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DEVICE FOR SIMULATION OF TRANSFER LOW POTENTIAL GEOTHERMAL HEAT WITH HEAT PIPE AND WITH FORCED CIRCULATION OF HEAT CARRIER

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Abstract
This article describes the acquisition of low potential of geothermal energy with vertical ground heat exchangers. This system will be part of the device (simulator) for the transport of low-potential heat. This facility will include U-tube with forced circulation and heat pipes, through which the phase transition in evaporating and condensing section of the tube at temperatures below 0° C will receive low potential energy. The device thus allows the development of research activities in the verified production technology heat pipe suitable for the use of low-potential heat of the earth in a laboratory environment. The content of the paper is the structural design of these devices. The role of the individual components of the device is to allow research thermo-kinetic parameters of transport of heat from the rocks to heat the carrier to transport simulator for low-potential heat. The device allows the physical modeling of heat flow from the rock into the heat transfer fluid.

Keywords: low-potential geothermal energy, ground exchanger, simulator of transport geothermal heat.

1. Introduction

Slovakia as a member of the European Union committed itself to increase a share of energy production from renewable sources up to 20% by 2020. Slovakia adopted a strategy, which states that "sustainable use of resources in Slovakia" should be based on the gradual replacement of non-renewable sources for renewable energy, including a substantial enhancement by using domestic renewable raw materials. The statements mentioned above show that the described activities contribute to meet the commitments of the SR in the field of renewable energy sources.

Appealing to OPVaV-2008/2.2/01-SORO Operational Program for Research and Development - Transfer of knowledge and technology from research and development into practice (ITMS-26220220057), whose strategic goal is "device to use low-potential geothermal heat without forced circulation of the heat carrier in a deep borehole, near the University of Zilina implemented two deep wells (80-150 m) (Fig. 1)". The purpose of these wells is their connection to technology, vertical ground heat exchanger with forced circulation and the technology of gravity U-tube without forced circulation of the heat carrier. Before the realization of this goal, there is a needed for making a prototype of the apparatus for low-potential geothermal energy gain in the comparative test wells in the exterior. With this facility it is possible to compare the innovative heat pipe technology with technology that is commonly used. (R. Lenhard, PCO 2010...)

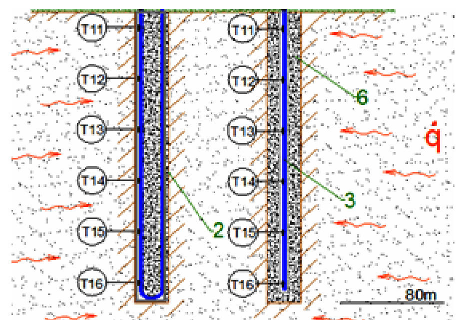


Fig.1: Deep wells technology with vertical ground exchanger (left) and heat pipe (right)

2. Source low-potential energy of earth

The territory of Slovakia is in terms of geothermal energy rated above average. The geological survey has demonstrated a higher geothermal activity in Slovakia, which puts Slovakia into the same position as the countries with an increase in heat flow (64.5W.m^{-2}) than the world average (60W.m^{-2}). Also, the value of geothermal gradient is higher (33 K.m^{-1}) than the world average value (30 K.m^{-1}). Low-potential heat as a kind of geothermal energy is limited to 100 °C.

As a source of heat, there is used groundwater with low temperature and surface soil, in which low-potential heat is based on two factors (Fig.2):

- Flux of solar radiation strikes upon the surface of the Earth,
- Radiogenic heat flow from the center of the Earth.

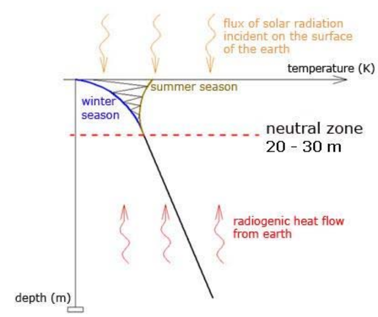


Fig.2: Low-potential heat sources

Seasonal and daily changes of solar radiation intensity and outside air temperature cause fluctuation of temperature on the external layers of the Earth. The Depth of a penetration of the daily fluctuation of the outside air temperature and the intensity of incident solar radiation usually depends on soil and climatic conditions that could vary in the range of several ten of centimeters to a meter and a half. The Depth of a penetration of seasonal fluctuation of the external temperature and the intensity of incident solar radiation usually does not exceed 15 - 20 m. The depth of 20 - 30 m is so-called neutral zone, where the soil temperature is constant. A thermal regime of soil layers located below the depth of the neutral zone is formed by the effect of heat energy from Earth's interior and practically does not depend on seasonal and daily changes in the parameters of the environment. The Temperature of soil with depth increases according to geothermal gradient (about 3 °C per 100 m).The Size of radiogenic heat flow from Earth's interior within various areas is different. For Central Europe the size ranges from 0.05 to 0.12 Wm^{-2}. (R. Lenhard, M. Jakubsky, PCO 2010…)

3. Heat pump

Choosing the appropriate pump depends on several factors. To gain a sufficient amount of energy by pumping from the ground, there is expected to know the needs of heat and cold that a concrete building needs. The Compressor heat pump in the ground - water system works under constant temperature, without any significant changes in pressure, which extends equipment´s life. The Amount of pumped heat depends on several parameters, such as a cutting depth, temperature gradient between the coolant and the wall of borehole, thermal resistance between them, the thermal conductivity of rocks, rocks and the thermal capacity of internal heat loss (heat transfer between the output and the ascending branch of the heat collector in the borehole and the route from wells to house). (R. Lenhard, J. Jandačka, Žilina 2010...).

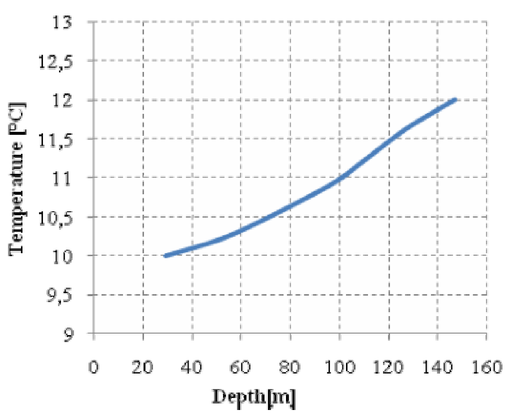
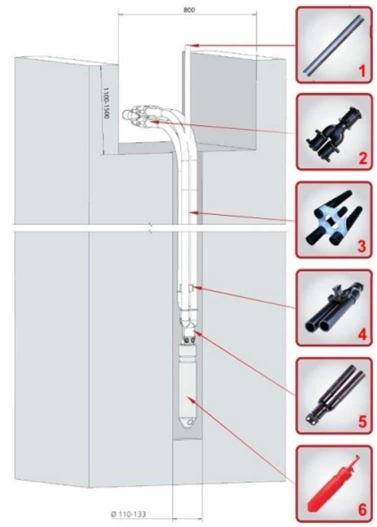


Fig.3. Dependence of temperature on the deep borehole

The Temperature increases with depth according to geothermal gradient of 3 to 4 °C to 100 vertical meters (Fig.3). Below the 30 m, the temperature steadily increases by 1 °C per 32.7 m. At a depth of 3 km is the temperature about 100 °C, at a depth of 10 km for about 300 °C. The Soil temperature from 10 to 30 meters is around 10 °C. The soil temperature around 10-15 m is influenced by seasonal fluctuations. The maximum penetration limit line of sunlight is 15 metres. This all is caused by the thermodynamic principle of heat spread toward the area with lower temperature. The rock massifs in a depth of 15 meters or more under the natural conditions have the temperature higher than the temperature of the overburden. (R. Lenhard, M. Vantúch, Ostravice 2010...)

4. Vertical ground exchanger

It is also called ground probes. PE tubes are formed, that are embedded into the deep wells. Vertical ground exchangers (Fig. 4) use low-potential thermal energy from soil depths deeper than the neutral zone (20-30 m). It is easier to achieve a higher energy effect by them than the horizontal ground exchangers. The Vertical heat exchangers are not really vast and dependent on the solar radiation reaching the Earth surface.



1. Pressure grouting of the borehole
2. Reduce the number of branches from the PE
3. Distance part of DIHA
4. CENTRIFIX
5. Return bend
6. Weights for the GVS

Fig.4. A vertical ground exchanger in a deep borehole (Handbill – GEROtop, Vystrojení vrtu pro tepelná čerpadla.pdf)

However, in comparison with the horizontal heat exchangers, they are much more expensive. The Horizontal heat exchangers are able to work in any kinds of soil, except the soils with low conductivity, dry sand and gravel. The field of its application is wide. The Depth of vertical wells is from 50 to 200 meters, where the polyethylene tube circulates heat carrier fluid. The most widespread is heat exchanger U-type and coaxial heat exchanger. U-type heat exchanger contains two parallel tubes that are connected at the bottom. One or two (sometimes three) pairs of such tubes are placed in one of the wells. The advantage of such schemes is relatively low-cost production (Fig. 5 and 6).

Fig.5: A vertical ground exchanger in deep borehole

Fig.6: A vertical ground exchanger in deep borehole

5. Design heat pipe for acquisition low-potential geothermal heat without use of forced motion heat carriers

Into The Borehole will be embedded the heat pipe designed for this type of exploitation of the Earth's heat and will be designed to suit the conditions of Earth's massif. Several places at the heat pipe, fluid temperature will be sensed by temperature sensors located on its surface. After placing the tube into the borehole, the tube will be put in a mixture of bentonite.

The main problem is to design the heat pipe. Taking into consideration the size of the heat pipe (HP) and its length, it is necessary to consider several factors:

- all-metal construction of the heat pipe would be technically very complicated, regarding difficult conditions
- to design a filling tube system for the performance of the medium,
- a need to ensure the smooth tube placement into the ground and its connection to the heat exchanger on the surface of the ground.

The Heat pipe itself (Fig.7) consists of a heat exchanger and polyethylene body.The Connections between the components must be perfectly sealed up (gastight). On the top of the HT is connected with the filling system of HT. The Pressure vessel filled with CO2 (or NH3) is connected with the drain valve on the heat pipe. Both loops are separated by ball valves. The air Pressure gauge on input informs about the pressure in the tube. Along the side of the tube will be mounted temperature sensors that are connected to a PC, to subsequently process the information. The heat pipe will run a phase transition of working medium in heat gradients resulting a natural (gravitational) circulation media, while the transport of heat exchanger in the ground marking the top of the heat pipe.

5.1 Working medium for heat pipes

- Working medium CO2 (R 744)

During the last decade of CO2 (R 744) research, this medium has been investigated in dimension as working fluid for various applications. For example, a heat pump for a hot water heating, an air conditioning in the car and so on. The CO2 heat pipes used as a heat carriers from the soil to a heat exchanger for a heat pump, where the absorption of heat happens beyond the critical pressure (temperature-level is around 0 °C).The saturation vapor pressure of CO2 is from 4 to 12 times greater than the conventional use of refrigerants.

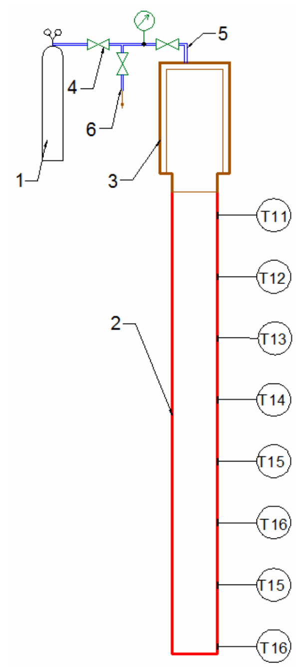


Fig.7: Proposal for a heat pipe
[1 - Pressure vessel filled with (CO2 or NH3), 2 - heat pipe (plastic body PE), 3 - Metal upper part - HE heat pipe, 4 - ball valve, 5 - inlet pipe filling mixture, 6 - vacuum pump connection]

- Working medium NH3 (R 717)

NH3 (R717) is from a thermodynamic point of view very effective working substance (Fig. 8). The disadvantage is the flammability, an explosiveness and a toxicity, therefore, applicable particularly in the systems with indirect (secondary) distribution. Its molecular weight is 17.031 g / mol. The melting in the isobaric pressure is -77.73 ° C is the boiling point -33.34 ° C.

6. Device for simulation of transfer low potential geothermal heat

The Geothermal heat transport simulator serves to simulate the different heat flows corresponding with the heat flow in the deep borehole The simulator sets different sizes of the heat flows along with the different sizes of the height of the simulator. To the simulator are connected devices for a transport simulating of heat from deep borehole into the heat transfer fluid used for heating by availing a forced circulation of the heat carrier (Fig. 4) or without the forced circulation of the heat carrier (Fig. 7). The Equipment using a forced circulation heat carrier responds to the currently used constructions of equipments to transport the heat from a deep borehole. The device without the use of a forced circulation heat carrier is based on the use of heat pipes to transport the heat from a deep borehole with different working substances (CO2, NH3).

6.1 Construction of device

The Outer construction of the cylinder represents a bore with the surrounding soil environment (Fig. 8). The construction is barred from the external environment by the reflective insulation foil. The "focus" of all the potential heat of the rocks is put into the heat exchanger, therefore into the well, where the heat is collected by the collectors.

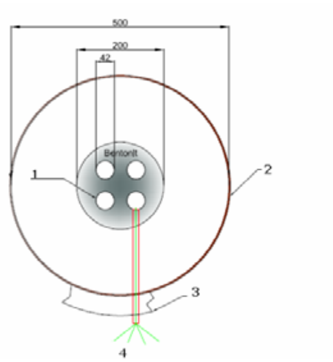


Fig.8 cross-section model of borehole
[1 – Bentonit, 2 – Heating pipes, 3 – Isolation
4 – Thermocouples]

The internal structure is formed by an annulus area, which filled with the soil, that the geological composition is identical with the location of the wells. On the basis of the known diameters and the heights, it is possible to calculate the volume of space of annulus. After a suitably chosen average density of soil massif, the substantiality is obtained, which has to be taken into consideration while making the design. Fig. 11 shows a device that an inner part is formed by four PE tubes ending with the ground probe. It is a system with a forced circulation. The second device is structurally identical with the exception of heat removal system, where instead of PE U-tubes the heat pipe is used. Such a system is without the forced circulation.

The top of the device is covered by the cover that concludes the whole device. However, allowing an excess of the heat pipes, with the heat exchanger mounted to them. The cold water flows into the exchanger, the water washes a heat pipe and increases its potential and then flows into a heat pump (Fig. 9).

1 - outer cylindrical shell (D = 500 mm, H = 5000 mm)
2 - base - cylindrical anchoring device
3 - construction of an anti-roll deflections (H ≥ 5000 mm)
4 - internal parts

Fig.9 External and internal simulator structure

7. Engaging devices for heating circuit

The Diagram (Fig. 12) consists of 3 separate external circuits. Each circuit contains of the following elements: a thermostat, a pump, and a thermostatic control, 2 x thermometer, 2 gauges, a drain valve and a flow meter. Three lines allow dividing the model well into 3 sections with different temperature, the highest one at the bottom, and the lowest one at the top of the borehole. By this way it is possible to emulate the soil temperature at the various depths. The Involvement of circuits allows switching the lines into one single circuit by means of three-way valves.

8. Discussion

Designed equipment (simulators) of heat transport enables a valid comparison with the thermal power transmitted from the hot rocks by U-tubes and the heat pipe with the thermosiphon effect under the same conditions. This problem is not possible to solve within the classical borehole, because the borehole rock characteristics are different to each other. That simulator is suitable for the testing to determine the potential of geothermal heat well. Based on the given parameters of the rocks (thermal conductivity, a capacity, moisture rocks) is possible during the testing of potential well to verify the measured heat output (from the temperature difference and a flow of the liquid) and find the relationship between the rock properties in the borehole and its temperatures.

9. Recommendations

The designed simulator should be used to test a heat pipe structure and to optimize a heat pipe filling. The Simulator with a conventional U- tube heat exchanger serves as a reference model. The advantage of the simulators is the ability to change temperature parameters of the rock and characteristics of the rock (mineral).

10. Conclusion

This paper describes the construction design, the scheme and the involvement of the simulator, located in the laboratory. Its task is to verify the acquired knowledge, technology solutions, and processes and apply them in real life deep boreholes. The device to simulate a low transformation potential of geothermal energy to heat allows to imitate the processes occurring in borehole. By examining these processes in laboratory conditions it is about to obtain knowledge on the best heat transfer fluids, an exercise, a heat transfer, a conduction of the soil etc. Final task is to compare the two technologies using this device.

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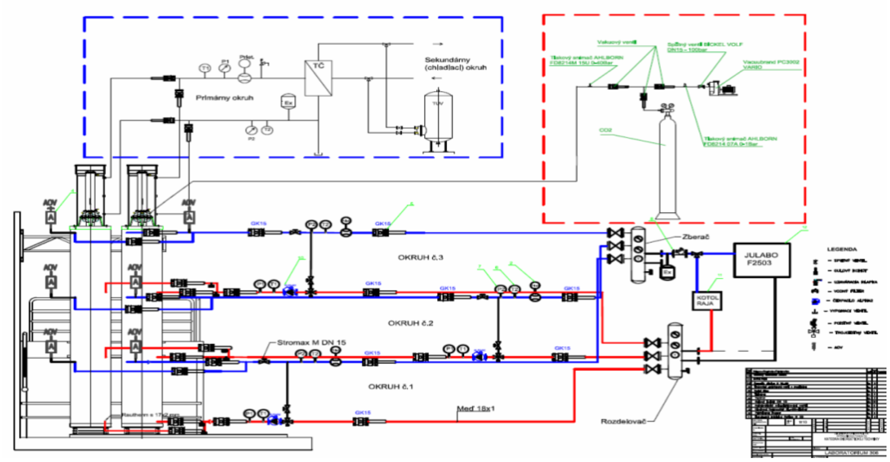

Fig.10: Equipment wiring diagram