EFFECT OF VARIABLE FREQUENCY ELECTROMAGNETIC FIELD ON DEPOSIT FORMATION IN INSTALLATIONS WITH GEOTHERMAL WATER IN SIJARINJSKA SPA, SERBIA

by

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In this paper we have examined the effect of variable frequency electromagnetic field generated with a homemade device on deposit formation in installations with geothermal water from Sijarinjska spa. The frequency alteration of the electromagnetic field in time was made by means of the sinusoidal and saw-tooth function. In laboratory conditions, with the flow of geothermal water at 0.015 l/s and temperature of 60 °C for 6 hours through a zig-zag glass pipe, a multiple decrease of total deposit has been achieved. By applying the saw-tooth and sinusoidal function, the decrease in contents of calcium and deposit has been achieved by 8 and 6 times, respectively. A device was also used on geothermal water installation in Sijarinjska Spa (Serbia), with the water flow through a 1" diameter non-magnetic prochrome pipe at 0.15 l/s and temperature of 75 °C in a ten-day period. A significant decrease in total deposit and calcium in the deposit has also been achieved.

Key words: *geothermal water, effect of electromagnetic field, deposit formation in installations*

Introduction

Owing to its availability and harmlessness for the environment, it is expected that geothermal energy will assume a more significant role. When running through pipe installations, geothermal water forms deposits which reduce heat transfer and the inner pipe diameter. One of the options for prevention of this deposit formation is the treatment of geothermal water by means of magnetic field. However, the mechanism of water treatment by means of magnetic field has not been clarified yet. Because of big importance for various industrial processes, it has been the subject matter of numerous studies and there are a lot of hypotheses concerning it [1-6]. In their thorough study on the mechanism of magnetic water treatment, Kozic *et al.* [2] have concluded that the modified crystallization and agglomeration result

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from magnetically modified hydration and Lorentz force effects of magnetic devices. The effects of magnetic water treatment depend on water regime and its contents. Magnetic water treatment is, apart from its simplicity and economic profitability, in compliance with ecological requirements regarding environmental protection. Since calcium carbonate is one of the predominant elements in the deposit, the majority of studies on effect of magnetic field on deposit formation was related to studying the effect on calcium-carbonate precipitation. [1, 4, 7-9]. Calcium carbonate is slightly soluble in pure water, but more soluble when carbon dioxide is present in water:

$$Ca(HCO_3)_{2(aq)} \leftrightarrow CaCO_{3(s)} + CO_{2(g)} + H_2O \quad (1)$$

As the solubility of carbon dioxide decreases with increasing temperature or decreasing pressure, the solution tends to restore the equilibrium (1) by the shift toward calcium carbonate precipitation [4].

Within the physical treatment of water aimed at deposit decrease, in addition to magnetic water treatment, there is information about electric field treatment as well [10]. Choi *et al.* provides a scientific explanation for the operating principle of the electric anti-fouling technology [10].

Sijarinjska spa is located in the south of Serbia and has 18 springs of mineral water of different chemical contents and temperature. Besides its use in the treatment of various diseases, the geothermal water of Sijarinjska Spa is used for heating the "Geyzer" Hotel there. With regard to its total hardness (9.1-10.6 dH), the geothermal water of Sijarinjska spa ranks among the moderately hard waters. This water contains 1017-1083 mg/l of sodium, 42-60 mg/l of calcium and 2867-3111 mg/l of bicarbonate [11].

In this paper we have examined the effect of variable frequency electromagnetic field generated with a homemade device on deposit formation in installations with geothermal water from Sijarinjska spa. The frequency alteration in electromagnetic field was achieved by means of sinusoidal and saw-tooth function. The experiments have been conducted in the laboratory conditions (with the geothermal water flow rate at 0.015 l/s and water temperature of 60 °C through a zig-zag glass pipe in a six-hour period and on the geothermal water installations in Sijarinjska spa (with the water flow through 1" diameter non-magnetic prochrome pipe at 0.15 l/s and water temperature of 75 °C in a ten-day period). After completion of the experiment, the contents of total deposit as well as the amount of calcium in the sedimented deposit have been determined.

To our knowledge, there are no papers dealing with geothermal water treatment with variable frequency electromagnetic field.

Experimental part

Geothermal water

The geothermal water used for examination in this paper was sampled from the B-4 well in Sijarinjska spa. The temperature at the well is 75 °C whereas flow rate is 30 l/s.

Description of the laboratory equipment

Figure 1 shows the apparatus for measuring the effect of variable frequency electromagnetic field on the decrease in deposit formation in laboratory conditions. The experiments have been carried out with the geothermal water at the flow rate of 0.015 l/s and water temperature of 60(±0,1) °C through a zig-zag glass pipe which is 230 cm long and 10 mm in diameter.

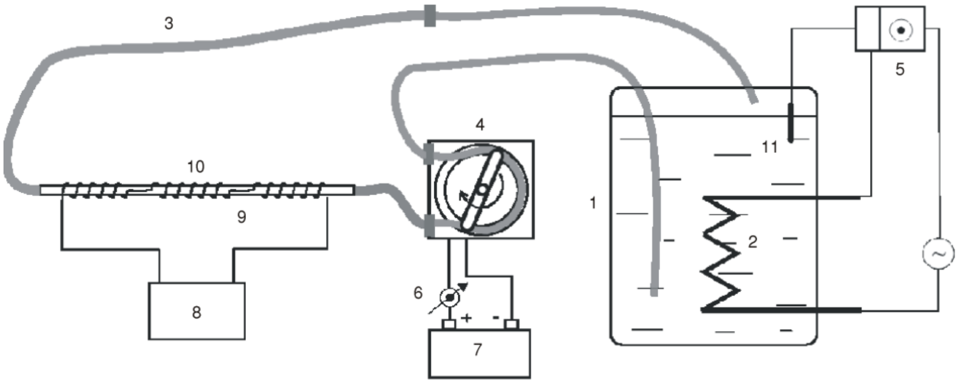

Figure 1. Apparatus for examining effect of variable frequency electromagnetic field on decrease in deposit formation in laboratory conditions
1 – tank with geothermal water, 2 – heater, 3 – hose, 4 – peristaltic pump, 5 – thermoregulator, 6 – potentiometer, 7 – source of power (power supply), 8 – generator of electromagnetic field, 9 – pipe, 10 – solenoid, 11 – temperature probe

The geothermal water flow was enabled by means of Tesa S. A. peristatic pump (Renens, Switzerland). The peristaltic pump revolution has been regulated by means of a Symmetry SK 313 potentiometer with the following characteristics: 400 $W_{max.}$ power, 230 V voltage, and 50 Hz frequency.

Thermoregulation has been done by means of SYMMETRY Thermoregulator SK 302 apparatus (Leskovac, Serbia) with the following characteristics: temperature range of 1-200 °C, 230 V power supply, 50 Hz, 230-2000 V output, and Pt 100 sensor.

The signal for formation of variable frequency electromagnetic field in solenoid was generated in a homemade device. The frequency alteration in electromagnetic field was achieved by sinusoidal and saw-tooth function. The frequency was altered in the range of 200 Hz to 4 kHz. The law of change in sinusoidal function is shown by eq. (2) whereas law of change in saw-tooth function is shown by equations (3a) and (3b).

$$f_{(t)} = f_{(m)}\left[\frac{1+\alpha}{2} + \frac{1-\alpha}{2}\sin\frac{2\pi}{T}\left(t-\frac{T}{4}\right)\right] \tag{2}$$

$$f_{(t)} = f_{(m)}\left(\alpha + \frac{2}{T}t\right) \text{ for } iT < t < (2i+1)\frac{T}{2} \tag{3a}$$

$$f_{(t)} = f_{(m)}\left[1 - \frac{3}{T}(1-\alpha)\left(t-\frac{T}{2}\right)\right] \text{ for } (2i+1)\frac{T}{2} < t < (i+1)T \tag{3b}$$

where t is the time, T = 1, 2 s – the adjustable period; i = 0, 1, 2, 3, ..., n, – the cycle number, $f_{(m)} = f_{min.}$, and $\alpha = f_{max.}/f_{min.}$.

The solenoid was set along the 30 cm long pipe. The solenoid had 353 threads, whose diameter is equal to 1 mm, onto the 12 mm diameter pipe. Solenoid is being excited with alternating current (AC) or by change imulse fervency $f_{(t)}$, where the impulse amplitude may range from i_1 = 0.1 A to i_2 = 0.9 A.

Description of the geothermal water installations in Sijarinjska Spa

Figure 2 shows the geothermal water installations in Sijarinjska spa. A branch pipe with a valve was set off the pipe from the well to which a 1-metre long pro chrome pipe with solenoid was connected.

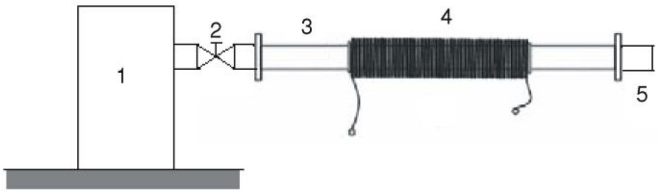

Figure 2. Technological scheme of geothermal water installations in Sijarinjska spa
1 – well 2 – valve, 3 – pro chrome pipe, 4 – solenoid, 5 – geothermal water outlet

Determination of the amount of calcium in total deposit

The amount of calcium in total deposit was determined by means of potentiometric titration using the 848 Titrino plus device (Metrohm ion analysis, Switzerland) with the following parameters: minal incement 10 μl, signal drift 10 mV/minute, equilibration time 52 s, temperature 25 °C, and limit of detection $1 \cdot 10^{-6}$ g/l.

Results and discussion

In laboratory conditions, with the geothermal water flow rate of 0.015 l/s and water temperature of 60 °C for 6 hours through a zig-zag glass pipe by using variable frequency electromagnetic field, a multiple decrease in total deposit has been achieved. Namely, the total amount of deposit in the above mentioned pipe, without water treatment by means of electromagnetic field was 2.07 g whereas the total amount of deposit after using saw-tooth and sinusoidal function was 0.23 g and 0.30 g, respectively. All examinations were done in triplicate and the above mentioned data represent the average values of total deposit.

By using variable frequency electromagnetic field, a multiple decrease in the amount of calcium in the deposit was achieved. Namely, the average value of calcium amount in deposit during the experiment without geothermal water treatment with electromagnetic field was 43.24 mg. The average value of calcium amount in deposit after treatment by means of saw-tooth and sinusoidal function was 5.57 mg and 7.11 mg, respectively. Therefore, the use of saw-tooth and sinusoidal function accounted for decrease in the amount of calcium in the deposit by 8 and 6 times, respectively, compared to the amount of calcium in the deposit without treatment.

After achieving good results in laboratory conditions, the apparatus for generating variable frequency electromagnetic field was also used on the geothermal water installations in Sijarinjska spa with water flow through 1" diameter non-magnetic prochrome pipe with water flow rate of 0.15 l/s and temperature of 75 °C in a ten-day period. Since the saw-tooth function signal proved to be more efficient in decreasing deposit contents as well as calcium amount in the deposit, this function has been applied for frequency alteration in electromagnetic field. The amount of the deposit at 157 g was found in a 1 m long pipe without water treatment by electromagnetic field. The average value (two measurings) of calcium in the deposit amounted at 1422.2 mg. By applying the saw-tooth function in the same pipe, the total deposit amounted at 2 g, whereas the average calcium content in deposit amounted at 17.9 mg. Therefore, a decrease in total deposit and amount of calcium in the deposit as many as 78 times has been achieved by using variable frequency electromagnetic field.

A decrease in total deposit and amount of calcium in deposit achieved in the geothermal water installations in Sijarinjska spa considerably bigger than in laboratory conditions can be explained by different material used for making pipes and different conditions in which the experiment was conducted (pipe diameter, flow, experiment duration). Also, the flow regime of geothermal water in the installation in Sijarinjska spa itself has probably influenced the yield. Namely, there was a turbulent flow regime in these installations caused by high amount of gases (1 l of water contains 4.4 l of gases, mainly carbon-dioxide), whereas in laboratory conditions the examination was carried out on decarbonated geothermal water from the same spring.

The results of the experiment carried out under this work indicate that it is possible to use the described homemade device in order to decrease the deposits in geothermal water installations. To our knowledge, this is the first work that depicts the geothermal water treatment by means of variable frequency electromagnetic field.

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