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(54) Titre : DISPOSITIF D'ECHANGEUR GEOTHERMIQUE LINEAIRE
(54) Title: A LINEAR GEOTHERMAL HEAT EXCHANGE DEVICE

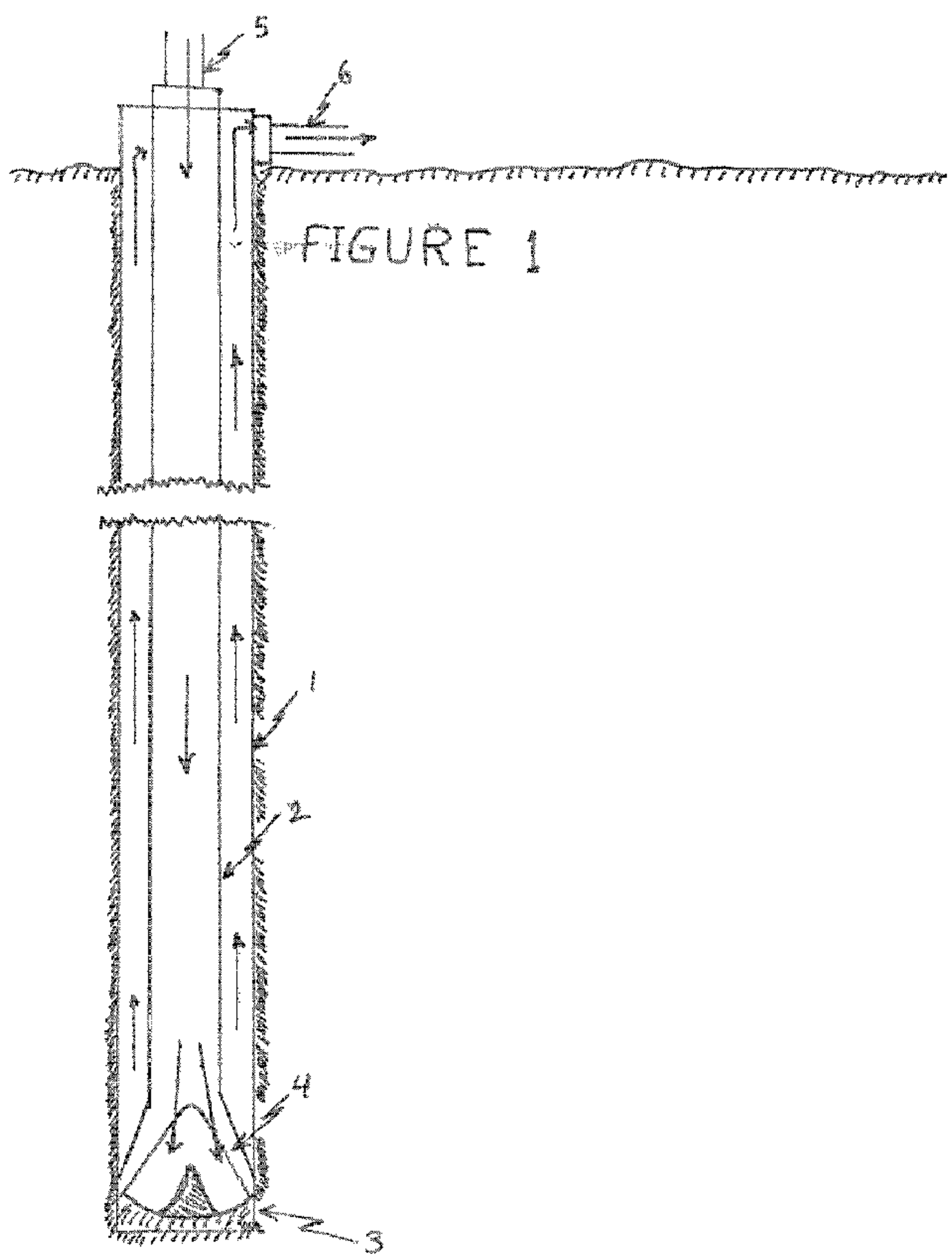

FIGURE 1

(57) Abrégé/Abstract:
The purpose of the device is to improve recovery of geothermal energy using existing boreholes and enhanced technology. The invention consists of an outer and an inner pipe operating in pre-existing boreholes. Cool fluids are pumped down the inner pipe

(57) Abrégé(suite)/Abstract(continued):
and returned to the surface through the outer pipe. Subterranean heat increases the temperature of the cool fluid and this heat is returned to the surface where the heat is harvested. The fluid with the heat removed is then pumped back down the borehole in a closed loop system to be re- heated. The total length of the downhole piping apparatus is designed to act as a long, linear heat exchanger. The intention of the invention is to eliminate the cost of drilling additional wells, and to minimize impact on the environment.

Patent Application for

A Linear Geothermal Heat Exchange Device

January 7, 2016

Abstract

The purpose of the device is to improve recovery of geothermal energy using existing boreholes and enhanced technology. The invention consists of an outer and an inner pipe operating in pre-existing boreholes. Cool fluids are pumped down the inner pipe and returned to the surface through the outer pipe. Subterranean heat increases the temperature of the cool fluid and this heat is returned to the surface where the heat is harvested. The fluid with the heat removed is then pumped back down the borehole in a closed loop system to be re-heated. The total length of the downhole piping apparatus is designed to act as a long, linear heat exchanger. The intention of the invention is to eliminate the cost of drilling additional wells, and to minimize impact on the environment.

Specification

Background

Below the earth's surface, temperature increases with depth. The rate of temperature increase, or geothermal gradient, averages about 30 Celsius degrees per 1 000 metre depth. However, in some regions, the gradient can be significantly higher with very hot temperatures found closer to the earth's surface. Current technologies are exploiting some of these near surface hot spots for electrical power generation and space heating. Hot zones at greater depths and have seen very limited exploitation to date. Similarly lower enthalpy zones at shallower depths are mostly undeveloped.

Most geothermal recovery systems at depth mainly rely on drilling a pair of boreholes, one well for injecting cooler fluid and the other well for producing the heated fluid or steam. The wells are usually connected at depth by an aquifer or by fracturing the rock material between the wells. This induced permeable zone between the wells acts as the conduit for the water and heat transfer. This open loop binary system has several drawbacks. It is difficult to control fluid losses in to the rock formations in the connected zone between the well pairings. This requires a significant amount of pumping to counteract the fluid loss and to pump the heated water back to surface in the production well. Further, the fluid returned to the surface normally contains contaminants that can be hazardous and have to be re-injected at depth. Also, the produced water can be corrosive to pipes and pumps thus reducing their life expectancy.

Drilling wells for geothermal energy is expensive and adds significantly to the cost of development. This is a deterrent to transferring production/injection well technology to areas where higher temperatures are at greater depths. Attempts have been made to develop technologies for single borehole geothermal development. Various patents have been granted, and some single well technologies have been tested with some success. However, most existing commercial geothermal operations still use the binary production/injection process described previously.

The challenge and the opportunity for wider spread geothermal energy development are to reduce cost, and lessen the environmental impacts of that development. The intent of the invention is to address both of these issues.

Current Patent Status

Several patents or patent applications related to single or multiple well geothermal energy recovery are as follows:

Trevisani: US 11/648,936

Horton: US 07/809,518

Montgomery: US 2008/073653

Van Huisen: US 05/375,751

Nagase: US 4512156 A

These patents or patent applications focus mainly on recovering high temperature geothermal energy for electrical power generation. Therefore the technology is designed to recover fluids or steam hot enough to drive gas turbines. In order to do so, higher temperature heat sources are required. The heat exchange happens in a zone near the bottom of the well where temperatures are highest. Piping systems above the targeted heat zones are insulated in order to convey the superheated fluid to the surface so the fluid can be converted to steam to drive turbines. Pipes are also coated to prevent deterioration by corrosive fluids. In addition, the Horton patent calls for the cold fluid to be pumped down between the inner and outer pipes and the heated fluid returned to surface in the inner, insulated pipe.

Instead of using insulated and coated pipes to bring high temperature geothermal energy to surface, this invention uses higher heat exchange materials for the pipe, therefore turning the entire piping system into a long, vertical heat exchanger. The primary use of this invention is to recover lower temperature geothermal energy for direct heating applications rather than higher temperature power generation applications. However, in certain conditions, this invention may also have application for power generation.

Other design features of this invention are:

1. Use of existing boreholes and piping to reduce capital costs.
2. Use of a closed fluid loop to eliminate contaminants and reduce pumping requirements
3. Use of smooth pipe to reduce friction.
4. Use surface pumps instead of submersible pumps to reduce obstructions in the well.
5. Use of special purpose circulation fluids to increase system efficiency and life expectancy.
6. Development of a heat envelope around the borehole that can act as a barrier to fugitive emissions adjacent to the well.

Summary of the Invention

In general, the invention is designed to repurpose existing deeper boreholes to recover heat at depth using a closed loop fluid system. The invention essentially combines the injection and production wells into one borehole. It consists of two pipes (Figures 1 and 2). The outer, larger diameter casing pipe separates the rock formation from the open borehole. A second inner pipe is placed within the outer pipe to the targeted total depth. Prior to installing the inner pipe the well is properly sealed to prevent inflow of formational fluids or gases. Lower temperature fluid is pumped down the inside of the inner pipe to the borehole bottom then returned to the surface via the void between the inner pipe and the outer casing pipe. Once the heated fluid reaches the surface it flows through heat exchangers for heat recovery using existing technologies. The cooled fluid is then recirculated to the well to recover additional heat.

The invention can operate as an individual well or as a grouping of wells, each with the two pipe closed loop system. The invention can operate in vertical and directional wells.

Existing geothermal production wells target recovery of heat from a zone at the bottom of the borehole. This invention uses the dual pipe configuration as a linear heat exchanger along the total length of the borehole. A cool water based fluid, entering the top of the inner pipe, starts to warm at the surface through heat transfer from the heated fluid moving upward between the inner and outer pipes. Heat loss from the up-flowing heated water is replaced from the induced heat envelope around the well bore. The heat exchange and retention can occur over twice the distance from surface to the wellbore depth, half of it while the lower temperature fluid is flowing downward through the inner pipe, and again when the heated fluid returns to the surface through the void between the inner and outer pipe strings.

Detailed Description of the Invention

Figures 1 and 2 illustrate the invention's components and operation.

A pre-existing borehole can have already installed (from top to bottom) surface, intermediate and production casing. The top or surface casing has the largest diameter and each pipe component below has a progressively smaller diameter. These pipe components are connected to each other and act as a barrier between the rock formation and the drill hole. Where present, these casings are used in this invention as the outer pipe (Figures 1 and 2, Item 1). If the casing is not sealed properly or does not extend to the target heat zone, an additional liner pipe with high thermal transfer capacity is inserted where required to properly seal the borehole from the rock formation. To maximize fluid flow efficiency, the inside surface of the outer pipe should be as smooth and free of obstructions as feasible. This surface pipe supplies the cold fluid that is pumped down the well to be heated.

The upper end of the outer pipe is fastened to a thermally insulated surface pipe (Figure 1, Item 6) running to the heat recovery exchanger system and pump. Surface pumps are used in the invention rather than downhole submersible pumps which can restrict fluid flow in the well.

The upper end of the inner pipe is fastened to a thermally insulated surface pipe (Figure 1, Item 5) running from the heat recovery exchanger system and pump. This surface pipe supplies the cold fluid that is pumped down the well to be heated.

The lower end of the inner pipe is configured with a metal base plate (Figure 1, Item 3). The metal plate has a flat base, and a top surface shaped as a concave bowl with a tapering down cone in its center (Figure 1, Item 3). The base plate is slightly smaller than the diameter of the narrowest inside point of the outer pipe. The metal base plate has three purposes. The plate stabilizes the inner pipe string preventing pipe whip. The plate prevents erosion of the borehole bottom, and the concave/cone upward configuration will deflect the downward flow of fluid from the inner pipe to the upward flow in a way that improves the fluid flow efficiency.

The diameter of the base plate should by tapered downward in order to prevent damage to the inner and outer pipes and to avoid the inner pipe getting hung up in the well when the inner pipe assembly is lowered into the borehole. The base plate is fastened to the lower end of the inner pipe by at least three high strength metal legs (Figure 1, Item 4). The dimensions of the metal legs should be as narrow as possible while meeting engineering tolerance limits. The reason for minimum dimensions is to reduce blockage of fluid flow. Boreholes will have differing fluid volume requirements as well as bottom hole and inner pipe diameters. The base plate and leg dimensions will vary depending on bottom-hole conditions and dimensions of individual borehole. During emplacement the base plate shall rest on the cemented bottom of the hole with sufficient weight to prevent movement. This is to provide stability to minimize the risk of metal fatigue and component failure. The inner pipe assembly must be retrievable from the borehole and therefore should not be fastened to the borehole bottom.

The upper end of the inner pipe is supported at the surface on a concrete pad of sufficient bearing strength to carry the total weight of the inner pipe and components. The weight of the pipe should be carried at the surface in order to keep the inner pipe centered inside the outer pipe for the total length of the apparatus.

The outer surface of the inner pipe (Figures 1 and 2, Item 2) should be smooth and be free of obstructions that could hamper fluid flow. Fluid pressure will be equal on the interior and exterior sides of the inner pipe allowing for thin walled construction. High thermal transfer capacity materials are to be used for the inner pipe. The inner pipe should have an inside diameter sufficient to match the volume of the upward fluid flow between the inner and outer pipes.

The circulating fluid should be free of particulates that can cause damage to pipe walls over time. The fluid must also be free of air to reduce the risk of rusting on the pipe surfaces. To further extend the life of the pipe and pump systems, friction and corrosion inhibiting additives will be introduced into the fluid. Any circulating fluid will be contained and sealed in the closed loop system at one atmosphere. Under these conditions the only power required by the circulating pump is to overcome drag from fluid friction in the system. Thus pump capacity and energy used are reduced to a minimum.

Invention Operation

Once the downhole and surface apparatus are assembled, the pump circulates fluid through the closed loop system. During normal operation, the heat that escapes from the wellbore into the adjacent rock develops a heat envelope around the well. The heat envelope provides two benefits. The first benefit is any heat loss from the up-flowing fluid is replaced by heat from the surrounding heat envelope. The second benefit is, as the heat envelope develops, the rock adjacent to the well expands and seals micro fracturing. During the drilling process some rock fracturing occurs adjacent to the borehole which can act as conduits for fugitive Greenhouse Gas (GHG) emissions and groundwater. It is proposed that heating and subsequent expansion of the rock adjacent to the borehole can close the micro-fracturing, reducing or eliminating any potential GHG emissions and ground water leakage into up-hole aquifers or to the surface.

Studies from geothermal wells elsewhere indicate that it can take up to a week of continuous operation before the well head temperature of the circulating fluid and the heat envelope around the borehole come to equilibrium at the approximate bottom-hole temperature.

Except for the inside surface of the inner pipe, all other pipe surfaces, that come into contact with the closed loop fluids, should be as smooth and free of any attachments as feasible. This is to reduce drag friction between fluids and the pipe walls in order to minimize pumping requirements. The inside surface of the inner pipe can remain unpolished. Small imperfections inside of the inner pipe cause eddy currents in the down-flowing fluid. This minor agitation in the fluid flow enhances heat transfer within the fluid.

Fluid flow volumes can be adjusted to match the heating requirements at the ground surface. Currently the use of direct heating from geothermal wells has common applications in agriculture including greenhouses, aquaculture, and heating buildings. Geothermal heat is a renewable resource and can replace space heating currently using non-renewable fossil fuels.

Claims

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. The invention is designed to recover geothermal energy from an existing borehole in a manner that reduces costs and better manages risk of deleterious products being released to the environment.
2. Said reductions in capital and operating costs will make geothermal energy development possible in regions not currently considered economic.
3. The use of previously drilled boreholes significantly reduces the cost to produce geothermal energy while deriving an economic benefit from boreholes that would otherwise represent a liability.
4. The invention design and operating practices optimize heat exchange up to twice the distance of the actual borehole depth, rather than just the geothermal energy recovered from a zone near the base of the borehole.
5. The use of water in a closed loop circuit reduces water requirements.
6. The use of a closed loop circuit avoids any negative impact on aquifers.
7. The use of a closed loop circuit at 1 atmosphere significantly reduces pumping and energy requirements.
8. The use of a closed loop circuit enables the use of friction reduction additives, corrosion inhibitors, and special purpose fluids to increase the efficiency and longevity of the system, and reduce systems maintenance costs.
9. The maximum use of smooth pipes reduces fluid friction, pump capacity and energy requirements.
10. The use of an unsmoothed surface on the inner surface of the inner pipe produces minor fluid agitation causing more rapid heat transfer.
11. The use of the metal base plate comprising a tapering down cone centered in a concave up bowl improves the flow efficiency and prevents erosion at the base of the borehole.
12. The use of attached support legs and base plate on the bottom of the inner pipe string extends the life cycle of components by minimizing any movement of the inner pipe string during operation mode.
13. The development of a heat envelope around the borehole can minimize the risk of fugitive fluid and gas release from the formational rock adjacent to the outer casing pipe.

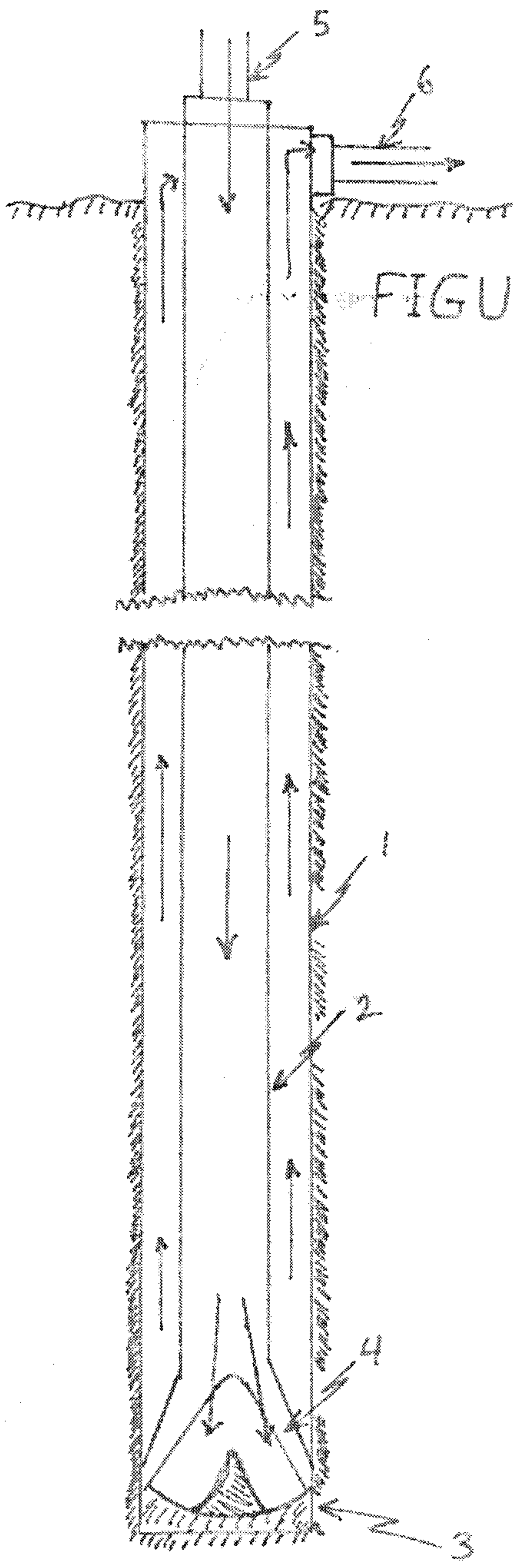

FIGURE 1

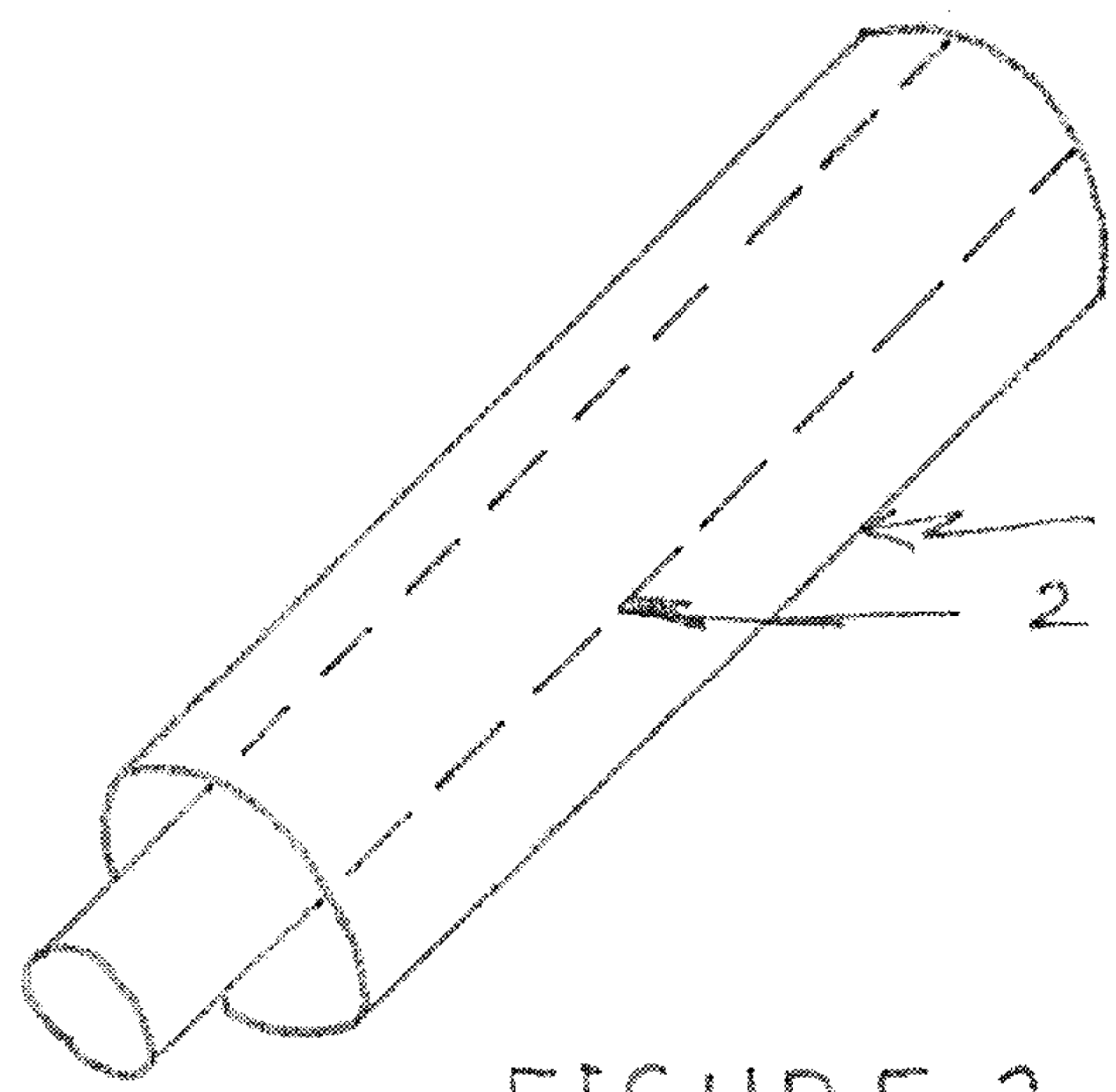

FIGURE 2

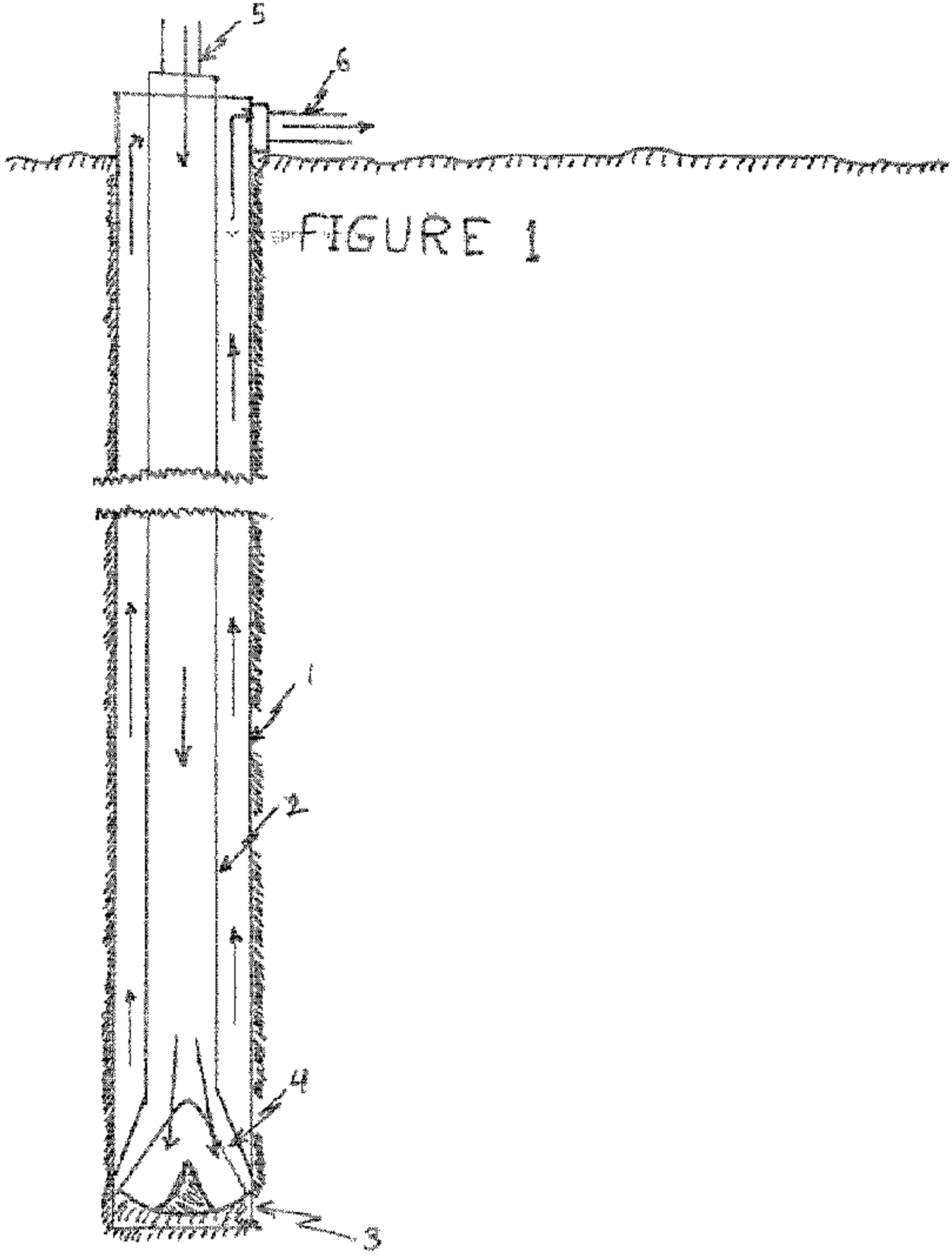

FIGURE 1