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CA 2806070 C 2017/11/21

(11)(21) **2 806 070**

(12) BREVET CANADIEN / CANADIAN PATENT

(13) **C**

(22) **Date de dépôt/Filing Date:** 2013/02/14

(41) **Mise à la disp. pub./Open to Public Insp.:** 2014/08/14

(45) **Date de délivrance/Issue Date:** 2017/11/21

(51) **Cl.Int./Int.Cl.** ***E21B 33/13*** (2006.01)

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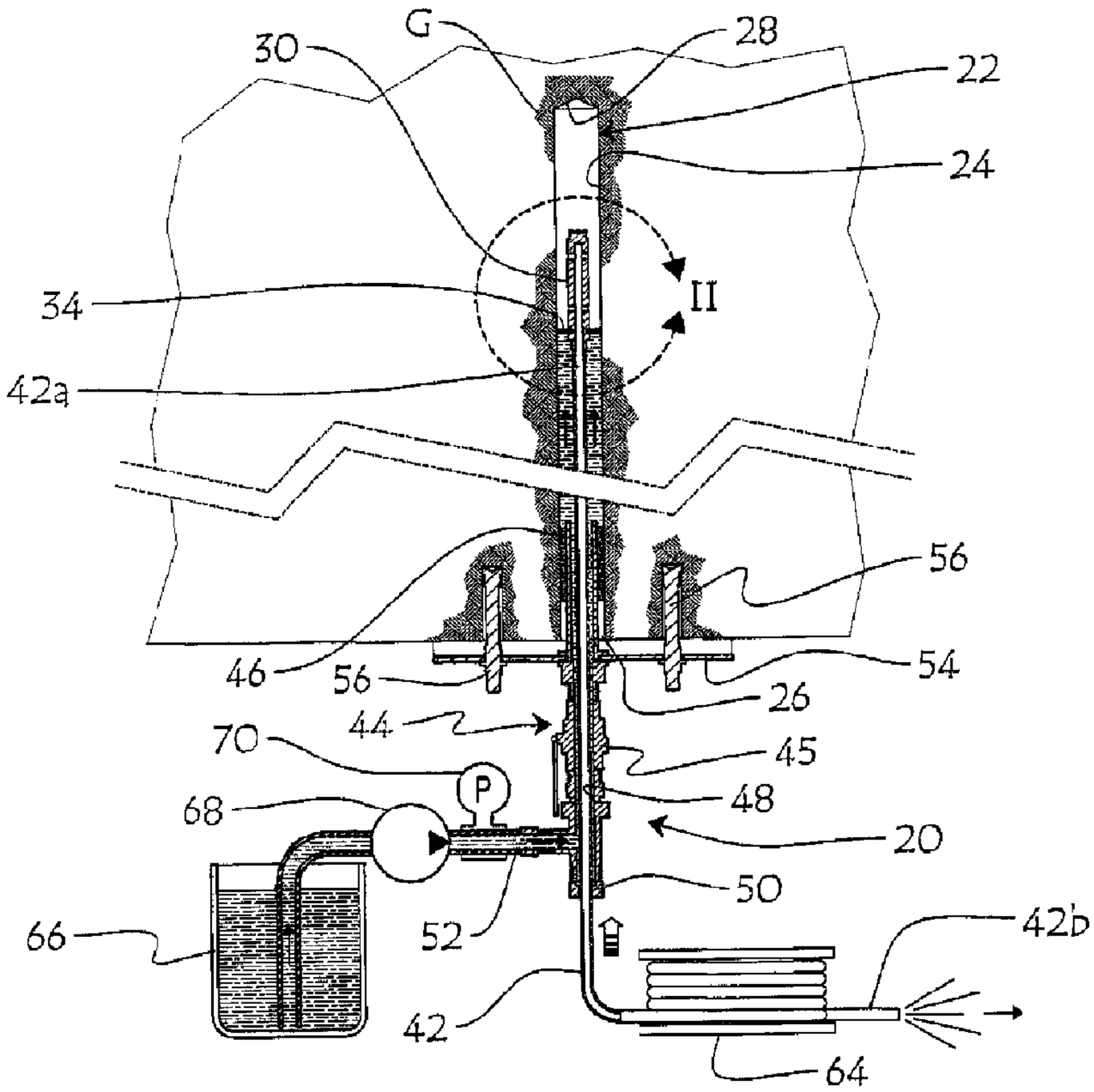
(54) **Titre : METHODE, TROUSSE ET SYSTEME D'INJECTION DE MORTIER LIQUIDE DANS UN TROU DE FORAGE, METHODE DE DEPLOIEMENT D'UN TUBE DANS UN TROU DE FORAGE EN VUE DE L'INJECTION DE MORTIER LIQUIDEET POINTE SERVANT DANS UN SYSTEME D'INJECTION DE MORTIER LIQUIDE**

(54) **Title: METHOD, KIT AND SYSTEM FOR INJECTING GROUT INTO A BOREHOLE, METHOD OF DEPLOYING A TUBE INTO A BOREHOLE FOR GROUT INJECTION AND LEADER FOR USE IN A GROUT INJECTION SYSTEM**



(57) **Abrégé/Abstract:**
The system and method to inject grout into a borehole uses a leader comprising opposite fore and aft portions, a pressure-bearing member between the fore and aft portions, and a leader passage extending from a fore opening at the leader fore portion to an aft

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(57) **Abrégé(suite)/Abstract(continued):**
opening in the leader aft portion. A tube is attached to the leader and connected to the leader aft opening. The leader is inserted into the borehole with the fore portion first. An impelling fluid is injected in the borehole downstream of the pressure-bearing member and exteriorly of the tube, resulting in pressure being applied on the pressure-bearing member and the leader consequently advancing towards the borehole bottom end, the leader carrying the tube with it to deploy the tube in the borehole. Upstream fluid located in the borehole upstream of the pressure- bearing member is evacuated out of the borehole through the leader passage and the tube. The injection of the impelling fluid is stopped when the leader reaches a leader target position and grout is then injected in the borehole, gradually filling the borehole. The impelling fluid is evacuated from the borehole through the leader passage and the tube while the grout is injected.

ABSTRACT

The system and method to inject grout into a borehole uses a leader comprising opposite fore and aft portions, a pressure-bearing member between the fore and aft portions, and a leader passage extending from a fore opening at the leader fore portion to an aft opening in the leader aft portion. A tube is attached to the leader and connected to the leader aft opening. The leader is inserted into the borehole with the fore portion first. An impelling fluid is injected in the borehole downstream of the pressure-bearing member and exteriorly of the tube, resulting in pressure being applied on the pressure-bearing member and the leader consequently advancing towards the borehole bottom end, the leader carrying the tube with it to deploy the tube in the borehole. Upstream fluid located in the borehole upstream of the pressure-bearing member is evacuated out of the borehole through the leader passage and the tube. The injection of the impelling fluid is stopped when the leader reaches a leader target position and grout is then injected in the borehole, gradually filling the borehole. The impelling fluid is evacuated from the borehole through the leader passage and the tube while the grout is injected.

TITLE OF THE INVENTION: METHOD, KIT AND SYSTEM FOR INJECTING GROUT INTO A BOREHOLE, METHOD OF DEPLOYING A TUBE INTO A BOREHOLE FOR GROUT INJECTION AND LEADER FOR USE IN A GROUT INJECTION SYSTEM

FIELD OF THE INVENTION

The present invention relates to the mining industry, and more particularly to methods, kits and systems for injecting grout into a borehole for filling the borehole.

BACKGROUND OF THE INVENTION

In the mining industry, boreholes may be drilled for exploration or definition purposes. Exploration refers to the act of obtaining ground samples, usually minerals, and evaluating what elements constitute those samples and in what proportion. Definition refers to the act of obtaining ground samples wherein determined elements are known to exist and evaluating in what proportion these elements are present in the samples obtained.

Exploration and definition boreholes can be very long, sometimes up to 1000 meters in length. Their diameter is usually relatively small, such as between 1 and 5 inches. They may be drilled downwardly, such as from the ground level or from the floor of a mine shaft; upwardly such as from the ceiling of a mine shaft; or generally at any angle, such as inclined upwardly or downwardly.

Boreholes, when drilled, may cross water veins and as such may allow water to flow into the mineshaft in which they were drilled. If the water debit rate is important, the borehole should be plugged or filled.

Boreholes may also compromise the structural integrity of the ground surrounding mine shafts, with undesirable consequences that may include cave-ins.

Finally, leaving boreholes unattended is also undesirable because of the use of explosives in the mineshafts. Indeed, the boreholes allow the blast to travel, for example between mineshafts that cross the boreholes.

Consequently, filling a borehole is usually desirable. This is accomplished with grout, which may be cement or the like suitable filling substance. The grout will be poured into the borehole and, when it sets, will consolidate the adjoining rock forming the ground into a solid mass. This both plugs the borehole and solidifies the ground around it.

If the borehole is very short, for example 15 meters or less, and is downwardly oriented, it is usually possible to simply pour grout into the borehole to fill it. However, if the borehole is long, for example 15 meters or more, the grout will not flow to the bottom of the borehole, usually stopping at about 15 meters, as a result of the grout setting and/or the air pressure in the borehole below the grout preventing the grout from flowing further into the borehole. If the borehole is upwardly oriented, pouring grout into the borehole through its open end is simply not possible without a pump, but otherwise the same problems as noted above exist.

Prior art systems for circumventing these problems include a rigid hollow injection tube that is inserted into the borehole. This injection tube comprises a number of injection tube sections that come in lengths of about three meters and can be threaded one at the end of the other to gradually form the injection tube into the borehole. An injection machine is located outside the borehole to help with this operation. Once the bottom of the borehole is reached – which can be determined by counting the number of tubes inserted into the hole times their length – it is possible to start grout injection. This is accomplished by pumping grout into the hollow injection tube with the injection machine. The borehole will thus be filled from its bottom towards its open end. The air

or water will be evacuated through the borehole open end, around the injection tube, preventing pressure buildup in the borehole.

Such a system indeed circumvents the problems mentioned above, however it suffers the important drawback of being very tedious to handle and very time-consuming to install. It can take up to a full day of work for two workmen to install all the tube sections required to reach the bottom of a 1000 meter borehole. Also, grout and other fluids present in the borehole such as water are still allowed to flow out through the borehole during the installation and filling operations if the borehole is an uphole or is upwardly inclined.

SUMMARY OF THE INVENTION

The invention relates to a method of injecting grout into a borehole, said borehole comprising a peripheral wall, an open end allowing access from outside said borehole into said borehole and a bottom end opposite said open end, said method comprising:

- providing a leader comprising opposite fore and aft portions, a pressure-bearing member between said fore and aft portions, and a leader passage extending from a fore opening at the leader fore portion to an aft opening in the leader aft portion;
- providing a tube attached to said leader and connected to said leader aft opening;
- inserting said leader into said borehole with said fore portion first, said borehole defining an upstream portion located upstream of said pressure-bearing member and a downstream portion located downstream of said pressure-bearing member;

- allowing said tube to extend outside of said borehole and to slide into said borehole as it is deployed therein;
- injecting an impelling fluid in said borehole downstream portion exteriorly of said tube resulting in pressure being applied on said pressure-bearing member and said leader consequently advancing towards said borehole bottom end, said leader carrying said tube with it to deploy said tube in said borehole; while upstream fluid located in said borehole upstream portion is evacuated out of said borehole through said leader passage and said tube;
- stopping the injection of said impelling fluid when said leader reaches a leader target position;
- injecting grout in said borehole downstream portion; and
- evacuating said impelling fluid from said borehole through said leader passage and said tube while said grout is injected, including allowing said impelling fluid to flow from said borehole downstream portion to said borehole upstream portion.

In one embodiment, the method further comprises:

- sealing said borehole open end before injecting said impelling fluid in said borehole downstream portion; and
- providing a downstream fluid connection allowing access to said borehole downstream portion exteriorly of said tube from outside said borehole, with the step of injecting an impelling fluid in said borehole downstream portion being accomplished through said downstream fluid connection and with the

step of injecting grout into said borehole downstream portion being accomplished through said downstream fluid connection.

In one embodiment, the step of allowing said grout to flow from said borehole downstream portion to said borehole upstream portion comprises disabling said pressure-bearing member.

In one embodiment, said pressure-bearing member comprises a leader main body and a leader seal attached to and located outwardly of said main body, said impelling fluid applying pressure against said leader seal to force said leader towards said borehole bottom end, said leader seal substantially sealing an area between said leader main body and the borehole peripheral wall, the step of disabling said pressure-bearing member comprising said leader seal rupturing when a threshold pressure is achieved in said borehole downstream portion.

In one embodiment, said leader target position corresponds to said borehole bottom end and said threshold pressure will be achieved when said leader reaches said borehole bottom end and is prevented from further advance while impelling fluid continues to be injected into said borehole downstream portion.

In one embodiment, the step of sealing said borehole open end is accomplished with a borehole interface member inserted in said open end, said borehole interface member comprising a plug that seals said borehole open end, an inner channel extending through said plug, and a tube seal sized to receive said tube therethrough, said tube seal preventing fluid to flow out of said borehole through said inner channel but allowing said tube to slide into said borehole through said tube seal and said inner channel.

In one embodiment, said downstream fluid connection is provided on said borehole interface member such that access to said borehole downstream portion is allowed through said borehole interface member inner channel exteriorly of said tube.

In one embodiment, stopping the injection of said impelling fluid when said leader reaches said leader target position is accomplished in either one of the following cases:

- if there is a marked increase in impelling fluid flow out of said borehole through said tube; and
- if there is a marked increase of pressure in said borehole downstream portion.

In one embodiment, the method further comprises the step of stopping the injection of said grout when grout overflows out of said borehole through said leader passage and said tube.

In one embodiment, said impelling fluid comprises water.

The present invention also relates to a method of deploying a tube into a borehole for injecting grout, said borehole comprising an open end allowing access from outside said borehole into said borehole and a bottom end opposite said open end, said method comprising:

- providing a leader comprising opposite fore and aft portions, a pressure-bearing member between said fore and aft portions, and a leader passage extending from a fore opening in said leader fore portion to an aft opening in said leader aft portion;
- providing a tube attached to said leader and connected to said leader aft opening;
- inserting said leader into said borehole with said fore portion first, with said borehole defining an upstream portion located upstream of said pressure-bearing member and a downstream portion located downstream of said pressure-bearing member;
- allowing said tube to extend outside of said borehole and to slide into said borehole as it is deployed therein;

- injecting an impelling fluid in said borehole downstream portion exteriorly of said tube resulting in pressure being applied on said pressure-bearing member and said leader consequently advancing towards said borehole bottom end, said leader carrying said tube with it to deploy said tube in said borehole; while upstream fluid located in said borehole upstream portion is ejected out of said borehole at least partly through said leader passage and said tube; and
- stopping the injection of said impelling fluid when said leader reaches a leader target position.

In one embodiment, the method further comprises:

- sealing said borehole open end before injecting said impelling fluid in said borehole downstream portion; and
- providing a downstream fluid connection allowing access to said borehole downstream portion exteriorly of said tube from outside said borehole, with the step of injecting an impelling fluid in said borehole downstream portion being accomplished through said downstream fluid connection.

In one embodiment, said impelling fluid is one of grout and water.

The invention further relates to a grout injection kit for use in assembling a grout injection system for injecting grout into a borehole, comprising:

- a leader comprising opposite fore and aft portions, a pressure-bearing member between said fore and aft portions, and a leader passage extending from a fore opening in said leader fore portion to an aft opening in said leader aft portion;
- a tube attachable to said leader and connectable to said leader aft opening;
- a borehole interface member comprising:

- a plug;
- an inner channel extending through said plug and sized to allow said tube to loosely extend and slide therethrough ;
- a tube seal in said inner channel, sized to allow said tube to extend and slide therethrough while preventing fluid flow between said tube seal and said tube; and
- a downstream fluid connection allowing fluid access into said inner channel exteriorly of said tube.

In one embodiment, the grout injection kit further comprises a fluid pump connectable to said downstream fluid connection.

In one embodiment, the grout injection kit further comprises an additional fluid pump connectable to said tube.

In one embodiment, said pressure-bearing member comprises a leader seal designed to rupture at a determined pressure threshold.

The present invention also relates to a grout injection system for injecting grout into a borehole, comprising:

- a leader comprising opposite fore and aft portions, a pressure-bearing member between said fore and aft portions, and a leader passage extending from a fore opening in said leader fore portion to an aft opening in said leader aft portion, said leader for insertion into said borehole with said fore portion first and said borehole thus defining an upstream portion located upstream of said pressure-bearing member and a downstream portion located downstream of said pressure-bearing member;

- a tube attached to said leader and connected to said leader aft opening;
- a plug for sealing the borehole;
- a tube channel for allowing said tube to slidingly extend into said borehole from outside the borehole;
- a downstream fluid connection for allowing fluid access into said borehole downstream portion exteriorly of said tube; and
- a fluid pump connectable to said downstream fluid connection.

In one embodiment, the grout injection system further comprises an additional fluid pump connectable to said tube.

In one embodiment, said leader comprises a main body and said pressure-bearing member comprises a leader seal attached to and located outwardly of said main body, said leader seal for substantially sealing an area between said leader main body and the borehole peripheral wall, said leader seal designed to rupture upon a threshold pressure being applied thereagainst.

In one embodiment, the grout injection system further comprises a borehole interface member that carries said plug, said tube channel comprising an inner channel extending through said borehole interface member including through said plug, and said downstream fluid connection connects to said inner channel through said borehole interface member.

The present invention further relates to a leader for use in a grout injection system, said leader comprising opposite fore and aft portions, a pressure-bearing member between said fore and aft portions, and a leader passage extending from a fore opening in said leader fore portion to an aft opening in said leader aft portion.

In one embodiment, the leader further comprises a main body, said pressure-bearing member comprising a leader seal attached to and located outwardly of said main body, said leader seal designed to rupture upon a threshold pressure being applied thereagainst.

DESCRIPTION OF THE DRAWINGS

In the annexed drawings :

Figure 1 is a schematic cross-sectional view of the grout injection system of the present invention, operatively installed about and within a borehole drilled in the ground, during the impelling fluid injection phase before the leader reaches the borehole bottom end;

Figure 2 is an enlarged view of the area circumscribed by line II in figure 1;

Figure 3 is a an enlarged view of the area in figure 1 near the borehole open end, particularly showing the borehole interface member and the tube;

Figure 4 is similar to figure 1, but shows the leader having reached the borehole bottom end, the leader seal having ruptured and the impelling fluid flowing from the borehole downstream portion into the borehole upstream portion, the leader passage and the tube;

Figure 5 is an enlarged view of the area circumscribed by line V of figure 4;

Figure 6 is similar to figure 1, but shows the grout injection system during its grout injection phase; and

Figure 7 is an enlarged view of the area circumscribed by line VII of figure 6.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Figures 1-7 show a grout injection system 20 for injecting grout into a borehole 22. Borehole 22 may be, for example, an exploration or definition borehole for mining purposes that has

been made in ground G with any suitable drilling equipment. The grout to be injected in borehole 22 probably has the purpose of filling borehole 22, although how much grout is injected is up to the system operator. The term "grout" used herein refers to any suitable filling material for filling borehole 22, such as cement for example.

Figures 1-3 show that borehole 22 comprises a peripheral wall 24 of generally cylindrical shape. Borehole 22 has an open end 26 allowing access from outside borehole 22 into borehole 22 and a bottom end 28 opposite open end 26. Borehole 22 may be an uphole as suggested in the drawings, or it could alternately be a downhole, or inclined at any angle upwardly or downwardly.

Grout injection system 20 comprises a leader 30 (figures 1 and 2) comprising an elongated, generally cylindrical main body 32 about which a pressure-bearing member in the form of an annular leader seal 34 is installed. Leader 30 defines opposite fore and aft portions 30a, 30b on either side of leader seal 34.

A leader passage 36 extends within leader main body 32. Passage 36 includes a number of fore openings 38 in leader fore portion 30a, an aft opening 40 located at leader aft portion 30b and a central orifice 39 between fore and aft openings 38, 40.

Grout injection system also comprises a flexible tube 42 that can be made, for example, of plastic material. Although tube 42 could theoretically be rigid, for example by providing threadable tube sections, this is seen as unpractical and providing a flexible tube is much more advantageous. Tube 42 comprises opposite first and second ends 42a, 42b and is attached to leader 30 at the tube first extremity 42a. More particularly, first extremity 42a is connected to a coupling 43 provided at leader aft opening 40 about aft opening 40.

Grout injection system 20 further comprises a borehole interface member 44 (figures 1 and 3) for insertion into the open end 26 of borehole 22. Borehole interface member 44 comprises

a main body 45 that carries an annular plug 46 made of a suitably fluid-tight material, such as rubber or the like, that seals the borehole open end 26 in fluid-tight fashion. An inner channel 48 extends through main body 45. As detailed hereinafter, tube 42 loosely extends through inner channel 48. Borehole interface member 44 also comprises a tube seal 50 provided at an extremity of main body 45 opposite plug 46. Tube seal 50 restricts inner channel 48 and is sized to snugly receive tube 42 therein for preventing fluid to flow out of borehole 22 around tube 42 while allowing tube 42 to slide into borehole 22 through tube seal 50. A downstream fluid connection in the form of a downstream fluid conduit 52 extends transversely away from main body 45. Downstream fluid conduit 52 is in fluid connection with inner channel 48 for allowing fluid access into borehole 22 through inner channel 48 exteriorly of tube 42.

The main body 45 of borehole interface member 44 may comprise several body portions that are screwed to each other to facilitate installation and maintenance. For simplicity, main body 45 has been shown schematically in the figures as a unitary element, but it is understood that its construction could be fragmented or otherwise customized as will be obvious for someone skilled in the art.

Although the friction-fit of plug 46 in borehole 22 contributes to retain borehole interface member 44 in borehole open end 26, a retaining plate 54 is used to hold main body 45 in place, with retaining plate 54 being bolted to the ground with rock bolts 56. Retaining plate 54 has an aperture 58 through which main body 45 extends and main body 45 is fixedly attached to retaining plate 54, for example with two body portions of main body 45 being screwed to each other on either side of aperture 58 to sandwich retaining plate 54.

Main body 45 comprises a valve 60 controlled by an activation handle 62 allowing inner channel 48 to be selectively closed. Valve 60 allows closure of inner channel 48 even if tube 42 extends therethrough, the tube 42 then being compressed and closed by valve 60. Valve 60

remains opened until the filling of borehole 22 with grout is completed, as detailed hereinafter. Valve 60 can be of any known type, for example a ball valve.

As shown in figure 1, while the first extremity 42a of tube 42 extends into borehole 22, its second extremity 42b extends outside of borehole 22. The portion of tube 42 located outside of borehole 22 is wound on a spool 64 to facilitate handling of tube 42. Even if thusly wound on spool 64, tube 42 is not compressed to the point of fluid being prevented from flowing therein. Indeed, as will be seen later, fluid will flow out of the second extremity 42b of tube 42 even while it is still wound on spool 64. As tube 42 is fed into borehole 22 as detailed hereinafter, spool will rotate to unwind tube 42 therefrom. If additional lengths of tube 42 than that available on a single spool 64 is required during operation of grout injection system 20, additional spools with additional lengths of tube may be used, with the additional lengths of tube being suitably connected end to end with the previously installed lengths of tube.

Grout injection system 20 further comprises an impelling fluid reservoir 66 containing impelling fluid. Downstream fluid conduit 52 links impelling fluid reservoir 66 to main body 45 of borehole interface member 44. A fluid pump 68 is provided along impelling fluid conduit 52 to convey fluid from reservoir 66 into inner channel 48 and borehole 22, as detailed hereinafter.

A manometer 70 is provided on downstream fluid conduit 52 to measure the impelling fluid pressure at that position. Since downstream fluid conduit 52 is in substantially unrestricted fluid connection with the borehole downstream portion, the pressure measured at manometer 70 will be representative of, if not equal to, the pressure in the borehole downstream portion.

In use, it is possible to inject grout with grout injection system 20 into borehole 22, to partly or completely fill borehole 22. Since the purpose of injecting grout into a borehole is usually

to fill it entirely, the following description will refer specifically to such an operation of completely filling borehole 22. However, it is understood that the system operator may decide to inject any desired quantity of grout into borehole 22.

To accomplish the grout injection, parts of a grout injection kit according to the present invention will be assembled. The grout injection kit comprises at least leader 30, tube 42 and borehole interface member 44 and fluid pump 68. It is noted that the grout injection kit could be sold separately from fluid pump 68 whereby purchasers could provide the pump themselves, or the grout injection kit could be sold including fluid pump 68. It is assumed that the purchasers of the grout injection kit would use their own reservoirs 66, 74, 75.

To operatively install the grout injection system 20 from the grout injection kit, and as shown in figures 1-3, the tube first end 42a is first inserted through the inner channel 48 of borehole interface member 44 until tube 42 extends entirely through borehole interface member 44. Tube 42 notably extends through tube seal 50 so as to be slidable therein without however allowing fluid flow between tube seal 50 and tube 42. The tube first end 42a is securely attached to aft coupling 43 of leader 30 so that tube 42 is in fact connected to the leader passage 36 through leader aft opening 40.

Leader 30 is then inserted into borehole 22 with its fore portion 30a first and with the tube 42 extending outside of borehole 22 such that its second end 42b will be situated exteriorly of borehole 22. Once leader 30 is located inside borehole 22, leader seal 34 substantially seals an annular area between leader main body 32 and borehole peripheral wall 24. Borehole 22 thus defines an upstream portion located upstream of leader seal 34 and a downstream portion located downstream of leader seal 34, with these upstream and downstream portions being of variable dimensions as leader 30 travels in borehole 22, as detailed hereinafter. It is noted that it is likely that borehole 22 will have a somewhat irregular peripheral wall 24 as a consequence of the drilling

operation, and the seal between leader seal 34 and the borehole peripheral wall 24 may be imperfect in practice resulting in some fluid being allowed to flow between the borehole upstream and downstream portions, albeit in limited fashion. This is why the present specification refers to leader seal 34 "substantially" sealing the area between leader main body 32 and borehole peripheral wall 24, in that the seal may not be perfect.

Borehole open end 26 is then sealed by inserting borehole interface member 44, and more particularly plug 46, into bore hole 22 at open end 26. This includes the installation of retaining plate 54 that is sandwiched within main body 45 of borehole interface member 44; retaining plate 54 is bolted to the ground with rock bolts 56. Borehole interface member 44 is consequently securely installed at and within borehole open end 26.

In the embodiment shown in the drawings, the portion of main body 45 opposite seal 46 extends exteriorly of borehole 22, allowing easy access to downstream fluid conduit 52. Downstream fluid conduit 52 is connected to fluid pump 68 that is in turn connected to impelling fluid reservoir 66 to ultimately link reservoir 66 to inner channel 48 of borehole interface member 44.

Fluid pump 68 is actuated to inject impelling fluid from reservoir 66 through conduit 52 and the inner channel 48 of borehole interface member 44 exteriorly of tube 42 and into the downstream portion of borehole 22. Impelling fluid will notably fill the area between leader seal 34 and tube seal 50 at which point the pressure in this section will increase until the force exerted on leader seal 34 becomes sufficient to force leader 30 to advance into borehole 22. Continued injection of impelling fluid in the borehole downstream portion will force leader 30 to advance gradually towards borehole bottom end 28.

As leader 30 advances in borehole 22, it carries tube 42 with it to deploy tube 42 in borehole 22. Tube 42 is allowed to slide into borehole 22 from outside borehole 22 through tube seal 50.

As suggested in figures 1-3, as leader 30 advances in borehole 22, upstream fluid is evacuated from the borehole upstream portion to prevent an augmentation of the pressure in the borehole upstream portion. This upstream fluid comprises any fluid naturally present in borehole 22, such as air, and is likely to also comprise some limited quantities of impelling fluid that may seep between leader seal 34 and borehole peripheral wall 24 from the borehole downstream portion into the borehole upstream portion. The evacuation of this upstream fluid will be accomplished through the leader inner passage 36 and then through tube 42 to be exhausted out through tube second end 42b. More particularly, the upstream fluid will flow from the borehole upstream portion, through leader fore openings 38, leader central orifice 39 and leader aft opening 40 into tube 42. A receiving reservoir (not shown) could optionally be provided if the upstream fluid is required to be recuperated, for example if substantial quantities of impelling fluid are evacuated at this stage.

The injection of impelling fluid will be stopped by stopping the operation of pump 68 when leader 30 reaches a leader target position. The leader target position of leader 30 may correspond to the position of leader 30 when it reaches the borehole bottom end 28 as suggested in figure 4, or at any other desired intermediate injection position along borehole 22 as determined by the system operator. An intermediate injection position could be reached if for example a determined length of tube 42 has been deployed in borehole 22. In any event, when pump 68 is stopped, the advance of leader 30 will be interrupted at the leader target position if leader 30 is not otherwise prevented from further advancing into borehole 22 such as by leader 30 hitting the borehole bottom end 28 or by tube 42 having reached a maximum deployment length and its feeding into borehole 22 being consequently stopped by the system operator, e.g. by blocking spool 64.

As suggested in figures 4 and 5, leader seal 34 is disabled when leader 30 reaches its leader target position. Although this could be commanded remotely from outside borehole 22 and accomplished with a mechanical, electromechanical or other suitable disabling devices (not shown), according to the present invention leader seal 34 is disabled by rupturing under increased pressure by the impelling fluid. This increased pressure occurs when leader 30 is prevented from further advance, such as when leader 30 will reach the borehole bottom end 28, and before fluid pump 68 is stopped. That is to say, fluid pump 68 will continue to feed impelling fluid into the borehole downstream portion once leader 30 reaches its leader target position, increasing the pressure in the borehole downstream portion until leader seal 34 ruptures. Leader seal 34 is consequently designed to rupture when a given pressure threshold is reached, and operation of the grout injection system 20 assumes that this pressure threshold will be calibrated according to expected operating pressures within a given borehole.

If the operator of grout injection system 20 wishes to confirm whether leader 30 has reached its leader target position over and beyond leader 30 being blocked in its advance, he can have tube 42 be marked for length so as to be able to measure the length of tube 42 that has been inserted into borehole 22 at all times. If leader 30 blocks at an undesirable intermediate position along borehole 22 and the operator realizes that this undesirable intermediate position does not correspond to the desired leader target position per the length of tube that has been deployed into borehole 22, the operator may stop the injection of impelling fluid and retrieve tube 42 and leader 30 from borehole 22, optionally evacuating the impelling fluid from borehole 22, to then use a drilling device to ensure that the borehole 22 is properly cleared and its peripheral wall 24, properly smooth. The entire grout injection system installation can then be restarted as detailed above, including insertion of leader 30 into borehole 22 up to the point where it was before, and beyond.

When leader 30 reaches the borehole bottom end 28 and the leader seal 34 ruptures, impelling fluid will be allowed to flow from the borehole downstream position to the borehole upstream position, then through leader passage 36 into tube 42, this resulting in a marked increase in impelling fluid flow out of borehole 22 through the tube second end 42b as shown in figure 4. Leader 30 not advancing anymore in borehole 22 while impelling fluid continues to be pumped into borehole 22 will also result in a marked increase in first fluid pressure as measured at manometer 70, especially before the rupturing of leader seal 34. Either one or both of these situations will cue the operator to stop the operation of pump 68 and consequently the injection of impelling fluid and suggest that leader 30 has reached the bottom end 28 of borehole 22, i.e. its leader target position.

When seal 34 ruptures, it may help stabilize the position of leader 30 in borehole 22 in its leader target position to avoid subsequent accidental movement of leader 30. Indeed, upon rupturing, seal 34 will form flanges that will interact in a wedging relationship with the borehole peripheral wall 24.

As suggested in figure 6, once the injection of impelling fluid has been stopped, the emptied impelling fluid reservoir 66 is replaced by a grout reservoir 74. Grout reservoir 74 is operatively connected to fluid pump 68 and to downstream fluid conduit 52. An evacuation reservoir 75 is optionally connected to the tube second end 42b. To facilitate this last operation, tube 42 could be cut at a desired length outside of borehole 22 and its newly cut second end 42b inserted into evacuation reservoir 75, with spool 64 and any useless excess length of tube 42 being removed.

Optionally, a distinct additional pump (not shown) could be installed for pumping grout, instead of using fluid pump 68 that may be specific to a certain type of impelling fluid.

As suggested in figures 6 and 7, fluid pump 68 is actuated to inject grout in borehole 22. More particularly, grout will be pumped from grout reservoir 74 in downstream fluid conduit 52,

borehole interface member inner channel 48 exteriorly of tube 42 and into the borehole downstream portion

While grout fills borehole 22 from its open end 26 towards its bottom end 28, the impelling fluid is gradually evacuated from borehole 22. With leader seal 34 having been previously disabled, impelling fluid located in borehole 22 will flow from the borehole downstream portion to the borehole upstream portion, then through leader passage 36, tube 42 and into evacuation reservoir 75.. The grout itself, through the action of fluid pump 68, will push on the impelling fluid to achieve this result. Of course, suitable relative liquid/gaseous states and relative densities of the grout and impelling fluid should be considered for this result to be achieved.

Injection of grout will be stopped by the operator by cutting off fluid pump 68. This can be done for example when grout overflows out of borehole 22 through tube 42 into evacuation reservoir 75, cueing the operator that borehole 22 is filled with grout. Alternately, the volume of injected grout could be measured by the operator and the grout injection could be stopped at a determined target volume.

When grout injection is completed, the grout will gradually set, effectively at least plugging borehole 22 and possibly filling it entirely, to help prevent fluid flow through borehole 22 and structural failure about borehole 22.

Valve 60 can optionally be closed with handle 62 to prevent accidental fluid outflow from borehole 22 while the grout sets. All tubing, pumps and reservoirs located outside of borehole 22 can be removed. The borehole interface member 44 is intended to remain at borehole open end 26 with its plug 46 maintaining an airtight seal at the borehole open end 26.

According to the present invention, the impelling fluid can comprise water or any other suitable fluid including liquid or gas such as air.

According to the present invention, it can consequently be seen that the grout injection is possible in boreholes having any orientation, including upholes or downholes. With a flexible tube 42, even curved holes can be filled. The advance of leader 30 and the injection of the impelling fluid and the grout are indeed all independent of the gravity in their operability. Borehole interface member 44, with its plug 46, prevents water or grout to spill out of the borehole as it is being filled even if it is upwardly inclined.

According to the present invention, borehole 22 can be filled with grout from its open end 26 towards it bottom end 28 without pressure buildup, since the leader 30 is first moved to the borehole bottom end 28, carrying tube 42 with it, before grout injection begins. Fluid located in borehole 22 may be evacuated through leader passage 30 and tube 42 during both the impelling fluid injection and the grout injection.

One advantage of the present invention is that deploying tube 42 to the bottom end 28 of borehole 22 is simple: even for very long holes, such as those that measure about 1000 meters, it can take only about an hour or two to deploy the tube therein, and a single operator is sufficient to accomplish this task. This is a very significant time saving compared to the manual section-by-section installation of prior art rigid hollow injection tubes that took two workmen up to a full workday to accomplish.

The present invention also generally relates to a method of deploying tube 42 into borehole 22 for grout injection, whereby tube 42 may be used to evacuate air for the injection of an impelling fluid that may, in fact, be the grout itself. Indeed, by injecting grout directly in the borehole downstream portion, the advance of leader 30 will still be enabled by the grout applying pressure on leader seal 34. Also, the upstream fluid is still evacuated through the leader passage 36 and tube 42, preventing pressure buildup upstream of leader 30 and the injected grout. However, this method of injecting grout into the borehole 22 without first deploying tube 42 in borehole 22 is more

risky: it would be very difficult to correct any problem occurring during the advance of leader 30 since the borehole 22 would be partly filled with grout already, making it very difficult if not impossible to retrieve the leader 30 and start over if a problem occurs such as if leader 30 becomes stuck in borehole 22 during its advance before it reaches the borehole bottom end 28.

According to the present invention, grout injection system 20 generally comprises a tube channel for allowing tube 42 to slidingly yet sealingly extend into borehole 22 from outside borehole 22. In the embodiment shown in the drawings, the tube channel is formed by the borehole interface member inner channel 48; however in an alternate embodiment (not shown) the tube channel could be distinct from the borehole interface member, for example being provided as a conduit, or even simply a hole, that extends through ground G exteriorly of the borehole interface member 44 and through which tube 42 extends. Similarly, the downstream fluid connection, in the embodiment shown in the drawings, is shown as the downstream fluid conduit 52 that connects to the borehole interface member inner channel 48, but it could be entirely distinct from the borehole interface member 44 and be embodied by an alternate downstream fluid conduit or access (not shown) that extends exteriorly of the borehole interface member 44 and allows access to the borehole downstream portion.

In one alternate embodiment (not shown), if the borehole is a downhole or is downwardly inclined, it could be envisioned to inject impelling fluid to push the leader into the borehole without however sealing the borehole open end. Of course, this would not be as efficient and is not a preferred way to carry out the invention, since applying pressure on the leader's pressure bearing member would be more difficult. In this alternate embodiment, no borehole interface member is used and the borehole downstream portion is readily accessible through the borehole's open end through which the tube may loosely slide.

Leader seal 34 could be made of any material capable of allowing leader to be pushed along borehole 22 while rupturing when submitted to a pressure equal to or greater than the threshold pressure value. Semi-rigid Rubber is envisioned as one acceptable material that could further allow leader seal 34 to slightly resiliently deform against the borehole peripheral wall 24 when leader 30 is inserted into borehole 22 to obtain the above-mentioned substantial seal between leader seal 34 and borehole peripheral wall 24. More generally, it should be noted that the pressure bearing member, shown as leader seal 34 in the drawings, could alternately be formed differently than an annular seal 34. The general purpose of the pressure bearing member is to allow pressure by the impelling fluid to bear thereon for forcing the leader towards the borehole bottom end. The pressure bearing member can be formed integrally with the leader's main body, or be a distinct part attached thereto.

In an alternate embodiment (now shown), grout could be injected through the tube once leader 30 has reached the borehole bottom end 28, instead of being injected through the downstream fluid conduit 52. The pump 68 (or the above-mentioned additional pump) would then be connected to the tube second end 42b. The impelling fluid would be evacuated through the borehole interface member inner channel 48 and downstream fluid conduit 52. A problem with this embodiment, however, is the risk that the leader will be carried towards the borehole open end 26 with the injected grout and that the leader and tube jam somewhere along the borehole 22.

CLAIMS

1. A method of injecting grout into a borehole, said borehole comprising a peripheral wall, an open end allowing access from outside said borehole into said borehole and a bottom end opposite said open end, said method comprising:

- providing a leader comprising opposite fore and aft portions, a main body, a pressure-bearing member about said main body between said fore and aft portions, and a leader passage extending from a fore opening at the leader fore portion to an aft opening in the leader aft portion;
- providing a tube attached to said leader and connected to said leader aft opening;
- inserting said leader into said borehole with said fore portion first, said borehole defining an upstream portion located upstream of said pressure-bearing member and a downstream portion located downstream of said pressure-bearing member;
- allowing said tube to extend outside of said borehole and to slide into said borehole as it is deployed therein;
- injecting an impelling fluid in said borehole downstream portion exteriorly of said tube resulting in pressure being applied on said pressure-bearing member and said leader consequently advancing towards said borehole bottom end, said leader carrying said tube with it to deploy said tube in said borehole; while upstream fluid located in said borehole upstream portion is evacuated out of said borehole through said leader passage and said tube;
- stopping the injection of said impelling fluid when said leader reaches a leader target position;

- injecting grout in said borehole downstream portion; and
- evacuating said impelling fluid from said borehole through said leader passage and said tube while said grout is injected, including allowing said impelling fluid to flow from said borehole downstream portion to said borehole upstream portion.

2. A method as defined in claim 1, further comprising:
   - sealing said borehole open end before injecting said impelling fluid in said borehole downstream portion; and
   - providing a downstream fluid connection allowing access to said borehole downstream portion exteriorly of said tube from outside said borehole, with the step of injecting an impelling fluid in said borehole downstream portion being accomplished through said downstream fluid connection and with the step of injecting grout into said borehole downstream portion being accomplished through said downstream fluid connection.

3. A method as defined in claim 2, wherein the step of allowing said grout to flow from said borehole downstream portion to said borehole upstream portion comprises disabling said pressure-bearing member.

4. A method as defined in claim 3, wherein said pressure-bearing member comprises a leader seal attached to and located outwardly of said main body, said impelling fluid applying pressure against said leader seal to force said leader towards said borehole bottom end, said leader seal substantially sealing an area between said leader main body

and the borehole peripheral wall, the step of disabling said pressure-bearing member comprising said leader seal rupturing when a threshold pressure is achieved in said borehole downstream portion.

5. A method as defined in claim 4, wherein said leader target position corresponds to said borehole bottom end and said threshold pressure will be achieved when said leader reaches said borehole bottom end and is prevented from further advance while impelling fluid continues to be injected into said borehole downstream portion.

6. A method as defined in claim 2, wherein the step of sealing said borehole open end is accomplished with a borehole interface member inserted in said open end, said borehole interface member comprising a plug that seals said borehole open end, an inner channel extending through said plug, and a tube seal sized to receive said tube therethrough, said tube seal preventing fluid to flow out of said borehole through said inner channel but allowing said tube to slide into said borehole through said tube seal and said inner channel.

7. A method as defined in claim 6, wherein said downstream fluid connection is provided on said borehole interface member such that access to said borehole downstream portion is allowed through said borehole interface member inner channel exteriorly of said tube.

8. A method as defined in claim 5, wherein stopping the injection of said impelling fluid when said leader reaches said leader target position is accomplished in either one of the following cases:

- if there is a marked increase in impelling fluid flow out of said borehole through said tube; and
- if there is a marked increase of pressure in said borehole downstream portion.

9. A method as defined in claim 8, further comprising the step of stopping the injection of said grout when grout overflows out of said borehole through said leader passage and said tube.

10. A method as defined in claim 2, wherein said impelling fluid comprises water.

11. A method of deploying a tube into a borehole for injecting grout, said borehole comprising an open end allowing access from outside said borehole into said borehole and a bottom end opposite said open end, said method comprising:

- providing a leader comprising opposite fore and aft portions, a main body, a pressure-bearing member about said main body between said fore and aft portions, and a leader passage extending from a fore opening in said leader fore portion to an aft opening in said leader aft portion;
- providing a tube attached to said leader and connected to said leader aft opening;
- inserting said leader into said borehole with said fore portion first, with said borehole defining an upstream portion located upstream of said pressure-bearing member and a downstream portion located downstream of said pressure-bearing member;
- allowing said tube to extend outside of said borehole and to slide into said borehole as it is deployed therein;

- injecting an impelling fluid in said borehole downstream portion exteriorly of said tube resulting in pressure being applied on said pressure-bearing member and said leader consequently advancing towards said borehole bottom end, said leader carrying said tube with it to deploy said tube in said borehole; while upstream fluid located in said borehole upstream portion is ejected out of said borehole at least partly through said leader passage and said tube; and
- stopping the injection of said impelling fluid when said leader reaches a leader target position.

12. A method as defined in claim 11, further comprising:

- sealing said borehole open end before injecting said impelling fluid in said borehole downstream portion; and
- providing a downstream fluid connection allowing access to said borehole downstream portion exteriorly of said tube from outside said borehole, with the step of injecting an impelling fluid in said borehole downstream portion being accomplished through said downstream fluid connection.

13. A method as defined in claim 12, wherein said impelling fluid is one of grout and water.

14. A grout injection kit for use in assembling a grout injection system for injecting grout into a borehole, comprising:

- a leader comprising opposite fore and aft portions, a main body, a pressure-bearing member about said main body between said fore and aft portions, and a

leader passage extending from a fore opening in said leader fore portion to an aft opening in said leader aft portion, said pressure bearing member capable of receiving fluid pressure for forcing said leader to advance in a borehole;

- a tube attachable to said leader and connectable to said leader aft opening;
- a borehole interface member comprising:
    - a plug;
    - an inner channel extending through said plug and sized to allow said tube to loosely extend and slide therethrough ;
    - a tube seal in said inner channel, sized to allow said tube to extend and slide therethrough while preventing fluid flow between said tube seal and said tube; and
    - a downstream fluid connection allowing fluid access into said inner channel exteriorly of said tube.

15. A grout injection kit as defined in claim 14, further comprising a fluid pump connectable to said downstream fluid connection.

16. A grout injection kit as defined in claim 15, further comprising an additional fluid pump connectable to said tube.

17. A grout injection kit as defined in claim 14, wherein said pressure-bearing member comprises a leader seal attached to and located outwardly of said main body and designed to rupture at a determined pressure threshold.

18. A grout injection system for injecting grout into a borehole, comprising:

- a leader comprising opposite fore and aft portions, a main body, a pressure-bearing member about said main body between said fore and aft portions, and a leader passage extending from a fore opening in said leader fore portion to an aft opening in said leader aft portion, said leader for insertion into said borehole with said fore portion first and said borehole thus defining an upstream portion located upstream of said pressure-bearing member and a downstream portion located downstream of said pressure-bearing member;
- a tube attached to said leader and connected to said leader aft opening;
- a plug for sealing the borehole;
- a tube channel for allowing said tube to slidingly extend into said borehole from outside the borehole;
- a downstream fluid connection for allowing fluid access into said borehole downstream portion exteriorly of said tube; and
- a fluid pump connectable to said downstream fluid connection

wherein said pressure bearing member is capable of receiving fluid pressure for forcing said leader to advance in the borehole.

19. A grout injection system as defined in claim 18, further comprising an additional fluid pump connectable to said tube.

20. A grout injection system as defined in claim 18, wherein said pressure-bearing member comprises a leader seal attached to and located outwardly of said main body, said leader

seal for substantially sealing an area between said leader main body and the borehole peripheral wall, said leader seal designed to rupture upon a threshold pressure being applied thereagainst.

21. A grout injection system as defined in claim 18, further comprising a borehole interface member that carries said plug, said tube channel comprising an inner channel extending through said borehole interface member including through said plug, and said downstream fluid connection connects to said inner channel through said borehole interface member.

22. A leader for use in a grout injection system, said leader comprising opposite fore and aft portions, a main body, a pressure-bearing member about said main body between said fore and aft portions, and a leader passage extending from a fore opening in said leader fore portion to an aft opening in said leader aft portion, said pressure bearing member capable of receiving fluid pressure for forcing said leader to advance in a borehole.

23. A leader as defined in claim 22, further comprising a main body, said pressure-bearing member comprising a leader seal attached to and located outwardly of said main body, said leader seal designed to rupture upon a threshold pressure being applied thereagainst.

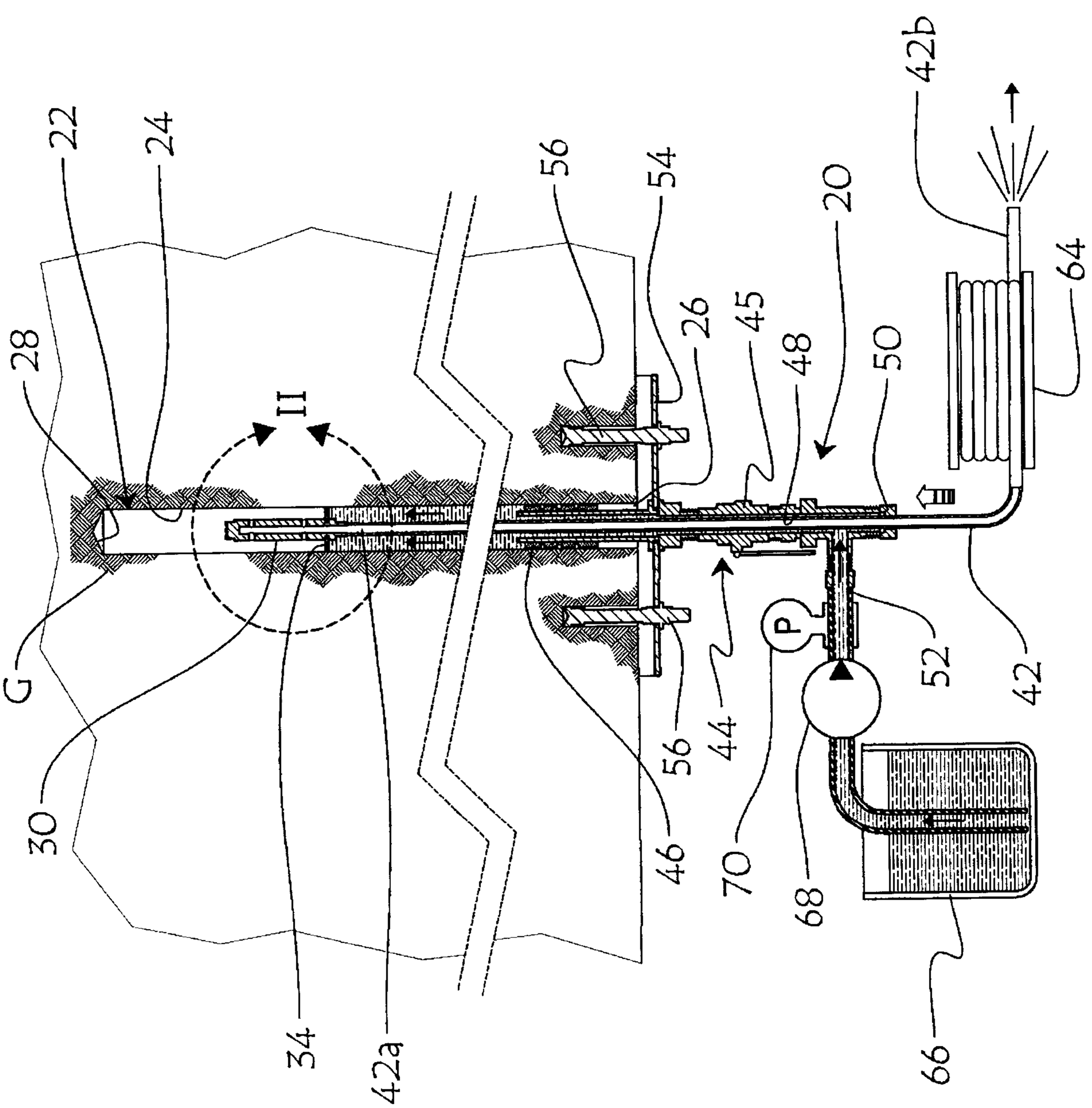
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Fig.1

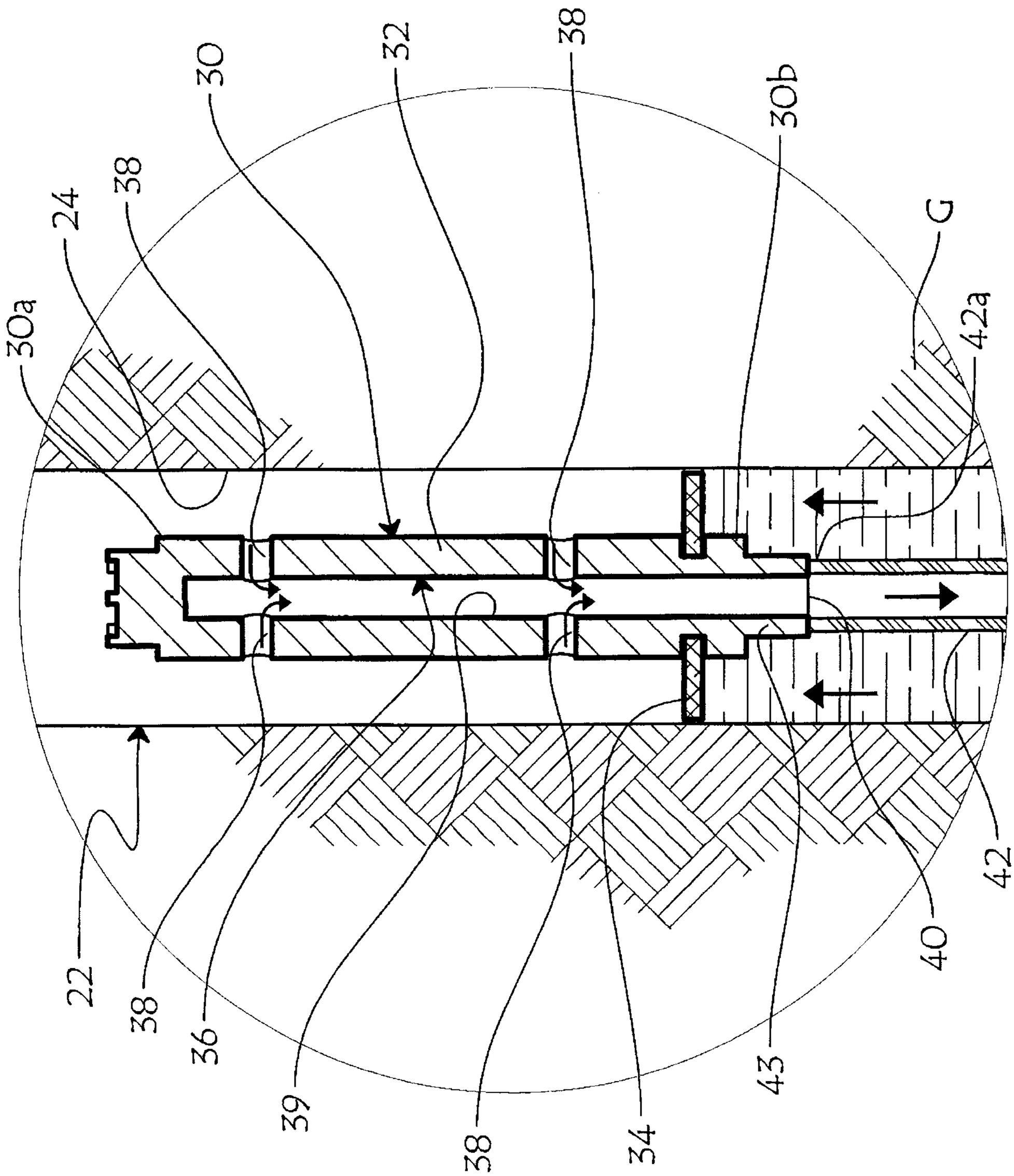


Fig.2

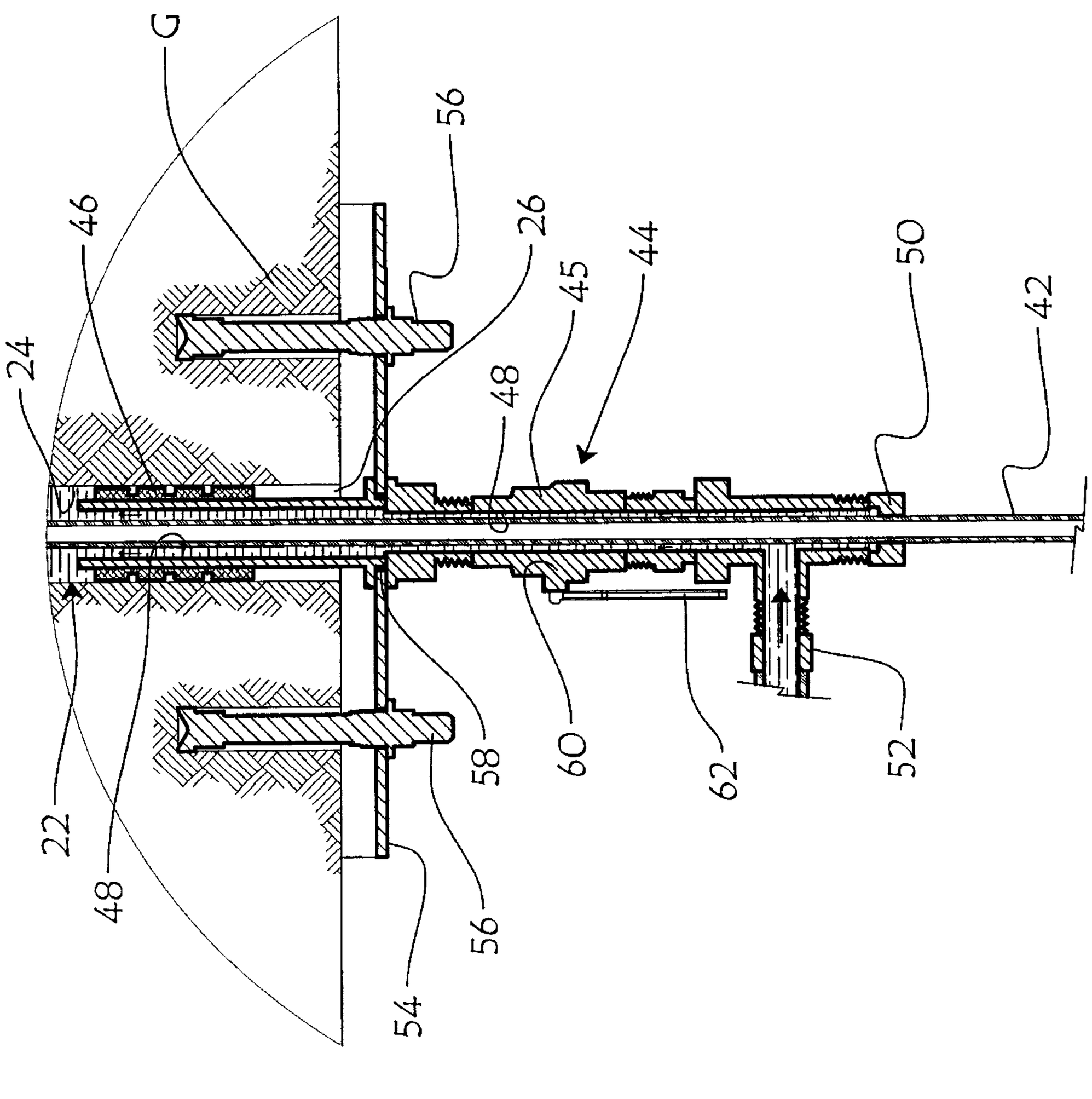


Fig.3

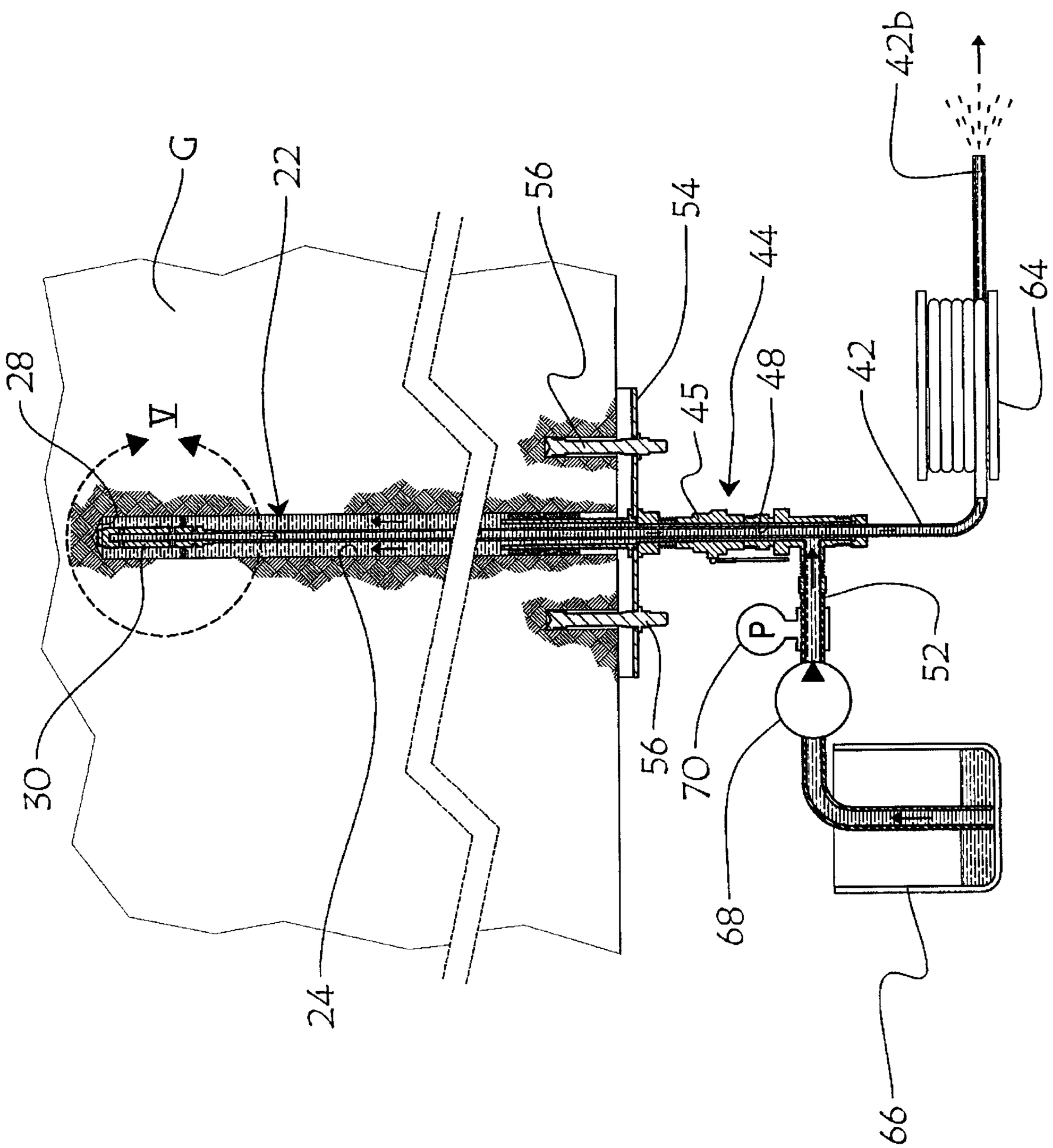


Fig.4

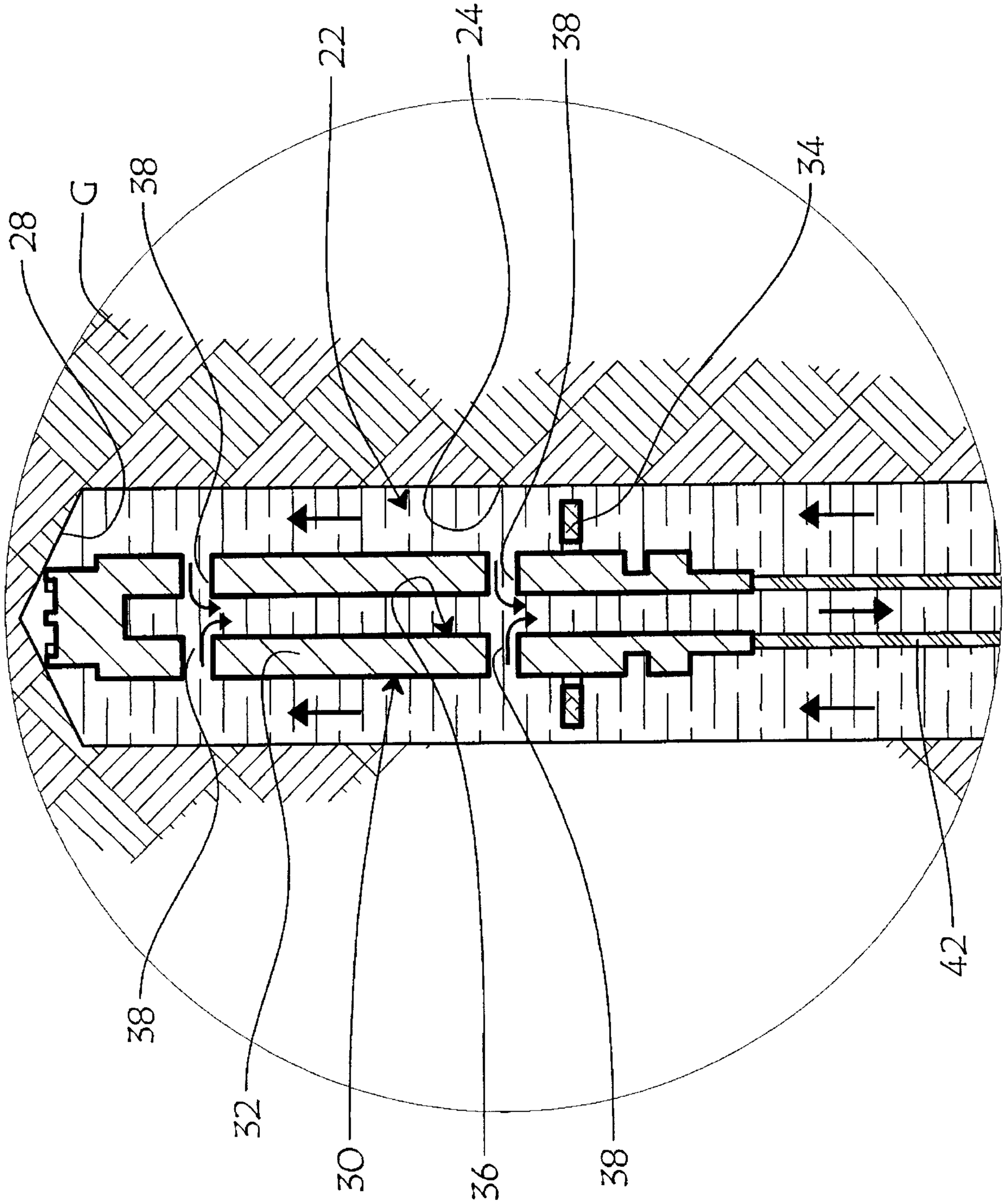


Fig.5

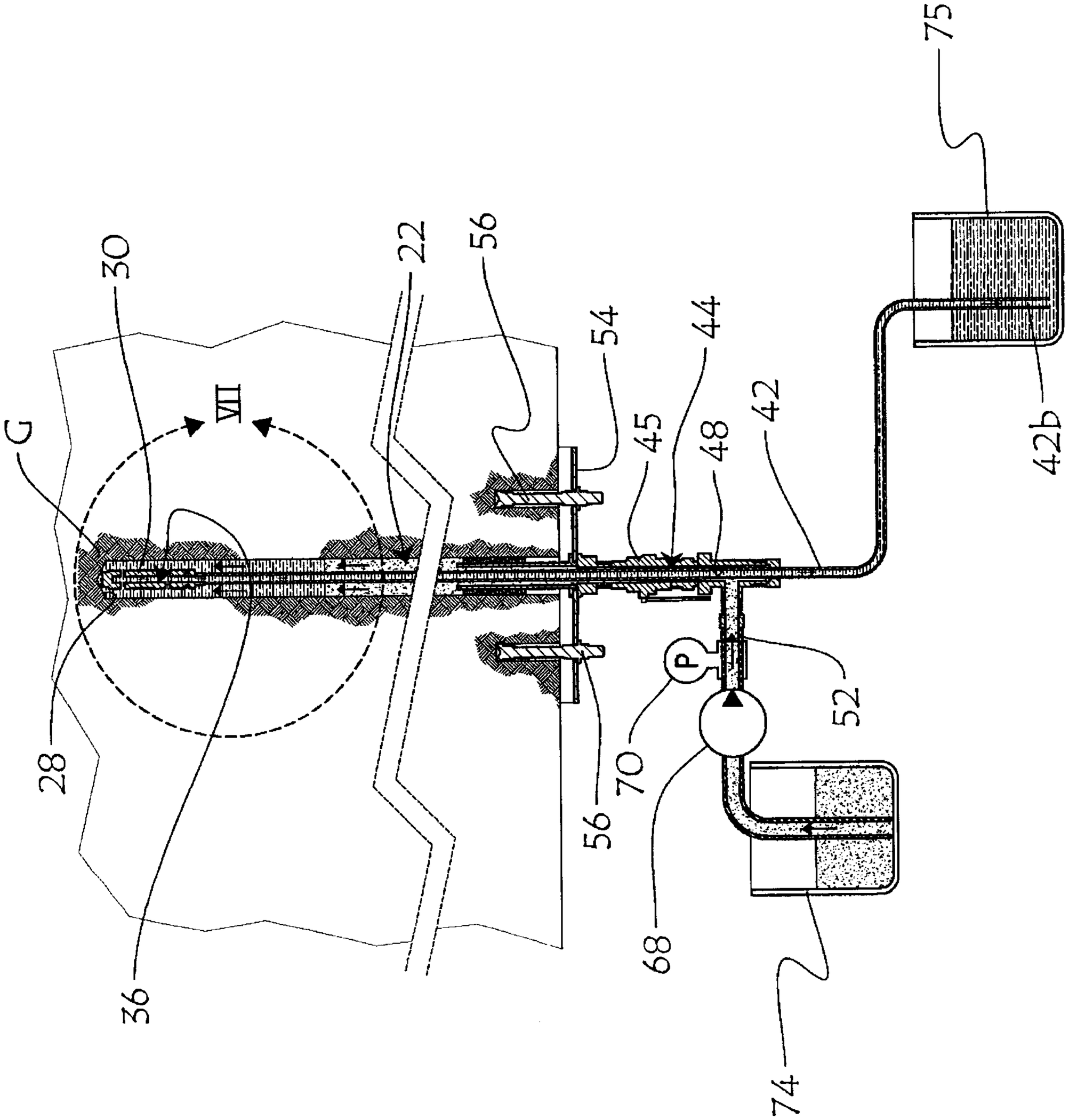


Fig.6

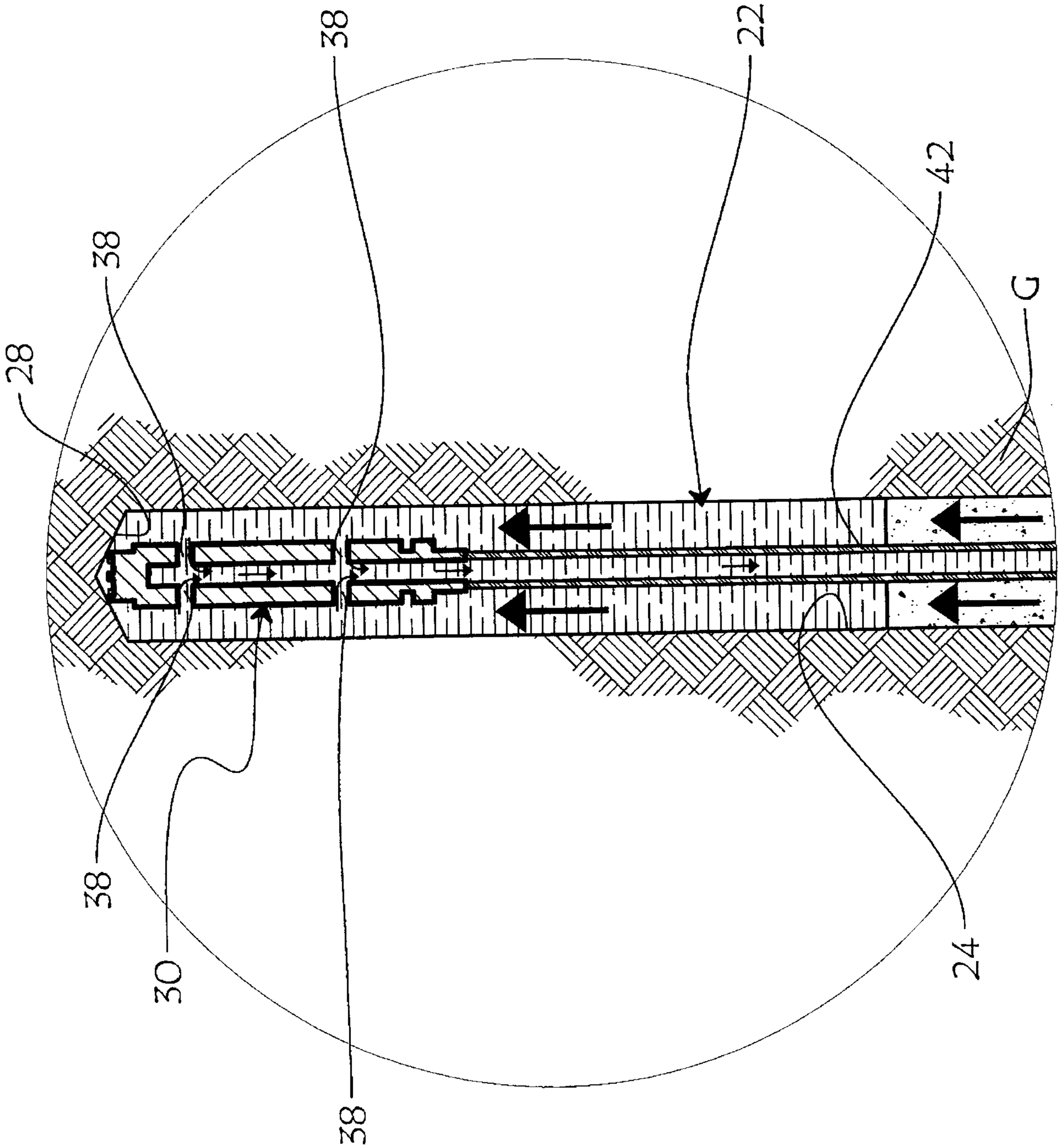
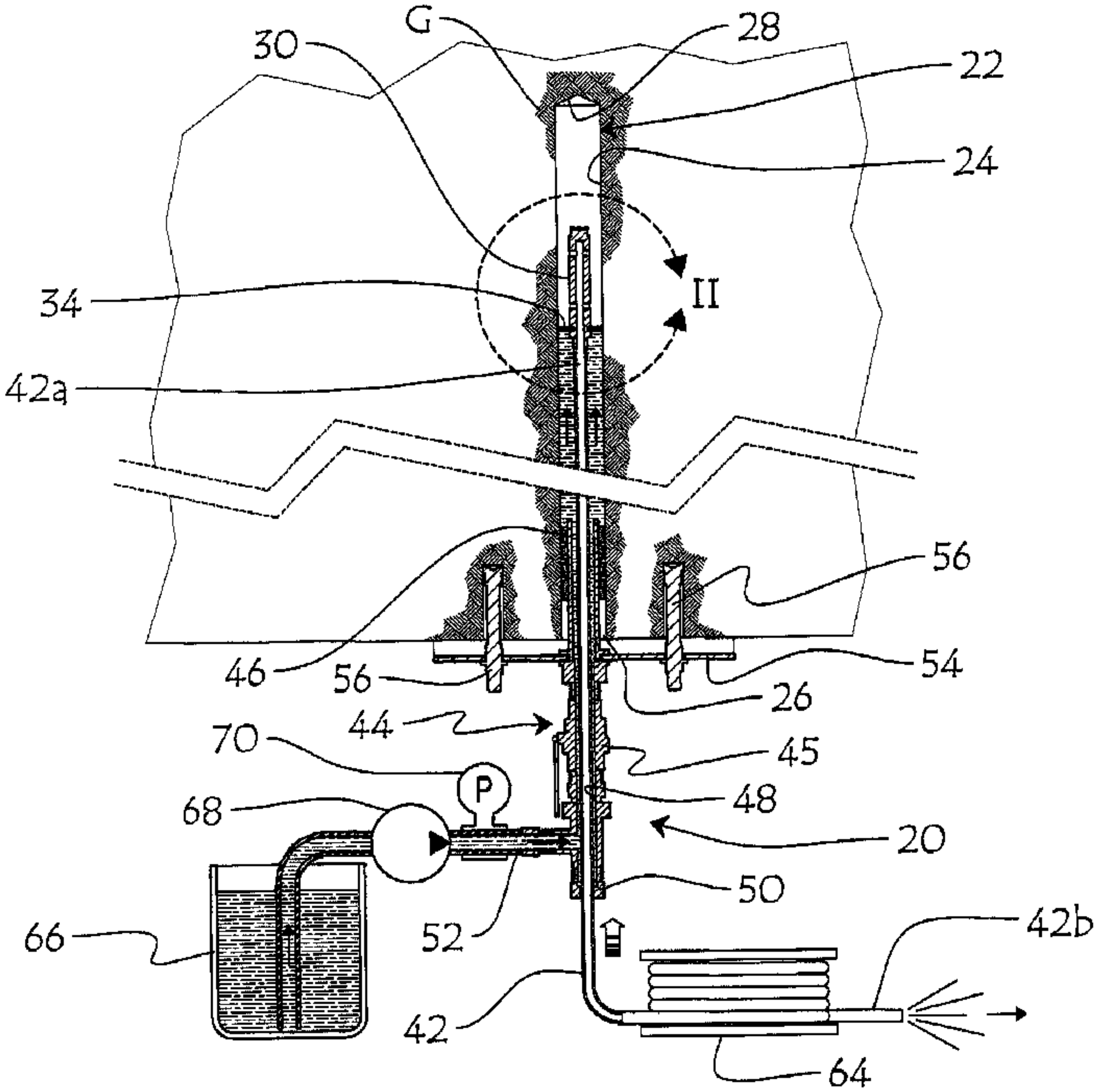


Fig.7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