Energy saving using solar air heater collectors

Abstract. In this study, the issue of providing heat energy to a small utility room from a solar air heater collector in the climate of Uzbekistan was considered. A diamond-shaped heat exchange accelerating element is used in the installed solar air heater collector. The total working surface is 1 m². After installing the solar air heater collector, the thermal energy balance of the service room was compiled. As a result, it was determined that 81355 W of thermal energy is required during the day to maintain the room temperature at a normal level. The amount of heat required for the sunny time of the day was 28873 W. The amount of heat received from the solar air heater collector was 1350 W. As a result of the calculations, it was found that the total working surface is 21 m² on average to provide 100% of the required amount of heat in sunny weather with the help of a solar air heater collector. The calculation process was carried out for 06.01.2023. Covering the daily amount of heat required by the consumer with the help of a solar air heater collector is considered very complicated and requires a lot of money. Therefore, during the design of the heat supply from the solar air heater collectors, it is appropriate to determine the average amount of heat for the season at 15-20%.

1 Introduction

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70,09 kW/month for January and 262 kW/month for July, respectively. For comparison, the amount of annual solar energy for the regions of Central European countries is 1000 kW, for the Mediterranean Sea it is about 1700 kW. 

The territory of the Republic of Uzbekistan is 448,900 square kilometers, 70% of which are desert areas. The abundance of desert areas means that the possibility of using solar energy is more convenient. The territory of the republic is located between 37° to 45° north latitude and 56° to 73° east longitude. Solar energy potential is 98,5% of the total potential.

2 Materials and methods

It can be concluded that the use of solar energy in the climate of Uzbekistan has great efficiency. It is possible to achieve energy savings as a result of supplying buildings with heat energy using a solar air heater collector (Fig. 1), which is effective in obtaining heat energy from devices working on the basis of solar energy.

![Fig. 1. A building with a solar air heater collector.](image)

Geometric dimensions of the building:
- L = width 4000 mm;
- D = length 7000 mm;
- H = height 2500 mm;
- \( S_{p} \) = the surface of the floor part of the building 25 m\(^2\);
- \( S_{sh} \) = the surface of the ceiling part of the building 25 m\(^2\);
- \( S_{s} \) = the total surface of the side walls 40 m\(^2\);
- \( S_{o} \) = common glass surface on the side wall and door 7 m\(^2\);
- \( S_{e} \) = plastic part of the entrance doors 2 m\(^2\).

The external and internal air temperatures and the thermal conductivity and thermal conductivity of the external walls were taken into account when creating the heat balance of the external walls.

Calculation work was carried out for 6.01.2023 at 11:00 hours. The flow of sunlight was 380 W, the outside air temperature was -2 °C, the inside air temperature was 18 °C, and the soil part under the floor was an average of 4 °C.

Heat transfer coefficients of the materials used in the wall construction are required to calculate the heat losses in the external walls.

Heat losses were calculated by the following formula:
\[ Q = S_{out} \frac{1}{R_0} (T_1 - T_2) \]

\[ R_0 = \frac{\delta}{\lambda} \]

3 Results and discussion

\[ \lambda_b = 0.51 \]
\[ \lambda_e = 0.18 \]
\[ \lambda_o = 0.284 \]
\[ \lambda_{sh} = 0.622 \]
\[ \lambda_p = 0.131 \]

\[ \delta_b = 0.4 \]
\[ \delta_e = 0.05 \]
\[ \delta_o = 0.003 \]
\[ \delta_{sh} = 0.35 \]
\[ \delta_p = 0.42 \]

\[ R_b = \frac{\delta}{\lambda} = 0.4 \frac{0.4}{1.51} = 0.78 \]
\[ R_e = \frac{\delta}{\lambda} = 0.05 \frac{0.05}{0.18} = 0.277 \]
\[ R_o = \frac{\delta}{\lambda} = 0.03 \frac{0.03}{0.284} = 0.105 \]
\[ R_{sh} = \frac{\delta}{\lambda} = 0.35 \frac{0.35}{0.622} = 0.563 \]
\[ R_p = \frac{\delta}{\lambda} = 0.42 \frac{0.42}{0.31} = 1.35 \]

\[ Q_b = S_b \frac{1}{R_b} (T_1 - T_2) = 40 \frac{1}{0.78} (18 - (-2)) = 1025 \]
\[ Q_e = S_e \frac{1}{R_e} (T_1 - T_2) = 2 \frac{1}{0.277} (18 - (-2)) = 144 \]
\[ Q_o = S_o \frac{1}{R_o} (T_1 - T_2) = 4 \frac{1}{0.105} (18 - (-2)) = 761 \]
\[ Q_{sh} = S_{sh} \frac{1}{R_{sh}} (T_1 - T_2) = 25 \frac{1}{0.563} (18 - (-2)) = 888 \text{ kW} \]

\[ Q_p = S_p \frac{1}{R_p} (T_1 - T_2) = 25 \frac{1}{1.35} (18 - (4)) = 370 \text{ kW} \]

\[ \Sigma Q = Q_b + Q_e + Q_o + Q_{sh} + Q_p = 1025 + 144 + 761 + 888 + 370 = 3190 \text{ kW} \]

Table 1.

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<thead>
<tr>
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<td>761</td>
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<td>888</td>
<td>370</td>
<td>3190</td>
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</tr>
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</table>

As a result of the structure of the thermal energy balance, the total amount of heat lost in the utility room for the balance of the room where the entrance door was constantly changing due to changes in external factors. The amount of heat lost through the floor (Table 1) was calculated by the following formula:

\[ W = \Sigma Q \]

Time and temperature data correspond to the greenhouse guards' stay, and the power lost by the greenhouse per hour (01.06.2023 at 11:24) was used for the calculation.
As we can see from Fig. 2, depending on the temperature, the wasted heat energy is increasing. We will determine the amount of heat energy obtained when installing the CHP in the greenhouse (for January 6, 2023). The radars were set at 90 degrees relative to the Azimuth angle, and 61 degrees relative to the ground. The data presented in the above tables are the results of many experiments. During the experiment, as a result of making changes and additions to the device and the experiment method, the perfect experiment method was selected, and the final experiments were conducted and the results were obtained through this method.

The amount of heat (Q) W obtained from the solar air heater collector was calculated as follows:

\[
Q = G \cdot C_p \cdot (T_{out} - T_{in}),
\]  

(3)

where

- \(G\) – air consumption, kg/s;
- \(C_p\) – heat capacity of air, J/kg °C;
- \(T_{in}\) – SAHK inlet air temperature, °C;
- \(T_{out}\) – SAHK outlet air temperature, °C.

Air consumption was calculated as follows:

\[
G = \frac{\pi d^2}{4} \cdot v \cdot \rho,
\]  

(4)

where:

- \(d\) – pipe diameter, mm;
- \(v\) – air speed, m/s;
- \(\rho\) – air density, kg/m³.

The difference of temperatures entering and exiting the collector of the solar air heater was calculated using the following expression:

\[
\Delta T = (T_{out} - T_{in}),
\]  

(5)

where:

- \(T_{in}\) – SAHK inlet air temperature, °C;
- \(T_{out}\) – SAHK outlet air temperature, °C.

The efficiency of the solar air heater collector is determined as follows:

\[
\eta = \frac{G \cdot C_{p} \cdot (T_{ch} - T_{kir})}{F \cdot H_t},
\]  

(6)
The solar radiation receiving working surface of the solar air heater collector is represented by:

\[ F = a \cdot b \]

where:
- \( F \) is the working surface, \( m^2 \)
- \( a \) is the length of the solar air heater collector, \( mm \)
- \( b \) is the width of the solar air heater collector, \( mm \)

Table 2. The amount of heat energy received from the solar air heater collector.

<table>
<thead>
<tr>
<th>№</th>
<th>Time (hours)</th>
<th>Solar radiation (W)</th>
<th>Heat from the SAHK (W)</th>
<th>Amount of energy (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0800</td>
<td>120</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0900</td>
<td>210</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1000</td>
<td>280</td>
<td>168</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1100</td>
<td>300</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1200</td>
<td>350</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1300</td>
<td>360</td>
<td>216</td>
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<td>7</td>
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<td>270</td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>1500</td>
<td>210</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1600</td>
<td>150</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

Using the data presented in Table 2, the total amount of solar radiation reaching the surface of 1 \( m^2 \) for the specified time period is 2250 W, taking into account that the total working surface of the collectors is 1 \( m^2 \), in the time period from 0800 to 1600 we can see that the amount of sunlight falling on 1 \( m^2 \) surface is 2250 W, and the total amount of heat received from solar panels is equal to 1350 W, so we can see that 60% of the sunlight flow is transferred to the room as heat energy (Fig. 3).

![Fig. 3. The graph of the change of heat loss after the installation of the solar air heater collector.](https://doi.org/10.1051/e3sconf/202450802001)
Conclusion

It was determined that 81355 W of heat energy is required during the day to maintain the temperature in the oven at a normal level. The amount of heat required for the sunny time of the day was 28873 W. The amount of heat received from the collector of the solar air heater with a working surface of 1 m$^2$ on the calculation day was 1350 W. As a result of the calculations, it was determined that a solar air heater collector with a total working surface of 21 m$^2$ would be needed to cover 100% of the required amount of heat in the sunny season with the help of solar air heater collectors.

References

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