ENERGY BALANCE OF GREENHOUSE WITH GROUND WARMING INSTALLATION

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Abstract: Geothermal energy, solar energy, industrial thermal effluents, etc. mainly offer low-temperature waters. Heating installation or system, originally developed for one of the alternative energy source. The problem of low-temperature heating of greenhouses is not characteristically only for direct application of geothermal energy but is connected to the problem of all the "alternative" energies use for that purpose. Calculations determine the losses of heat transfer, losses from the application of heat and benefit from the use of hot water. Calculated is necessary and permissible temperature of the floor, the recommended speed of the fluid and plan for layout of pipes in the ground of greenhouse.

Keywords: ENERGY BALANCE, GREENHOUSE, INSTALLATION, GEOTHERMAL ENERGY;

1. Introduction

Main advantages of alternative energies is that they are free of charge or much cheaper than the fossil fuels. Their main disadvantage is that in most of the cases heating fluids are available with rather low temperatures.

The problem of low temperature greenhouses is connected with all alternative energies that is use for that purpose. But heating installation that is originally developed for one alternative energy source is or can often be convenient for use of the other.

The choice of a technically, technologically and economically feasible heating system for concrete greenhouse and plant culture is one of the most difficult technical design problem. When taking in account all the influencing factors it is not possible to define with a strict methodology which gives straight answers for concrete situation. Therefore, the solution is in the definition and listing of influencing factors and by estimation of the importance of each one of them for concrete case to determine possible optimal solutions.

2. Flow of heat in the greenhouse

The indoor climate in greenhouse differs from the outside due to the impact of these active participants on the heat balance (Fig.1)
- Sun's energy flux of radiation;
- Atmosphere with radiation;
- The surrounding area also with radiation;
- External air by convective heat transfer to (or from) the greenhouse located;
- Construction of greenhouse by radiation, convection and conduction heat transfer to (or from) the environment;
- Internal air, with convective and latent heat transfer;

- The roof of the greenhouse and the heat transfer through radiation, convection and conduction;
- The ground and its heat transfer through convection, conduction and evaporation;
- Installations for heating and cooling by convection, radiation and latent heat transfer, depending on the type of used heat exchangers;
- Ventilation with latent heat transfer caused by the filtration of the outside air entering the greenhouse;
- Irrigation with latent heat transfer caused by changes in the interior humid air and wet ground;

3. Installation of ground heat

Fig. 2 Simplified scheme of installation for heating in the ground

Fig. 3 Vertical temperature profile in the heated greenhouse with installation in the ground
4. Calculation of greenhouse

Fig. 4 Vertical temperature profile in the heated greenhouse with installation in the ground

- predicted internal temperature 20°C;
- predicted outside temperature 5°C;
- predicted wind speed 40 km/h;
- double-layered roof $U = 14.9$ kJ/m²K;
- walls of fiberglass $U = 21.6$ kJ/m²K;

The values for $U$ are adopted from next Table 1:

Table 1. $U$-values for different wind speeds (kJ/m²K)

<table>
<thead>
<tr>
<th>Material</th>
<th>0</th>
<th>8-2.24</th>
<th>16-4.47</th>
<th>32-8.94</th>
<th>40-11.2</th>
<th>48-13.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>15.6</td>
<td>19.4</td>
<td>21.2</td>
<td>23.3</td>
<td>23.7</td>
<td>24.1</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>14.2</td>
<td>17.7</td>
<td>19.4</td>
<td>21.1</td>
<td>21.6</td>
<td>22.0</td>
</tr>
<tr>
<td>Single layer</td>
<td>16.5</td>
<td>20.4</td>
<td>22.3</td>
<td>24.3</td>
<td>24.7</td>
<td>25.1</td>
</tr>
<tr>
<td>Double-layered roof</td>
<td>10.9</td>
<td>12.9</td>
<td>13.8</td>
<td>14.6</td>
<td>14.9</td>
<td>15.0</td>
</tr>
</tbody>
</table>

- surface of arc ≈ 0.165 m² (approximately 1/6 of the circle with r=w);
- area of the Double-layered roof: $1/3 \cdot \pi \cdot w \cdot L = 1/3 \cdot (\pi \cdot 13) \cdot 36 = 490$ m²;
- surface of the walls of fiberglass: $2 \cdot (2.5 \cdot 36+2.5 \cdot 13 \cdot 13^2) = 301$ m²;

4.1. Losses of Heat Transfer

- Two layers: $A \Delta T U = 490 \cdot (20-5) \cdot 14.9 = 109505$ kJ/h = 30,42 kW
- fiberglass: $A \Delta T U = 310 \cdot (20-5) \cdot 21.6 = 97524$ kJ/h = 27,09 kW

Total: 207039 kJ/h = 57,51 kW

4.1. Losses of conducting heat

Data on the change of the air in various materials (AC/H) are taken from next Table 2.

Table 2. Change of the air in various materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Change of the air (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single glass</td>
<td>2.5-3.5</td>
</tr>
<tr>
<td>Double glazing</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>Single layer roof</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Dual-layer roof</td>
<td>0.0-0.5</td>
</tr>
<tr>
<td>Single roof/fiberglass lower side</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>Double roof/fiberglass lower side</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Single roof/fiberglass larger side</td>
<td>1.5-2.0</td>
</tr>
<tr>
<td>Dual-layer roof/fiberglass larger side</td>
<td>1.0-1.5</td>
</tr>
</tbody>
</table>

- Volume of greenhouse $36 \cdot 13 \cdot 2.5 + 0.165 \cdot 13^2 \cdot 36 = 2174$ m³
- heat loss $AC/H \cdot B \Delta T = 1.21 \cdot 15 \cdot 2174 \cdot (20-5) \cdot 5\text{°C} = 59187$ kJ/h = 16.44 kW

4.3. Total loss of heat

Total: $q = 207039 + 59187 = 266266$ kJ/h = 74 kW

4.4 The products of combustion are used through the heat exchangers with $t = 120\text{°C}$ and exit with $t=70\text{°C}$, and water from greenhouse enters in heat exchangers with $t=50\text{°C}$ and exit with $t=60\text{°C}$ shown in Fig. 5.

Fig. 5. Input-output parameters of the media in the heat exchanger

- Required flow $Q = \frac{q}{15040 \cdot \Delta T} = \frac{266000}{15040 \cdot (60-50)} = 1.77 \Delta T \cdot \frac{m^3}{s} = 106 \cdot \frac{m^3}{h} = 150 \cdot \frac{m^3}{day}$

5. Warming soil

5.1 Calculation of the required temperature on the floor to determine the thermal load on the floor surface (reduced by 10%) = 13.36 $0.9 = 421$ m²

$\frac{q}{A} = \frac{\text{termal load / surface of floor}}{421} = \frac{632}{kJ \cdot m^2} = 0.1755 \frac{kW}{m^2}$

5.2 Calculation of the IST (internal temperature area) Dual-layer roof:

IST$_1 = IDT - (0.0291 \cdot U \cdot \Delta T)$

IST$_1 = 20\text{°C} - (0.0291 \cdot 14.9 \cdot 15) = 13.5\text{°C}$

IDT - planned internal temperature
Single layer fiberglass:

\[ \text{IST}_2 = 20° \cdot (0,0291 \cdot 21,6 \cdot 15) = 10,6° \]

\[ \text{AUST} = \text{A} \cdot \text{IST} + \text{A} \cdot \text{IST} \]

\[ \text{AUST} = 490 \cdot 13,5 + 301 \cdot 10,6 \]

\[ \frac{490 + 301}{153} = 12,4° \]

- **Fig. 6. Circulation of water through the floor area of greenhouse**

**Required flow:**

\[ Q = \frac{q}{(15040 \cdot \Delta T)} = \frac{266000}{15040 \cdot (60 - 50)} = 1,77 \frac{\ell}{s} = 106 \text{ min} = 153 \text{ m}^3 \text{den} \]

**5.3. Calculation of the floor surface temperature -Tp (°C)**

\[ q = 1,70 \cdot [(\frac{1,8 \cdot T_p + 492}{100})^4 - (\frac{1,8 \cdot T_{AUST} + 492}{100})^4] + 78,7 \cdot (T_p - T_{o})1,32 \]

\[ T_{o} = 33,3°C \]

The maximum allowable temperature is \( \approx 30° \), and calculated 33,3°C is high, but can afford by bringing the smaller heat loading per m².

So for 30°C is brings only 524kJ / hm², respectively 0,146kW/m² or (0,146 / 0,1755) 100 = 83% of predicted load.

**5.4. Average water temperature**

\[ \Delta T = \frac{Q}{15040 - O} \]

\[ AWT = T_S - \frac{\Delta T}{2} = 60 \cdot \frac{10}{2} = 55° C \]

- **Fig. 7. Heat output of radiation floor system**

\[ Q = 266000 \cdot 0,83 = 1,47 \frac{\ell}{s} \]

- **Fig. 8. Single and double serpentine tube**

182m long tubes, placed on surface with 12m width and 35m length. 182m/6=30,33 circles, and because it's a double serpentine tube has \( \approx 16 \) steps on the floor.

[Corrected area: \( 35m / (16 \times 16) = 0,365m \)]
Note: For others (100 - 83 ) = 17% thermal load, must be set as heating system above the ground (warming units or fine tubes).

5.4.5 Plan the layout of the floor

6. Conclusion

This type of heating system is suitable for controlling the temperature of the root and to cover the minimum temperature requirements. This makes it suitable for very moderate climatic conditions if used as a single installation in greenhouse. But on the other hand very well suited in combination with other types of heating installations also for moderate and cold climates. Simple disassembly can be a good and cheap solution for the group of crops. The part of the base used obligatory must be processed. Expensive regulation set is economically justified only if it is part of the regulation set for full climate control (i.e. if other heating installations are present in greenhouse). For Mediterranean climate plants are not economically justified.

7. References

9. Vadiee, A., Martin, V.: Energy management in horticultural applications through the closed greenhouse concept, state of the art, Renewable and Sustainable Energy Reviews, 2012;