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(54) GEOTHERMAL SYSTEM

(57) The present invention belongs to the field of energy and heat exchange and relates to the use of geothermal energy for heating and cooling applications by means of a geothermal system comprising

at least one geothermal cistern (1, 1A, 1B) configured for being buried in the ground, the cistern (1, 1A, 1 B) exchanging heat with the ground;
each cistern (1, 1A, 1B) comprising a perimetral surface (1.1), said perimetral surface (1.1) comprising a first opening (1.1.1) and a second opening (1.1.2),
a first pipe (2) coupled to the first opening (1.1.1) of at least one cistern (1, 1A, 1B), the first pipe (2) having a first end (2.1) located at a lower part of said cistern (1, 1A, 1 B);
a second pipe (3) coupled to the second opening (1.1.2) of at least one cistern (1, 1A, 1B), the second pipe (3) having a second end (3.1) located at an upper part of said cistern (1, 1A, 1B);
a geothermal heat pump (5) coupled to the first pipe (2) and to the second pipe (3).

Two or more cisterns may be connected either in series or in parallel.

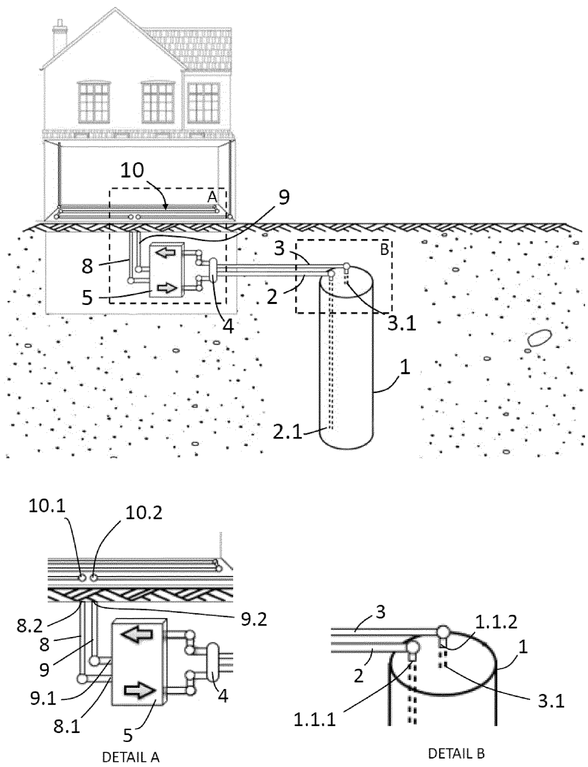

FIG. 1

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention belongs to the field of energy and heat exchange. More particularly, the present invention relates to the use of geothermal energy for heating and cooling applications in predetermined spaces.

BACKGROUND OF THE INVENTION

[0002] Geothermal energy is related to the energy stored in the Earth crust. Unlike most clean renewable energy sources, geothermal energy is constantly available and is regarded as the most abundant source of energy.

[0003] Since prehistorical times, humans have taken advantage of geothermal energy by finding shelter in caves. Thermal energy stored in the ground maintained very stable temperatures in the interior of the caves. Homes were also excavated inside the Earth allowing humans for stable temperatures that felt warm in the winter and cool in the summer.

[0004] At a later stage, linked to the use of heat pumps, thermal energy begun to be extracted from the ground and conducted into homes and buildings of every sort both, for heating and cooling purposes.

[0005] Current geothermal systems are mostly independent, single-home closed loop systems. They consist of pipe lines laying horizontally at a depth of 2 to 3 meters underground, covering an area of approximately 3 times the size of the surface to be heated or cooled. This is what is called a horizontal loop system.

[0006] Another common geothermal system is a "U" shaped pipe installed perpendicularly into the ground. This is known as vertical loop system. In order to insert the pipe in a vertical loop system, excavation of a deep borehole of approximately 80-150 meters is needed. Often, in order to enhance thermal conductivity between the ground and the buried pipe, a clay/cement-like filler is inserted into the borehole. Disadvantageously, the likelihood of altering and contaminating aquifers is high when using this technique.

[0007] Another less common system, due to availability and regulatory restrictions, is based on performing the temperature exchange into an open body of water (known as open loop system), such as a lake or river.

[0008] Hot springs and geysers are normally utilized as a continuous source of heat. Energy companies use this thermal energy to generate electricity at an industrial level. In some cases, industrial plants achieve capacities over 500 MW. In total, it is estimated that approximately 8% of the electricity in the world is generated by geothermal energy.

[0009] The scope of the present art focuses on obtaining thermal energy accumulated overtime in the earth crust as a result of its exposure to the atmospheric temperatures and solar radiation. This process of obtaining thermal energy from the ground by exchange of thermal energy is also known as earth-coupling.

[0010] Prior art installations face financial and physical challenges. Sometimes, the installation-payback requires many years and the hefty up-front costs are not widely available for financing unlike it occurs with other more popular green energies such as solar energy.

[0011] The large space required for installation or the hardness of the ground at certain depths make some installations physically impossible to install. Trench and boring costs in prior art systems normally represent about half the total cost in a typical geothermal installation.

SUMMARY OF THE INVENTION

[0012] The present invention provides a geothermal system according to claim 1, a method for heating a space according to claim 11, a method for cooling a space according to claim 12 and a method of installing a geothermal system according to claim 13. The dependent claims define preferred embodiments of the invention.

[0013] The geothermal system of the invention allows the heating and/or cooling of spaces based on temperature exchange between a fluid contained in an underground cistern and the ground surrounding said cistern. Proximity between the space to be heated or cooled by said geothermal system is desirable so that excavation costs are minimized. Occasionally, cisterns may be buried underneath a building, and in case it includes a basement, excavation synergies may be created.

[0014] Moreover, the methods of the present invention refer to the heating and/or cooling of said space, which is close to the area where the cistern is buried, as well as to the method of installation of the geothermal system such that it allows the performance of said heating and/or cooling of the predetermined space.

[0015] In a first inventive aspect, the invention provides a geothermal system comprising:

- at least one geothermal cistern configured for being buried in the ground and to exchange heat with the ground, each cistern comprising a perimetral surface, said perimetral surface comprising a first opening and a second opening;
- a first pipe coupled to the first opening of at least one cistern, the first pipe having a first end located at a lower part of said cistern;
- a second pipe coupled to the second opening of at least one cistern, the second pipe having a second end located at an upper part of said cistern;
- a geothermal heat pump coupled to the first pipe and to the second pipe.

[0016] Each of the cisterns is configured by means of the perimetral surface, which provides a continuous wall that houses a cavity configured to contain a first fluid. During its use, said first fluid, contained inside the cistern, exchanges heat with the ground through the continuous wall formed by the perimetral surface.

[0017] When the geothermal system is installed, each of the cisterns is buried in the ground, preferably at a depth larger than 2 meters. Ground temperature at this depth at subtropical zones of the Earth is approximately 50 degrees Fahrenheit or 10 degrees Celsius constantly throughout the year.

[0018] The aim of the present invention is to create a convenient system to reliably provide a first fluid to a geothermal heat pump at a temperature similar to the ground temperature at depth of about 2-3 meters. To achieve this, the present invention utilizes at least one cistern to either heat or cool the first fluid coming out of the geothermal heat pump until it achieves a temperature similar to the temperature of the ground where the cistern is located. The first fluid contained in the at least one cistern conveniently circulates through the first and second pipes, into the geothermal heat pump in alternative directions depending if the objective is to provide heat or cool to the space subject to climatization. The movement of said first fluid renovates said first fluid contained inside each cistern, which, in contact with the ground through the perimetral surface, exchanges heat with said ground by means of conduction processes, whilst, simultaneously, heat is also exchanged inside the cistern and convection occurs within the first fluid inside the cistern, implying the circulation of the first fluid therein. The present invention takes advantage of fluid temperature stratification created by the convection inside the at least one cistern to strategically locate the pipes that come and go into the geothermal heat pump in such way that it ensures the temperature exchange is achieved while it optimizes the size of the at least one cistern and the excavation needed.

[0019] The at least one cistern along with the first and second pipes through which the first fluid flows configure a first closed circuit through which the first fluid can circulate.

[0020] Additionally, a second closed circuit comprising a second fluid is configured inside the space to be heated or cooled.

[0021] The geothermal heat pump is defined as a system which comprises:

- a pump, and
- a heat exchanger,
  wherein the first closed circuit is connected with the pump, said pump ensuring the circulation of the first fluid from the at least one cistern up to the heat exchanger.

[0022] Additionally, the second closed circuit is also configured to be coupled with the heat exchanger of the geothermal heat pump.

[0023] In order to heat or cool the defined space, the second fluid exchanges heat with the heat exchanger, which simultaneously exchanges heat with the first fluid drawn up by the pump from the at least one cistern.

[0024] The present invention provides a very cost efficient geothermal system to perform temperature exchange with the ground so that the energy required by the geothermal heat pump in order to heat or cool a predetermined space is minimized.

[0025] Such a geothermal system is configured to be coupled to any heating, ventilation and air conditioning system (HVAC system), which allows such a heating or cooling of a predetermined space, the elements needed for such a heating or cooling of the mentioned space being part of said HVAC system.

[0026] The present invention also allows for energy saving. Similarly to other closed loop systems, the system of the invention can be pressurized in order to facilitate fluid circulation. However, advantageously, the proposed system avoids the need of running fluids over extremely lengthy tubes, thus being more efficient.

[0027] An efficient heating and cooling process using the Earth to exchange temperature is possible by the use of one or several cisterns inserted into the ground at depths preferably larger than 2 meters.

[0028] Thus, as mentioned, during use, the fluid contained in the cistern exchanges heat with the ground surrounding the cistern. Inside the cistern, different fluid temperatures are found more prominently at different areas of the cistern due to the indicated convection process. In particular, fluid at higher temperatures is less dense and therefore it will concentrate at the upper portion of the cistern whilst cooler fluid, at lower temperatures, is denser and will concentrate in the lower part of the cistern.

[0029] For a system having a single cistern, in order to heat a space, preferably a closed space such as a home, the geothermal system of the invention inserts cool fluid at the lower part of the cistern, through the first pipe, while simultaneously extracts fluid from the upper part of the same cistern, through the second pipe. The temperature of the fluid extracted from the cistern would have traveled from the bottom of the cistern onto the top as it gains thermal energy in the mentioned heat exchange with the ground, thus becoming less dense (hotter) than the fluid in the bottom of the cistern. For cooling a space as the one defined, the above mentioned process is reversed and fluid which is to exchange heat with the ground is inserted at the upper part of the cistern and extracted from the bottom. In both cases, the first fluid is circulated from and to the cistern through the first and second pipes, by means of a geothermal heat pump. This geothermal heat pump, as mentioned, may be a part configured to be coupled to a larger HVAC system in any of its multiple forms.

[0030] In an embodiment the cistern is elongated. In this embodiment the cistern is preferably buried with its longest side vertically arranged inside the ground. Advantageously, this significantly reduces the trench and boring costs of the hole to be made in said ground while reducing the amount of terrain needed to be excavated.

[0031] In an embodiment the geothermal system further comprises a valve adapted to operate in a first position and in a second position, the valve being fluidically connected with the first pipe, the second pipe and the geothermal heat pump. Said valve intervenes in the circulation of the first fluid through the first and second pipes, when the pump is in operating mode. Particularly, the valve allows the passage of the first fluid through different paths depending on its position, and thus provides control on the circulation of the first fluid from and to the cistern.

[0032] In an embodiment the first position of the valve allows for the first fluid to enter at least one cistern through the first pipe while extracting the first fluid from at least one cistern through the second pipe, and the second position of the valve allows the first fluid to enter at least one cistern through the second pipe while extracting first fluid from at least one cistern through the first pipe.

[0033] In an embodiment, the valve is a four port directional valve, which provides a different coupling for the first and second pipes, as well as two additional couplings for pipes in order to provide a closed circuit for the fluid.

[0034] In an embodiment the geothermal system comprises two or more cisterns. In this embodiment the first end of the first pipe is located at a lower part of a cistern and the second end of the second pipe is located at an upper part of a cistern. Depending on the configuration, the first pipe and the second pipe may be coupled to the same cistern or to different cisterns. The geothermal system comprises additional pipes to connect the cisterns one to another and/or to the first and/or second pipe to provide a closed circuit. The first pipe, the second pipe and the additional pipes are coupled to the cisterns such that each cistern has a pipe end at its lower part and a pipe end at its upper part.

[0035] For a system having two or more cisterns, the cisterns can be connected in series or in parallel.

[0036] In a series connection the first end of the first pipe is located at a lower part of a first cistern and the second end of the second pipe is located at an upper part of a second cistern. The geothermal system comprises at least one third pipe, each third pipe being arranged connecting two cisterns one to another. Each third pipe has a third end located at a bottom part of one cistern and a fourth end located at an upper part of another cistern, such that each cistern has a pipe end at a bottom part and a pipe end at an upper part and is connected to the preceding and/or following cistern. For a system having two cisterns a single third pipe is sufficient to connect the first cistern and the second cistern. For a system comprising N cisterns, N-1 third pipes are used to connect the cisterns to one another.

[0037] In a parallel connection the geothermal system comprises at least one third pipe and at least one fourth pipe, the at least one third and fourth pipes being connected with a corresponding cistern present in the geothermal system. That is, each third pipe has a third end located at a lower part of one cistern and a fourth end connected to the first pipe, whereas each fourth pipe has a fifth end located at an upper part of one cistern and a sixth end connected to the second pipe. According to such connection, each cistern releases and receives the same volume of first fluid at the same time.

[0038] In an embodiment the at least one cistern contains a first fluid, particularly a liquid such as water. Preferably, the at least one cistern contains a mixture of water and coolant fluid. In an embodiment the coolant is ethylene glycol. Said coolant provides the advantage of being an antifreeze for the pipes when the outer temperatures surrounding the installation are very low.

[0039] In an embodiment, the perimetral surface of the cistern is made of metal, concrete or polymer. Said materials provide of different advantages which are useful depending on construction budget and the characteristics of the ground in which the cistern is intended to be buried.

[0040] Advantageously, a cistern which perimetral surface is made of a metal such as aluminium or stainless steel, has a higher thermal conductivity although it may not be suitable for certain types of soil. A cistern which perimetral surface is made of concrete might be more easily available and cost-effective, whilst a cistern made of polymer is durable and lighter, also having an easy manufacturing process although providing a lower thermal conductivity.

[0041] In an embodiment the perimetral surface of the cistern is made of a material having high thermal conductivity, such as metal (>30 W/m K) or concrete (> 0,7 W/m K). Preferred embodiments for the material of the perimetral surface of the cistern have thermal conductivities equal to or greater than 0,15 W/m K, preferably equal to or greater than 0,7 W/m K.

[0042] In a preferred embodiment the cistern is made of precast concrete which includes an inner metal or carbon fiber mesh to reinforce the cistern structure while enhancing thermal conductivity.

[0043] In an embodiment the perimetral surface of the cistern is made of a polymer, preferably having a thermal conductivity equal to or greater than 0,15 W/m K. Such a polymer might also constitute one of the layers of a cistern made of precast concrete.

[0044] In an embodiment, the geothermal system of the first inventive aspect further comprises:

- a first connection tube comprising a first end and a second end, and
- a second connection tube comprising a first end and a second end,

  wherein the first end of the first connection tube and the first end of the second connection tube are directly connected to the geothermal heat pump, particularly to the heat exchanger of the geothermal heat pump, whilst the second end of the first connection tube and the second end of the second connection tube are configured to be correspondingly coupled to an inlet and an outlet of a fluid circuit present in a space.

[0045] That is, the geothermal system is configured to be coupled with an HVAC system for heating or cooling said space. Such HVAC system may include the piping of an in-floor radiant system, an air conditioning system, a water heater tank, a heat pump or a combination of any of these.

[0046] This way, the space to be cooled/heated is provided with the second closed fluid circuit through which the second fluid coming from the geothermal heat pump goes into the space, already at an adequate temperature which has been obtained from the heat exchange with the geothermal heat pump, particularly with the heat exchanger and indirectly, with the first fluid present in the first closed fluid circuit. Said first closed fluid circuit between the geothermal heat pump and the at least one cistern, sends from the geothermal heat pump a volume of first fluid into the one or more cisterns while receiving the same volume of first fluid that has performed thermal exchange with the Earth crust inside the at least one cistern. The first and second fluids inside both circuits are moved by means of the geothermal heat pump through each of the mentioned circuits in an independent manner. The first closed fluid circuit is connected to the first and second connection tubes by means of their corresponding first ends, whereas the second closed fluid circuit is connected to the first and second connection tubes by means of their corresponding second ends. Therefore, the fluid circuits are created.

[0047] Cylindrical shape is preferred for the cisterns as it significantly reduces the excavation effort while allowing to utilize many medium sized excavation means that are widely available and considered standard for the excavation and construction industries, for example, in the construction of bored piles and shallow wells.

[0048] Therefore, the present invention provides the following advantages:

i. reducing installation costs,
ii. providing a practical solution to many households lacking of physical capacity to install a traditional system
iii. reducing electrical energy required by the geothermal heat pump, which reduces the electrical bill and the size of the infrastructure necessary to operate said geothermal heat pump, and
iv. avoiding environmental damages associated to deep boreholes and large excavations.

[0049] In a second inventive aspect the invention provides a method for heating a space comprising a closed fluid circuit which comprises a second fluid, the heating of the space being performed by means of a geothermal system according to the first inventive aspect, the method comprising the following steps:

a) actuating the geothermal heat pump to simultaneously circulate a first fluid to enter a cistern through the first end of the first pipe and exit a cistern through the second end of the second pipe,
b) exchanging heat between the first fluid and the second fluid in a heat exchanger of the geothermal heat pump, and
c) heating the space by exchanging heat from the second fluid of the closed fluid circuit with said space.

[0050] This method allows providing the geothermal heat pump with fluid at a temperature that reduces the energy required by the geothermal heat pump for heating a space. Providing fluid at a constant temperature is achieved by creating a first and second closed fluid circuits by means of a geothermal system according to any of the embodiments of the first inventive aspect, wherein the geothermal heat pump circulates the first fluid in a first closed fluid loop by simultaneously forcing the fluid to enter a cistern through the first end of the first pipe and to exit a cistern through the second end of the second pipe. Similarly, a second closed loop with a second fluid is created between the geothermal heat pump and the space to be heated or to another machine that takes advantage of the thermal energy provided by the geothermal heat pump.

[0051] In a particular embodiment, the system comprises a valve and the method comprises fixing the valve in a first position, the system thus functioning in the heating mode.

[0052] In a third inventive aspect the invention provides a method for cooling a space comprising a closed fluid circuit which comprises a second fluid, the cooling of the space being performed by means of a geothermal system according to the first inventive aspect, the method comprising the following steps:

a) actuating the geothermal heat pump to simultaneously circulate a first fluid to enter a cistern through the second end of the second pipe and exit a cistern through the first end of the first pipe,
b) exchanging heat between the first fluid and the second fluid in a heat exchanger of the geothermal heat pump, and
c) cooling the space by exchanging heat from the second fluid of the closed fluid circuit with said space.

[0053] This method for cooling is thus performed by a second fluid circuit and by means of a geothermal system according to any of the embodiments of the first inventive aspect, wherein the geothermal heat pump circulates the first fluid in a first closed fluid loop by simultaneously forcing the first fluid to enter a cistern through the second end of the second pipe and to exit a cistern through the first end of the first pipe, the geothermal heat pump simultaneously circulating a second fluid which cools the mentioned space.

[0054] In a particular embodiment, the system comprises a valve and the method comprises fixing the valve in a second position, the system thus functioning in the cooling mode.

[0055] In a fourth inventive aspect the invention provides a method for installing a geothermal system according to the first inventive aspect, for heating and/or cooling a space, the method comprising the following steps:

a) providing at least one cistern,
b) performing an excavation in the ground, the excavation being at least the size of the at least one cistern,
c) introducing the at least one cistern in the excavation, covering it in the ground, and partially introducing the first and second pipes in the ground,
d) locating the first end of the first pipe at a lower part of a cistern and the second end of the second pipe at an upper part of a cistern;
e) coupling the first pipe to the first opening of a cistern and the second pipe to the second opening of a cistern, and
f) connecting the geothermal heat pump to the first pipe and to the second pipe.

[0056] The connection performed in step f) allows for a first fluid circuit to be created in order to circulate the first fluid contained in the at least one cistern.

[0057] In an embodiment the method further comprises the following step:
g) connecting the geothermal heat pump to a second fluid circuit mounted in the space.

[0058] In an embodiment the method further comprises in step f) the coupling of a valve between the first and second pipes and the geothermal heat pump.

[0059] All the features described in this specification (including the claims, description and drawings) and/or all the steps of the described method can be combined in any combination, with the exception of combinations of such mutually exclusive features and/or steps.

DESCRIPTION OF THE DRAWINGS

[0060] These and other characteristics and advantages of the invention will become clearly understood in view of the detailed description of the invention which becomes apparent from a preferred embodiment of the invention, given just as an example and not being limited thereto, with reference to the drawings.

Figure 1 illustrates a geothermal system according to a first embodiment of the invention, as well as two enlarged details thereof.

Figure 2 shows the temperature of the ground and the temperature distribution of the fluid inside the cistern at different altitudes within the cistern, in the present embodiment when colder fluid is poured into the cistern through the first pipe.

Figure 3 shows the temperature of the ground and the temperature distribution of the flow of fluid inside the cistern at different altitudes within the cistern, in the present embodiment when warmer fluid is poured into the cistern through the second pipe.

Figure 4 shows a geothermal system according to a second embodiment of the invention.

Figure 5 shows a geothermal system according to a third embodiment of the invention.

Figure 6 shows a geothermal system according to a fourth embodiment of the invention.

Figure 7 shows a geothermal system according to a fifth embodiment of the invention.

Figure 8 shows a geothermal system according to a sixth embodiment of the invention, as well as an enlarged detail thereof.

DETAILED DESCRIPTION OF THE INVENTION

[0061] Figure 1 illustrates an embodiment of the geothermal system of the invention installed to heat and/or cool a house. For illustration purposes a single home has been displayed. However the system of the invention would work equally in any other application such as to heat and/or cool an office building, an industrial facility, a farm, a greenhouse, or any other space requiring temperature control.

[0062] In figure 1, the geothermal system is fluidically connected to a pipe network (10) which configures a second fluid circuit of the house, namely to the pipe network (10) of an in-floor radiant system, which configures a particular HVAC system. However, the geothermal system is also applicable to an air conditioning system using fan coils, water heater tanks or a combination of these, configuring different HVAC systems according to the needs of the user.

[0063] The system of figure 1 includes a single cistern (1) having a perimetral surface and at least two openings (1.1.1, 1.1.2) for the connection of pipes, visible at enlarged detail B of figure 1. In this embodiment the two openings (1.1.1, 1.1.2) are located at a top portion of the perimetral surface of the cistern (1). One of the openings (1.1.1) allows connection of a first pipe (2), the first pipe (2) having a first end (2.1) located at a lower part of the inner volume of the cistern (1). The second opening (1.1.2) allows connection of a second pipe (3), the second pipe (3) having a second end (3.1) located at an upper part of the inner volume of the cistern (1). The cistern (1) may include one or more additional openings, such as a third opening to connect two cisterns together through an additional pipe.

[0064] The cistern (1) according to the invention allows for liquid temperature exchange with the ground. Specifically, the present invention provides a closed system that allows the temperature of the first fluid to intervene in the fluid movement in the system, particularly in a first fluid circuit configured by means of the cisterns and their connecting pipes and the geothermal heat pump of the present geothermal system. By doing so, the cistern (1) is able to provide the geothermal system with the first fluid that has exchanged most thermal energy when being in contact with the ground through the perimetral surface of the cistern (1). It does so by strategically locating the first (2) and second (3) pipe respectively at bottom and top of the cistern (1), where the first fluid with extreme temperatures is located, and by selecting the flow direction in the first (2) and second (3) pipe in order optimize the liquid thermal energy exchange with the cistern. The effect of temperature distribution of the first fluid inside the cistern (1) is improved when the cistern (1) has an elongated shape and is buried in the ground with its longest dimension vertically located.

[0065] The geothermal system of figure 1 also includes a geothermal heat pump (5) and a valve (4), both fluidically connected to the first pipe (2) and to the second pipe (3). When the geothermal system is also connected to the in-house pipe network (10) such as a radiant floor, a second closed-loop system is achieved. The geothermal heat pump (5) may also be part of an HVAC system that provides heating or cooling through an air conditioner as mentioned.

[0066] Enlarged detail A of figure 1 shows the connection of the geothermal system, particularly of the geothermal heat pump, to the in-house pipe network (10) and thus the second closed-loop circuit. Specifically, the geothermal system comprises a first connection tube (8) comprising a first end (8.1) and a second end (8.2), and a second connection tube (9) comprising a first end (9.1) and a second end (9.2). When the geothermal system is installed, the first end (8.1) of the first connection tube (8) and the first end (9.1) of the second connection tube (9) are connected to the geothermal heat pump (5), whilst the second end (8.2) of the first connection tube (8) and the second end (9.2) of the second connection tube (9) are respectively coupled to an inlet (10.1) and an outlet (10.2) of the in-house pipe network (10).

[0067] The cistern (1) is able to provide thermal energy independent of climate variations from day to day or from season to season.

[0068] Figures 2 and 3 illustrate the temperature distribution of the first fluid due to convection inside the cistern (1) in two situations. For illustration purposes temperature variations are shown as having linear progression whereas in reality the temperature variation will tend to be logarithmic.

[0069] In figure 2 a ground temperature of 10° C is considered to schematically show what occurs inside the cistern (1) when a constant liquid inflow is provided from the geothermal heat pump (5) at 3°C, particularly through the first pipe (2).

[0070] When the geothermal heat pump (5) inserts colder liquid in the cistern (1) the geothermal system exchanges thermal energy with the ground. The thermal energy obtained from the ground with the first liquid is then used by the geothermal heat pump (5) to obtain a temperature of the second liquid which is closer to the one required to heat or cool the in-house pipe network (10), thus it minimizes the energy consumption required to heat or cool a space. Liquid colder than the ground temperature is delivered to the cistern (1) at its bottom part, namely through the first pipe (2). This configuration can be achieved by setting the valve (4) in a first position.

[0071] As the liquid at 3°C which arrives to the cistern (1) from the geothermal heat pump (5) gains temperature by temperature exchange with the ground, it also gains altitude within the cistern (1). Liquid at the center of the cistern (1) is less exposed to higher temperatures from the earth, and consequentially sinks to the lower part of the cistern (1), creating a circular flow as long as these temperature differences remain, by means of a convection process due to heat exchange with the ground and the rest of the liquid inside the cistern.

[0072] A portion of the liquid is extracted from the top of the cistern (1) through the second pipe (3), which has a second end (3.1) close to the top of the cistern (1). The extracted liquid has a temperature close to the temperature of the surrounding ground. This liquid is then suctioned by the geothermal heat pump (5) to continue the cycle.

[0073] Figure 3 schematically shows the opposite cycle, where the geothermal heat pump (5) inserts in the cistern (1) through the second pipe (3) water at 25°C, therefore hotter than the ground temperature of 10°C. In such setting, the valve (4) is set in a second position, in such manner that the liquid enters the cistern (1) through the second pipe (3). As the liquid exchanges temperature with the ground through the cistern perimetral surface, it gradually cools off, increases density and travels down the cistern (1). Liquid at the center of the cistern (1) is less exposed to lower temperatures from the surrounding ground, and consequentially goes back up into the upper part of the cistern (1).

[0074] A portion of the liquid will be extracted from the lower part of the cistern (1) at a temperature close to the temperature of the surrounding ground by the first pipe (2), which has a first end (2.1) strategically located at the bottom part of the cistern (1). The extracted liquid is suctioned by the geothermal heat pump (5) to continue the cycle.

[0075] Thus, according to the mentioned functioning modes of the present geothermal system, in an operative mode in order to heat the predetermined space, the geothermal heat pump (5) inserts cold fluid at the lower part of the cistern (1), through the first pipe (2), while simultaneously extracts fluid from the upper part of the cistern (1), through the second pipe (3), whereas for cooling the predetermined space, the above mentioned process is reversed and hot fluid is inserted at the upper part of the cistern (1), through the second pipe (3), while cooler fluid is extracted from the bottom of the cistern (1), through the first pipe (2).

[0076] The cistern (1) is waterproof and pressure-tight. It may be built from numerous materials, such as plastic, rubber, metal or fiberglass. However, in a preferred embodiment the material of the cistern (1) is precast concrete reinforced with wire mesh. This preferred embodiment offers high durability, high thermal conductivity according to the aforementioned preferred materials, and global accessibility to the materials needed for its construction.

[0077] The fluid to be contained in the cistern (1) may be a liquid and is preferably a mixture of water and a coolant fluid, particularly an antifreeze, such as Ethylene Glycol. The use of antifreeze prevents damage to the pipes present in the geothermal system in the event of extreme cold weather as well as potential damage to the geothermal heat pump (5) during its regular operation due to freezing. However, depending on climate conditions and geothermal heat pump characteristics the geothermal system may run simply on water.

[0078] Depending on the size of the space to be heated or cooled and the fluid inflow needed by the geothermal heat pump (5), some installations may need more than one cistern (1) as part of the geothermal system. In such cases the cisterns (1) may be installed in series or in parallel.

[0079] Figure 4 depicts a preferred configuration of a series connection of two cisterns (1A, 1B), each cistern (1A, 1B) comprising a perimetral surface (1.1). Said perimetral surface (1.1) comprises a first opening (1.1.1) and a second opening (1.1.2). A first pipe (2) is coupled to the first opening (1.1.1) of a first cistern (1A). As visible in the figure, the first pipe (2) has a first end (2.1) located at a lower part of the first cistern (1A). A second pipe (3) is coupled to the second opening (1.1.2) of the second cistern (1B), the second pipe (3) having a second end (3.1) located at an upper part of the second cistern (1B). A geothermal heat pump (5) is coupled to the first pipe (2) and to the second pipe (3). A valve (4) is fluidically connected with the first pipe (2), the second pipe (3) and the geothermal heat pump (5).

[0080] In the embodiment of figure 4, the geothermal system includes a third pipe (6) coupled to the openings of the cisterns (1A, 1B), namely to the second opening of the first cistern (1A) and to the first opening of the second cistern (1B). The third pipe (6) has a third end (6.1) located at a lower part of the second cistern (1B) and a fourth end (6.2) located at an upper part of the first cistern (1A). This configuration makes the fluid to travel the farthest possible distance within the cisterns (1A, 1B).

[0081] Therefore, for heating a house, the first pipe (2) inserts fluid at the bottom of the first cistern (1A) while the third pipe (6) collects fluid at the top of the first cistern (1A) and delivers the fluid at the bottom of the second cistern (1B). Fluid is then collected from the second pipe (3) at the top of the second cistern (1B) and circulated to the in-house pipe network (10).

[0082] For cooling a house, the order at which fluid enters and exits the cisterns is reversed, meaning fluid enters cistern (1B) through the second pipe (3) and exits cistern (1A) through the first pipe opening (2.1).

[0083] In figures 1 and 4 the openings in the perimetral surfaces of the cisterns (1, 1A, 1B) are arranged at a top portion of the perimetral surfaces and a portion of the first pipe (2) and a portion of the third pipe (6) are placed within a cistern, said portions extending from the location of the opening to the location of the end of the pipe at a lower part of said cistern.

[0084] In the embodiment of figure 5 a different configuration is shown, where only one of the openings is located at a top portion of the cisterns (1A, 1B) and the other opening is located at a lower part of the cisterns (1A, 1B). In this embodiment, instead of having a portion of the pipes inside the cisterns, the pipes are located at the exterior of the cisterns (1A, 1B), with their ends coupled to the openings of the cisterns (1A, 1B). The other features of the embodiment of figure 5 are analogous to those described for figure 4, excepting also the presence of the valve (4), which is omitted in the embodiment of figure 5.

[0085] Figure 6 shows an embodiment similar to the ones shown in figures 4 and 5, but including three cisterns (1A, 1B, 1C) connected in series. As in the embodiments of figures 4 and 5, each cistern (1A, 1B) comprises a perimetral surface (1.1). Said perimetral surface (1.1) comprises a first opening (1.1.1) and a second opening (1.1.2). A first pipe (2) is coupled to the first opening (1.1.1) of a first cistern (1A), with a first end (2.1) of the first pipe (2) located at a lower part of the first cistern (1A). A third pipe (6A) connects the first cistern (1A) and a second cistern (1B). The third pipe (6A) is coupled to the second opening of the first cistern (1A) and to the first opening of the second cistern (1B). The third pipe (6A) has a third end (6A.1) located at a lower part of the second cistern (1B) and a fourth end (6A.2) located at an upper part of the first cistern (1A). An additional third pipe (6B) connects the second cistern (1B) and a third cistern (1C). The additional third pipe (6B) is coupled to the second opening of the second cistern (1B) and to the first opening of the third cistern (1C). The additional third pipe (6B) has a third end (6B.1) located at a lower part of the third cistern (1C) and a fourth end (6B.2) located at an upper part of the second cistern (1B). A second pipe (3) is coupled to the second opening (1.1.2) of the third cistern (1C), the second pipe (3) having a second end (3.1) located at an upper part of the third cistern (1C). A geothermal heat pump (5) is coupled to the first pipe (2) and to the second pipe (3), establishing a path for the fluid involving the first (2) and second (3) pipes as well as the additional third pipe (6).

[0086] Thus, in a series configuration of two or more cisterns (1A, 1B, 1C), the first pipe (2) and the second pipe (3) are connected in different cisterns (1A, 1C) with their ends located in opposite heights of the inner space of said cisterns (1A, 1C). Third pipes (6, 6A, 6B) coupled between pairs of cisterns (1A, 1B, 1C) will take or deliver fluid at heights opposite to the ones where the ends of the first pipe (2), of the second pipe (3) or of a third pipe (6, 6A, 6B) are located in each of the cisterns (1A, 1B, 1C).

[0087] A parallel connection of the cisterns is also possible for a geothermal system including two or more cisterns. An embodiment of a parallel connection of two cisterns (1A, 1B) is shown in figure 7. In this embodiment, a first pipe (2) is coupled to a first opening (1.1.1) of a first cistern (1A), the first pipe (2) having a first end (2.1) located at a lower part of the first cistern (1A). A second pipe (3) is coupled to the second opening (1.1.2) of the first cistern (1A), the second pipe (3) having a second end (3.1) located at an upper part of the first cistern (1A). A third pipe (6) connects a second cistern (1B) with the first pipe (2), the third pipe (6) having a third end (6.1) located at a lower part of the second cistern (1B) and a fourth end (6.2) connected to the first pipe (2). The geothermal system comprises a fourth pipe (7) arranged to connect the second cistern (1B) with the second pipe (3). The fourth pipe (4) has a fifth end (7.1) located at an upper part of the second cistern (1B) and a sixth end (7.2) connected to the second pipe (3). The connections of the third pipe (6) and the fourth pipe (7) with the first pipe (2) and second pipe (3), respectively, are visible in enlarged detail C of figure 7. According to this embodiment, each cistern (1A, 1B) has a pipe end (the first end of the first pipe or the third end of the third pipe) at its lower part and a pipe end (the second end of the second pipe or the fourth end of the fourth pipe) at its upper part.

[0088] In this embodiment the cisterns (1A, 1B) are connected in such manner that the fluid jointly circulates from all cisterns (1A, 1B) within the system. A geothermal heat pump (5) is coupled to the first pipe (2) and to the second pipe (3), establishing a path for the first fluid involving the first (2) and second (3) pipes as well as the additional third (6) and fourth (7) pipes. A valve (4) is fluidically connected with the first pipe (2), the second pipe (3) and the geothermal heat pump (5).

[0089] Although two cisterns (1A, 1B) are shown in the embodiment of figure 7, additional cisterns may be connected in parallel by including additional third (6) and fourth (7) pipes to respectively connect the additional cisterns to the first pipe (2) and second pipe (3). For example, the embodiment of figure 8 shows three cisterns (1A, 1B, 1C) connected in parallel. As in the embodiment of figure 7, a first pipe (2) is coupled to the first opening of a cistern (1A) and a second pipe (3) is coupled to the second opening of a cistern (1A). The first pipe (2) has a first end (2.1) located at a lower part of the cistern (1A) and the second pipe (3) has a second end (3.1) located at an upper part of the cistern (1A). In the embodiments of figures 7 and 8 the first pipe (2) and the second pipe (3) are coupled to the same cistern (1A), but in other embodiments the first pipe (2) and the second pipe (3) may be coupled each to a different cistern.

[0090] In the embodiment of figure 8 the geothermal system comprises two third pipes (6A, 6B), each third pipe (6) being arranged to connect one cistern (1B, 1C), other than the cistern (1A) to which the first pipe (2) is coupled, to the first pipe (2). Each third pipe (6A, 6B) has a third end (6.1) located at a lower part of the cistern (1B, 1C) and a fourth end (6.2) connected to the first pipe (2). The geothermal system comprises two fourth pipes (7A, 7B), each fourth pipe (7A, 7B) being arranged to connect one cistern (1B, 1C), other than the cistern (1A) to which the second pipe (3) is coupled, to the second pipe (3). Each fourth pipe (7A, 7B) has a fifth end (7.1) located at an upper part of the cistern (1B, 1C) and a sixth end (7.2) connected to the second pipe (3). Thus, each cistern (1A, 1B, 1C) has a pipe end at its lower part and a pipe end at its upper part.

[0091] Cisterns (1) displayed in figures 1 and 4 to 8 have been depicted in a preferred elongated cylindrical shape. However, other shapes (preferably elongated) are possible, for example rectangular, triangular or conical.

Claims

1. A geothermal system, comprising:

   at least one geothermal cistern (1, 1A, 1B) configured for being buried in the ground, the cistern (1, 1A, 1B) exchanging heat with the ground;
   each cistern (1, 1A, 1B) comprising a perimetral surface (1.1), said perimetral surface (1.1) comprising a first opening (1.1.1) and a second opening (1.1.2),
   a first pipe (2) coupled to the first opening (1.1.1) of at least one cistern (1, 1A, 1B), the first pipe (2) having a first end (2.1) located at a lower part of said cistern (1, 1A, 1B);
   a second pipe (3) coupled to the second opening (1.1.2) of at least one cistern (1, 1A, 1B), the second pipe (3) having a second end (3.1) located at an upper part of said cistern (1, 1A, 1B);
   a geothermal heat pump (5) coupled to the first pipe (2) and to the second pipe (3).

2. The geothermal system according to claim 1, further comprising a valve (4) adapted to operate in a first position and in a second position, the valve (4) being fluidically connected with the first pipe (2), the second pipe (3) and the geothermal heat pump (5).

3. The geothermal system according to the previous claim, wherein:

   the first position of the valve (4) allows for a fluid to enter at least one cistern (1) through the first pipe (2) while extracting the fluid from at least one cistern (1) through the second pipe (3), and the second position of the valve (4) allows the fluid to enter at least one cistern (1) through the second pipe (3) while extracting fluid from at least one cistern (1) through the first pipe (2).

4. The geothermal system according to any of claims 2 to 3, wherein the valve (4) is a four port directional valve.

5. The geothermal system according to any of the previous claims, comprising two or more cisterns (1A, 1B), wherein:

the first end (2.1) of the first pipe (2) is located at a lower part of a first cistern (1A);
the second end (3.1) of the second pipe (3) is located at an upper part of a second cistern (1B);
the geothermal system comprises at least one third pipe (6), each third pipe (6) being arranged to connect two cisterns (1A, 1B) one to another, each third pipe (6, 6A, 6B) having a third end (6.1, 6A.1, 6B1) located at a lower part of one cistern (1B, 1C) and a fourth end (6.2, 6A.2, 6B.2) located at an upper part of another cistern (1A, 1B), such that each cistern (1A, 1B) has a pipe end at its lower part and a pipe end at its upper part.

6. The geothermal system according to any of claims 1 to 4, comprising two or more cisterns (1A, 1B, 1C), wherein:

the geothermal system further comprises at least one third pipe (6), each third pipe (6, 6A, 6B) being arranged to connect one cistern (1B, 1C) to the first pipe (2), each third pipe (6, 6A, 6B) having a third end (6.1) located at a lower part of the cistern (1B, 1C) and a fourth end (6.2) connected to the first pipe (2); and
the geothermal system comprises at least one fourth pipe (7, 7A, 7B), each fourth pipe (7) being arranged to connect one cistern (1B, 1C) to the second pipe (3), each fourth pipe (7, 7A, 7B) having a fifth end (7.1) located at an upper part of the cistern (1B, 1C) and a sixth end (7.2) connected to the second pipe (3);
such that each cistern (1A, 1B, 1C) has a pipe end at its lower part and a pipe end at its upper part.

7. The geothermal system according to any of the previous claims, wherein the at least one cistern (1, 1A, 1B, 1C) contains a first fluid such as water or a mixture of ethylene glycol and water.

8. The geothermal system according to the previous claim, wherein at least one cistern (1, 1A, 1B, 1C) has an elongated shape.

9. The geothermal system according to any of the previous claims, wherein the perimetral surface (1.1) of the cistern (1, 1A, 1B, 1C) is made of a material having high thermal conductivity, preferably equal to or greater than 0,15 W/m K, and more preferably equal to or greater than 0,7 W/m K.

10. The geothermal system according to any of the previous claims, further comprising:

- a first connection tube (8) comprising a first end (8.1) and a second end (8.2),
and
- a second connection tube (9) comprising a first end (9.1) and a second end (9.2),
wherein the first end (8.1) of the first connection tube (8) and the first end (9.1) of the second connection tube (9) are connected to the geothermal heat pump (5), whilst the second end (8.2) of the first connection tube (8) and the second end (9.2) second connection tube (9) are configured to be correspondingly coupled to an inlet (10.1) and an outlet (10.2) of a fluid circuit (10) present in a space.

11. Method for heating a space comprising a closed fluid circuit (10) which comprises a second fluid, the heating of the space being performed by means of a geothermal system according to any of claims 1 to 10, the method comprising the following steps:

a) actuating the geothermal heat pump (5) to simultaneously circulate a first fluid to enter a cistern (1, 1A, 1B, 1C) through the first end (2.1) of the first pipe (2) and exit a cistern (1, 1A, 1B, 1C) through the second end (3.1) of the second pipe (3),
b) exchanging heat between the first fluid and the second fluid in a heat exchanger of the geothermal heat pump (5), and
c) heating the space by exchanging heat from the second fluid of the closed fluid circuit (10) with said space.

12. Method for cooling a space comprising a closed fluid circuit (10) which comprises a second fluid, the cooling of the space being performed by means of a geothermal system according to any of claims 1 to 10, the method comprising the following steps:

a) actuating the geothermal heat pump (5) to simultaneously circulate a first fluid to enter a cistern (1, 1A, 1B, 1C) through the second end (3.1) of the second pipe (3) and exit a cistern (1, 1A, 1B, 1C) through the first end (2.1) of the first pipe (2),
b) exchanging heat between the first fluid and the second fluid in a heat exchanger of the geothermal heat pump (5), and
c) cooling the space by exchanging heat from

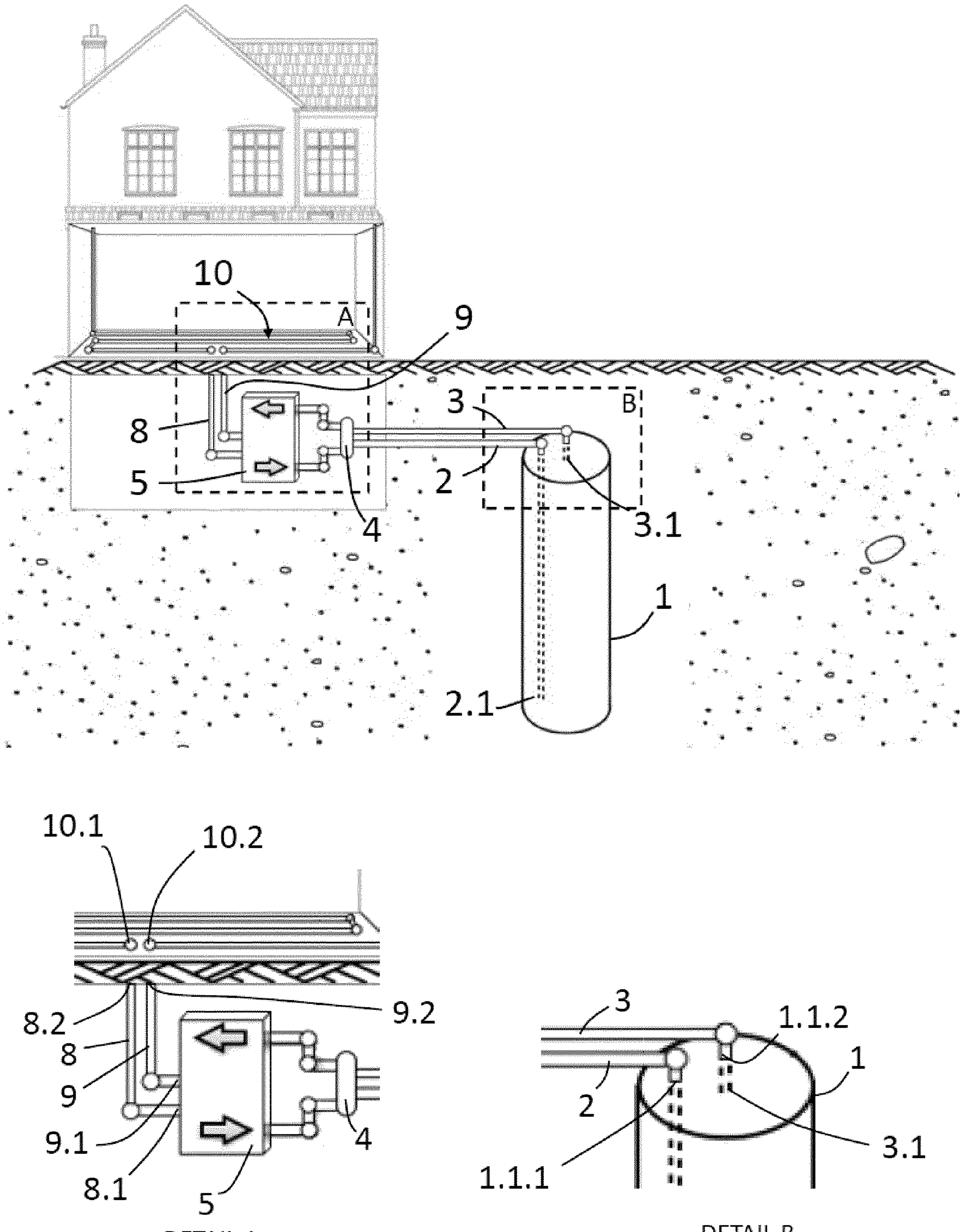
the second fluid of the closed fluid circuit (10) with said space.

13. Method for installing a geothermal system according to any of claims 1 to 10 in a ground, the method comprising the following steps:

a) providing at least one cistern (1, 1A, 1B),
b) performing an excavation in the ground, the excavation being at least the size of the at least one cistern (1, 1A, 1B),
c) introducing the at least one cistern (1, 1A, 1B) in the excavation, covering it in the ground, and partially introducing the first (2) and second (3) pipes in the ground,
d) locating the first end (2.1) of the first pipe (2) at a lower part of a cistern (1, 1A, 1B) and the second end (3.1) of the second pipe (3) at an upper part of a cistern (1, 1A, 1B);
e) coupling the first pipe (2) to the first opening (1.1.1) of a cistern (1, 1A, 1B) and the second pipe (3) to the second opening (1.1.2) of a cistern (1, 1A, 1B), and
f) connecting the geothermal heat pump (5) to the first pipe (2) and to the second pipe (3).

14. Method for installing a geothermal system according to the preceding claim, the method further comprising the following step:
g) connecting the geothermal heat pump (5) to a fluid circuit (10) mounted in the space.

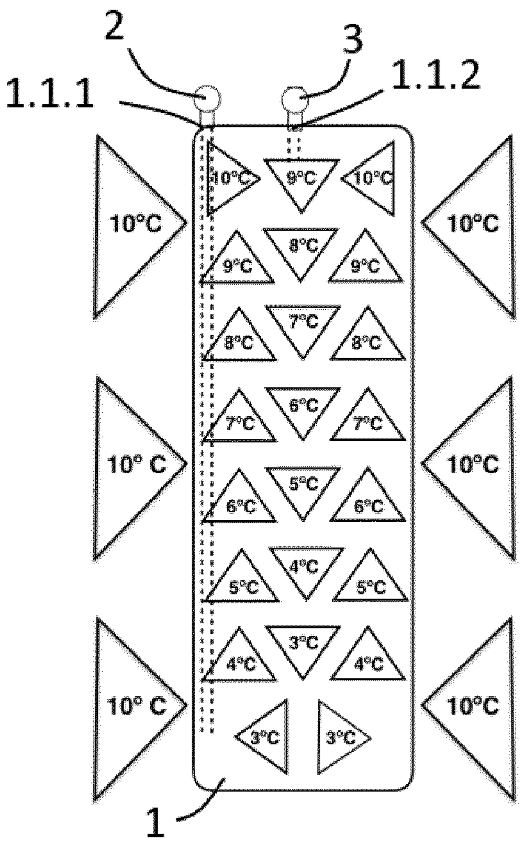
15. Method for installing a geothermal system according to any of claims 13 or 14, the method further comprising in step f) the coupling of a valve (4) between the first (2) and second (3) pipes and the geothermal heat pump (5).



DETAIL A

DETAIL B

FIG. 1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6°C
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FIG. 2

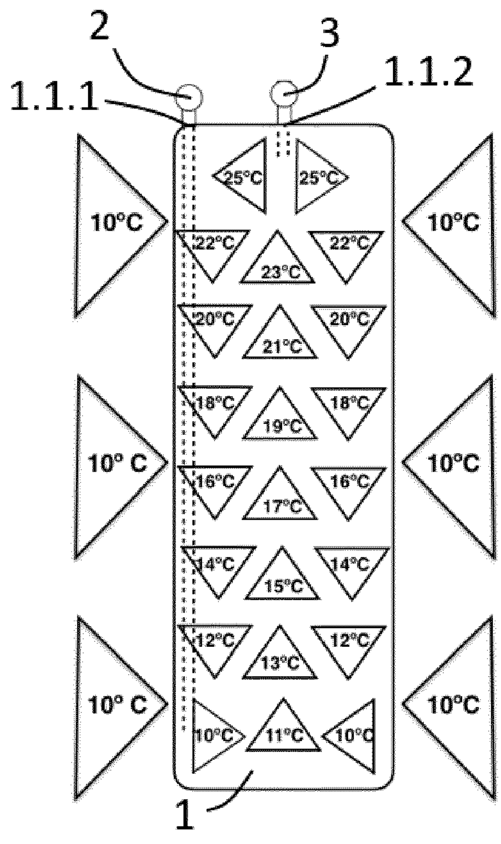
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FIG. 3

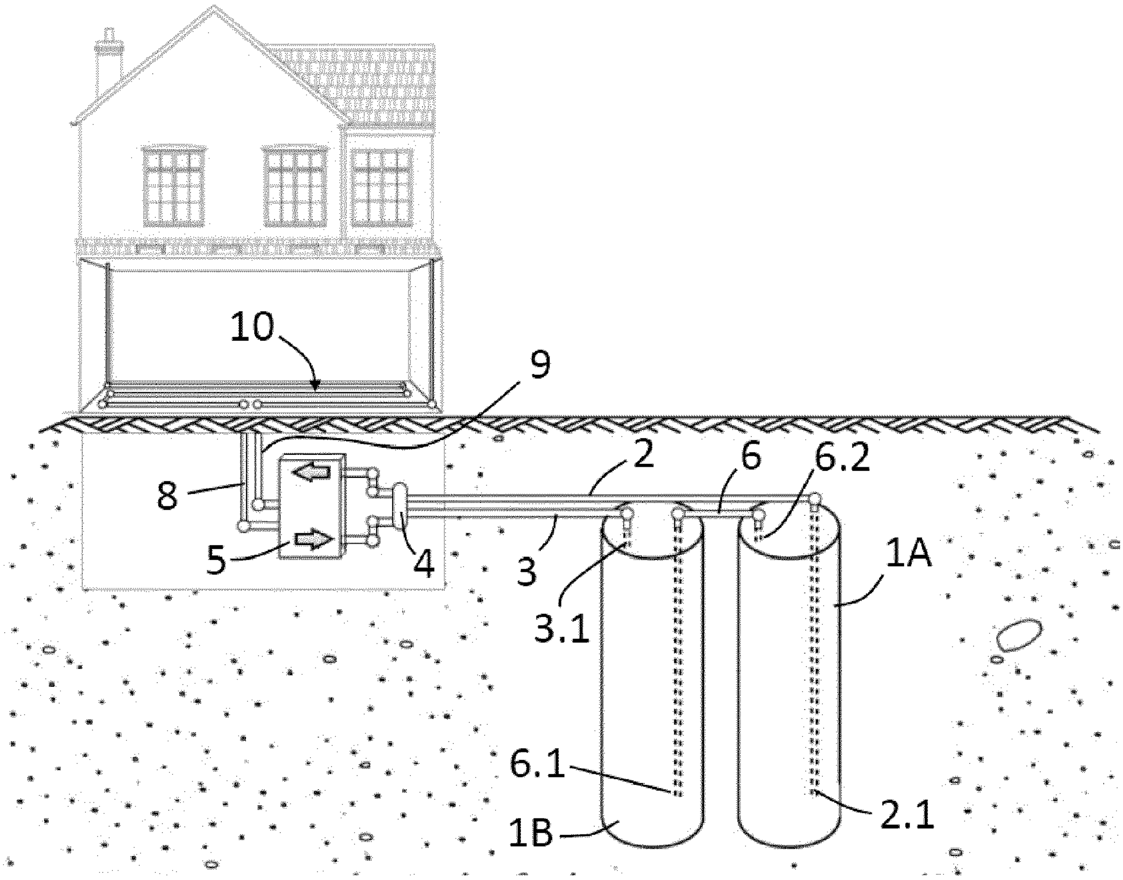


FIG. 4

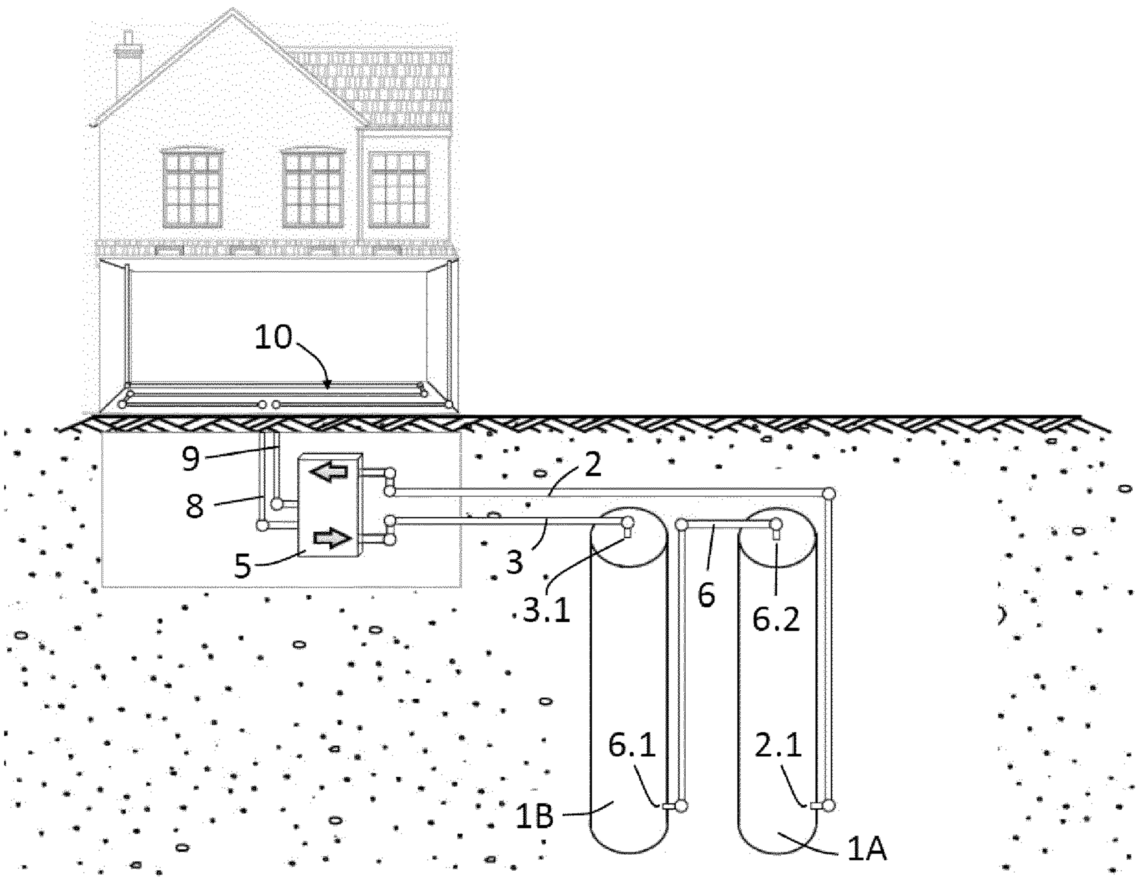


FIG. 5

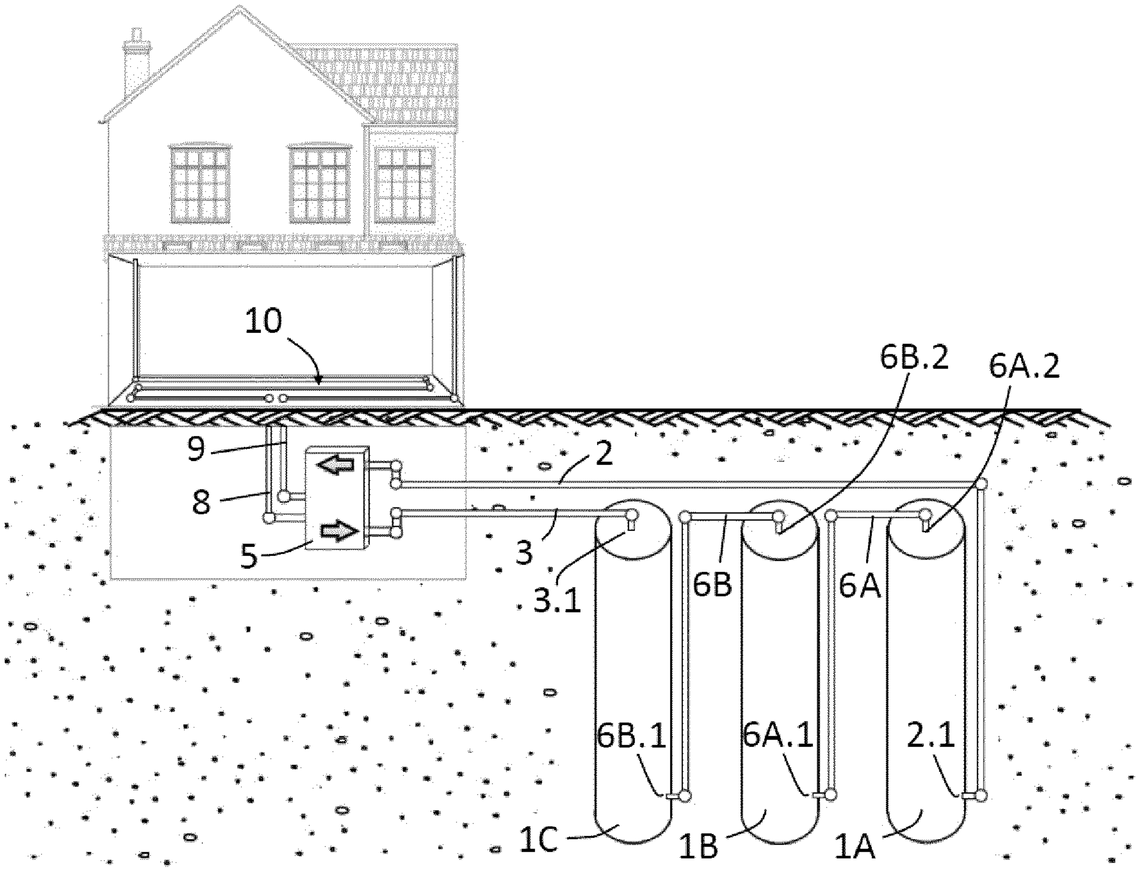
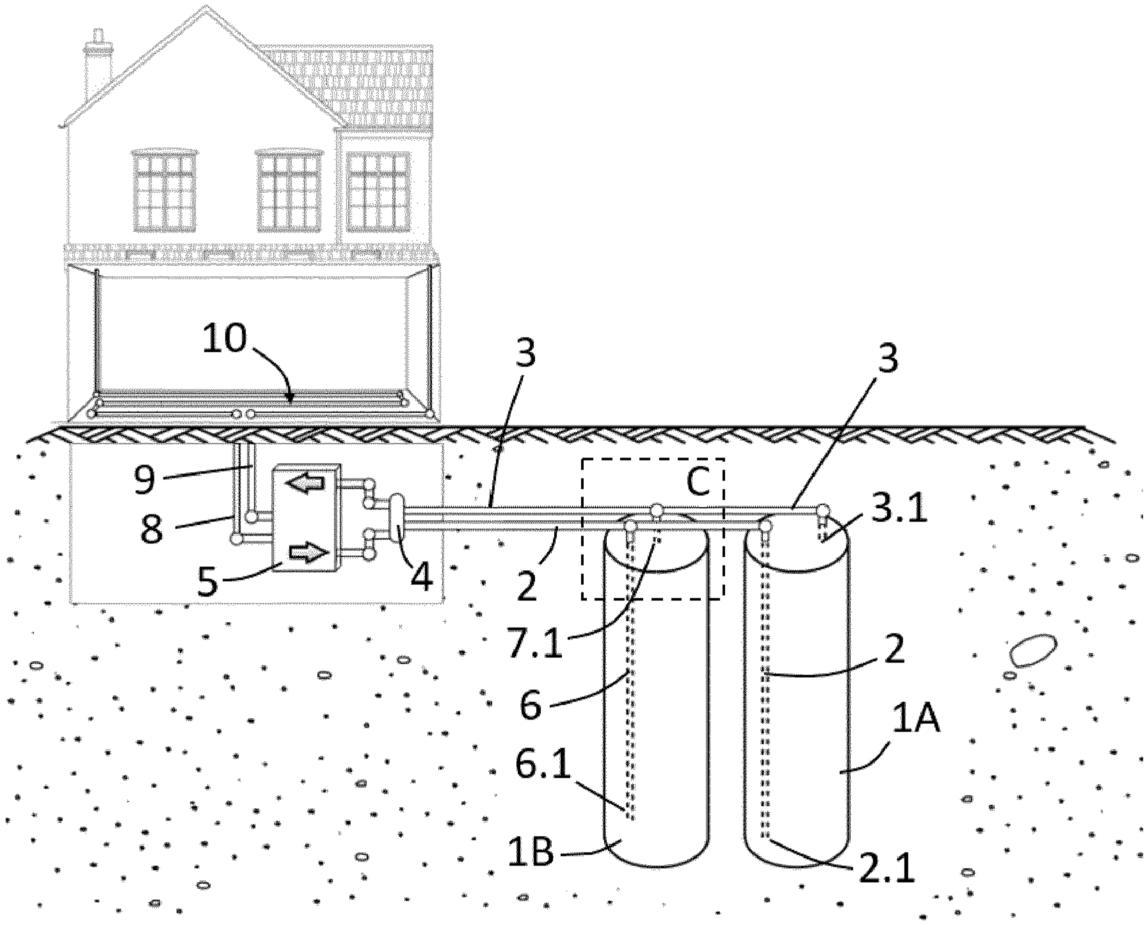
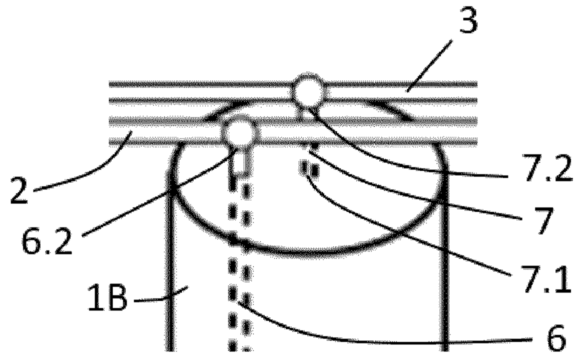


FIG. 6





DETAIL C

FIG. 7

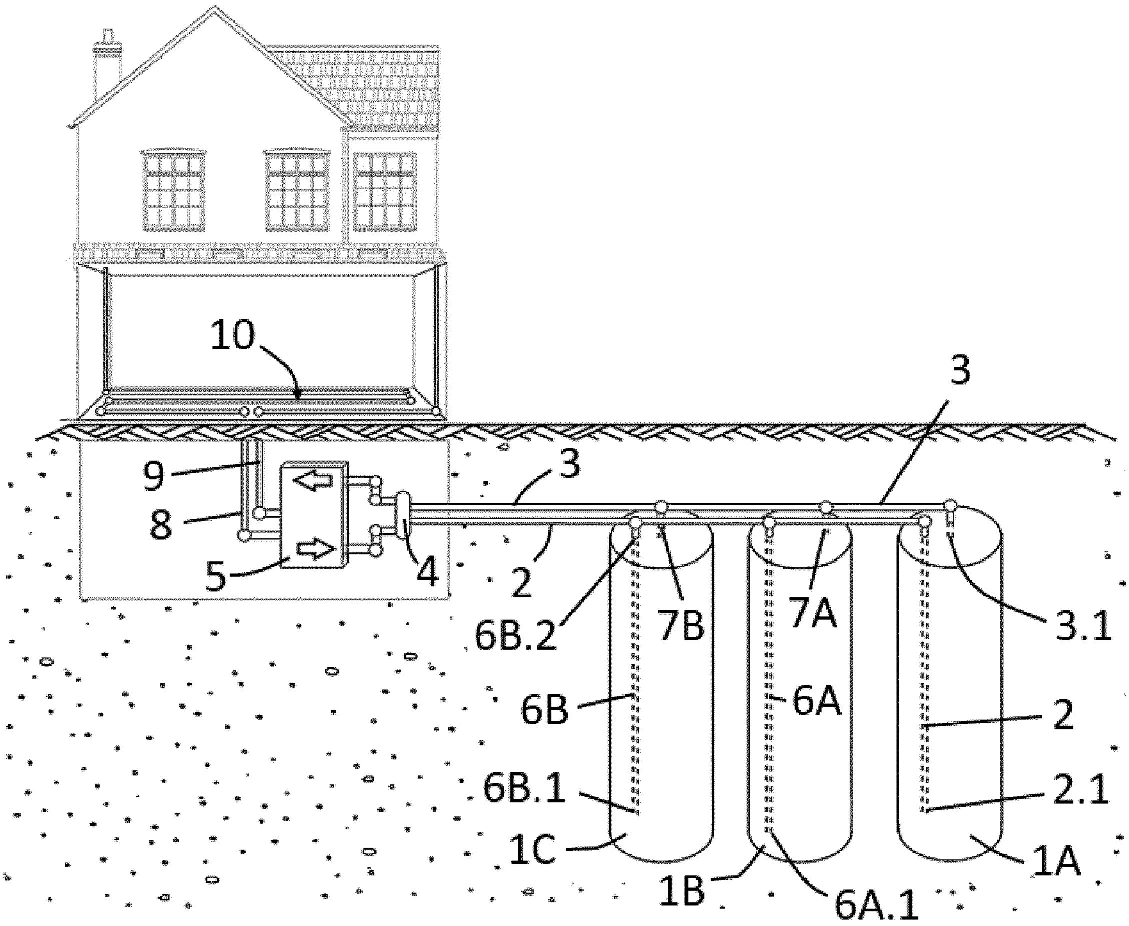


FIG. 8

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	11 August 2021	Oliveira, Casimiro

CATEGORY OF CITED DOCUMENTS

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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O : non-written disclosure
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D : document cited in the application
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& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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