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Study of regularities of changes in the temperature near the *U*-shaped ground heat exchangers

The article considers the results of a study heat transfer process is in ground heat exchangers, used for geothermal heat pumps. At the research facility performed experiments and calculations, confirming about the best of thermophysical indicators of moistened of sand. The experimentally determined the temperature distribution regularities in a neighborhood *U*-shaped of underground heat exchangers.

Key words: renewable energy, heat pumps, underground heat exchangers, the temperature distribution.

At the use of the low potential renewable energy of ground via of geothermal heat pumps for heating and cooling of buildings with one of the main elements is a underground of heat exchanger. Analysis of different types of ground heat exchangers showed that the best thermal and operating characteristics possess of the heat exchangers installed in vertical wells, which in tubes circulates low interest ethylene glycol solution as antifreeze [1, 2].

The vertical ground heat exchanger efficiently works practically in all types of geological environments, except for soils with low heat conductivity, for example, of dry sand or dry gravel. The systems with the vertical ground heat-exchanger do not require the areas of large area and does not depend on intensity of solar radiation falling on a surface. The systems with the vertical ground heat-exchangers got very wide distribution [3–5].

In works [6–8] a mathematical model and experiment, offered extraction of geological heat vertical heat exchangers. Studies of process of freezing of ground undertaken by means of smooth and finned thermal pipes. However, authors hired for research of heat exchange use not polyethylene pipes.

The main advantages of polyethylene pipes are: high durability and inflexibility allow pipes to maintain intrinsic pressure to 1,6 MPa and external loading of soils; resistance to chemical influence of aggressive soils and chemicals; the low coefficient of elastic modulus of material allows to reduce the maximal size of dynamic pressure during hydroblows; there is not necessity of external isolation of pipelines from corrosion and arrangement of electrochemical protection; flexibility, inflexibility, lıght weight and high impact resistance facilitate installation, reduce expenses; the calculated serviceable life of polyethylene pipelines makes 50 years [8].

Bearing in mind the foregoing characteristics of polyethylene pipes and irresistibility of metal pipes to chemical influence of aggressive soils and chemicals, we consider actual use of polyethylene pipes in creation of heat exchangers.

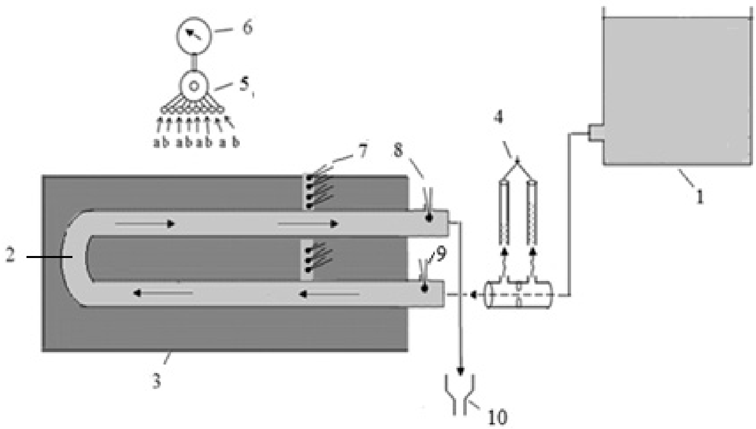
The main purpose of the work is research of heat exchangers of tubular elements of ground heat exchangers. For gaining of the purpose it is necessary to define dependences of temperature distribution in soil in the vicinity of the pipe, and also to get change of temperature on time in dry and wet soils.

The parameters of the heat-exchange setting of type are examined «ground-water» for research of heat exchange an experimental way: expense of cold streams and difference of temperature of the chilled soil by means of thermal pipes. For this purpose it is necessary to develop and create the experimental unit, to carry out experiments of the main characteristics of process of heat transfers.

Border terms for the calculation of experiment: input temperature of cold water t_{input} = 10 ^{o}C, soil temperature on the site of the studied pipe input t_s = 23 ^{o}C. An ambient temperature made 23 ^{o}C.

For the achievement the purpose set at the laboratory of hydrodynamics and heat exchange the experimental stand for model operation of process of heat exchange in heat removable elements of heat pump in soil water systems was assembled.

The experimental stand is shown in figure 1.



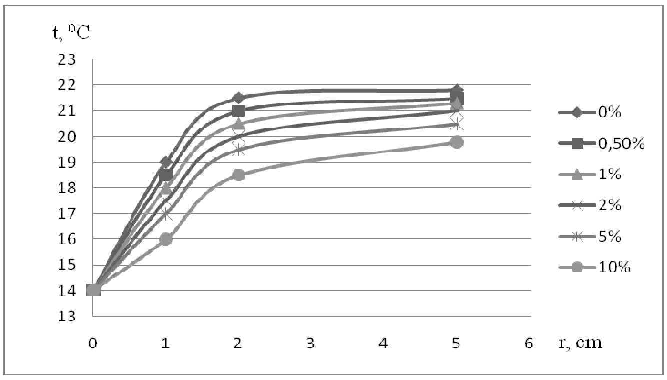
1 — a tank with water; *2* — a pipe; *3* — heat-section of with the ground; *4* — differential manometers;
5 — switch is thermocouples; *6* — potentiometer for measuring the EMF of thermocouples;
7 8 9 — thermocouples; *10* — municipal sewer spill pipe

Figure 1. An experimental stand for the simulation of heat transfer in heat pulling elements of the heat pump for systems of «ground-water»

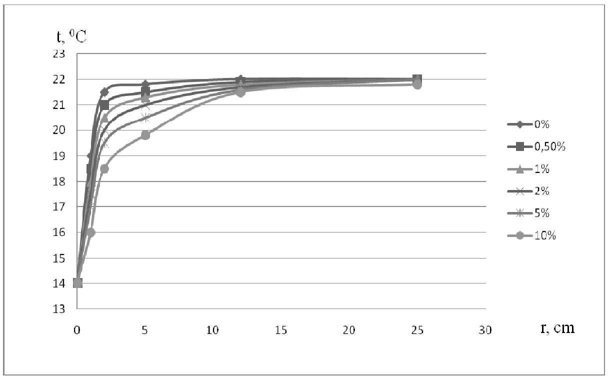
The stand consists of two contours: 1) the internal contour with heat removable pipe of the heat pump; 2) the external contour of the heat giving site with sand. The internal contour with heat removable pipe of heat pump consists of thermostat, flow-measuring washer, heat removable site and differential pressure manometer. External diameter of a heat removable pipe of heat pump is 32 mm, thickness is 3,5 mm. At the beginning and at the end of the studied pipe thermocouples are installed. The external contour includes heat-transmitting site with soil in the form of the cylinder with a diameter of 600 mm. Also the system comprises the switch of thermocouples, thermocouples, potentiometer for the EMF of thermocouples and the tap of adjustment of expense of the heat carrier.

Carrying out experiment. Cold water from the tank enters to the heat removable pipe of the heat pump. The consumption of cold water is regulated by the tap, and the differential pressure manometer shows the speed of the arriving liquid in the heat removable pipe which is located on the center of the cylindrical module with a length of 5m filled with soil. The tank imitates a well which is filled at first with a dry soil, and then it is humidified at the different percentage by water mass. Percentage of water weight in sand made 0,5%, 1%, 2%, 5% and 10%. For monitoring of temperatures the thermocouples attached to the ruler at different distances from the pipe surface are installed. They show distribution of temperatures in soil in the vicinity of the pipe. Experiments were made in the site where there is hydrodynamic stabilization of liquid.

The parameters of heat transfer are determined by the obtained experimental data and the schedules of dependence shown in figures 2 and 3 are constructed.



a)



b)

Figure 2. Schedule of temperature dependence on radius: a) - 0≤r≤5 cm; b) - 0≤r≤25 cm

In figure 2 the graphic changes of temperature are represented at different radial distances. From the schedule it is visible that at the closest distance of 0 – 2 cm change of temperature in different humidities of soil is parallel as the diameter of the cylinder changes to 6 cm temperature increases. In some moment the temperature of the soil is equated to ambient temperature. From figure 3 it is seen that distribution of temperature in the soil decreases relatively from distance which is counted from the pipe surface. It is known that heat conductivity sharply increases in the process of increase in humidity of soil as heat conductivity of the air which is forced out by water from rock pores is about 30 times less than heat conductivity of water.

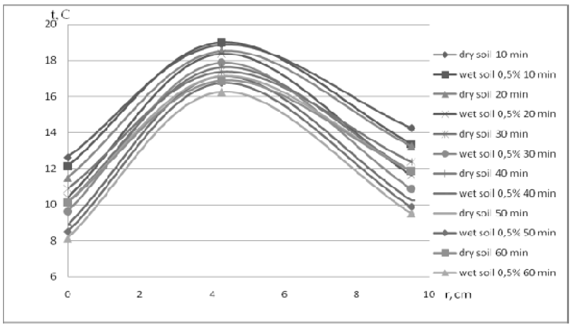


Figure 3. Changes of temperatures in the sand between the U-shaped tube of the heat exchanger

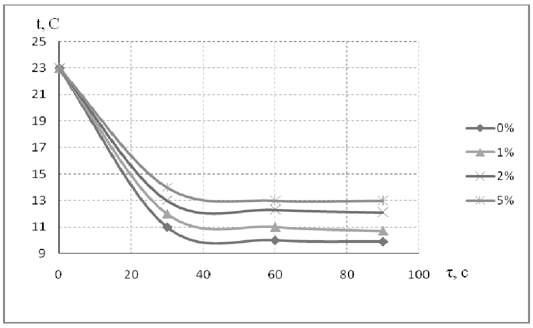


Figure 4. The change in temperature by time

Figure 3 shows the change in temperature across the sand moisture between the U-shaped heat exchanger tubes. The incoming flow of liquid temperature varies more than in the tube with the opposite direction of the fluid.

From schedules in figure 4 we see that the difference of temperature of soil decreases with increase of humidity. In figure 4 dependence of temperature of soils with various humidity on time is shown. In dry soil temperature changes by about 12 ^{o}C per hour, and in the wet soil only by 7 ^{o}C and 9 ^{o}C. From this it follows that the wet soil increases heat removal.

As now there are no heat exchangers for extraction of heat from soil, such systems have to be designed for each concrete object separately. It should be noted that from the point of view of thermal physics the soil is the quite composite system.

By means of experiment studies on stands the dependences of temperature change of dry and wet soils on time and distribution of temperatures in soil in the vicinity of the polyethylene pipe used as heat removable elements of the heat pumps. The carried out experiments confirmed that on dry soil change of temperature will be more, than on the wet. It gives the chance of application the wet soil as filler of wells of ground heat exchangers.

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U-тәрізді жер асты жылуалмастырғыштары маңындағы температураның өзгерісін зерттеу

Мақалада геотермалды жылу сорғыларында қолданылатын жер асты жылуалмастырғыштарындағы жылуалмасу үдерістерін зерттеу нәтижелері қарастырылған. Зерттеу қондырғысында тәжірибелер жүргізіліп, ылғал құмның ең жақсы электрофизикалық параметрлерін дәлелдейтін есептеулер келтірілген. *U*-тәрізді жер асты жылуалмастырғыштарының маңындағы температуралардың таралу заңдылықтары тәжірибелер жүзінде анықталды.

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Исследование изменения температуры в окрестности *U*-образного грунтового теплообменника

В статье рассматриваются результаты исследования процесса теплообмена в грунтовых теплообменных аппаратах, используемых для геотермальных тепловых насосов. На исследовательской установке проведены эксперименты и выполнены расчеты, подтверждающие лучшие теплофизические показатели увлажненного песка. Экспериментально определены закономерности распределения температуры в окрестности *u*-образного грунтового теплообменника.

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