PILOT PLANT FOR EXPLOITATION OF GEOTHERMAL WATERS

by

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In Sijarinska spa, there are some 15 mineral and thermomineral springs, that are already being used for therapeutic purposes. For the exploitation of heat energy boring B-4 is very interesting. It is a boring of a closed type, with the water temperature of about 75 °C and a flow rate of about 30 l/s. Waters with the flow rate of about 6 l/s are currently used for heating of the Gejzer hotel, and waters of the flow rate of about 0,121 l/s for the pilot drying plant. The paper presents this pilot plant.

Key words: *geothermal water, heat energy, drying, pilot plant.*

Introduction

Geothermal energy is energy accumulated in the fluids and masses of the rocks in the earth's crust. Geothermal fluids and possibilities for their application have been known for a long time. The most important advantages of geothermal energy usage in comparison to the other energy sources are less environment pollution and significantly lower exploitation costs [1].

Geothermal springs in Sijarinska spa were known and used even by Romans and Sases. There are about 15 mineral springs in the spa [2]. For the thermomineral waters heat energy exploitation, only the springs with the water temperature over 50 C are interesting. Therefore, the tab. 1 shows fundamental data only for these springs.

Table 1. Springs in Sijarinska spa

Locality	Spring/boring	Temperature [°C]	Flow rate [l/s]	Heat power [kW]
Sijarinska spa	A-1	65	1.5	175.6
	A-2	61	1	100.3
	Grand geyser	71	2.8	398.0
	Main spring	63	0.07	7.6
	Inhalator	65	0.8	93.7
	Sn-2A	65.5	0.08	9.5
	B-4	75	30	4766
			Total	5550.7

From the aspect of the heat potential, the most interesting boring is boring

B-4 with 1232 m depth. It should be noted that at the depth of 300 m, the flow rate of 60 l/s appeared. For the purpose of further examinations, the boring went deeper and reached the depth of 1232 m. At this depth, the flow rate was about 33 l/s, and for that reason it was damped. In the dependence of the dumping the flow rate changes according to the data in diagrams on fig. 1. In the dependence of the dumping, the flow rate can be regulated in the range from a few liters to 33 l/s (fig. 1) [2]. Observations made from 1991 to nowadays showed that water temperature was in the range from 75-78 C, and flow rate at the open boring was over 30 l. These data were for the observation period of about twenty days [2]. For the supposed stable flow rate of 25 l/s and temperature of 75 C, cooling this water to the temperature of 37 C may give about 5 MW of heat power. At these flow rate values, boring dumping should be of the value order of 1.5 bar. Beside geothermal water, the accompanying gas with the gas factor 1:4,4 can also be used [2, 3].

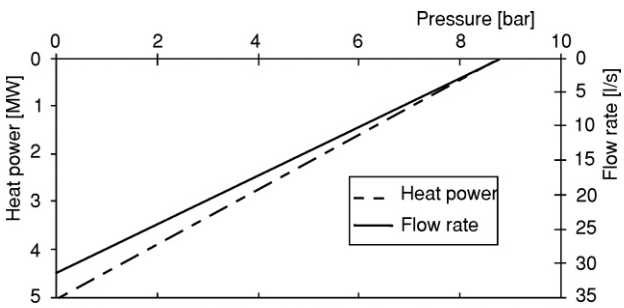

Figure 1. Flow rate and heat power dependence on the degree of dumping (pressure)

Minimum temperature at the outlet of the heat exchanger is 37 C in order to pressure biological stability of the thermomineral water, *i. e.* in order not to come to the system biopollution.

Nowadays, geothermal potential of the deep boring B-4 is used as follows. PVC pipeline takes to the hotel 5-6 l/s of geothermal water with the temperature at 75-76 C. In the exchange sub-station (plate exchangers) a part of the geothermal water energy

Boring B-4 (1991)

Boring B-4 (today)

is given over to the hotel building. The above-mentioned flow rate of the geothermal water is sufficient for the heating of the entire hotel. Only on extremely cold days, the additional heating is necessary.

It should be noted that the entire primary part of the hotel heating has been done in the double installation version – at a given moment, only one pipeline and one exchanger are active, while the other ones are in reserve or under repair. Due to the chemical composition of geothermal water and having in mind the length of the primary pipeline, double installations are logical solution.

Geothermal water shows great inclination towards sediment formation in pipelines. Experience of the maintenance service has shown that in a year, the installation walls become covered by deposits of calcium carbonate – aragonite a few centimeters up to about 20 centimeters thick [4].

Chemical composition at geothermal water from boring B-4

Table 2 (see on next page) shows the examination results of the geothermal water chemical composition with the dates of examinations.

Regarding the tendency towards stone deposits and corrosive action of the water, Langelier's saturation index and Ryzner's stability index (estimation of the tendency towards calcium carbonate deposits on metals) are used [3-7]. The obtained values for Langelier's index and Ryzner's index were L. I. (1.25-1.85) and R. I. (4.10-4.78), respectively.

Positive Langlier's index value (tab. 3) shows that the examined water is not aggressive, does not dissolve the protective calcium carbonate layer (deposited on the pipes walls), shows no tendency towards corrosion. Ryzner's index shows that the examined water has an obvious tendency towards carbonate deposits. These methods take into consideration only carbonate, bicarbonate, and carbon acid content in water, while the influence of other factors in neglected [1, 3, 7, 8].

Table 3. Measured pH values and calculated Langlier's and Ryzner's index values

	13. 11. 1990	07. 04. 2004	17. 09. 2004	13. 10. 2004	03. 11. 2005
Temperature	75	75	75	78	75
pH	7.13	7.4	7.4	7.8	7.6
pHs	5.88	6.09	6.023	5.95	6.05
L. I.	1.25	1.31	1.377	1.85	1.55
R. I.	4.63	4.78	4.646	4.10	4.50

Table 2. Geothermal water chemical composition

	Unit	MAC*	24. 04. 1990	13. 11. 1990	17. 09. 2004	13. 10. 2004	03. 11. 2005
Sodium	mg/dm^3	150	1057	1083.17	1065	1050	1017
Calcium	mg/dm^3	200	44.04	60.06	43	48	42
Magnesium	mg/dm^3	50	19.42	24.27	12	10	15
Bicarbonates	mg/dm^3	–	3000	3000	3111	3050	2867
Chlorides	mg/dm^3	200	58.0	56.0	125.0	145	125.0
Sulphate	mg/dm^3	250	73.6	76.8	–	54.8	56.4
Phosphates	mg/dm^3	0.15	0.4	–	–	0.14	0.10
Ammonia	mg/dm^3	0.1	0.04	0.1	0.03	0	0
Iron	mg/dm^3	0.3	0.60	0.57	0.15	0.25	–
Total hardness	°dH	–	10.64	14.0	8.74	9.10	9.41
Permanent hardness	°dH	–	–	–	2.69	1.96	1.12
Dry reside	mg/dm^3	–	3055	3060	–	2994	2992
m-alkality	cm^3/l 0.1 M HCl	–	520	497	510	500	470
Electro conductiviti	μS/cm	1000	3955	3006	4608	4420	4620
Turbidity	NTU	–	5.0	2.1	0.97	0.48	0.78
Potassium	mg/dm^3	12	58.3	46.84	–	–	31.5
Copper	mg/dm^3	2	0.006	0.007	–	–	0.04
Zink	mg/dm^3	3	0.008	0.011	–	–	0.025
Cadmium	mg/dm^3	0.003	0.0005	0.0005	–	–	<0.009
Nickl	mg/dm^3	0.02	–	–	–	–	<0.04
Mercury	mg/dm^3	0.001	0.0002	0.0002	–	–	–
Lead	mg/dm^3	0.01	0.01	0.005	–	–	–
Fluor	mg/dm^3	1.2	2.28	2.28	–	–	–

* max. allowed concentration

Stainless steel C4574 has been used, which, as experimental examinations in literature have shown, has lessened tendency towards corrosion in geothermal installations.

Technological scheme of the pilot plant

Figure 2 shows the technological scheme of the pilot plant, drying plant for fruit and vegetable drying, which uses geothermal water heat energy. The pilot plant is placed in the exchange station at the Gejzer hotel in Sijarinska spa. From the feeding pipeline connected to the boring B-4, geothermal water with temperature 72 C (heat pipeline from the boring B-4 to the hotel is about 500 m long, which causes the drop in temperature from 75 to 72 C, is introducted into a pipe exchanger with the cover plate filling. At the exchanger outlet, water temperature is 63 C. It is taken trough a return pipeline to the canal. Fresh air at 23 C temperature is blown by a fan trough the heat exchanger filling. At the outlet of the exchanger, air temperature is 53 C and it is taken into drying plant through a conic shape canal. At the outlet of the drying plant, air temperature is 24 C.

Cover plate filling surface of the built in exchanger is 11.1 m^2, so it can accept larger quantities of carrot for drying in one cycle.

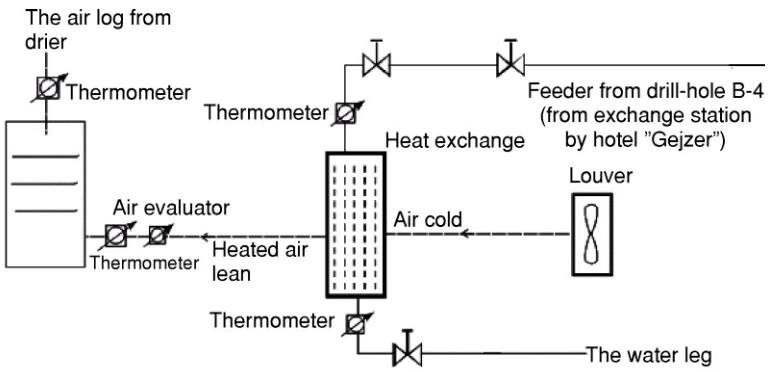

Figure 2. Technological scheme of the pilot plant

Previous calculation of the pipe heat exchanger with the cover plate filling

The calculation has been made for the following parameters of carrot drying:
- drying temperature, t_2 – 53 C,
- drying time (cycle) – 4,5 h,
- drying plant capacity – 15 kg/cicle,
- moisture content for the raw material-carrot – 93,7%, and
- moisture content for material at the end of drying – 11,8%.

Drying plant

Moisture quantity taken away in one drying cicle:

$$m_r = 15(0.937 - 0.118) = 12.285 \text{ kg}$$

Moisture quantity taken away in an second:

$$m_r \quad \frac{12.258}{4.5 \quad 3600} \quad 0.00075833 \text{ kg/s}$$

Latent heat needed to take moisture out of the material, according to Rebinder, Krisher, and Kye, r = 4000-10000 kJ/kg. We accept the latent heat of the carrot, r = 6000 kJ/kg.

Heat quantity needed:

$$Q = m_r r = 4550 \text{ W}$$

Specific heat of air, c_p = 1200 J/kgK.

Outer air temperature, $t_1 \quad 24 \quad \text{C}, \quad r \quad 53 \quad 24 \quad 29 \quad \text{C}.$

Air flow needed:

$$m \quad \frac{Q}{c_p \quad t} \quad 0.130 \text{ kg/s} \quad 470.69 \text{ kg/h}$$

Exchanger

The necessary geothermal water flow trough the exchanger is calculated from the following balance of geothermal water $\dot{Q}_{\text{gv}} \quad \dot{m}_{\text{gv}} \quad c_{p\text{gv}} \quad t_{\text{gv}}$ where indexes gv relate to geothermal water, $t_{\text{gv}} = 72 - 63 = 9$ °C. V is the pipe volume of the heat exchanger length unit and it is equals to $V = \quad a\, b\, l = 0.0263$ dm^3, where a = 14 mm and b = 6 mm are halfaxes lengths of the ellipse pipe cross-section. From the previous equation, it follows:

$$\dot{m}_{\text{gv}} \quad \frac{\rho V}{t_{\text{v}}} \quad \frac{Q_{\text{gv}}}{c_{p\text{gv}} \quad t_{\text{gv}}}, \text{ and } \frac{V}{t_{\text{v}}} \quad \frac{Q_{\text{gv}}}{\rho c_{p\text{gv}} \quad \Delta t_{\text{gv}}} \quad 0.121 \text{ l/s}$$

In the previous equation, the time is marked with t_{v}.

The geothermal water flow necessary for the pilot plant working is about 0.1 l/s. Figure 1 helps determine the dumping adequate for this flow, which is about 8.5 bar. Geothermal water temperature of the inlet/outlet: $t_1 \quad 72 \quad \text{C}$ and $t_2 \quad 63 \quad \text{C}$.

Mean logarythm temperature difference:

$$t_{\ln} \quad \frac{(t_1 \quad t_2) \quad (t_2 \quad t_1)}{\ln \dfrac{t_1 \quad t_2}{t_2 \quad t_1}} \quad 27.81 \quad \text{C}$$

Velocity of the air flow around the pipes: v = 3 m/s.

Coefficient of heat transfer from area with exchange to air:

$$\alpha_1 \quad 2 \quad 10\sqrt{v} \quad 19.32 \text{ W/m}^2\text{K}$$

Coefficient of heat transfer from the water to the pipe is accepted as α_2 = 500 W/m^{2}K.

Coefficient of heat conductivity for the pipes (steel) is λ = 35 W/m^{2}K.

Pipe thickness is δ = 2 mm.

Coefficient of heat passing:

$$K = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2}} = 18.58 \text{ W/m}^2\text{K}$$

Exchanger surface neccessary for the exchanger is 4550 W:

$$S = \frac{Q}{K \, t_{\ln}} = 8.80 \text{ m}^2$$

Geothermal water flow necessary for the pilot plant working is about 0.121 l/s.

Technical-technological drying plant parameters

Technical-technological drying plant parameters are as fellows (for carrot):

- fan rotation number is 750/min. and can be regulated from the zero to the maximum value, on the scale from 1 to 10; for carrot it is 625/min.,
- fan electro motor power is 400 W,
- surface of the cover plate filling of the exchanger is 11.1 m^2,
- air velocity and flow rate can be regulated by changing electro motor turn number,

Pilot plant

Experimental drier

- geothermal water flow is regulated by values at the heat exchanger and at the outlet of the exchanger,
- outer air temperature is about 24 °C (the drying plant is in the exchange station so the temperature is almost constant),
- geothermal water temperature at the exchanger inlet is 72 °C,
- water temperature at the exchanger outlet is 63 °C,
- air temperature of the drying plant inlet is 53 °C,
- air temperature of the drying plant outlet is 39.5 °C, and
- number of drying plant is 4 (one more can be added).

Table 4 shows technical-technological optimum values parameters, experimentaly obtained while drying carrot, and theoretical values for drying raspberry, celery (leaves), and parsley (leaves and root).

Table 4. Optimum values parameters for drying carrot, raspberry, celery, and parsley

Goods for drying	Carrot	Apple	Raspberry	Plum	Parsley (leaves)	Celery (leaves)
Initial moisture content [%]	85	86.30	80.33	85	91	92
Final moisture content [%]	6	18	18	20	6	6
Latent heat [kJ/kg]	4000	7000	7000	7000	5000	5000
Necessary heat quantity [W]	4388	6650	6062	6321	5905	5970
Necessary air flow [kg/h]	376.2	570	516	541.8	506.14	511.7
Yield regarding 20 kg raw material	4.2	3.23	4.64	3.60	1.91	1.70

Conclusions

On the basis of the calculation of heat exchanger, with the geothermal water flow of only 0.121 l/s heat power of about 5000 W is achieved, by decreasing geothermal water temperature at the exchanger outlet to 63 °C. For an industrial plant, under the identical conditions of the heat exchange by using geothermal water flow of, for instance 15 l/s, available heat power of 2.5 MW. In the case of the maximum flow rate of 30 l/s, under the same conditions the available power of 5 MW would be obtained.

On the of all above-mentioned, a conclusion can be made that in Sijarinska spa an industrial plant for geothermal water use can be built.

There is an idea to build an exchange station beside the boring B-4 with the maximum capacity, wherefrom heat energy would be transported to further users by chemically prepared water, in order to avoid formation of thick deposits in pipelines.

If the possibility of CO_2 exploitation the quantity of which is 1:4.4 in relation to the water is taken into consideration, then the effects are considerably greater.

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