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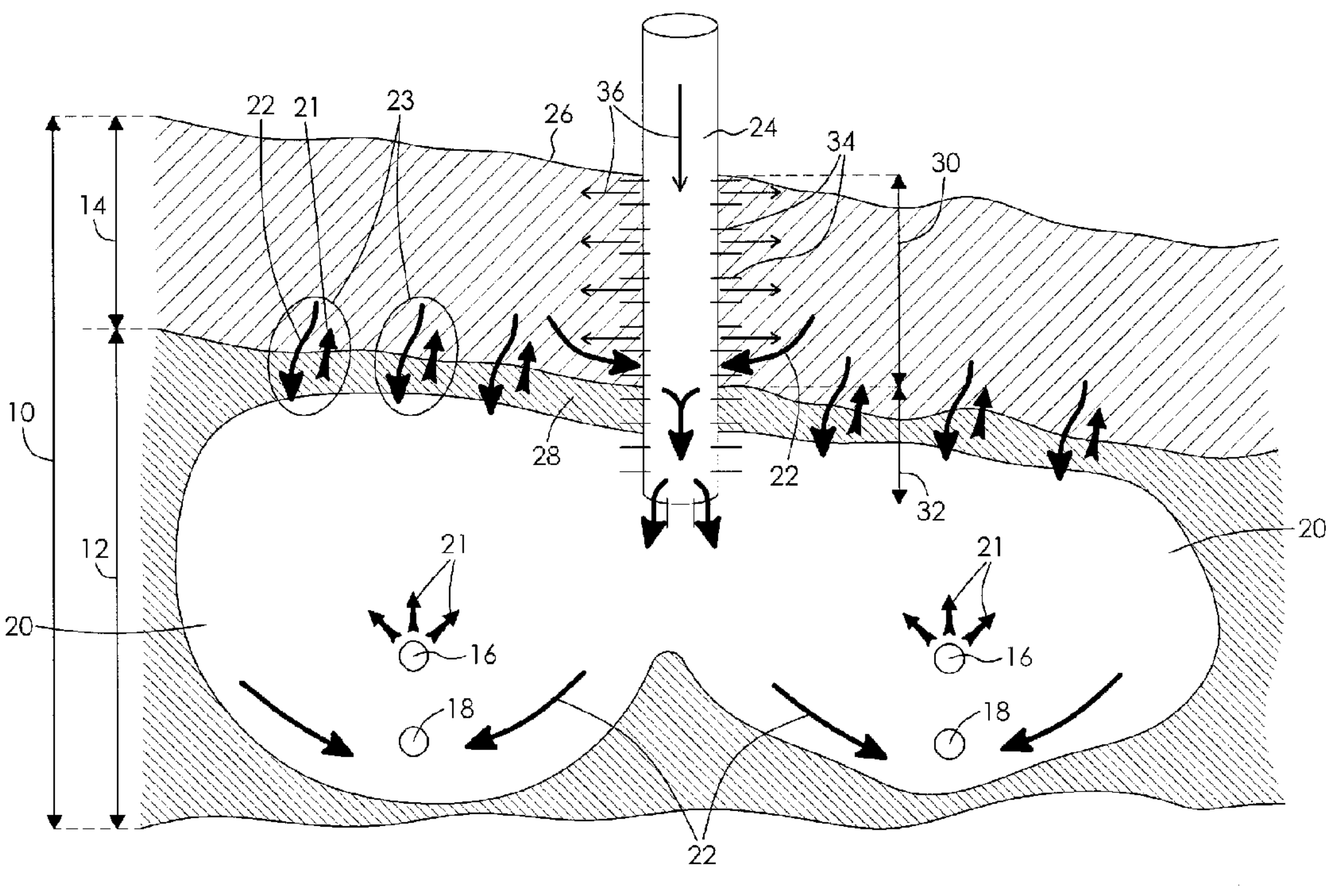
(54) **Titre : RECUPERATION D'HYDROCARBURE SUR PLACE PAR INJECTION DE FLUIDE DANS LA STRATE HETEROLITHIQUE INCLINEE ET DANS LA ZONE PAYANTE SUPERIEURE PAR UN PUITS VERTICAL**
(54) **Title: IN SITU HYDROCARBON RECOVERY WITH INJECTION OF FLUID INTO IHS AND UPPER PAY ZONE VIA VERTICAL WELL**



(57) **Abrégé/Abstract:**
There is provided a method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS). The method includes operating a steam-assisted gravity drainage well pair in the main pay zone to form a steam chamber and produce hydrocarbons from the main pay zone, the steam chamber extending upward within the main pay zone toward the IHS. The method also includes providing a well extending from the surface into the IHS and a top region of the main pay zone; and injecting a non-condensable gas (NCG) via the well through the perforations into the IHS, to form an NCG-enriched zone in the IHS.

ABSTRACT

There is provided a method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS). The method includes operating a steam-assisted gravity drainage well pair in the main pay zone to form a steam chamber and produce hydrocarbons from the main pay zone, the steam chamber extending upward within the main pay zone toward the IHS. The method also includes providing a well extending from the surface into the IHS and a top region of the main pay zone; and injecting a non-condensable gas (NCG) via the well through the perforations into the IHS, to form an NCG-enriched zone in the IHS.

IN SITU HYDROCARBON RECOVERY WITH INJECTION OF FLUID INTO IHS AND UPPER PAY ZONE VIA VERTICAL WELL

FIELD

[0001]The technical field generally relates to in situ recovery of hydrocarbons and, more particularly, to hydrocarbon recovery operations employing the injection of a fluid, such as non-condensable gas (NCG).

BACKGROUND

[0002]Steam-assisted gravity drainage (SAGD) is an enhanced hydrocarbon recovery technology for producing hydrocarbons, such as heavy oil and/or bitumen, from subsurface reservoirs. Typically, a pair of horizontal wells is drilled into a hydrocarbon-bearing reservoir, such as an oil sands reservoir, and steam is continuously injected into the reservoir via the upper injection well to heat and reduce the viscosity of the hydrocarbons. The mobilized hydrocarbons drain into the lower production well and are recovered to the surface. Over time, a steam chamber forms above the injection well and extends upward and outward within the reservoir as the mobilized hydrocarbons flow toward the producer well.

[0003]Certain reservoirs, such as oil sands reservoirs, often include a main pay zone including relatively permeable matrices, such as sandy matrices, and can also include inclined heterolithic strata (IHS). IHS are often located at an upper part of the reservoir and overly the main pay zone. Generally speaking, IHS can be thought of as heterogeneous deposits that exhibit notable depositional dip, and include layers of higher permeability material (e.g., sandy oil-bearing layers) and lower permeability material (e.g., shale lamina and/or mud-dominated layers). IHS can be found, for example, in the McMurray formation in Alberta, Canada. Recovering hydrocarbons from IHS zones can be relatively challenging due to the permeability barriers and baffles that are present.

[0004]In the case of reservoirs including IHS, producing hydrocarbons by gravity drainage from the IHS zone overlying a main pay zone can be difficult. The difficulties can be due to challenges in establishing a counter-current flow between the IHS zone and the main pay zone. In a gravity drainage process, an injected mobilizing fluid, such as steam, a surfactant, and/or a solvent, moves upward into and occupies the space previously occupied by hydrocarbons so that the mobilized hydrocarbons can drain downward toward the producer well. In a reservoir which does not include IHS, this counter-current flow phenomenon can occur more easily throughout the permeable pay zone of the reservoir. However, in a reservoir having an interval including IHS, heating the IHS as well as draining the hydrocarbons from the IHS can be relatively slow and inefficient at least partly because of the difficulty of establishing a counter-current flow between the main pay zone and the IHS zone.

[0005]Co-injection of non-condensable gas (NCG) and steam into a permeable pay zone via SAGD injection wells is known. However, co-injection of steam and NCG via the SAGD injection well can lead to NCG being produced to surface within the production fluid instead of accumulating in the SAGD chamber as intended. In the case of reservoirs including a main pay zone and an overlying IHS, it may be difficult for the co-injected NCG to reach the interior of the IHS zone.

[0006]IHS zones can also contain relevant quantities of hydrocarbons, which are relatively challenging to recover.

SUMMARY

[0007]In some implementations, there is provided a method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS, the method comprising: operating a steam-assisted gravity drainage (SAGD) well pair in the main pay zone which includes a steam chamber and producing hydrocarbons from the main pay zone, the steam chamber extending upward within the main pay zone toward the IHS; providing a vertical well extending from the surface into the IHS and a top region of the main pay zone, the vertical well comprising: an IHS well portion within the IHS; and a pay zone well portion extending from the IHS well portion into an upper region of the main pay zone; wherein the IHS well portion and the pay zone well portion comprise a completion with perforations; and injecting a non-condensable gas (NCG) via the vertical well through the perforations into the IHS, forming an NCG-enriched zone in the IHS.

[0008] In some implementations, the NCG is further injected into the upper region of the main pay zone and the NCG-enriched zone extends into the top region of the main pay zone.

[0009] In some implementations, injecting the NCG is performed so as to provide gas drive to promote displacement of hydrocarbons in the IHS downward into the main pay zone.

[0010] In some implementations, the displacement of hydrocarbons in the IHS downward into the main pay zone comprises flowing from the IHS into the pay zone well portion through the perforations, and then out of an open end of the pay zone well portion into the main pay zone of the reservoir.

[0011] In some implementations, injecting the NCG is performed so as to create a back pressure sufficient to reduce steam override from the steam chamber into the IHS.

[0012] In some implementations, the vertical well is located substantially directly above the SAGD well pair.

[0013] In some implementations, the vertical well is located in between two adjacent SAGD well pairs.

[0014] In some implementations, the method further includes: isolating the vertical well with an isolation packer so as to provide an upper injection segment for injecting NCG into the IHS, and a lower conduit segment for allowing fluids to flow from the IHS through the lower conduit segment into the main pay zone.

[0015]In some implementations, there is provided a method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS) is provided, the method including: operating a thermal in situ hydrocarbon recovery process including: injecting a mobilizing fluid into the main pay zone of the reservoir, and producing mobilized hydrocarbons from the main pay zone, thereby forming a hydrocarbon-depleted zone; and operating a vertical well section extending into the reservoir, the vertical well section including an IHS well portion within the IHS and having perforations providing fluid communication between the vertical well section and surrounding permeable layers of the IHS, wherein the operating includes injecting non-condensable gas (NCG) via the vertical well section into the surrounding permeable layers of the IHS.

[0016]In some implementations, injecting the NCG is performed so as to form an NCG-rich insulation layer above or at a top region of the main pay zone.

[0017]In some implementations, injecting the NCG is performed so as to provide gas drive to promote displacement of hydrocarbons in the IHS downward into the main pay zone.

[0018]In some implementations, the vertical well section is a lateral branch section extending from an overlying or underlying horizontal well.

[0019]In some implementations, the vertical well section is part of a single vertical well extending downward from the surface.

[0020]In some implementations, the thermal in situ hydrocarbon recovery process includes SAGD.

[0021]In some implementations, the thermal in situ hydrocarbon recovery process includes cyclic steam stimulation (CSS).

[0022] In some implementations, there is provided a method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS), the method including: injecting a mobilizing fluid into the main pay zone to obtain mobilized hydrocarbons and pressurise the main pay zone at a pay zone pressure; producing the mobilized hydrocarbons from the main pay zone, thereby forming a hydrocarbon-depleted zone; and operating an IHS well section extending into the IHS and having perforations providing fluid communication between the IHS well section and surrounding permeable layers of the IHS, wherein the operating includes: injecting an injection fluid into an upper region of the IHS via the perforations of the IHS well section, wherein the IHS well section is kept at a well section pressure equal to or higher than the pay zone pressure; and allowing hydrocarbons to flow from a lower region of the IHS to the main pay zone through a corresponding portion of the IHS well section.

[0023] In some implementations, the injection fluid includes NCG.

[0024] In some implementations, the NCG provides gas drive to promote displacement of hydrocarbons in the IHS zone downward into the main pay zone.

[0025] In some implementations, the injection fluid further includes at least one of a solvent and a surfactant.

[0026] In some implementations, the IHS well section is a vertical IHS well section.

[0027] In some implementations, the vertical well section is a lateral branch section extending from an overlying or underlying horizontal well.

[0028] In some implementations, the vertical well section is part of a single vertical well extending downward from the surface.

[0029] In some implementations, there is provided a method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS), the method including: operating an IHS well section extending into the IHS, the IHS well section including: an outer liner including perforations providing fluid communication between the IHS well section and surrounding permeable layers of the IHS; an inner tube located within the outer liner, the inner tube and the outer liner forming an annulus therebetween; an isolation packer located within the annulus to define an upper injection segment isolated from the tube and a lower production segment in fluid communication with the tube; wherein the operating of the IHS well section includes: injecting an injection fluid through the upper injection segment into an upper region of the IHS; and producing hydrocarbons from a lower region of the IHS, such that the hydrocarbons flow into the lower production segment and through the tube for recovery at surface.

[0030] In some implementations, the IHS well section is a vertical IHS well section.

[0031] In some implementations, the vertical well section is a lateral branch section extending from an overlying or underlying horizontal well.

[0032] In some implementations, the vertical well section is part of a single vertical well extending downward from the surface.

[0033] In some implementations, the outer liner includes a slotted liner.

[0034] In some implementations, there is provided a method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS), the method including: operating a multilateral IHS well including: a main well section; and multiple branch well sections extending from the main well section into the IHS and being in fluid communication with surrounding permeable layers of the IHS; wherein the operating of the multilateral IHS well includes: injecting an injection fluid via the branch well sections into the surrounding permeable layers of the IHS.

[0035] In some implementations, the main well section is a section of a horizontal well.

[0036] In some implementations, the horizontal well is located in the IHS.

[0037] In some implementations, the horizontal well is located in the main pay zone.

[0038] In some implementations, the multiple branch sections are vertical branch sections.

[0039] In some implementations, the injection fluid includes NCG.

[0040] In some implementations, the injection fluid further includes at least one of a solvent and a surfactant.

[0041] In some implementations, there is provided a system for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS), the system including: a SAGD well pair including: an injection well located within the main pay zone for injecting a first injection fluid therein; and a producer well located within the main pay zone for producing production fluids including the hydrocarbons; and a vertical well provided with perforations and drilled through the IHS and into an upper region of the main pay zone, the vertical well having an IHS well portion and a pay zone well portion and being configured to inject a second injection fluid into the IHS.

[0042] In some implementations, the vertical well facilitates providing fluid communication and equalization of the pressure between the IHS zone and the main pay zone.

[0043] In some implementations, the second injection fluid includes at least one of a NCG, a solvent and a surfactant.

[0044] In some implementations, the first injection fluid includes steam.

[0045] In some implementations, the vertical well is provided with a slotted liner.

[0046] In some implementations, the vertical well includes a casing.

[0047] In some implementations, the casing is a thermal casing.

[0048] In some implementations, the vertical well includes a thermal wellhead.

[0049] In some implementations, the vertical well includes thermal cement.

[0050] In some implementations, the vertical well allows the hydrocarbons from the IHS to flow from the IHS into part of the IHS well portion and through the pay zone well portion into the main pay zone.

[0051] In some implementations, the vertical well is provided with an isolation packer in the IHS well portion, thereby separating the IHS well portion into an upper injection segment and a lower production segment.

[0052] In some implementations, the second injection fluid is injected into the IHS via the upper injection segment.

[0053] In some implementations, the vertical well is located substantially directly above the SAGD well pair.

[0054] In some implementations, the vertical well is located in between two adjacent SAGD well pairs.

[0055] In some implementations, the system further includes additional vertical wells drilled through the IHS and into the upper region of the main pay zone, the additional vertical wells being configured to inject the second injection fluid into the IHS for driving hydrocarbons from the IHS to the main pay zone.

[0056] In some implementations, there is provided a system for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS), the system including: a SAGD well pair including: an injection well located within the main pay zone for injecting a first injection fluid therein; and a producer well located within the main pay zone for producing production fluids including the hydrocarbons; and a well drilled through the IHS and into an upper region of the main pay zone, the well having an IHS well portion and a pay zone well portion, the well including: an outer liner including perforations and providing fluid communication between the well and surrounding permeable layers of the IHS; an inner tube located within the outer liner, the inner tube and the outer liner forming an annulus therebetween; an isolation packer located within the annulus to define an upper injection segment isolated from the tube and a lower production segment in fluid communication with the tube; wherein the well is configured to inject a second injection fluid through the upper injection segment into an upper region of the IHS; and produce the hydrocarbons from a lower region of the IHS, such that the hydrocarbons from the lower region of the IHS flow into the lower production segment and through the tube for recovery at surface.

[0056a] In some implementations, there is provided a method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS), the method including: operating a gravity drainage well pair in the main pay zone which includes a mobilized chamber and producing hydrocarbons from the main pay zone, the mobilized chamber extending upward within the main pay zone toward the IHS; providing a vertical well extending from the surface into the IHS and a top region of the main pay zone, the vertical well including: an IHS well portion within the IHS; and a pay zone well portion extending from the IHS well portion into an upper region of the main pay zone; wherein the IHS well portion and the pay zone well portion include a completion with perforations; and injecting a non-condensable gas (NCG) via the vertical well through the perforations into the IHS, forming an NCG-enriched zone in the IHS.

BRIEF DESCRIPTION OF THE DRAWINGS

[0057] Figure 1 is a cross-sectional view of a steam-assisted gravity drainage (SAGD) operation and part of a vertical well drilled through inclined heterolithic strata (IHS).

[0058] Figure 2 is a cross-sectional view of part of a vertical well provided through IHS and including an isolation packer.

[0059] Figure 3 is a cross-sectional view of part of a vertical well drilled through IHS, and showing the co-injection of NCG and another injection fluid.

[0060] Figure 4 is a cross-sectional view of part of a vertical well drilled through IHS, and including additional tubing for injecting fluids.

[0061] Figure 5 is cross-sectional view of part of a vertical well drilled through IHS, and including additional tubing for producing hydrocarbons.

[0062] Figure 6 is a cross-sectional view of a SAGD operation and part of a vertical well drilled through IHS.

[0063]Figure 7 is a cross-sectional view of a SAGD operation and part of a multilateral IHS well having a horizontal section and several vertical branch sections extending into the IHS.

[0064]Figure 8 is a cross-sectional view of a SAGD operation where multiple discrete vertical wells are drilled through the IHS.

[0065]Figure 9 is a cross-sectional view of a SAGD operation.

[0066]Figure 10 is a top plan view schematic of a SAGD operation including a well pad, an array of well pairs, and a vertical well configuration.

[0067]Figure 11 is a top plan view schematic of a SAGD operation including a well pad, an array of well pairs, and another vertical well configuration.

[0068]Figure 12 is cross-sectional view of part of a vertical well drilled in IHS, and including additional tubing for producing hydrocarbons.

DETAILED DESCRIPTION

[0069]Various techniques that are described herein enable enhanced thermal in situ recovery operations, such as steam-assisted gravity drainage (SAGD), including the use of a well, which can be a vertical well, extending through inclined heterolithic strata (IHS) located above a main pay zone of the reservoir. An injection fluid, such as non-condensable gas (NCG) can be injected through the well into the IHS. The NCG can penetrate into higher-permeability layers, sandy hydrocarbon-bearing layers, of the IHS in order to mobilize IHS hydrocarbons. The NCG injection can further penetrate into the main pay zone of the reservoir to provide a NCG-enriched zone at the top of the reservoir so as to enhance the thermal in situ recovery operation.

[0070]The well (also referred to as an IHS well) can be vertical and can be provided above a SAGD operation in order to inject NCG. However, other implementations can include alternate IHS well configurations, thermal in situ recovery operations, and injection fluids. Some implementations of the technology will be described in greater detail below.

In situ hydrocarbon recovery operation implementations

[0071]Referring to Figure 1, in some implementations, there is provided a method for recovering hydrocarbons from a reservoir 10 having a main pay zone 12 and an overlying interval including IHS 14, where a vertical IHS well 24 is provided to enhance certain aspects of the process. In some scenarios, the IHS 14 has an inclination of between about 5° and 15°. In some implementations, one or more SAGD well pairs are provided in the main pay zone 12. Each well pair includes a SAGD injection well 16 and a SAGD producer well 18. In some implementations, the well pair is located near the bottom of the main pay zone 12, and the injection well 16 and the producer well 18 are spaced approximately five metres apart with the injection well 16 being placed above the producer well 18. It is understood that the main pay zone 12 can include one SAGD well pair, two SAGD well pairs (as shown in Figure 1), or several SAGD well pairs. In some implementations, the SAGD well pairs can extend from a common well pad. For example, the subsurface orientation of the SAGD well pairs (i.e., the well pattern) can be such that the SAGD well pairs are arranged in a generally parallel relation to one another. In some implementations, the SAGD well pair is operated to form a steam chamber 20 above the injection well 16 and to produce hydrocarbons 22 from the reservoir via the producer well 18 disposed in the main pay zone 12. The injection well 16 injects a mobilizing fluid including steam 21 into the main pay zone, so as to form the steam chamber 20, which extends upward and outward within the main pay zone 12 and toward the IHS zone 14. This results in the mobilization of hydrocarbons within the main pay zone 12, which can then drain along with steam condensate to the producer well 18 and be recovered to the surface as a produced fluid, by mechanical or artificial lift techniques. The produced fluid stream can contain the hydrocarbons 22 as well as other materials such as condensed water, gases and various solids/minerals. As the mobilizing fluid approaches the IHS zone 14, heat transfer can enable heating of the hydrocarbons of the IHS zone.

[0072]Depending on the geological properties and configuration of the reservoir 10, some degree of counter-current flow 23 can occur between the IHS zone 14 and the main pay zone 12 as the mobilizing fluid approaches the IHS zone. The counter-current flow 23 enables a small portion of the heated hydrocarbons 22 from the IHS zone 14 to flow downward to the main pay zone 12 while steam 21 moves upward from the main pay zone 12 into the IHS zone 14. Such counter-current flow 23 between the IHS zone 14 and the main pay zone 12 can account for some degree of the production of hydrocarbons 22 from the reservoir, but is usually limited or sometimes nonexistent in a reservoir having IHS zones due to impermeable layers present in the IHS zone.

[0073]It should also be noted that there may be different IHS zones within a given reservoir, occurring at different locations and elevations. In some scenarios, a primary dominant IHS zone is present overlying the main pay zone and extends substantially over the in situ hydrocarbon recovery wells, which can include multiple SAGD well pairs that can cover one or more square kilometres. Referring briefly to Figure 9, the IHS zone can include low permeability layers (also referred to as low permeability lamina, lenses or baffles) having different orientations, thicknesses and compositions, which form tortuous paths that generally discourage fluid flow.

[0074]While various implementations are described herein in relation to SAGD, other in situ hydrocarbon recovery operations can be used. For instance, cyclic steam stimulation (CSS), in situ combustion, solvent-enhanced methods, and/or other recovery processes can be used in order to recover hydrocarbons and form a hydrocarbon-depleted chamber within a main pay zone of the reservoir having an upper IHS zone. In general, in situ hydrocarbon recovery operations utilizing a mobilizing fluid to facilitate hydrocarbon recovery can have difficulty accessing IHS zones due to poor fluid permeability into and out of the IHS zones. As will be described further below, by providing and operating what may be called an "IHS well", such as a vertical well extending through the IHS zone for injection of NCG, hydrocarbon recovery operations can be enhanced.

Vertical IHS well implementations

[0075]Still referring to Figure 1, in some implementations, a vertical well 24 is provided to enhance hydrocarbon recovery. The vertical well 24 extends from the surface, past the cap rock 26, and into the IHS zone 14 and a top region 28 of the main pay zone 12. The vertical well 24 includes an IHS well portion 30 and a pay zone well portion 32. In some implementations, completion of the vertical well 24 is performed to enable fluid injection into the IHS zone. For example, the vertical well can have a casing, be provided with perforations and/or be provided with a slotted or wire-wrapped liner, or other suitable configurations that allow flow of fluid. The perforations 34 can be provided along the IHS and pay zone well portions 30, 32.

[0076]The expression "vertical well" refers to a well which is drilled substantially vertically with respect to the surface. In some scenarios, a well can have a certain degree of deviation and may be inclined to some degree and still be considered a "vertical well" in this application. A "vertical well" is a well which can be drilled without using directional or slant drilling.

[0077]It should be understood that the term "completion" can refer to processes of readying a well for injection and/or production and can also refer to equipment that is deployed within the well for such a purpose. As such, "completion" can involve preparing the well to required specifications, running into the well production and/or injection tubing, deploying instrumentation down the well, cementing the well casing, providing perforations and/or slotted liner, as desired. In some implementations, the vertical well also includes a thermal wellhead, a thermal casing and/or thermal cement. The thermal completion components of the well are provided in order to enable injection and/or production of hot fluids and maintain fluid isolation of the targeted zone.

[0078] Still referring to Figure 1, in some implementations, NCG 36 is injected via the vertical well 24 into the IHS zone 14, to form an NCG-enriched zone above the steam chamber 20. Optionally, and depending on the NCG injection pressure/conditions, as well as the configuration of the vertical well 24, the NCG 36 can also be injected via the vertical well 24 into the top region 28 of the main pay zone 12. In some scenarios, the NCG injection is performed into the IHS zone after the steam chamber has developed sufficiently so as to approach the lower part of the IHS zone. The NCG-enriched zone can facilitate prevention of heat loss and also encourage lateral growth of the steam chamber within the main pay zone 12. It should also be noted that the NCG injection conditions can be provided and controlled at different stages of the in situ hydrocarbon recovery operation, for example to increase or decrease NCG injection pressure or to add other injection fluids, to enable various recovery conditions.

[0079] In some scenarios, NCG injection into the top region 28 of the main pay zone 12 can facilitate maintaining reservoir pressure. More specifically, during the later production life of the reservoir, there is typically less demand for steam in the depleted reservoir and NCG can replace the steam for maintaining the pressure. Thus, during mature SAGD operations, the NCG can be injected at pressures and rates that provide a desired pressurizing effect within the reservoir. Further, the NCG-enriched zone can form an insulating layer in the general area between the IHS zone 14 and the main pay zone 12, thereby reducing the heat transfer from the main pay zone 12 to the IHS zone 14. Such an insulating layer can be used to reduce heat loss, for example when the IHS is depleted of hydrocarbons.

[0080] In some scenarios, the injection of NCG 36 can provide gas drive to promote displacement of hydrocarbons in the IHS zone 14 downward into the main pay zone 12. In some scenarios, the gas drive can increase the direct transfer of hydrocarbons from the IHS zone 14 downward into the main pay zone 12, and/or promote displacement of hydrocarbons in the IHS zone 14 into part of the vertical well 24 and then into the main pay zone 12. In the latter case, the vertical well 24 can thus act as a conduit for hydrocarbons in the IHS zone to bypass low permeability baffles and flow into the main pay zone from which the hydrocarbons can drain and eventually be recovered by the SAGD producer well.

[0081] In some scenarios, the injection of NCG 36 from the vertical well 24 into the IHS 14 and the top region 28 of the main pay zone 12 can also create a back pressure (i.e. the NCG creates a pressurized zone above the steam chamber that discourages upward growth of the steam chamber and encourages lateral growth) for the rising steam chamber 20, thereby reducing steam override in the reservoir 10. This can have the effect of promoting lateral growth or “widening” of the steam chamber 20 for improved steam coverage and hydrocarbon mobilization within the main pay zone 12, which can lead to greater hydrocarbon recovery and production rates. In the event that the IHS includes a high permeability fissure that would allow substantial steam loss, the NCG pressurization within the fissure can help in reducing steam loss.

[0082] In some scenarios, the drilling of the vertical well 24 into the IHS zone 14 and main pay zone 12, and the perforation of the vertical well 24 along the IHS and pay zone portions 30, 32 can facilitate providing fluid communication and equalization of the pressure between the IHS zone 14 and the main pay zone 12.

Pressure management implementations

[0083] In some scenarios, injection pressures of the NCG 36 in the IHS well 24 and of the mobilizing fluid 21 in the main pay zone 12 are selected such that the pressure in the IHS well 24 is equal to or greater than the pressure of the steam chamber in the main pay zone 12 (this allows for the steam of the steam chamber 20 to not be lost to the IHS zone 14). For example, the injection pressures can be selected such that a pressure gradient in the IHS well 24 allows for the NCG 36 to flow out of the IHS well 24 from a top portion of the IHS well 24 and for the hydrocarbons of the IHS to flow into the IHS well 24, down the lower end of the well, and then out of the lower well opening. It is understood that the injection pressures are selected to be below the maximum operating pressure at the injection zone. In other words, the operating pressures are selected such that the cap rock integrity is not compromised.

IHS well isolation implementations

[0084]Now referring to Figure 2, in some implementations, the interior of the IHS well 24 can be provided with an isolation packer 38 in order to facilitate certain functionalities. The packer 38 can enable the IHS well to be divided into an injection section through which NCG 36 or other fluids can be injected out, and a flow conduit section through which fluids are allowed to flow into the IHS well, down the lower end of the well, and then out of the lower well opening. In some implementations, the isolation packer 38 can be installed at a packer depth in the IHS portion 30 of the IHS well 24. For example, the packer 38 can be installed several metres above the main pay zone, such as about five metres above the main pay zone. The packer 38 can allow the NCG 36 to flow out of the IHS 24 and into the IHS zone 14 from an NCG region 30A of the IHS portion 30 of the IHS well 24. Similarly, the packer 38 can allow for hydrocarbons to flow down to the main pay zone via a producer region 30B of the IHS portion 30 of the IHS well 24. In addition, isolating the injection region can facilitate controlled injection of NCG, in terms of injection pressures and injection locations.

IHS injection fluid implementations

[0085]In some implementations, various injection fluids can be injected into the IHS in order to provide a desired effect on the process conditions. While NCG is discussed in detail with respect to injection via the IHS well, other fluids can be injected alone or co-injected with NCG.

[0086]Referring to Figures 3 and 4, in some implementations, an injection fluid can be injected into the IHS and/or the top region of the main pay zone from the IHS well. The injection fluid can include NCG, as described above, and can further include other injection fluids such as mobilizing agents 40. Examples of such mobilizing agents 40 include steam, solvents and/or other chemicals (e.g., surfactants). In some scenarios, injection fluids that do not include NCGs can be injected in the IHS well 24 as desired. The NCG 36 and the mobilizing agents 40 can be injected together from the IHS well 24 into the IHS zone 14 and top region 28 of the main pay zone 12 (as seen in Figure 3), or separately using a tubing 42 inserted into the casing of the IHS well 24 from the surface 26 down to the pay zone portion 32 (as seen in Figure 4) thus enabling injection of different fluids into different regions of the reservoir.

[0087]Referring to Figure 4, a packer 38 can be installed in the IHS well 24 for controlling the portion of the IHS well 24 from which NCG 36 and/or mobilizing agents 40 can be injected into the IHS zone 14 and/or the top region 28 of the main pay zone 12. The tubing 42 and packer 38 can have various configurations and positions in order to enable different fluid injection strategies.

IHS well production implementations

[0088]Now referring to Figure 5, in some implementations, the IHS well 24 is configured to produce hydrocarbons 22 from the IHS zone 14 to the surface. In the exemplary configuration shown, the IHS well 24 is provided with a tubing 42 and a packer 38. The tubing 42 extends from the surface through the IHS zone 14. A packer 38 is provided inside the IHS well 34, as described above. NCG 36 is injected into the IHS zone 14 via an annulus formed outside of the tubing 42 and through the perforations 34 located above the packer 38. Hydrocarbon fluids 22 from the IHS zone 14 can be recovered up to the surface via the tubing 42, using for example a pump (not shown) connected to the tubing 42. Hydrocarbon fluids can enter the tubing 42 via perforations 34A provided in the tubing 42 below the packer 38, or via the end opening of the tubing located at a depth below the packer 38.

[0089]In terms of operating the IHS well 24, in a first stage, NCG 36 can be injected into the upper part of the IHS zone in order to pressurize the area, drive some hydrocarbons downward into the lower part of the IHS zone and/or the main pay zone, and also partially dissolve into hydrocarbons to enhance mobility.

In a second stage, production can be initiated from tubing 42 of the IHS well 24 in order to recover hydrocarbons and/or depressurize the IHS zone. The recovery can be facilitated by mobilization of the hydrocarbons and gas drive facilitated by NCG injection as well as heating from the underlying steam chamber. In some scenarios, the production and/or depressurization via the IHS well 24 can be performed when the hydrocarbons cannot drain downward into the steam chamber. In some scenarios, production via the IHS well 24 can be performed prior to the steam chamber reaching the IHS zone, thereby depleting IHS zone of hydrocarbons and facilitating injection of additional NCG into the upper region of the reservoir.

IHS well arrangements and configurations

[0090]Now referring to Figures 1 and 6, the IHS well 24 can be located substantially directly above the SAGD well pair (as shown in Figure 6), or between two separate well pairs (as shown in Figure 1). Providing the IHS well 24 directly above a corresponding SAGD well pair can result in formation of the NCG-enriched zone expanding outward from a similar overlying position as the steam chamber, and can also enable hydrocarbons to drain from the IHS zone via the IHS well into a central part of the steam chamber. Providing the IHS well 24 in an offset position, for instance in between two adjacent SAGD well pairs, can result in the NCG-enriched zone extending to overly both SAGD well pairs, and can also enable hydrocarbons to drain from the IHS zone via the IHS well into a lateral part of the steam chamber.

[0091]Referring to Figures 8 and 10, in some implementations, multiple IHS wells 24 can be provided for an array of SAGD well pairs that extend from a common well pad. For instance, each IHS well 24 can be located in between two adjacent well pairs. For each adjacent pair of SAGD wells, a series of IHS wells 24 (e.g., three IHS wells) can be provided along the length of the SAGD wells. In each series, the IHS wells can be spaced apart from each other by about 200 metres to about 400 metres, for example. Various other configurations of IHS wells can be provided based on the SAGD well pair configuration, the steam chamber(s) of the SAGD operation, and/or the geological properties of the reservoir. Figure 11 illustrates one of many alternative configurations for the IHS wells 24. In some scenarios, a geometric placing of the IHS wells 24 can be used during the early production life of the reservoir, and a placing of the IHS wells 24 above a hot zone or a thick IHS zone can be desirable at during the later production life of the reservoir.

Multilateral IHS well implementations

[0092]The IHS wells 24 described above have been illustrated as single IHS wells that extend from the surface into the IHS and main pay zones. Alternatively, the IHS wells can be provided as well sections that are part of a multilateral well, as will be further described below.

[0093]Referring to Figure 7, in some implementations, a multilateral well 42 having at least one IHS well section 44 is provided to access the IHS zone 14. The multilateral well 42 includes a vertical section 46 connected to a main well section 24A from which multiple branch well sections 44 extend into the IHS zone. The branch well sections 44 can be substantially vertical well sections and can have various features of the IHS wells 24 as described herein. The main well section 24A can be horizontal or slanted, depending on the orientation of the IHS and/or other properties of the reservoir. The main well section 24A can also be drilled above, within or below the IHS zone. In some implementations, the branch well sections 44 include at least one vertical well section extending downward from the main well section 46.

[0094]In some implementations, the branch well sections 44 can include at least one downwardly inclined branch well section. For example, the branch well sections 44 can include several inclined branch well sections directed outwardly (i.e. directed towards the main pay zone and on either side of the main horizontal well section 24A). In other words, the branch well sections 44 can extend radially from the main well section 24A, towards the main pay zone and on either side of the main well section 24A.

[0095]The multilateral well 42 can be oriented such that the main well section 24A extends in parallel, perpendicular or in oblique relation to underlying SAGD well pairs. One or more multilateral wells 42 can be provided for a given array of SAGD wells. The multilateral well 42 can be operated for NCG injection or injection of one or more other fluids into the IHS zone, and can be completed for production capability as well.

NCG implementations

[0096]In some implementations, the NCG is selected from the group consisting of methane, carbon dioxide, nitrogen, air, natural gas and flue gas. The NCG can be selected according to process economics and/or desired effects.

IHS heating implementations

[0097]As discussed above, heating of the IHS zone 14 and mobilization of the hydrocarbons of the IHS zone can be achieved by heat transfer from the main pay zone 12, as the mobilizing fluid rises up from the injection well 16 to the upper region 28 of the main pay zone 12. In some implementations, heat can be provided to the IHS zone 14 by electrical heating or radio-frequency (RF) by antennas provided in the IHS well 24 or in the main pay zone 12. In some implementations, such heat is supplemental heat (i.e., additional heat to complement heating by heat transfer from the mobilizing fluid in the main pay zone 12). In some implementations, electrical heating or RF heating is the main source of heating, for example during the later production life of the reservoir when less steam is needed.

Non-continuous IHS well implementations

[0098]Referring to Figure 12, in some implementations, the IHS well 24 is provided in the IHS zone 14 but is not continuous with the main pay zone 12. The recovery of the hydrocarbons can be done by directly producing the hydrocarbons of the IHS zone 14 to the surface, and the recovery can be facilitated by mobilizing the hydrocarbons of the IHS using heat conduction from the underlying main pay zone 12, and/or electrical or RF heating in the IHS well 24, as described above. In some scenarios, the non-continuous IHS well is specifically designed and built as a non-continuous IHS well. In other scenarios, the non-continuous IHS well 24 is obtained by sealing the bottom of an IHS well initially built through the IHS zone 14.

Description of system implementations

[0099]In some implementations, there is provided a system for enhancing hydrocarbon recovery from a reservoir 10 having a main pay zone 12 and an overlying IHS 14 including permeable layers. In some scenarios, the system allows for the recovery of hydrocarbons from the IHS 14 located in a reservoir. The system includes a SAGD well pair 16, 18 located in the main pay zone, the SAGD well pair including an injection well 16 for injecting a first injection fluid in the main pay zone 12, and a producer well 18 for producing production fluids. The system also includes a vertical well 24 having an IHS well portion 30 and a pay zone well portion 32. The vertical well 24 is drilled through the IHS 14 and into an upper region 28 of the main pay zone 12. The vertical well 24 is configured to inject a second injection fluid into the IHS 14 for driving hydrocarbons from the IHS 14 to the main pay zone 12.

[0100]The first injection fluid can include steam. In some implementations, the first injection fluid can also include other fluids such as NCG, solvents and/or surfactant.

[0101]The second injection fluid includes at least one of a NCG, a solvent, water and a surfactant. For example, the NCG can include methane, carbon dioxide, nitrogen, air, natural gas or flue gas. For example, the solvent can include diluent, toluene, xylene, diesel, propane, butane, pentane, hexane, heptane and/or naphtha, or other suitable solvents for co-injection with the steam.

CLAIMS

1. A method for recovering hydrocarbons from a reservoir having a main pay zone and overlying inclined heterolithic strata (IHS), the method comprising:

   operating a multilateral IHS well comprising:

      a main well section; and

      multiple branch well sections extending from the main well section into the IHS and being in fluid communication with surrounding permeable layers of the IHS;

   wherein the operating of the multilateral IHS well comprises:

      injecting an injection fluid via the branch well sections into the surrounding permeable layers of the IHS.

2. The method of claim 1, wherein the main well section is a section of a horizontal well.

3. The method of claim 2, wherein the horizontal well is located in the IHS.

4. The method of claim 2, wherein the horizontal well is located in the main pay zone.

5. The method of any one of claims 1 to 4, wherein the multiple branch sections are vertical branch sections.

6. The method of any one of claims 1 to 5, wherein the injection fluid comprises NCG.

7. The method of claim 6, wherein the injection fluid further comprises at least one of a solvent and a surfactant.

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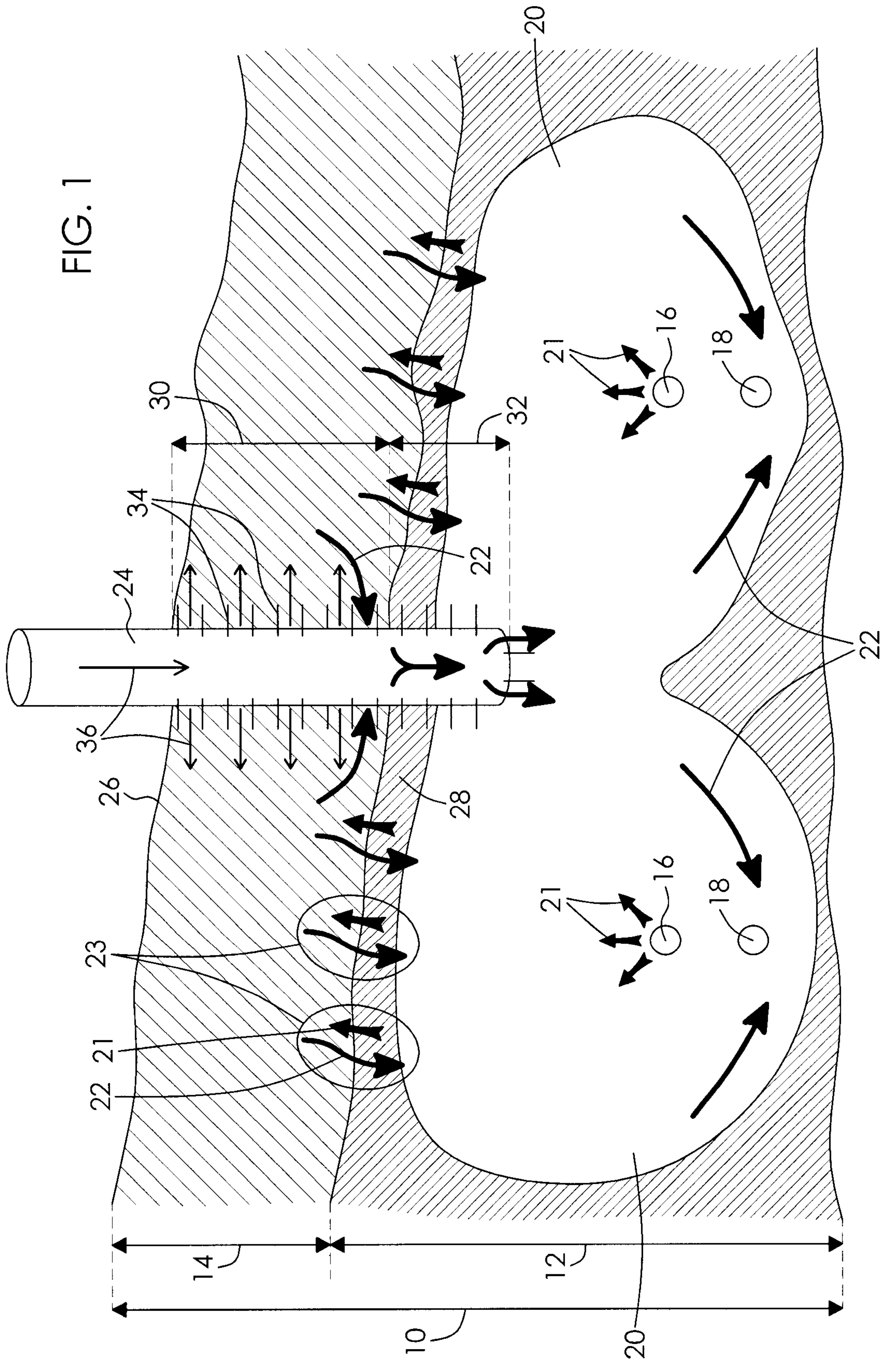

FIG. 1

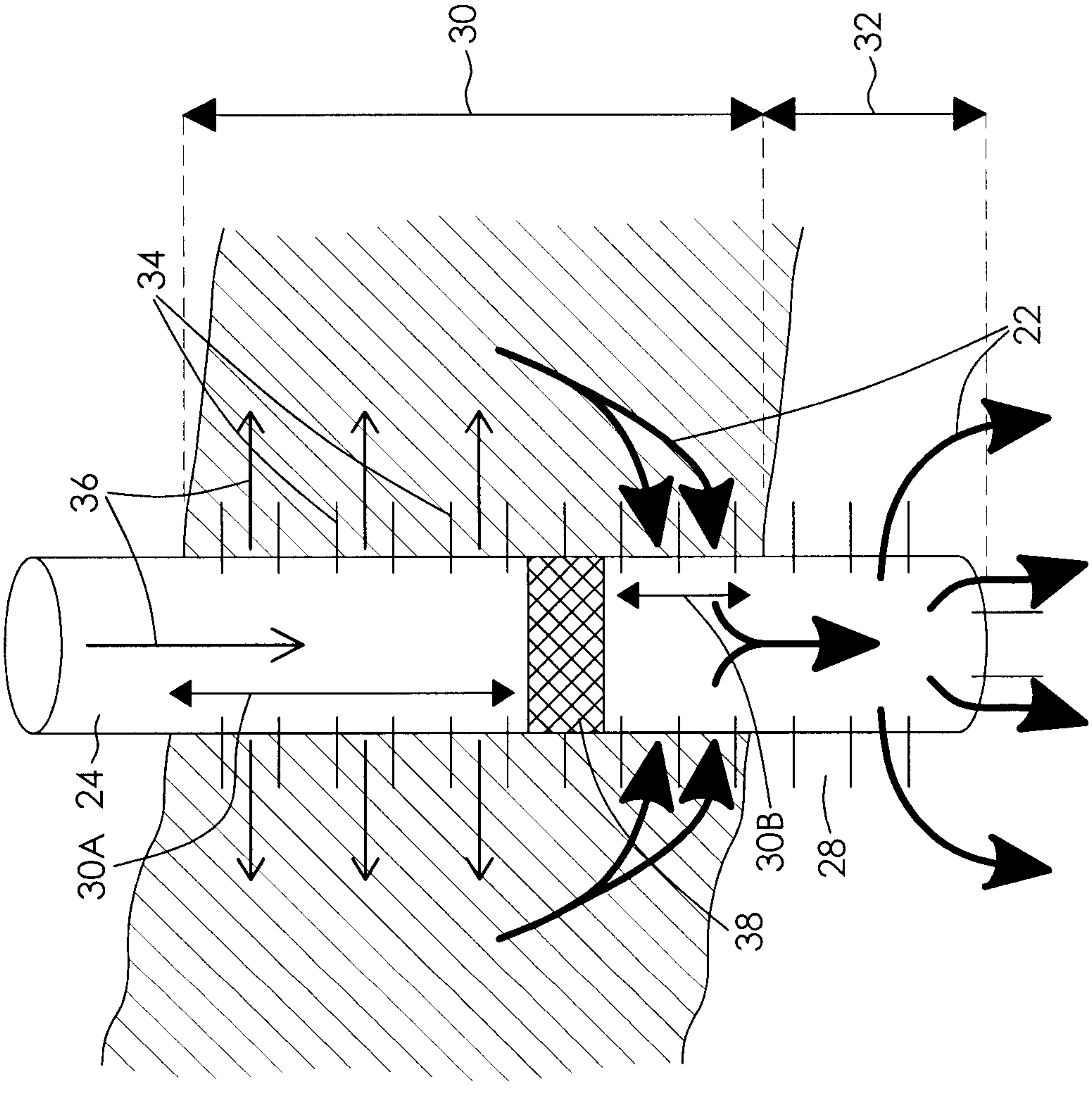

FIG. 2

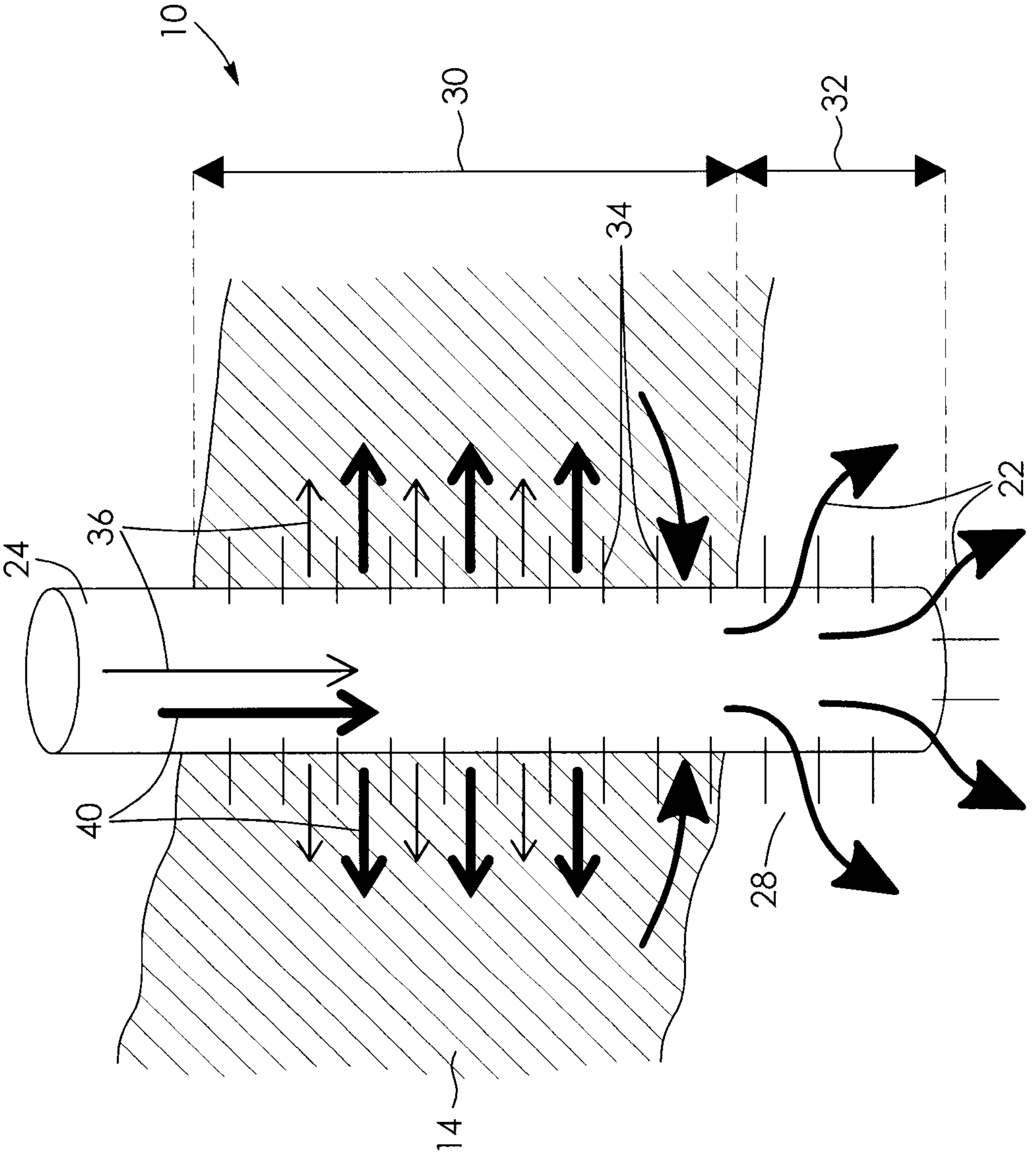

FIG. 3

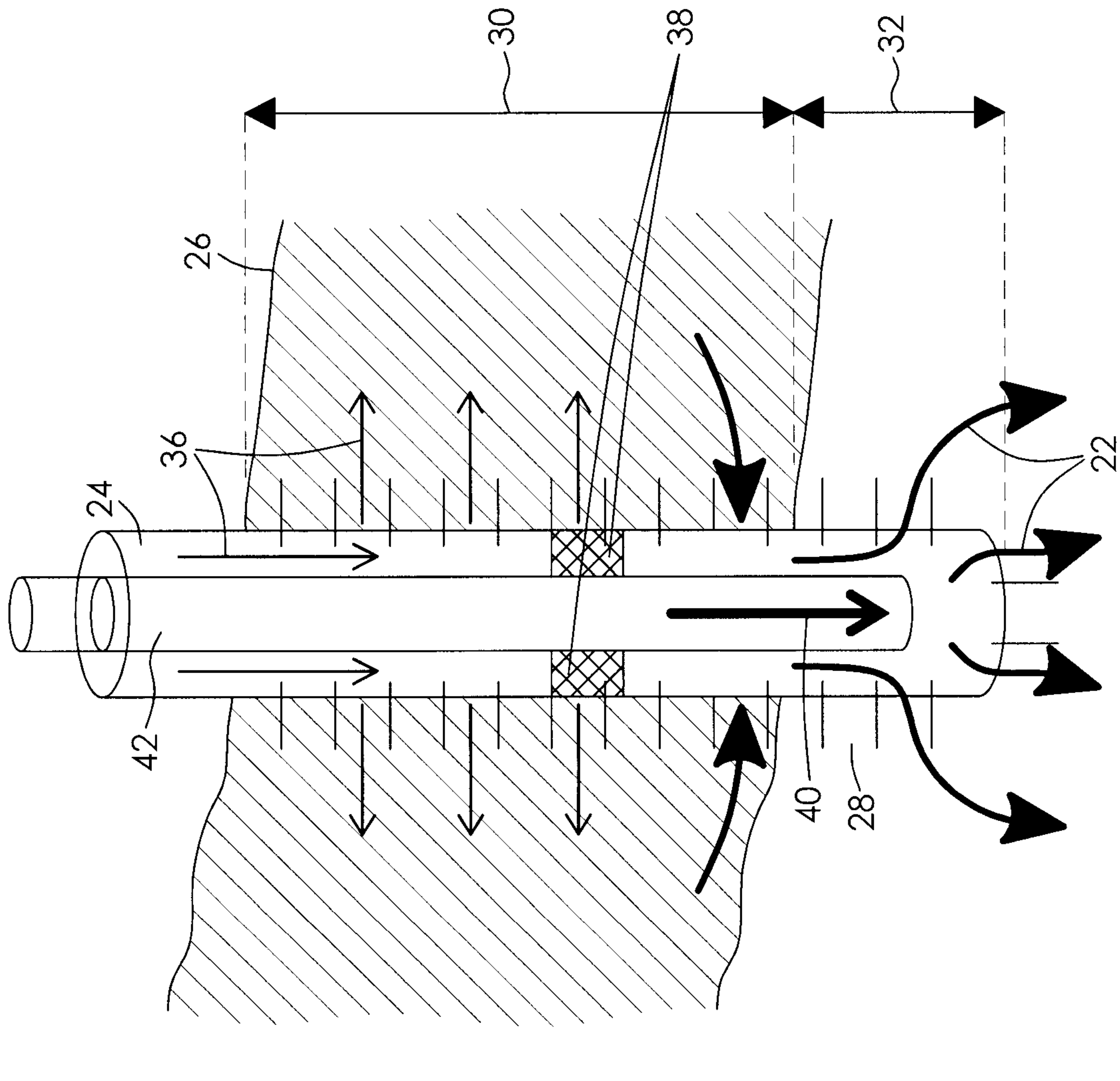

FIG. 4

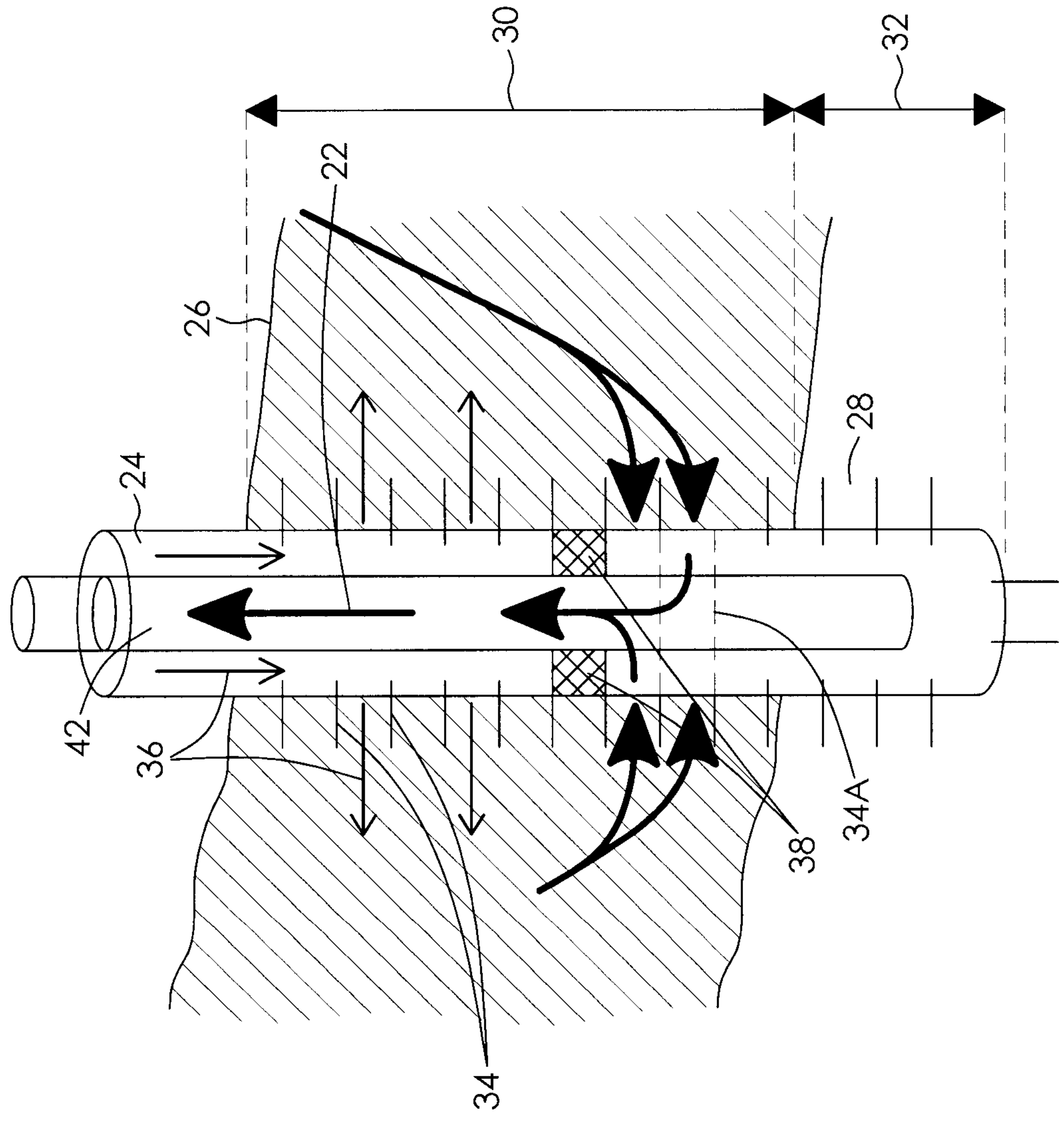

FIG. 5

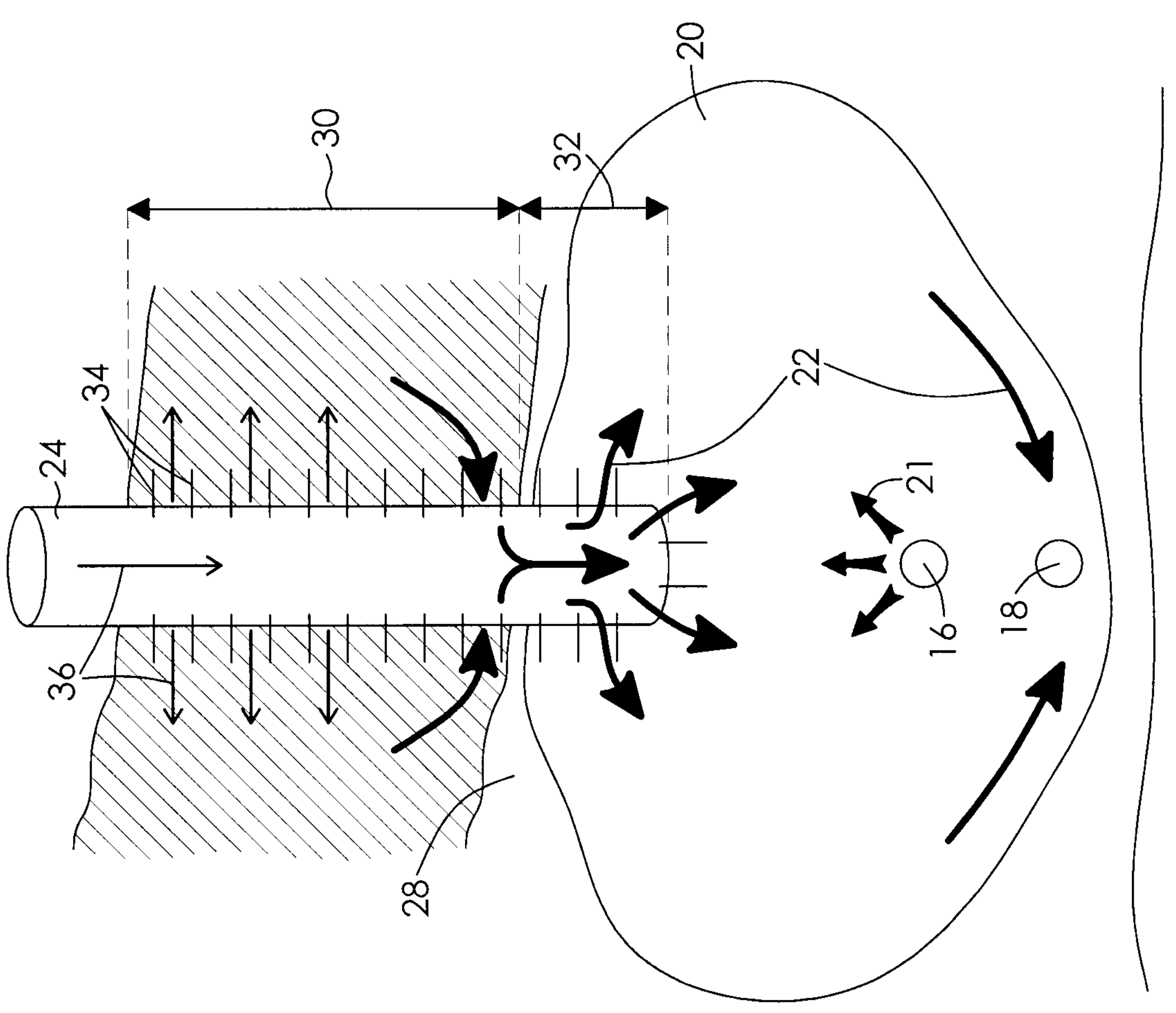

FIG. 6

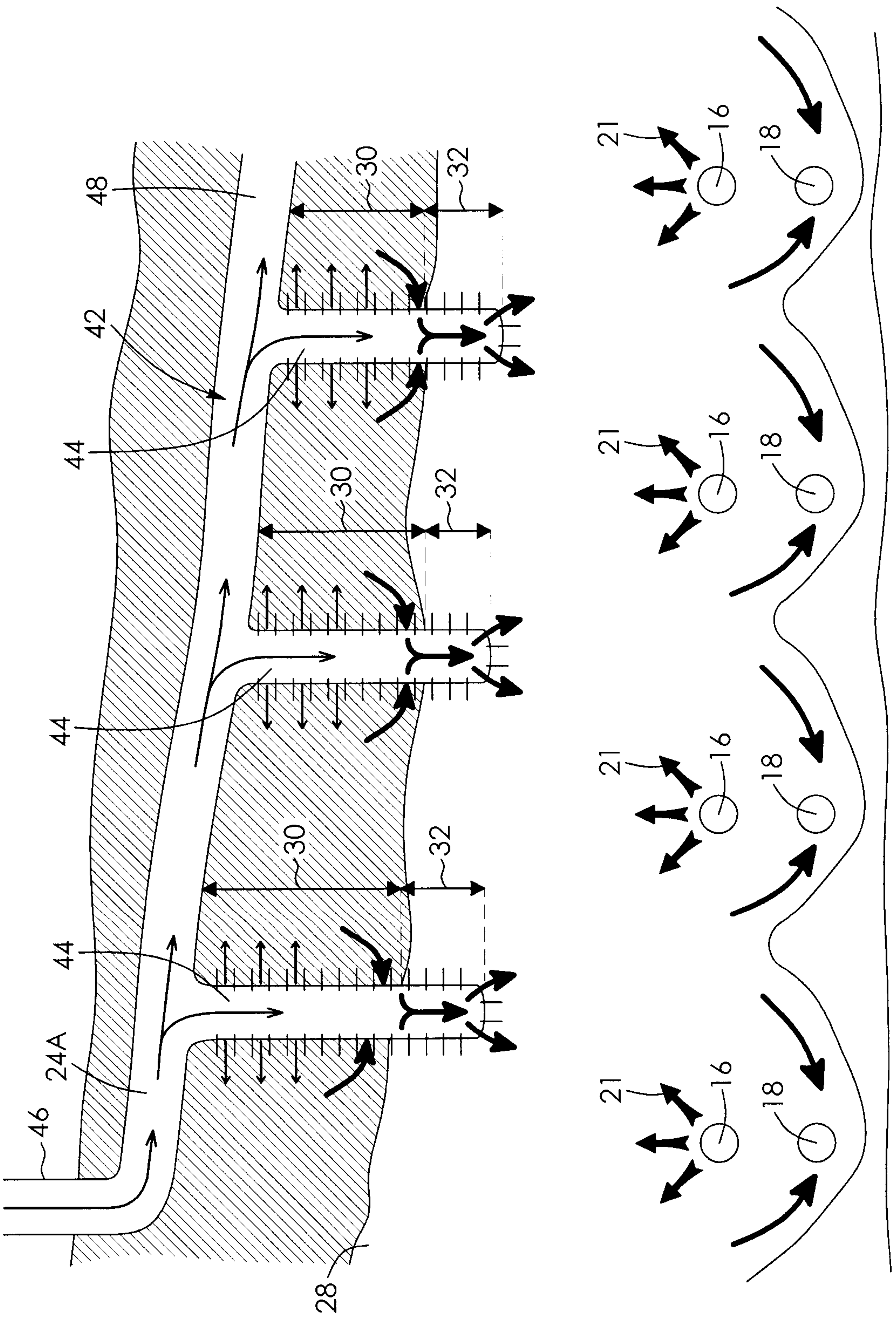
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FIG. 7

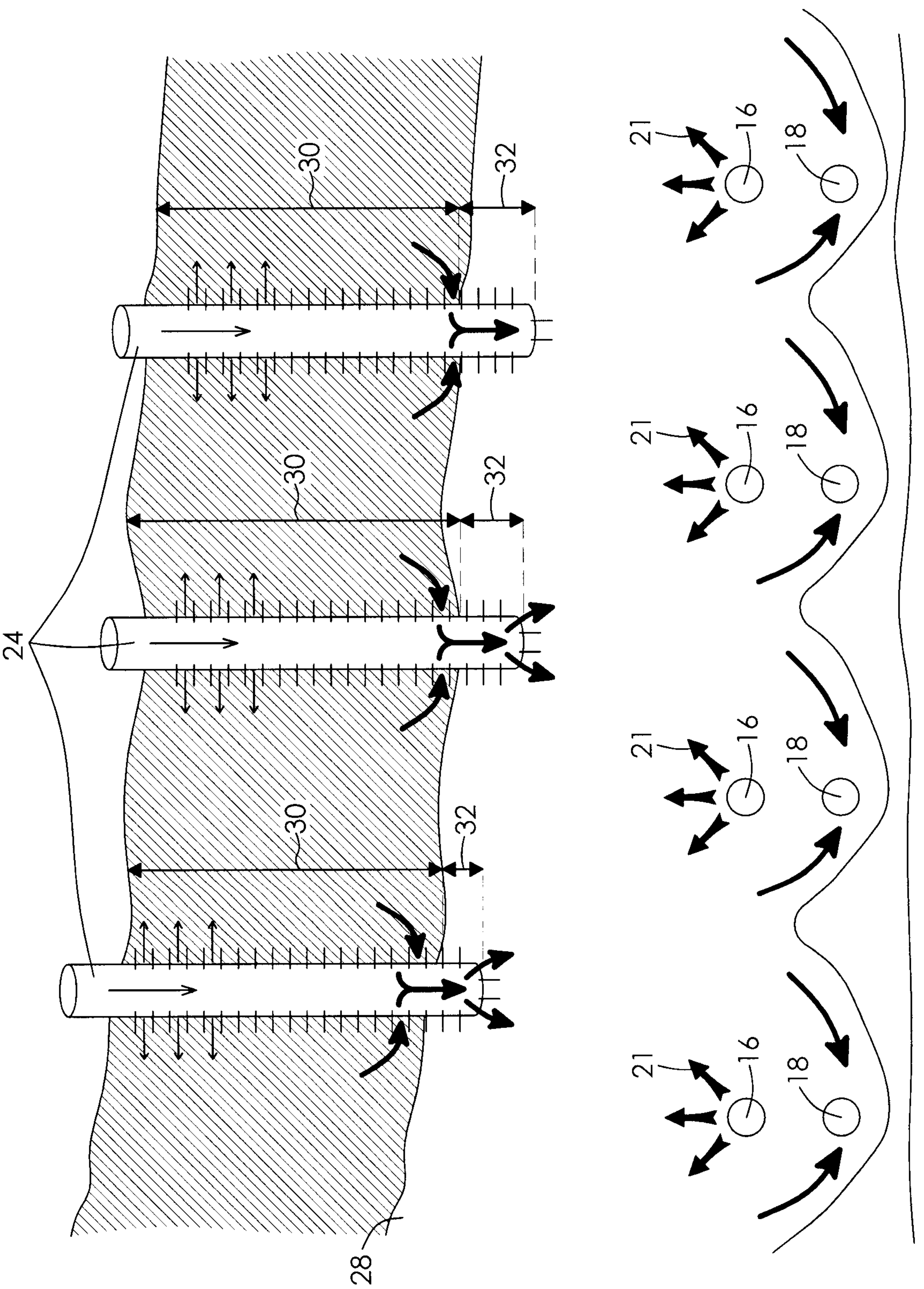


FIG. 8

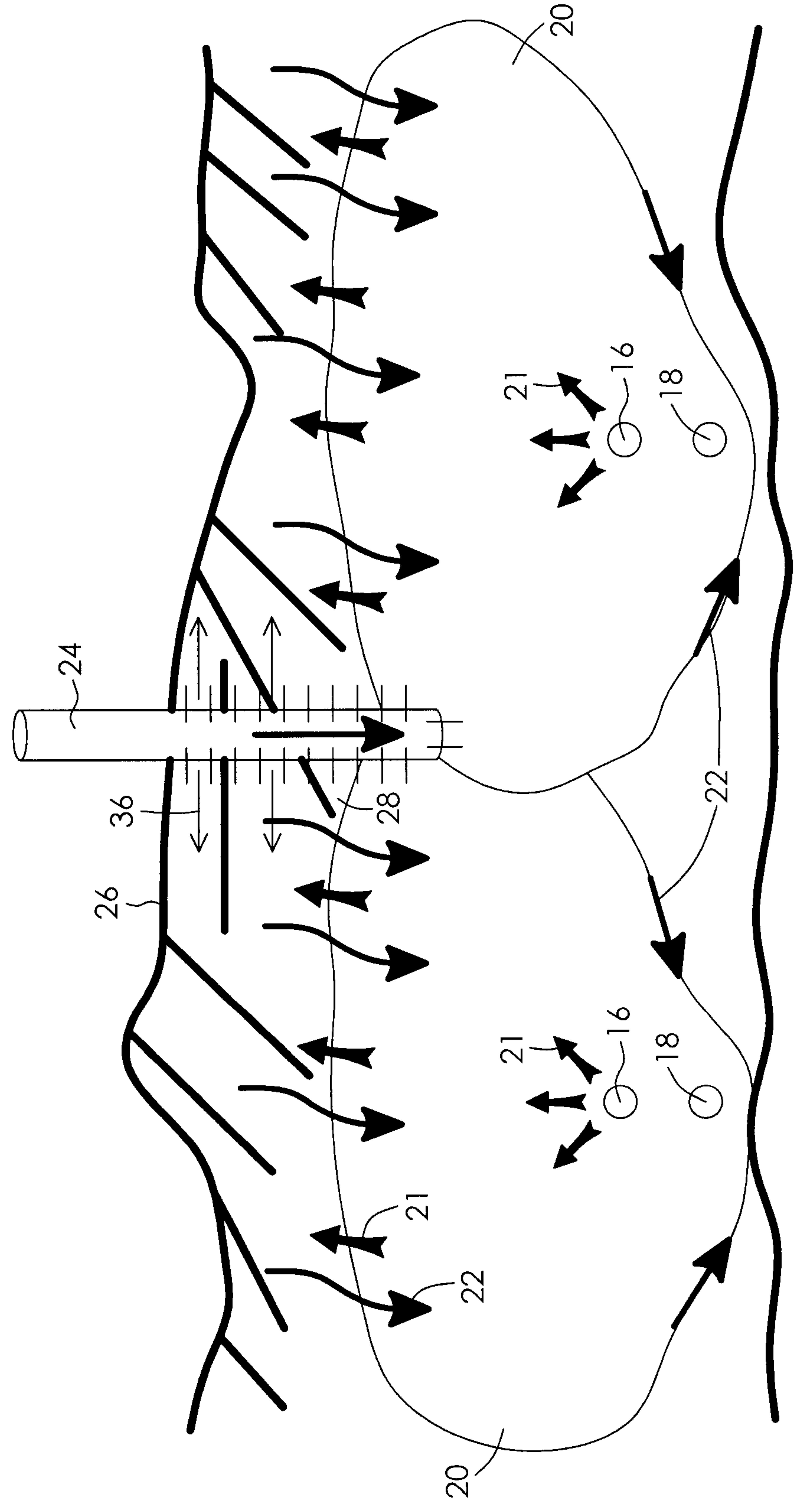


FIG. 9

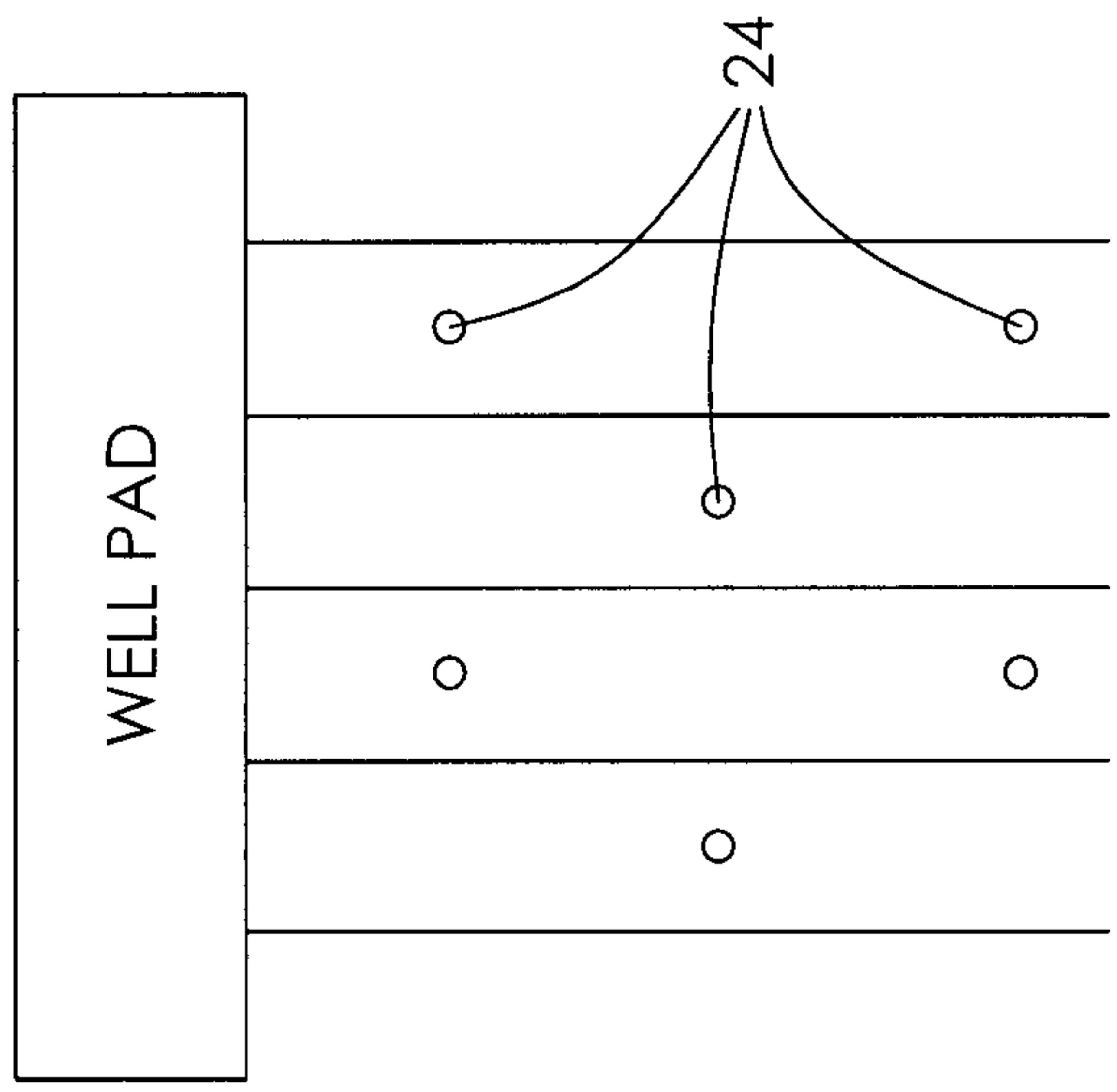


FIG. 11

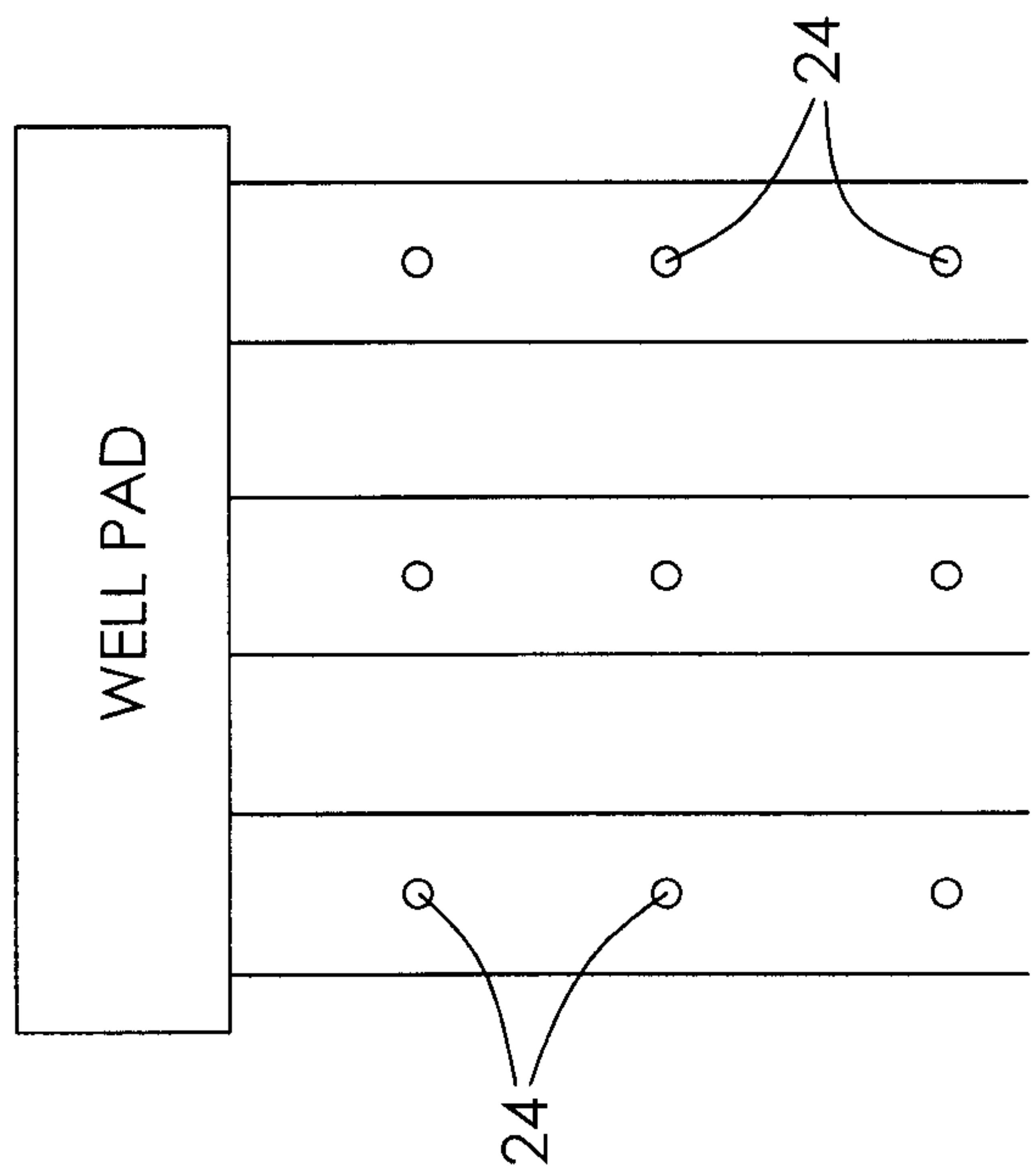


FIG. 10

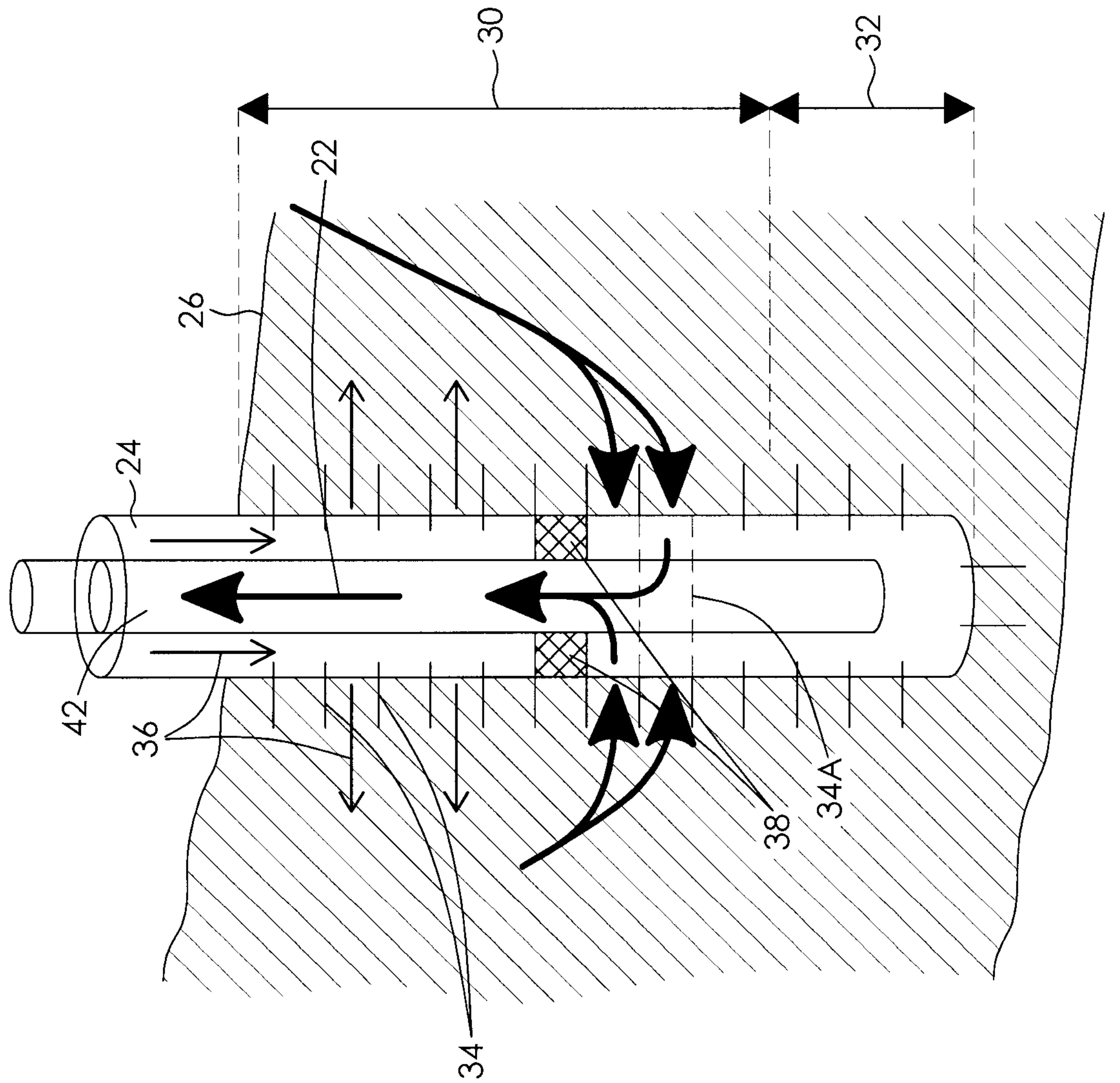
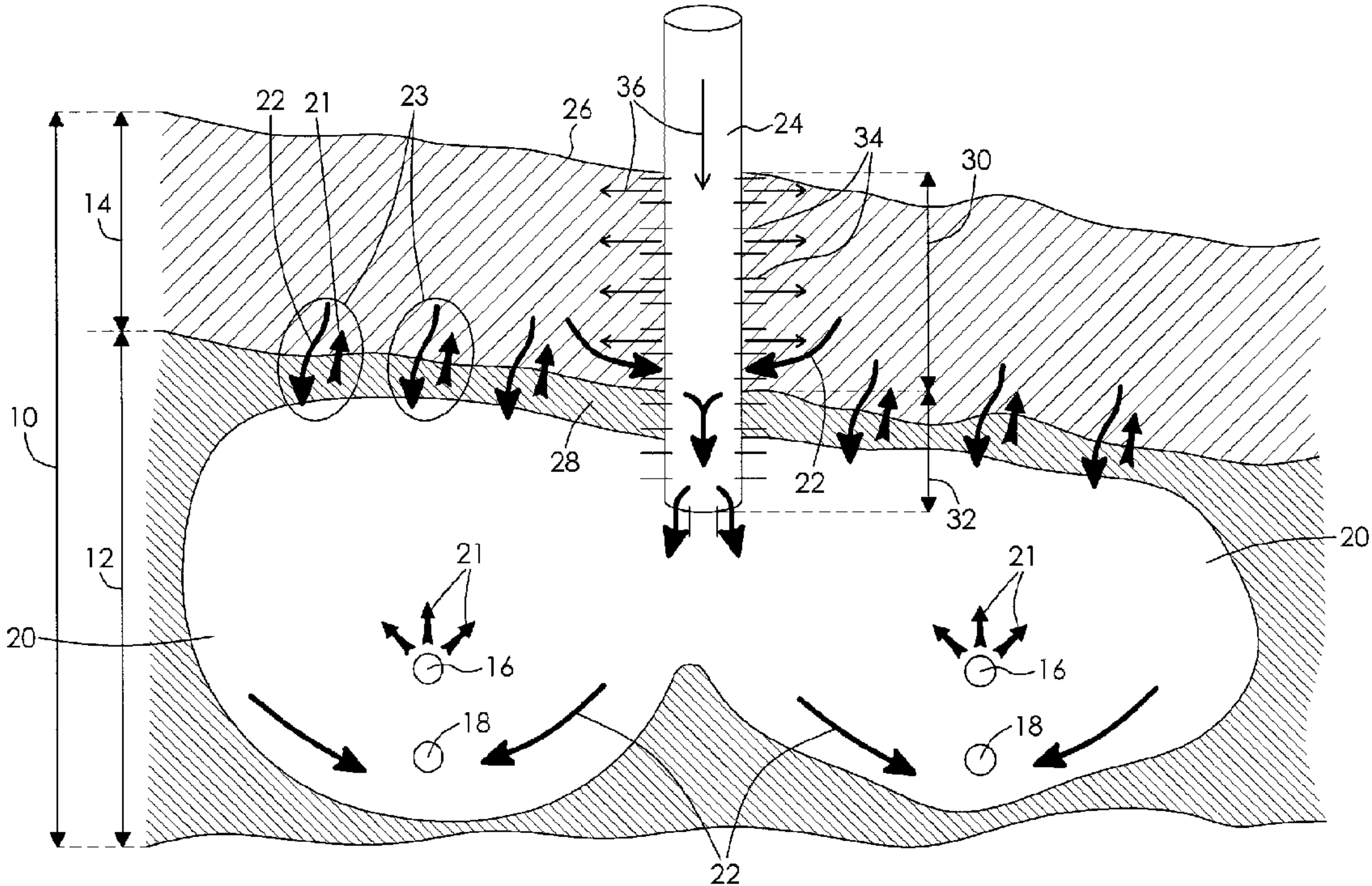


FIG. 12



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