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Research in the Field Using Solar Energy

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ABSTRACT: The article discusses the possible areas of use of the solar energy and brief characteristics of the modern solar installations.

Keywords: solar power plants, concentrators, solar energy, solar oven, reflecting surface, direction sensors, facet of a solar stat, tracking system.

Even in ancient times, thinkers of the East knew that the Earth is round and revolves around the Sun - the source of all living things. Even then, the light properties of the Sun were known. Knowing the peculiarity of mirrors and lenses to collect the sun's rays at one point, Abu Raikhan Beruniy and Ibn Sina (Avicenna) explained the possibility of obtaining very high temperatures. For example, Ibn Sina in his book "Danish - Nama" (The Book of Knowledge) explained the thermal effect of the sun's rays and the optical properties of lenses as follows: “Lighting through a magnifying glass occurs because there is a point in it that perceives rays from all sides. This point is strongly illuminated and, therefore, heats up a lot.”

The use of solar energy as a source of renewable energy in world practice was intensively developed mainly at the beginning of the twentieth century.

By now, quite powerful solar power plants are already in operation, in which solar energy concentrators are used. In the south of France (Odeillo), the world's largest solar furnace with a thermal power of 1000 kW was built [1]. Its dimensions are impressive - 40x50 m, but it consists of slightly twisted mirror elements. There are 9500 of them here. In front of the concentrator, on an area of 3000 m^2, there are 63 movable flat mirrors (heliostats) with an area of 45 m^2 each. They direct the sun's rays to a parabolic mirror, the focal zone of which has a diameter of about 40 cm, the temperature in the spot zone reaches 3800 °C. The individual elements of the solar oven are controlled by a computer.

In Uzbekistan, 50 km from Tashkent (Parkent), a solar furnace was built with a similar thermal power, but with more perfect optical characteristics [2]. The heliostat field is formed by 62 heliostats placed on a gentle mountain slope in a checkerboard pattern, which provide continuous tracking of the Sun during a working day to illuminate the entire mirror surface of the concentrator. All 62 heliostats in the complex have the same design and dimensions. The reflecting surface of the heliostat with a size of 7.5x6.5 m is flat, composite, includes 195 mirror elements - a facet with a size of 0.5x0.5 m and a thickness of 6 mm. The reflective facet layer is formed by vacuum deposition of aluminum on the back side and is protected with acrylic paint. The total number of facets is 12090 pieces, the area of the reflective surface is 3022.5 m^2.

The reflecting surface of the concentrator is a rectangular - stepped carving from a paraboloid of revolution with a focal length of 18 m, the height of the concentrator mid ship is 42.5 m, the lower edge is located at a height of 54 m from the ground, the width of the mid ship is 54 m, the total area of the mid ship of the reflecting surface is 1840 m^2, and the area of the surface itself is 2060 m^2.

The concentrator is assembled from 214 blocks in the form of parallelograms, with side dimensions 4.5x2.25 m each, but with different angles at the vertices determined by the coordinates of the block. Each block has 50 reflective elements - a rhombic facet. The total number of facets is 10700 pieces.

In Algeria, a solar furnace "Heliodina" with a concentrator diameter of 8.4 m and a thermal power of 32 kW is in operation. The temperature in the spot zone reaches 3200oK.

In the CIS, several solar ovens and solar power plants have been built in Crimea, Makhachkala and other places.

A solar optical furnace with a power of 20 kW was built in 1989 - 90 at the research site of the Institute of High Temperatures of the Academy of Sciences (IVTAN) of the Russian Federation "Sun" in the city of Makhachkala. The landfill is located on the coast of the Caspian Sea, 14 km from the city of Makhachkala at a geographical latitude of 43 °.

The climatic conditions of the landfill location are characterized by a large number of sunny days per year (about 290), a small amount of precipitation and insignificant air humidity. The average annual sunshine duration is about 2000 hours.

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The solar optical furnace with a power of 20 kW is designed for scientific experiments at high temperatures (up to 3000 ° K). Figure 1 shows a general view of a solar optical oven.

The concentrator of the solar furnace is a paraboloid reflective surface with dimensions of 4.6 x 12.6 m, made up of 575 spherical facets of the same size, stacked on a spherical supporting frame with a radius of curvature of 13.2 m. The optical axis of the concentrator is oriented towards the north. -south. The opening angle of the reflecting surface of the concentrator is 60 °, the focal length f = 6.0 m.

The solar radiation flux to the concentrator is directed by 10 flat heliostats, which are located on two terraces, each terrace serving its own area of the concentrating mirror.

The reflecting surface of each individual heliostat consists of 49 separate mirrors (facet) with dimensions of 40x40 cm, with a total area of 7.84 m^2 and attached to a supporting metal frame with dimensions of 3.0 x 3.0 m.

Each heliostat is equipped with an automatic system for tracking the reflected flow of solar radiation, including direction sensors, a control panel and electric drives with gearboxes.

The rotation of the supporting frame of each heliostat is carried out according to the azimuthal-zenith scheme.

The value of the maximum attainable temperature for a given object in the ideal case (energy and geometric losses in the optical system are absent) is determined by the formula [1].

$$T_F^{HD} = \sqrt[4]{\frac{E_F^{HD}}{G_0}}. \qquad (1)$$

Where $G_0 = 5.672 \cdot 10^{-8} \frac{\text{Вт}}{\text{м}^2}$, K^4 is the Stefan - Boltzmann constant

$$E_F^{HD} = R_S \frac{1.2}{\varphi_0^2} \sin U_m E_0 \qquad (2)$$

E_F^{HD} - irradiance at the focus of an ideal solar concentrator;

R_s - integral transmittance (specular reflection) of the system;

φ_0- is the angular radius of the Sun, equal to 0.004654 rad.

E_0- is the density of direct solar radiation;

U_m - opening angle of the concentrator.

Substituting in (2) the values R_S=1, φ_0=0.004654, E_0=814 Вт/м^2, U_m=60°, we obtain the limiting irradiance in the focal plane E_F^{HD}=33.9·10^6 Вт/м^2.

Using the calculated value E_F^{HD} and the Stefan-Boltzmann constant G_0 = 5.672 · $G_0 = 5.672 \cdot 10^{-8} \frac{\text{Вт}}{\text{м}^2}$, K^4 using formula (1) we calculate the maximum attainable temperature in the focus

$$T_F^{HD} = \sqrt[4]{\frac{33{,}9 \cdot 10^9\ \text{Вт/м}^2}{5{,}672\ \text{Вт/м}^2\text{K}^4}} = 4940°\text{к}$$

Thus, calculations show that in the focus of the described furnace, a maximum temperature of up to 4940 °K can be obtained. However, in the focus of a real concentrating system, the irradiance will be lower $(E_F < E_F^{HD})$, since the specular reflection coefficient R_S<*1*and there are losses due to non-observance of the geometry of the system. The results of measurements of the temperature of the solar furnace showed that the actual temperature at the focus of the concentrator reached 2750 °K.

According to the data presented, it can be seen that temperature losses are mainly a consequence of technological tolerances for the manufacture of reflective mirror surfaces.

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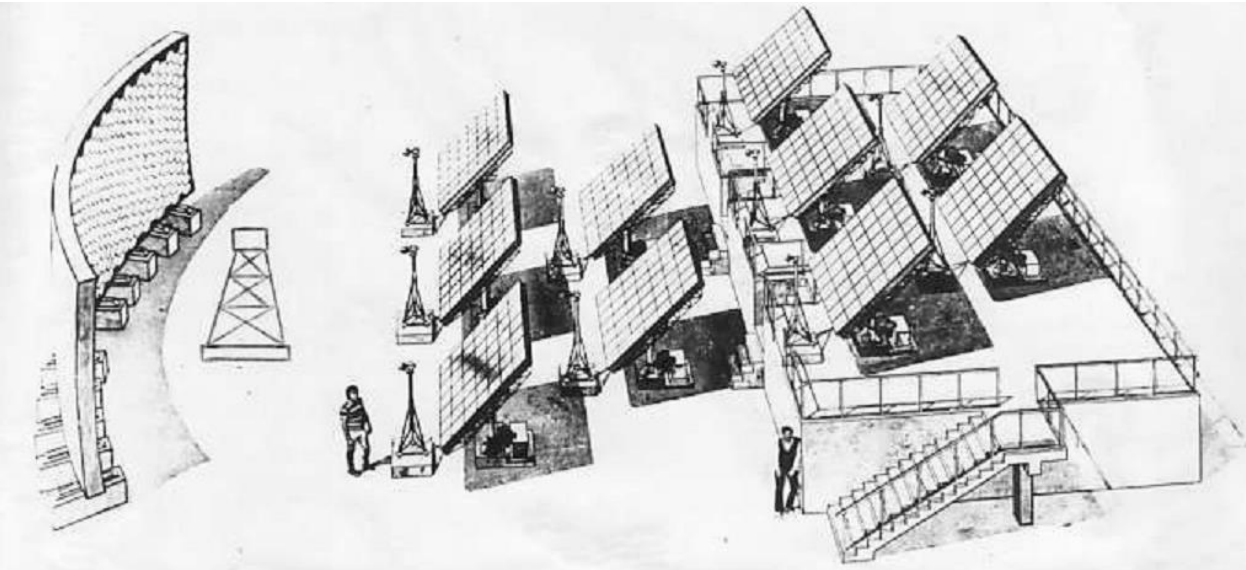

Figure 1: General view of a 20kW solar optical furnace.

For the considered furnace, the coefficients of specular reflection in the manufacture of facets of the heliostats and the concentrator were 0.8 and 0.9 respectively.

Taking into account that the useful area of the concentrator is 57 m^2, we obtain for the ideal setting and manufacture of the considered joint venture the power of the MID equal to 80 kW, which corresponds to the theoretical temperature of 4940 °K.

The actual power of the solar oven - Mf, taking into account the coefficients of the mirror cover, will be equal to 58 kW.

Hence, the actual temperature at the focus of the SP calculated by the formula

$$T_{\Phi}^{P} = \frac{T_F^{HD} M_{\phi}}{M_{HD}}$$

and for these parameters is equal to T_{Φ}^{P}=3700°K.

The difference between the calculated and measured temperatures, equal to 950°, is also a consequence of technological tolerances for compliance with the form of manufacturing of elements of reflecting surfaces and the quality of the geometric adjustment of the joint venture, which probably leads to a decrease in temperature of ≈500 °.

Thus, the study performed allows us to conclude that for a high-quality geometric adjustment of solar ovens, which is a multi-mirror system, it is necessary to determine the tolerances for the installation and alignment of its individual elements.

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