Improving the energy efficiency of a solar air heater with heat accumulator using flat reflectors

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Abstract. In the article, the authors researched the process of increasing the energy efficiency of the solar air heating collector with heat accumulator. In order to increase the energy efficiency of the solar air heating collector with a heat accumulator, it was proposed to install flat reflectors parallel to its sides. Flat reflectors with a surface area of 1.8 m² were installed on the sides of the solar air heating collector with a useful surface of 1.8 m², and a pilot-industrial version of the device was created. According to the results of the conducted research, it was determined that the energy efficiency of flat reflectors depends on the solar declination angle. Research results show that, the maximum heat capacity of the flat reflector solar air heating collector with a heat accumulator was 1020 W. The maximum temperature of the heat carriers, air + 75°C and heat accumulator + 85°C.

1 Introduction

The rational use of natural fuel and energy resources is one of the global problems of the countries of the world, and its successful solution will be crucial not only for the further development of the world community, but also for maintaining environmental stability. One of the promising ways to solve this problem is the use of new energy-saving technologies using renewable energy sources [1-2].

The depletion of traditional fossil fuels (coal, oil and gas) and the environmental consequences of burning them have led to a significant increase in interest in energy devices and technologies based on renewable energy sources in almost all developed countries of the world in recent years [3-5].

“GREEN” technologies that provide savings on traditional energy sources: natural gas, liquid, solid organic fuels and electricity.

Therefore, the issue of reconstruction of the energy base and finding ways to use environmentally friendly renewable energy sources is urgent [6].

In addition, in order to develop i-economy and ensure high growth rates, active implementation of “GREEN” technologies in all sectors, “Development Strategy” for 2022-2026, “Green economy” technologies are actively applied to all sectors. Through its

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implementation, increasing the energy efficiency of the economy by 20% and reducing the amount of harmful gases released into the air by 10% is a priority task [7].

In the southern regions of our republic, specifically in the city of Karshi, it is of great importance to determine the technical and economic efficiency of passive solar heating systems, taking into account the local climatic and meteorological parameters. To combine the main elements of passive and active solar heating systems, it is important to choose the optimal structural structure, to optimize the heat-technical parameters, and to verify the research results by conducting experiments. Passive the sun heating systems main from the indicators one this is their energy efficiency is [8].

The solar energy potential of the Kashkadarya region is high, that is, 300÷320 days are considered as sunny days, and the duration of solar radiation is 2950÷3050 hours $Q_{rad} = 1600 ÷ 1800$ kW hours/m$^2$ year $q_{tr} = 6850 ÷ 7050$ MDj/m$^2$. Based on this, the technical potential of solar energy of Kashkadarya region is equal to 26.5 million tons of conventional fuel.

2 Materials and methods

Under the influence of high solar radiation and ambient temperature, waste gas is released from solid household waste into the environment. Therefore, covering the temperature regime required for thermal processing of municipal solid waste under the influence of solar energy at the expense of solar energy allows saving natural fuel and energy resources. A flat reflector solar air heating collector with heat accumulator device was developed on the basis of the “Solar and bioenergetic devices” scientific laboratory of the Karshi Engineering-Economics Institute (Figure 1), and thermal-technical, pilot-research tests were conducted.

Solar air heating collector with a heat accumulator with a useful surface of 1.8 m$^2$. In order to increase the energy efficiency of the solar air heating collector, flat reflectors with a useful surface of 1.8 m$^2$ are installed parallel to its sides. As a heat accumulator, water and transformer oil are used. As a result, a flat-reflector solar air heating collector with a heat accumulator serves as an active solar heating system for different kind of energy systems.

The efficiency of solar air heating collector with heat accumulator flat reflector, heat efficiency, and the average temperature of heat carriers was determined on the basis of computational and experimental studies.

Fig. 1. Flat reflector solar air heating collector with heat accumulator.

The energy efficiency of a flat reflector depends on the amount of solar radiation falling on its surface, which depends on the angle of the sun’s declination, which we determine using the following equations.
The sun water, air heating up of the collector efficiency increase for his parallel to the sides of the hull flat reflectors installed. Flat of reflectors reflection carry on efficiency ($i_{surf.}$) to him coming down right the sun of radiation drop off to the corner related [8-10].

$i_{surf.}$ the following equation based on is:

$$i_{surf.} = \arccos \nu_x$$  \hspace{1cm} (1)

This on the $\nu_x$ -x axis across $\nu$ unity of the vector component being as follows defined as:

$$\nu = c - 2n(n \cdot c)$$  \hspace{1cm} (2)

This where, $n$ and $c$ are flat reflector and the sun of light unit normal vectors is considered.

In expression $\nu_x$ the following equation based on is:

$$\nu_x = -\cos \delta \sin \varphi \cos \omega (\tau_0 - \tau) - 2 \sin \alpha \cos i_p - \sin \delta \cos \varphi,$$  \hspace{1cm} (3)

This on the ground, $\delta$ - of the sun yearly deviation, $\varphi$ - local of the area geographical width, $\tau_0$ - real noon time, $\tau$ - day defined tim, $\omega = 1.5 \frac{grad}{hours}$ - of the earth own arrow around rotation angle speed:

$$\cos i_p = \cos \delta \cos (\varphi - \alpha) \cos \omega (\tau_0 - \tau) + \sin \delta \sin (\varphi - \alpha)$$  \hspace{1cm} (4)

$\cos i_p$ - that’s right the sun of radiation flat to the reflector drop off angle, $\alpha$ - flat of the reflector to the horizon relatively deviation corner.

Figure 2 is the sun water+air heating up of the collector parallel to the sides of the hull installed flat reflectors shown. Flat of the reflector reflection carry on efficiency ($i_{surf.}$) to him coming down right the sun of radiation drop off to the corner connected.

**Fig. 2.** Flat reflector solar air heating collector with heat accumulator to the horizon relatively the most acceptable deviation the corner determination scheme. 1st solar radiation energy, 2-transparent coating (mirror), 3-flat reflector, $i, i'$ - correct the sun of radiation drop off corner and flat reflector on the surface reflection to reach.
Half a day for:

\[ 2\beta + 90^\circ + \alpha^\text{opt}_{\text{ref}} = 180^\circ \]  \hspace{1cm} (5)

\[ \beta + \iota = 90^\circ \]  \hspace{1cm} (6)

Flat optimal deviation of the reflector corner \( \alpha^\text{opt}_{\text{ref}} \) the following to basically defined as:

\[ \alpha^\text{opt}_{\text{ref}} = 2\iota - 90^\circ \]  \hspace{1cm} (7)

This on the ground, \( \iota \) - right the sun of radiation drop off corner, it’s the same that’s it from the surface radiation reflection carry on corner \( \iota^\prime \) to equal to.

Heat with battery the sun water, air heating up collector light acceptance to do to the surface right the sun of radiation drop off corner \( \alpha_{\text{ref}} \) 4 expressions according to is determined, i.e.

In a dream \( i = 12 \)when \( \omega(t_0 - \tau) \) will be, therefore (4) for expression as follows is written:

\[ \cos i = \cos(\varphi - \alpha_{\text{ref}} - \delta). \]  \hspace{1cm} (8)

(8) from expression,

\[ i = \varphi - \alpha_{\text{ref}} - \delta. \]  \hspace{1cm} (9)

(9) into (6) replacing, that is, \( \alpha_{\text{ref}} = \alpha^\text{opt}_{\text{ref}} \) to equal to that in consideration we get the following to have we will be

\[ \alpha^\text{opt}_{\text{ref}} = 0.6667(\varphi - \delta) - 30^\circ. \]  \hspace{1cm} (10)

\( \delta \) size as follows defined as:

\[ \delta = 23.45\sin\left(\frac{284 + n}{365.26} \cdot 360\right) \]  \hspace{1cm} (11)

This on the ground from January \( n-1 \) starting from of days order number.

3 Results and Discussion

It is known that the Earth moves in an elliptical orbit around the Sun with an eccentricity equal to \( a=0.033 \). In this case, the inclined direction of the Earth’s axis is placed in space strictly at an angle of 23° 27′ = 23.45° to the normal of the plane of the Earth moving around the Sun In this case, the angle between the line directed towards the Sun and the plane of the Earth’s equator (Equatorial plane) is called the Sun’s declination. It is numerically equal to the angle between the normal transferred to the plane of the Earth’s rotation around the
Sun and the direction of the Earth’s axis of rotation. In the Northern Hemisphere, the angle is \( \delta = -23^\circ 27 \) for December 21 during the year from, to \( +23^\circ 27 \) for June 21, the solar equinoxes change to zero for March 21 and September 23. \( \delta^0(t) \) is equal to \( 23^\circ 45 \) determined by the maximum value of \( \delta^0 \).

As \( n \) - the average account number of the month and day for the months of the year I-XII is usually taken. 284 – the number of days from March 21 to December 31, 360\(^{0}\) is the value of a complete rotation of the Earth around the Sun in one year.

Below are the values for \( n \) and \( d \) during I-XII months.

<table>
<thead>
<tr>
<th>( n )</th>
<th>17</th>
<th>47</th>
<th>75</th>
<th>105</th>
<th>135</th>
<th>198</th>
<th>228</th>
<th>258</th>
<th>288</th>
<th>318</th>
<th>344</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta ), ( \text{grad.} )</td>
<td>-20.9</td>
<td>-13</td>
<td>-2.4</td>
<td>9.4</td>
<td>18.8</td>
<td>21.2</td>
<td>13.5</td>
<td>2.2</td>
<td>-9.6</td>
<td>-18.9</td>
<td>-23</td>
</tr>
</tbody>
</table>

Increase the energy efficiency of the solar air heating collector with a heat accumulator, it was proposed to install flat reflectors parallel to its sides. Flat reflectors with a surface area of \( 1.8 \text{ m}^2 \) were installed on the sides of the solar air heating collector with a useful surface of \( 1.8 \text{ m}^2 \), and a pilot-industrial version of the device was created. The results of the experiment are shown in the figure below.

**Fig. 3.** The results of the experiment.

### 4 Conclusion

As a result of experimental studies, the maximum heat capacity of the solar air heating collector with a heat accumulator was \( 730 \text{ W} \). The maximum temperature of the heat carriers showed \( \text{air} + 55^\circ \text{C} \) and \( \text{oil} + 70^\circ \text{C} \). Flat reflectors installed parallel to the sides of the solar air heating collector with a heat accumulator led to an increase in its energy efficiency. As a result, the maximum heat capacity of the flat reflector solar air heating collector with a heat accumulator was \( 1020 \text{ W} \). The maximum temperature of the heat carriers, \( \text{air} + 75^\circ \text{C} \) and \( \text{heat accumulator} + 85^\circ \text{C} \).

The flat reflector solar air heating collector with heat accumulator is energy efficient, and the installation of flat reflectors reduces the cost of the device along with reducing the
consumption of metal structures. The flat reflector solar air heating collector with heat accumulator can be used in autonomous energy supply systems.

References


