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POSSIBILITIES OF GETTING ELECTRICITY WITH THE HELP OF A SMALL SOLAR FURNACE

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ANNOTATION

The results on development of technology of conversion of concentrated solar energy into electricity at the Small Solar Furnace with thermal capacity of 2.0 kW are given. The results were analyzed and ways to improve the efficiency of the transformation were shown.

KEYWORDS: *solar furnace, focus, concentrator, receiver, steam turbine.*

INTRODUCTION

Currently one of the most important energy problems is the expected depletion of natural reserves of fossil fuels. In addition, the increased use of traditional energy sources has global environmental and climatic consequences. For this reason, it becomes necessary to significantly expand the use of renewable energy sources: solar, geothermal, wind, small streams and biomass. Among renewable energy sources, the Sun is considered the most highly efficient, because the Sun's energy is inexhaustible [1-3].

As you know one of the main branches of large-scale use of solar energy is its conversion into electrical energy using photoelectric and thermodynamic converters, as well as its use in a concentrated form for the purpose of high-temperature materials science - the synthesis of materials. In this direction, the development and creation of combined solar power plants with a capacity of about 2 kW based on mirror-concentrating systems (MCS) [4-6] is relevant.

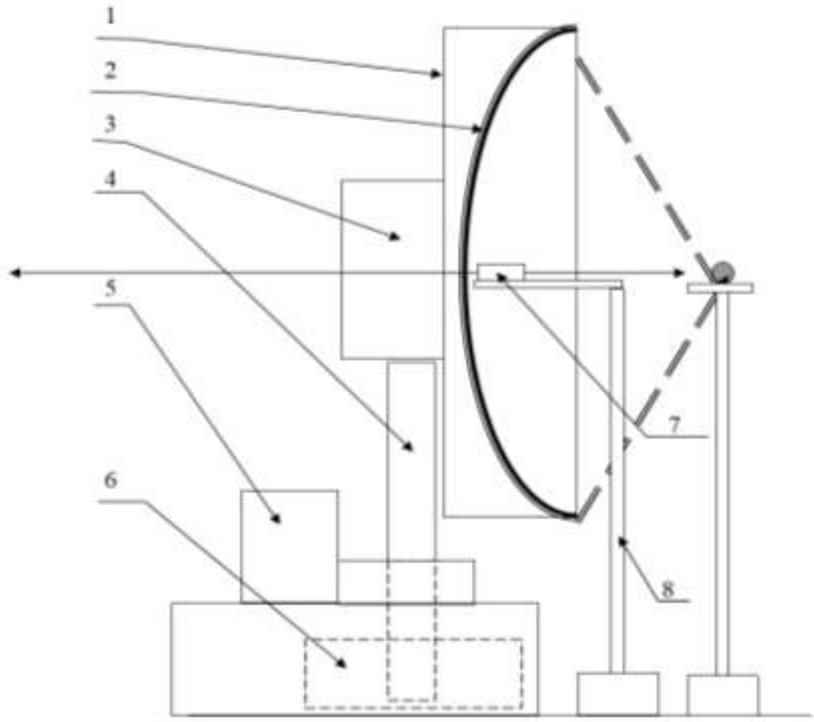
Thus the issues of practical use of solar radiation concentrators for the creation and development of combined heat and energy production processes require the development of new methodological and technical issues of creating a concentrator - receiver system for solar thermal power plants and the development of stands for studying the processes of simultaneous production of thermal and electrical energy. On the basis of many years of experience in the field of solar power plants at the Institute of Materials Science NPO "Physics-Sun", Small Solar Furnaces (SSF) with a thermal power of 2000 W were developed and created [4,7]. The SSF is equipped with an automatic tracking system for the Sun. The flux of radiant energy captured by the heliostat is directed to a parabolic mirror concentrator, which focuses the incident flux of radiant energy in the focal plane on the ray-sensing surfaces of the synthesized or tested materials [8-11].

METHODS AND MATERIALS

The purpose of this work was to develop a technology for converting concentrated solar energy at the focus of SSFs into electricity (Fig. 1).
To achieve the goal, the following tasks were solved.

1. Development and research of the system concentrator - receiver of solar thermal power plants.

To create an effective concentrator-receiver system, it is necessary to ensure optimal distribution of the concentrated flow over the working surface of the receiver. Such optimization can be carried out in the first approximation by calculation and further, refined on the basis of experimental studies of the field of concentrated solar radiation. As follows from the above, the literature review on the calculation of the optical-energy characteristics of concentrators and the concentrator-receiver system, the solution of these issues of optimization of the parameters of the K-P system, the operation of parabolic solar radiation concentrators and the control of their optical-energy characteristics require the development of calculated and experimental methods for determining their concentrating ability are more close to practice.



1-concentrator frame, 2- concentrator mirror, 3- angle electromechanical drive, 4- suspension unit, 5- azimuth electromechanical drive, 6- support unit, 7- light sensor, 8- light sensor support.

Fig. 1. The SSF consists of a self-tracking system concentrator with a thermal power of 2.0 kW.

In this regard, calculations were carried out on the regularities of the distribution of the concentrated flow in the focal plane and over the surface of the receiver, taking into account the inaccuracies of the concentrator, as well as the development of a methodology for calculating K-P systems with receivers of steam generators [12-14].

2. Development and research of receivers of steam generators of solar thermal power plants.

In general, a solar receiver steam generator performs the same functions as a conventional steam generator. However, in solar steam generators we have fewer possibilities for choosing the geometry of the radiation-receiving surfaces and, in this regard, we also have limitations on the design solutions of the receivers. The fact is that the receivers of solar installations are fundamentally open, have an inlet for supplying a concentrated solar flux, which is also a source of heat loss.

In the general case, the tasks of calculating the receiver-steam generator are to determine the following parameters:

1. Determination of the surface area of the evaporator – Ci..
2. Determination of the surface area of the superheater – Cp.
3. Choice of parameters of heating pipes - diameter D, wall thickness C, length - L for the evaporator and superheater.
4. Boiler steam output - S, [kg / s].
5. Geometry of the heating surface and its location.

The initial data for the calculation for solar installations are:

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1. Source power – **Θ**.
2. The diameter of the image spot in the focal plane - $\mathbf{D_p}$
3. Average flux density - $\mathbf{E_{sr}}$
4. Working steam pressure – $\mathbf{P_P}$

Let's consider the main stages of the calculation.
The calculated boiler productivity for steam - $\mathbf{S_P}$, [kg / s] is determined.

$$S_p = \Theta * \eta_K / h'' \qquad (1)$$

where η_K is the boiler efficiency, h" is the enthalpy of steam, [kJ / kg], including the heat of vaporization p and the enthalpy of water - h', heated to the saturation temperature.

Let us consider the option when the steam temperature is equal to the saturation temperature T_H = 1800C, ηK = 0.5, p =2at and Θ ≈ 2000Wt. h" = 14.1 [kJ/kg], or S_p = Θ *ηK / h''' = 500*0.5/14.1 = 0.714 *kg / sec*.

Heat exchange surface area (without superheater). The simplest scheme of the problem is heating water in a pipe (see Fig. 2) with the outer diameter of the D_H and the inner diameter of the D_W at constant flux density q_C or the temperature of the vehicle on the pipe wall. The problem is reduced to determining the length L of the pipe, from which we obviously determine the heating surface area.

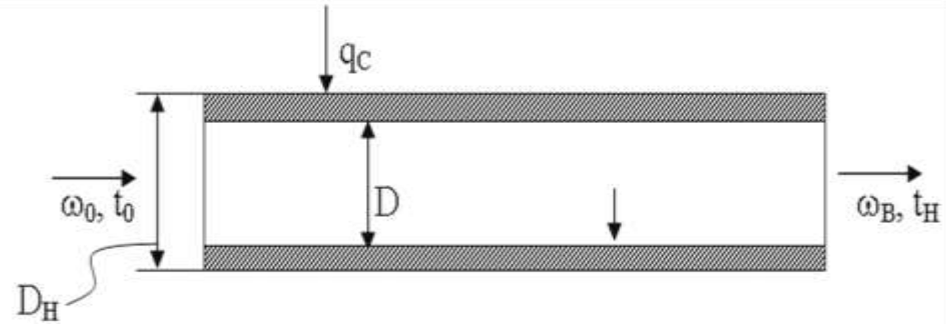

Fig. 2. Scheme of a tubular heater [12].

Determine the length of the pipe for its internal diameter adopted above D = 6 mm Assuming that the pipe wall thickness is 0.1 mm and it is irradiated from one side, we have

$$L = 2D_{LP} / \pi*(D+ 2C) =$$
$$2*0,01/(3.1416*(0,1+4)*10^{-3} = 0,366м.$$

3.Development of the layout of the steam turbine and the production of electrical energy.

For the boiling process to occur and superheated steam to be obtained, two conditions must be met: bringing the water temperature to saturation temperature at a given pressure in the system (liquid overheating relative to the saturation temperature), and the presence of a superheater.

RESULTS

Preliminary experiments have shown that it is desirable to make a water evaporator in the form vof a one-piece cylindrical pipe with a diameter of 10 mm, and a superheater in the form of a single spiral made of a pipe with an outer diameter of 6 mm made of steel grade BM100n40 (see Fig. 3). The spiral formed a cavity receiver with a shape close to a part of a sphere. The diameter of the outlet of such a receiver was *D* = 100 mm. The number of turns of the spiral superheater was 8.

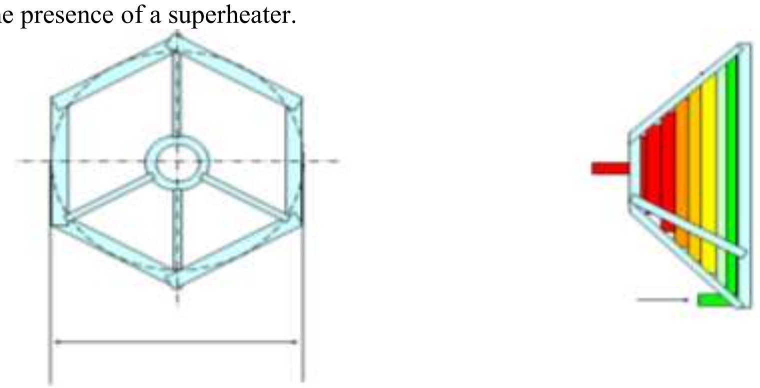

Fig. 3. Layout of a common superheater and spiral fastening diagram.

The installation works as follows. Water from the tank (the tank is installed 10 m in height from the installation to increase the water pressure) at a pressure of 2 atm, depending on the intensity of solar radiation, is supplied to the evaporator. With solar radiation of 800 *W / m2*, then a heliostat is directed

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to the concentrator at this time, a density of 20 *W / cm2* is reached at the focus of the SSF. Average flow rate of cold water 0.7-0.8 l/min. Preliminary experiments have shown that, depending on the power of the concentrated solar flux, the steam temperature can be brought up to 800 ^{0}C at a pressure of 2 atm, the operating temperature was lower, to 600-700 ^{0}C.

A jet of steam at a high speed comes from the nozzles into the channels of the rotor blades. Due to the curvilinear shape of the channel, the steam changes its direction of movement. In this case, a centrifugal force acts on each element of the working fluid jet. The presence of these forces causes an uneven distribution of pressure in the jet. As a result, the pressure on the concave surface of the blades is greater than the pressure on the back of the blades. This pressure difference is the force under which the blades rotate.

The connection between the steam consumption M *kg / sec*, the work of 1 *kg* of steam and the power of the rotating body N_{mech}, measured in watts, will be represented as:

$$N_{mech} = P*\omega \qquad (7)$$

$$\omega=2*\pi*н=2*3.14*2000\ rot/sec=209.12\ m/sec$$

$$P=M*W/m=0.093\ kg/sec*56.6m/sec/1=5.26\ n$$

$$N_{mech} =5,26*209,12=1100\ W=1,1\ kW$$

where, P - steam force; ω - angular velocity; t-time.

The table shows the parameters of the steam turbines of the combined system, the steam turbine of which is rigidly fixed on the same shaft with the 672 *W*, PH brand.

The speed of rotation of the turbine shaft depends on the pressure of the superheated steam and its specific volume. With an increase in pressure and temperature, the specific volume of superheated water vapor fits (table. №1).

Table № 1. Steam turbine parameters of the combined system.

Names of quantities	Stage №.		Parameters
	Designation	Dimension	
Steam consumption	m	кg/h	33,6
Average diameter	D	м	0,62
Peripheral speed	n	1/min	2000
Pressure	P_0	atm	12
Temperature	t	^{0}C	470
Blade height	l	мм	180
Mechanical power	$H_{мех}$	W	1100
Electric power	$P_{эл}$	W -	672
Coefficient of usefulness	η_l	-	0.62

However, to obtain current using a 336 *W* generator, you need steam with a pressure of up to 6-9 atm. At pressures below 6 atm, the current power fits up to 17 *W*, and at pressures above 9 atm, the generator armature will spin faster, causing a breakdown of the generator stabilizer, and it cannot produce an electric current.

CONCLUSION

Thus, the functionality of SCFs was expanded on the basis of the laws of distribution of the flux of concentrated solar radiation in the light receiver and methods of conversion into other types of energy. In addition, SSFs have the ability to generate electricity through engineering calculations and heat transfer experiments in a focal plane light receiver.

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