5278. Vol. 3, N 430 (2018). P. 18-27.

[10] Nuntaphan, Atipoang, Choosak Chansena, Tanongkiat Kiatsiriroat. Performance analysis of solar water heater combined with heat pump using refrigerant mixture // Applied Energy. 86, N 5 (2009): 748-756. doi:10.1016/j.apenergy.2008.05.014

[11] Shukla, Ruchi, K. Sumathy. Recent advances in the solar water heating systems: A review // Renewable and Sustainable Energy Reviews. 19 (2013): 173-190. doi:10.1016/j.rser.2012.10.048

[12] Agbo S.N., Okoroigwe E.C. Analysis of thermal losses in the flat-plate collector of a thermosyphon solar water heater // Res J Phys 1 (2007): 35-41. doi:10.3923/rjp.2007.35.41

[13] Pillar P.K., Agarwal R.C. Factors Influencing Solar Energy Collector Efficiency Applied Energy. 8 (1981): 205-213. doi:10.1016/0306-2619(81)90018-0

[14] Theodore L. Bergman, Frank P. Incropera, David P. DeWitt, Adrienne S. Lavine. Fundamentals Of Heat and Mass Transfer // John Wiley. Hoboken, NJ (2011).

[15] Douglas T. Crane, Gregory S. Jackson. Optimization Of Cross Flow Heat Exchangers For Thermoelectric Waste Heat Recovery // Energy Convers Manag. 45 (2004). P. 1565-1582.

[16] Shigayev D.T., Munsyzbay T.M. A Low-Power Solar Thermal Power Station With The Maximum Use Of Solar Energy // News of the National academy of sciences of the Republic of Kazakhstan. Physico-mathematical series. ISSN 1991-346X. Vol. 3, N 307 (2016). P. 56-61.

[17] Auelbekov O.A., Kataev N.S., Kunelbayev M.M., Salgaraeva G.I. Determination of Flat Solar Collectors of Heat Losses to the Environment // News of the National academy of sciences of the Republic of Kazakhstan. Physico-mathematical series. ISSN 1991-346x. Vol. 3, N 301 (2015). P. 28-33.

[18] Karboz Zh.A., Dossayeva S. K. Issledovaniye vodorodopronitsayemosti membran, pokrytykh razlichnymi metallicheskimi plenkami (obzor) // Complex Use of Mineral Resources. 2019. N 3(310). P. 48-54 (in Russ.). https://doi.org/10.31643/2019/6445.28

[19] Akhmediyarova A.T., Kuandykova J.R., Kubekov B.S., et al. Objective of modeling and computation of city electric transportation networks properties // Conference: International Conference on Information Science and Management Engineering (ICISME) Location: Thailand. Date: DEC 20-21, 2015. Sponsor(s): AdvSci&Ind Res Ctr. 2015. P.106-111. Published: 2015.

[20] Ildar Valiev, Yury Koshlich, Mussayeva D. Management innovations for enterprise development and effective decision making // Journal of Entrepreneurship Education. Vol. 21, Special Issue, 2018. ISSN: 1098-8394