USING GEOTHERMAL WATER FOR GREENHOUSE HEATING

by

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On construction with dimensions 15   5   2 m, conditions of temperature transmission and vegetables growth are examined. We have been cultivating pepper, cucumber, small cucumber, tomato, and lattice. Over ground heating has been used, consisting of one bent pipe with radius of 10 mm, in the shape of hairpin along the both sides of the construction. Underground heating consists of six pipes with radius of 20 mm on the depth of 350-400 mm. There have been measured the temperature inside construction, the temperature outside construction, the waterflow, and water temperature flowing into and out of the construction. The approximate heating flow factor K is determined by both the equation: heating balance equation and basic equation for temperature transmission. Vegetable growth has been watching during the period of time from March to November 2005.

Key words: *geothermal water, wells, heating, greenhouse, heating power, heat, fuel, vegetables*

Using geothermal water for greenhouse heating

Jošanica spa area is on the west side of Kopaonik mountain. This area is famous by geothermal water. The warm water wells, average temperature of 64 °C, have average capacity of 70 l/s. A part of this water, from the warmest well, is using for heating of primary school building. After going through school heating system, the water temperature is 60 °C. This water was used for heating greenhouse for vegetables cultivating. On the basis of calculation for available heat amount, it is concluded that geothermal water could be used either for heating town bigger than Jošanica spa, or dependent on cooling intensity and construction height, for vegetable cultivation on area bigger than 5 ha (tab. 1).

If available heat is expressed by heating power of conventional hard fuel (wood and coal), considering their market price it can be concluded that big heat amount is lost (the total could be expressed in almost million euros) (tabs. 2 and 3).

Table 1. Dependence between cultivation area and available heat amount

Water cooling intensity	Available heat [kW]	Construction volume [m^3] with heating of 200 kJ/m^{3}h	Heating construction area [ha]	
			Height 2,5 m	Height 3 m
64 to 34 °C	8780	158000	6.3	5.3
64 to 24 °C	11700	210670	8.4	7.0
64 to 14 °C	14630	263340	10.5	8.8
64 to10 °C	15800	284400	11.4	9.5

Table 2. Available heat amount, corresponding wood amount and its market value

Water cooling intensity	Available Q [kW]	Available Q in kJ per year	Spatial [m^3]	Price [€/m^3]	Total euro [€]
64 to 34 °C	8780	$2.73\ 10^{11}$	45200	20	904000
64 to 24 °C	11700	$3.64\ 10^{11}$	60270	20	1205400
64 to 14 °C	14630	$4.55\ 10^{11}$	75340	20	1506700
64 to 10 °C	15800	$4.91\ 10^{11}$	81360	20	1627200

Table 3. Available heat amount, corresponding coal amount and its market value

Water cooling intensity	Available Q [kW]	Available Q in kJ per year	Coal [t]	Price [€/t]	Total euro [€]
64 to 34 °C	8780	$2.73\ 10^{11}$	36400	12	436850
64 to 24 °C	11700	$3.64\ 10^{11}$	48540	12	582470
64 to 14 °C	14630	$4.55\ 10^{11}$	60670	12	728080

To follow vegetables growth and approximate heating flow factor, at primary school "Jošanica Spa" backyard it is mounted demonstration system with dimensions: 15 5 2 m. The construction is covered with two-layered plastics foil: inner foil width is 0,04 mm and outer foil width is 0,15 mm.

The construction has ellipse form and is leaned on six plastics pipes fixed by metal construction on concrete legs which are connected by steel wire.

Distance between outer and inner foils is: 100 mm along construction and 80 mm on front sides. The construction door is made from double outer foil with air layer of approximately 15 mm.

The system contains: underground heating system with next characteristics:

- plastics pipes are laid on depth of 35-40 cm,
- the pipes radius is 20 mm,
- pipes are installed in six rows,
- distance between pipes is 80 cm, and
- distance between the last row and construction end is 50 cm, and overground heating system containing of plastics pipes with 10 mm in radius, installed on height of 25 and

80 cm along construction, in the shape of hairpin; total pipes length is approximately 70 m (fig. 1).

To calculate heat flow factor, the next parameters are considered:

– temperature inside construction,
– external temperature,
– water flow rate through underground and overground system part, and
– water temperature on system input and output (fig. 2).

Figure 1. Construction for cultivation vegetables

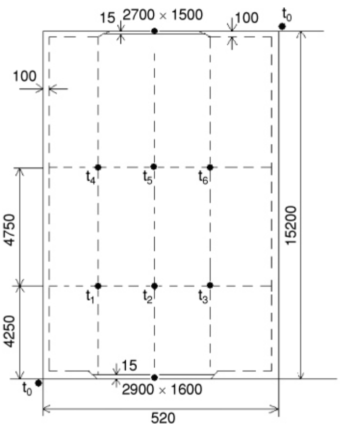

Figure 2. Construction basics (measure points are marked)

Measuring is done at night between April 24 and 25, 2005; measuring results are presented in tab. 4.

Table 4. Air temperature values measured inside system at height of 30 cm and outside temperature measured in C

Time [h]	t_0	t_1	t_2	t_3	t_4	t_5	t_6
23	9	12	12	12	13	13	13
02	7.5	12	11.5	12	12	12.5	12
05	5	10	10.5	10	10.5	11	11
07	7.5	12.5	12	12	12.5	13	13

On the basis of energy balance:

$$Q_{ul} \quad Q_{gub} \quad Q_{iz} \tag{1}$$

$$m_{\mathrm{p}} c_{\mathrm{p}} t_{\mathrm{pul}} \quad m_{\mathrm{n}} c_{\mathrm{p}} t_{\mathrm{nul}} \quad Q_{\mathrm{gub}} \quad m_{\mathrm{p}} c_{\mathrm{p}} t_{\mathrm{piz}} \quad m_{\mathrm{n}} c_{\mathrm{p}} t_{\mathrm{niz}} \tag{2}$$

$$Q_{\mathrm{gub}} \quad Q_{\mathrm{raz}} \quad m_{\mathrm{p}} c_{\mathrm{p}} (t_{\mathrm{pul}} \quad t_{\mathrm{piz}}) \quad m_{\mathrm{n}} c_{\mathrm{p}} (t_{\mathrm{nul}} \quad t_{\mathrm{niz}}) \quad KA \quad t_{\mathrm{sr}} \tag{3}$$

Calculating heat flow factor *K*:

$$K \quad \frac{m_{\mathrm{p}} c_{\mathrm{p}} (t_{\mathrm{pul}} \quad t_{\mathrm{piz}}) \quad m_{\mathrm{n}} c_{\mathrm{p}} (t_{\mathrm{nul}} \quad t_{\mathrm{niz}})}{A \quad t_{\mathrm{sr}}} \tag{4}$$

If construction area is 125.6 m^2, average temperature difference between temperature inside construction and outside temperature is 5 °C, water mass flow m_{p} is 0.15 kg/s, water is cooling from 60 to 51 C and m_{n} is 0.117 kg/s with cooling from 60 to 53 C, computed heat flow factor value is 14.4 W/m^{2}K.

Pepper, cucumber, lettuce, and tomato are cultivated in the system from March to November 2005. On the basis of measuring of product mass we computed yearly produce per hectare (tab. 5).

On the basis of mass of products we computed yearly expected income per hectare (tab. 6).

Table 5. Yearly produce per hectare

Pepper [t]	Tomato [t]	Cucumber [t]	Small cucumber [t]	Lettuce [piece]
20	30	72	48	256

Table 6. Vegetable mass and its value for different market prices

Type	Unit of measure	Amount	Price in dinars/kg				
Pepper	kg	20000	30	35	40	45	50
Tomato	kg	30000	20	25	30	35	40
Cucumber	kg	72000	20	25	30	35	40
Small cucumber	kg	48000	25	30	35	40	45
Lettuce	pieces	256000	20	25	30	35	40
Income per 1 ha (din.)			8.960,000	11.090,000	13.220,000	15.350,000	17.480,000
Income per 1 ha (€)*			103.900	128.600	153.300	178.000	202.700

* 1 € = 87 dinars

Installed heating system makes possible vegetables cultivating for nine months per year, although Jošanica spa is a mountain place.

Gained produces are respectable, thereby benefits from this cultivate method are obvious. On the basis of small changes of water temperature and big value of heat flow factor *K*, we conclude: there is small heat transmission from heating system and there is big loss of heat.

There is better solution which includes:

- bedewing big area for heat exchange toward construction,
- decreasing heat loss through increasing area layer depth, and
- more effective closing.

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