tHE IMPACT OF THE DEPTH OF A ONE-HOLE GEOTHERMAL HEAT EXCHANGER ON ITS CHARACTERISTICS (Style: “paper\_title\_English (start)”)

Stefan Stefański\*, Marek Markański\*\* (**Style: „a-author”**)

Institution, Department, (**Style: „a-author\_address”**)

al. Piastów 17, PL-70-310 Szczecin, Poland (**Style: „a-author\_address”**)

\*) e-mail: stefan.stefanski@xxx.pl, \*\*) e-mail: marek.markanski@xxx.pl (**Style: „a-author\_address”**)

Abstract: In the paper the authors present a computational model of a deep geothermal exchanger and the characteristics of a geothermal heat energy flux in a ……………. ………………. ………………… …………………….. ………………. ………………… ……………………………….. ……………………. ………………….. ………………….. (**style: “summary\_English (start)”**).

Nomenclature (style: “Nomenclature”)

 – constants,

 – diffusion coefficient of a rock, m2/s,

 – specific heat at constant pressure, J/(kgK),

 – diameter, m,

 – constants, °C,

 – heat transfer coefficient, W/(m2K),

 – length of exchanger, m,

 – temperature, °C,

 – reduced coordinate,

 – thermal capacity of heat flow, W/K,

Greek symbols (style: “Greek symb&Subscripts”)

 – mass density, kg/m3,

 – root of an algebraic equation,

 – thermal conductivity of a rock, W/(mK),

 – difference of temperature, K,

 – difference of temperature (), K,

Subscripts (style: “Greek symb&Subscripts”)

 – the first fluid and the second fluid (in a ring-shaped channel and in the inside
conductor of heat exchanger),

 – *i*- function (*i* = 1, 2),

 – production well,

 – injection well,

’ – the temperature or difference of temperature at input,

1. INTRODUCTION (style: “Heading”)

Winning energy of the earth in order to use it in heat plants and power stations demands appropriate production systems. Their solutions depend on the kind of gained energy. In the case of the geothermal energy the following systems are used: (**style: “Standard\_Text”**)

* two-hole systems with the injection well as well as production well, (**style: “bulleted\_text”**)
* one-hole systems with the injection and production well. (**style: “bulleted\_text”**)

One-hole deep heat exchangers may be used to win the geothermal heat energy. Employing the existing single holes, made during rock oil and gas explorations reduce the total capital cost. Poland is among the countries, which own about thousand closed deep drill-holes (Fig. 1) [5]. (**style: “Standard\_Text”**)

 (**style: “Figure”**)

Fig. 1. Deep wells in Poland [5] (**style: “Figure\_Caption”**)

Drilling the new holes of the appropriate depth is also possible but it increases the capital cost of the installation. (**style: “Standard\_Text”**)

2. computational model of a geothermal heat exchanger
of field's type (style: “Heading”)

The exchanger is located in impermeable rock massif, where temperature changes are linear. Overall heat transfer coefficient through the inside surface  is calculated from known classical formulae. The amount of exchanged heat between water flown through the outside part and the rock deposit is estimated by using a substitute overall heat transfer coefficient , which value changes within time. Values of the substitute overall heat transfer coefficient may be estimated on the basis of the formulae presented in known publications [1].

The thermal field of fluid with appropriate designations is given in Fig. 2.

On the basis of balance equations for a fluid flowing in a ring-shaped channel and in the inside conductor when the equations of heat exchange are taken into account and introducing , , , , , , , , we obtain the following system of differential first-order equations:

 , (**style: „Equation”**) (1)

 . (**style: „Equation”**) (2)

The above equations’ system has been solved by d’Alambert’s method [4] and it can be written as follows [3]:

 , (3)

where: , .

3. calculation results (style: “Heads\_of\_sections”)

3.1. First method (style: “Heads\_of\_subsection”)

The calculations (assuming constant work within 30 days) were done using the presented computational model for the following parameters:

* temperature of a rock massif at the depth 4000 m is 142°C, (**style: “bulleted\_text”**)
* an overall heat transfer coefficient of the inside pipe 0.91 W/(m·K),
* the parameters of a rock: 3.46 W/(m·K), 3200 kg/m3, 1.3·10-6 m2/s,
837.1 J/(kg·K).



Fig. 3. The impact of a volume flow of geothermal water , the temperature of injected water  and the temperature rise between extracted and injected water  on a flux of a gained geothermal heat  (variant without insulation, 4000m)

Table 1. Results of the calculations for the heat exchanger of the length 2870 m when using
different types of the inside pipe insulation (**Style: “Table\_title”**)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. |  |  | Perfect insulation | Air gap | Polyurethane foam |
| m3/h | °C |  |  |  |  |  |  |  |  |  |
| °C | kW | MWh/a | °C | kW | MWh/a | °C | kW | MWh/a |
| 1 | 2 | 10 | 69.98 | 138.03 | 1163 | 64.42 | 124.68 | 1050 | 20.01 | 22.98 | 194 |
| 2 | 2 | 15 | 70.01 | 126.48 | 1065 | 64.53 | 113.35 | 955 | 20.57 | 12.77 | 108 |
| 3 | 2 | 20 | 70.03 | 114.92 | 968 | 64.65 | 102.17 | 861  | 21.08 | 2.48 | 21 |
| 4 | 2 | 25 | 70.04 | 103.39 | 871 | 64.76 |  90.91 | 766 | 21.64 | –7.72 | –65 |
| 5 | 10 | 10 | 44.68 | 400.97 | 3378 | 44.23 | 394.68 | 3325 | 17.39 | 84.96 | 716 |
| 6 | 10 | 15 | 45.63 | 353.73 | 2980 | 45.21 | 347.93 | 2931  | 19.98 | 57.28 | 483 |

4. CONCLUSIONS

The analysis of the graphs shows the following conclusions:

* 1. with the increase in a volume flow of water in a heat distribution network there is the increase in a flux of gained geothermal heat whereas the temperature rise on a geothermal heat exchanger decreases and reciprocally (Figs. 3 – 6), (**style: “numbering\_text”**)
	2. insulation in the top part of a geothermal heat exchanger at the depth, where the temperature of injected water is the same as the temperature of the ground, causes the increment in a flux of gained geothermal heat as well as the increase in a temperature rise of water in a heat distribution network, (**style: “numbering\_text”**)
	3. there is a given boundary flow of water in a heat distribution network (heavy line) below which a flux of gained geothermal heat as well as the temperature rise in a heat exchanger decreases. (**style: “numbering\_text”**)

References (style: “Head\_of\_references”)

1. Diad’kin Ju. D., Giendler S. G.: *Prociessy teplomassopierienosa pri izwlecenii gieotiermalnoj eniergii*, Leningrad 1985. (**style: “References”**) for books
2. Kujawa T., Nowak W.: Shallow and Deep Vertical Geothermal Heat Exchanger as Lower Source of Heat Pumps, *3rd Baltic Heat Transfer Conference*, 1999, pp. 551–559. (**style: “References”**) for conference proceedings
3. Kujawa T., Nowak W., Szaflik W.: Mathematical model of a geothermal Field exchanger, *Archives of Thermodynamics*, 20, No. 1–2 (1999), pp. 39–50. (**style: “References”**) for journals
4. Morita K.: One Possible Way to Utilize Abandoned Deep Wells – the Application of the DCHE, *Technika Poszukiwań*, Vol. 5 (2001), pp. 129–148. (**style: “References”**)

This work was sponsored by the State Committee for Scientific Research, Grant No. KBN 9 T89Z 055 50. (**style: “Acknowledgements”**)

The authors would like to thank Professor D.B. Green of the University of Gobermind. (**style: “Acknowledgements”**)