



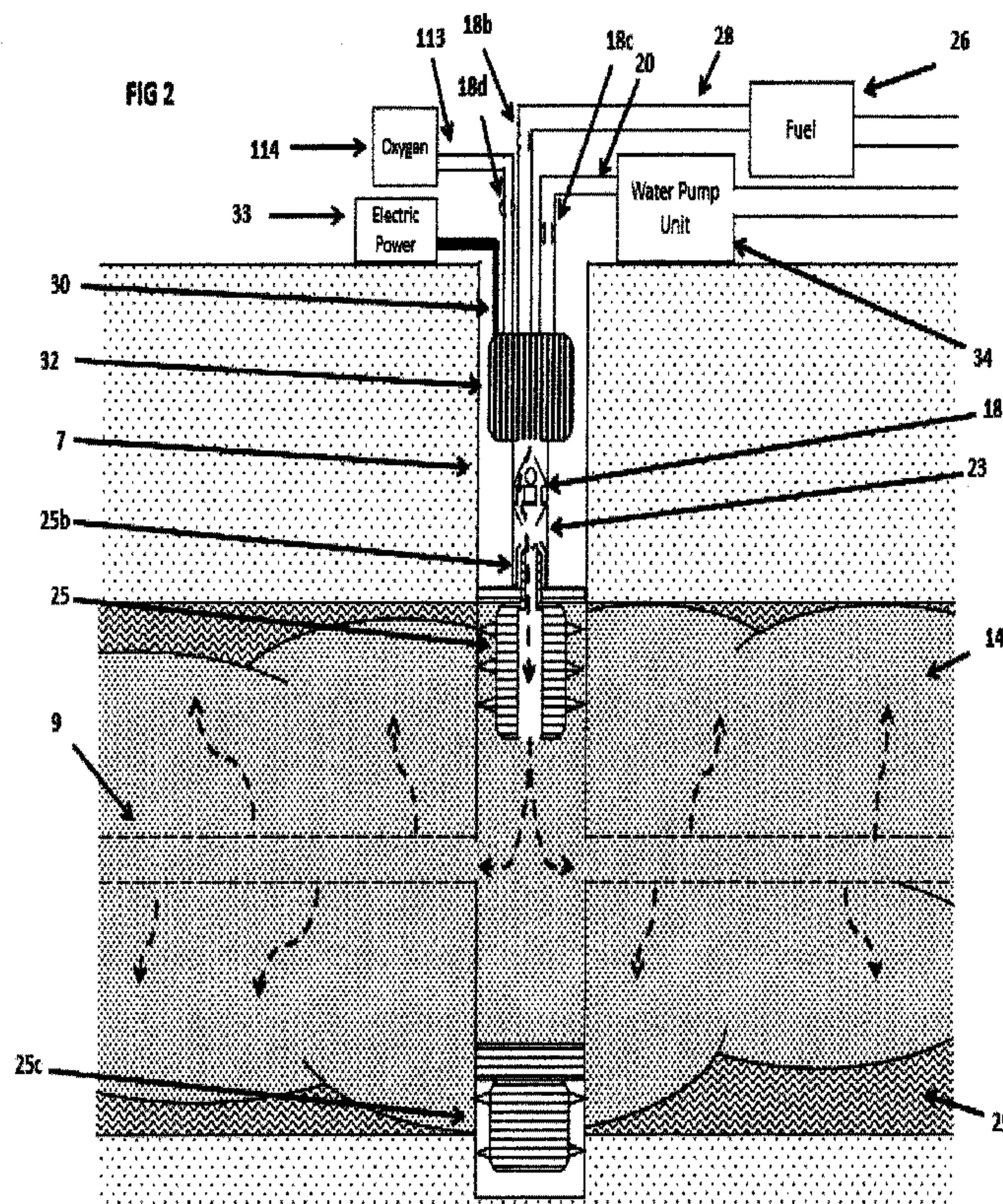
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(54) Titre : PRODUCTION ACCRUE D'HYDROCARBURES PAR STIMULATION THERMIQUE ET RADIALE
(54) Title: INCREASED HYDROCARBON PRODUCTION BY THERMAL AND RADIAL STIMULATION



(57) **Abrégé/Abstract:**

A system for increasing production of oil from subterranean formations comprising placement of heat or steam into the reservoir via radial drainage tunnels. The heat or steam may be created in the wellbore near the top of the well, downhole in the wellbore, or in-situ in the radials positioned in the reservoir.

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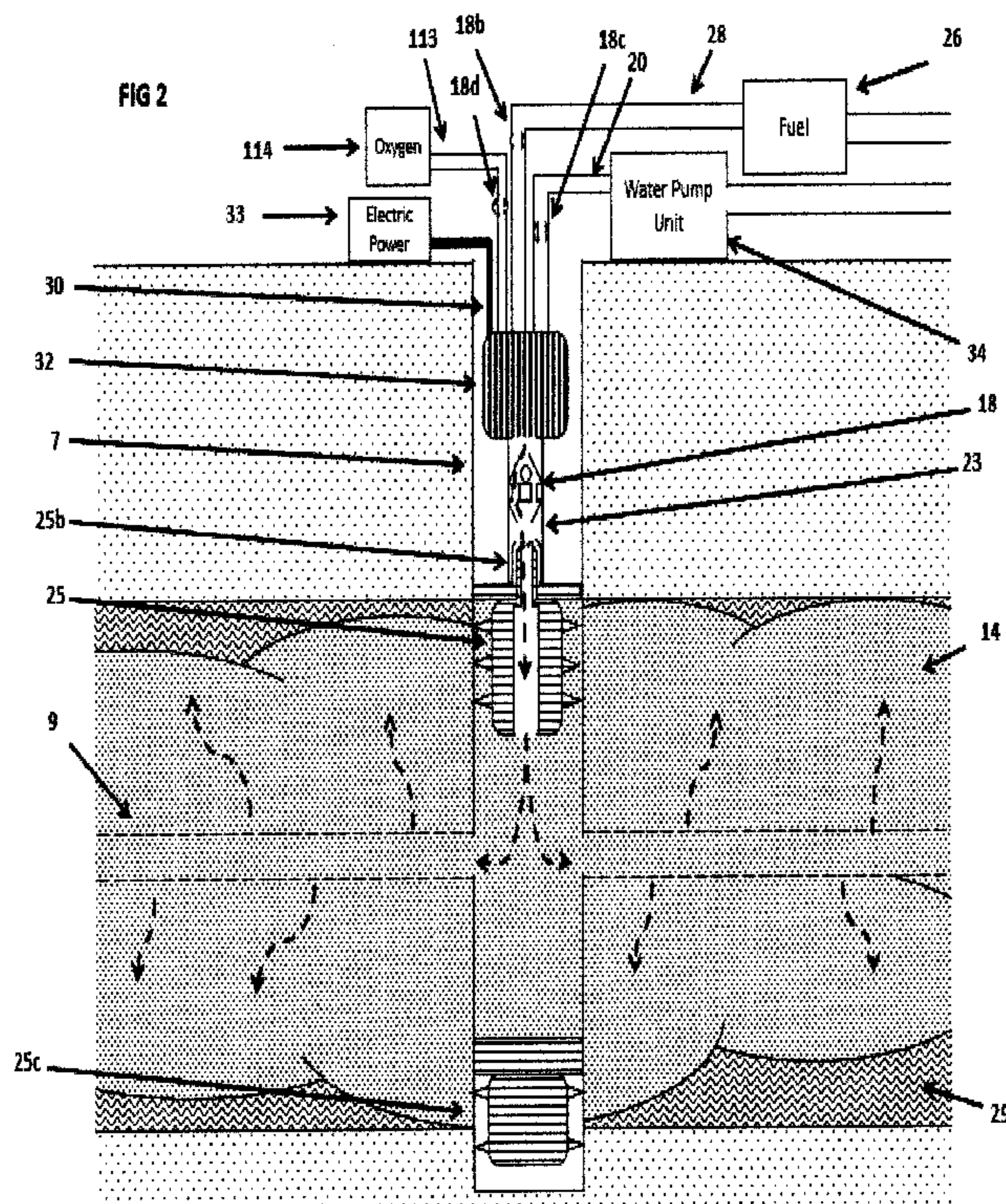
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(54) Title: INCREASED HYDROCARBON PRODUCTION BY THERMAL AND RADIAL STIMULATION



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INCREASED HYDROCARBON PRODUCTION BY THERMAL AND RADIAL STIMULATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present filing claims priority to US provisional patent application 62/386,573 filed on December 7, 2015.

FIELD

[0002] The present disclosure generally relates to radial drilling into subterranean oil and heavy oil reservoirs. More specifically, this disclosure discusses the innovative application of certain thermal (heat, hot water or steam) stimulations used in conjunction with radial drilling to stimulate oil recovery.

BACKGROUND

[0003] Natural resources such as oil can be recovered by drilling a well into subterranean formations. After the well is drilled, typically the tool string is pulled out of the wellbore and casing is placed downhole. Slurries such as hydraulic cement compositions are commonly employed in completing such wells. That is, cement is pumped into the annular space between the exterior of the well casing and the walls of the wellbore. As the cement sets, it forms a substantially impermeable barrier or sheath that limits the unwanted migration of fluids between zones or formations.

[0004] In radial drilling procedures, specialized tools are swept around the tight radius of a whipstock and are used to form one or more boreholes or tunnels radiating outward from the wellbore. Radial drilling is distinct from more-common coiled tubing drilling and conventional horizontal drilling in critical ways. For example, in conventional coil tubing and horizontal drilling procedures, the drilling tools are swept around a radius or “heel” that is hundreds or even thousands of feet in size. That is, in these procedures virtually all of the change in direction takes place outside of the original wellbore. By contrast, in radial drilling, the primary change of direction

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occurs within the tight radius of the whipstock itself. Moreover, because of the small size dictated by the radius in the whipstock, any long or large-diameter rigid tools, such as a mud motor, never moves into the radial that is being formed. In many radial drilling procedures a full 90 degree arc or “heel” is completed within the wellbore. As wells suited to radial drilling procedures commonly have a diameter of between about 4½” to 7” this equates to a heel of about 3 inches or 0.25 feet. Again, this contrasts markedly with coiled tubing drilling and conventional horizontal drilling, which require on the order of 250 feet to over 2,500 feet, respectively, for a full 90 degree heel. In short, conventional horizontal drilling operates at a scale that is 3 to 4 orders of magnitude larger than radial drilling.

[0005] Radial drilling procedures can be used on open-hole completed or cased hole wells. If no opening is present in a cased well, access to the formation is sometimes gained by milling out a section of the well casing. More commonly, however, a specialized tool string is moved down the wellbore and is used to drill a small, round hole (about ¾” to 1¾” in diameter) in the well casing. While such methods are familiar to practitioners of the radial drilling art, it is worth noting that these methods contrasts with conventional coiled tubing drilling, wherein one essentially uses a side-milling tool to form an extended slot in the well casing.

[0006] Once access to the formation has been gained, formation-drilling tools are then directed to the target formation by the whipstock. The formation forming tools are manipulated by some form of control-line, such as wireline unit, a coil tubing unit (CTU) or jointed-tubing. The radial boreholes themselves may be formed by one of several methods. For example, some methods utilize high pressure jetting nozzles despite the fact that these systems have proven ineffective in drilling hard rock formations and suffer from ambiguity as to where and how far any radials have been drilled. Other more-reliably methods utilize a form of mechanical drilling system; while yet others have proposed using lasers to vaporize the rock, high temperature flames to spall the rock or percussive drilling techniques.

[0007] Perforations typically reach about 1 to 2 feet into the reservoir, essentially, within the “near wellbore area”. Conventional horizontal drilling techniques reach 100s or even many 1000s of feet, essentially, to or beyond the “extended well area”. By contrasts radial drilling entails forming boreholes extending outward from about 5

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feet to about 100 feet from the wellbore, basically to the area best described as “well vicinity”. Given the large differences in scales between horizontal and radial drilling and the limitations imposed by the whipstock, it should not be a surprise that the tools used in radial drilling have great difficulty reaching beyond the well vicinity. Indeed, at present, the only known 3rd party validation of the distance of a radial borehole was performed under RPSEA 09123-03 under DOE prime award No. DE-AC26-07NT42677. Notably, this project involved a radial borehole drilled by one of the applicant’s mechanical drill systems. The distance reach on this project reached 32 feet, or about 1/3 of the “well vicinity” boundary, cited above.

[0008] The benefit of applying heat and/or steam in oil reservoirs, especially heavy oil reservoirs, is well known in the industry. Thermal stimulations of heavy oils can dramatically reduce their viscosity and hence improve their mobility. Additional benefits include reduced pore plugging by waxes and reduced interfacial tension. Indeed, without the application of steam, many heavy oil reservoirs could not be economically produced. Of course, the application of steam (over heat alone) has the further benefit of penetrating faster into reservoirs and of partially re-pressuring that zone.

[0009] There are several ways to generate steam for application downhole. One common method uses a large, central turbine/co-generation facility. The steam produced at the central-facility is then distributed via insulated pipes to the individual wells in the field. It is then conveyed downhole via insulated production tubing, where it enters the reservoir, typically via perforations in the steel well casing.

[0010] Systems utilizing centralized steam generation facilities suffer from severe losses, however. Sometimes these losses can exceed 50% of the latent BTU potential in the fuel source. Said in other words, often less than ½ of the BTU potential of the fuel source that powers the turbine is actually delivered into reservoir. Because of these losses, the economic limit of centrally generated surface steam only ranges to about 3,000 feet.

[0011] A number of methods have been developed to address the problem of poor thermal efficiency and to extend the economic depths to which thermal stimulations can be applied. Many of these systems rely upon electricity to power a heat source

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placed either at the individual wellsite or even downhole in the main wellbore. Such systems include: 1) resistive heating elements; 2) electrical resistance heating (“ERH”) processes; and 3) electromagnetic or radio frequency (“RF”) elements. Other approaches entail combining a fuel and oxidant (e.g. oxygen) in a combustion process or catalytic process to produce heat; and, then introduce water to generate hot water or steam.

[0012] While steam generated in or near a well, eliminates the sizable heat losses associated with distributing steam from a central-facility, such systems still experience heat losses associated with conveying the steam downhole. In fact, as much as 20% or so of the original BTUs can be lost in just delivering the thermal treatment from the wellhead into the subsurface reservoir. And, of course the deeper the reservoir, the higher these losses. To further reduce the heat losses, one can place the thermal source downhole in the main wellbore. While such a solution reduces heat losses, it does not eliminate heat losses to the steel casing, which is backed by an insulating layer of cement.

[0013] A further problem with certain current thermal stimulations stems from the inability to place high absolute quantities of hot water or steam in the reservoir. This phenomenon especially affects wells that have only been perforated. Basically, in these wells the limited contact area of the perforations acts as choke on the quantity or rate at which steam can be emplaced into the reservoir. Indeed, many reservoirs might warrant say a 5mm BTU/hour steam solution on a well, but perhaps only 1mm BTU/hour can be emplaced through the given “injection” well. Moreover, this same “choke” concept also applies oil recovery from the production wells in the reservoir. For example, a wellbore or reservoir might warrant a larger thermal source than is currently used, but it is pointless to make the expenditure for such an upgrade if one cannot extract sufficiently higher incremental volumes on the production well(s) to recoup the incremental investment. Indeed, it was largely this dynamic of poor steam injectivity volumes and poor extraction (choked injection and choked extraction) that has led to the development of steam assisted gravity drainage (SAGD) wells in heavy oil reserves.

[0014] As will be familiar to those in the art, current industry-practices suffer from the following shortcomings:

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- Heat losses in conveying steam from a central location to individual wells;
- Heat losses involved in conveying steam down a wellbore to the target zone;
- Heat lost due to conduction of steel well casing and the insulating effect of cement;
- Inability to emplace high volumes of steam into the reservoir, due in large measure to the perforation choke affecting cased wells; and
- Inability to extract high volumes of oil due to the choke / limited conductivity caused by perforations on production wells.

SUMMARY

[0015] This disclosure provides a means to address the various shortcomings that affect current industry practices related to thermal stimulations and recovery from conventional oil and heavy oil reservoirs. In instances, this disclosure utilizes radials to more efficiently emplace thermal stimulations directly into the reservoir (i.e. via radial injection radials). However, it also provides for radial production wells that more efficiently recover oil from the thermally stimulated reservoirs. While geared toward vertical wells, this disclosure also has applicability to horizontal wells.

[0016] It is a principal feature of this invention to create radial drainage tunnels that extend outward at least 5 feet from the wellbore and which exit the wellbore at between 45 and about 90 degrees. In creating these radials, one negates the choke created by the limited contact area of the perforations. That is, one dramatically improves the conductivity (and hence flow potential) between the wellbore and the payzone. Notably, these radials can be used to not only to improve the emplacement of thermal stimulations into the reservoir, but also to increase production from the reservoir. Another feature of this invention is to generate steam (vapor) that: more readily permeates into the reservoir rock; dissolves or returns waxes to solution; dries or shrinks clays; and, partially re-pressurizes the reservoir. Indeed, it is a specific objective of this invention to reduce the pressure required to emplace a given quantity of steam into a reservoir or to allow steam to penetrate further into the reservoir, as there is a reduced pressure drop in emplacing the steam.

[0017] Certain embodiments of this disclosure allow one to generate high quantities of steam near or in the wellhead (e.g. “at surface”) and to efficiently emplace pressurized hot water or steam into the reservoir. Other embodiments feature the ability to generate the heat, hot water or steam downhole in the main wellbore and to efficiently place it into the reservoir, while yet other embodiments actually generate the heat, hot water or steam in the radials themselves. Regardless of where the thermal stimulation is generated, all embodiments of this disclosure involve either: 1) the emplacement of the thermal stimulation into the reservoir through radials; 2) the production of oil from radials in a thermally-stimulated reservoir; or 3) both the emplacement of the thermal stimulation into the reservoir via radials and the production of oil from radials in the reservoir. Moreover, the radials used to emplace the thermal stimulation may be the same as those used to produce the oil, such as in a cyclic steam stimulation (CSS) procedure; or, altogether different radials may be used to recover the oil, such as might be employed on a continuous stimulation basis involving multiple wells.

[0018] Embodiments of this disclosure feature thermal stimulations (heat, hot water or steam) that are produced by an electrical power source using either: resistive heating elements or “heating cables”; by radio frequency (RF) heating systems; or by a series of resistive heating elements (RHE) defined by electrode arrays. Yet other embodiments define a combustion process, while yet others entail a catalytic process wherein a fuel is oxidized with the assistance of a catalytic bed. Regardless of the exact heat source, water can be introduced to generate hot water or steam.

[0019] It is also a feature of this invention to be used in individual wells and in sets of injection and production wells. For example, this disclosure can be used with a single vertical well or sets of vertical injection and production wells. Additionally, this invention can be employed in conjunction with individual horizontal wells or horizontal wells configured in conventional / “stacked” SAGD pairs. Moreover, as depicted in the figures, it is a feature of this invention to be used in configurations involving both vertical and horizontal wells.

BRIEF DESCRIPTION OF DRAWINGS

[0020] The accompanying views of the drawing are incorporated into and form a part of the specification to illustrate several aspects and examples of the present disclosure, wherein like reference numbers refer to like parts throughout the figures of the drawing. These figures together with the description serve to explain the general principles of the disclosure. The figures are only for the purpose of illustrating preferred and alternative examples of how the various aspects of the disclosure can be made and used and are not to be construed as limiting the disclosure to only the illustrated and described examples. The various advantages and features of the various aspects of the present disclosure will be apparent from a consideration of the figures.

[0021] Fig. 1a illustrates a wellbore in a heavy oil reservoir where one radial has been already formed and a second is being created by a flexible mechanical drill-string, which, in this case is powered by a mud motor.

[0022] Fig. 1b illustrates a wellbore with an electrically-powered steam generator position near the wellhead that is being used to emplace steam into a reservoir via radials.

[0023] Fig 2 illustrates a wellbore in which a catalytic heater has been positioned downhole and is being used to heat water that is being emplaced deep into the reservoir via radials.

[0024] Fig 3 illustrates a downhole steam generator that employs a combustion system fed by supply lines running to the surface. Large quantities of high quality steam are being emplaced in the reservoir with minimal pressure loss due to the large contact area provided by the radials.

[0025] Fig. 3b, 3c and 3d illustrates cross-sectional examples of the supply lines for the fuel, oxygen and water used to power various downhole hot water or steam generators.

[0026] Fig. 4 illustrates a wellbore where two radials have been drilled for continuous injection of steam into an oil zone. Water is being pumped downhole across heating cables in order to generate steam. The steam enters the reservoir via the radials, driving oil to an adjacent production well (not shown).

[0027] Fig 5a illustrates a reservoir in which radials have been emplaced from a wellbore and is being used in a cyclic steam simulation procedure incorporating an ESP and unique valve system that alternately allows the flow of water downhole, the shutting in of the well or the production from the reservoir. Fig 5b illustrates the wellbore of Fig 5a during the production phase, wherein the valve for reservoir inflow has been opened and an ESP is pumping oil to the surface.

[0028] Fig 6a illustrates a wellbore in which two radials have been formed into a reservoir containing medium API oil. A special guide device is being lowered on production tubing toward a landing nipple that is sitting upon an anchor that was previously left in the well from when the radials were formed. Fig 6b illustrates the wellbore of Fig 6a wherein a conductor line is attached to an ESP and flexible heating cables. The conductor line, ESP and heating cables are being lowered toward the special guide device. Fig 6c shows the wellbore of figure 6b with the flexible heating cables emplaced and generating heat in the radials. The heat is carried into the reservoir around the wellbore by conduction and convection and is reducing the viscosity of the oil.

[0029] In Fig 7 we see an RF based heat sourced used in conjunction with a gravity drainage configuration defined by radials emplaced in two different wells. The RF antenna is connected to and controlled by surfaced-based control equipment. The reduced viscosity oil is moving toward the lower radial with the assistance of gravity drainage.

[0030] Figure 8 shows an electric resistive heating system used in conjunction with radials positioned at different elevations in a reservoir. Water is being pumped down the well and is entering the radials, assuring that the space between the sets of electrodes retain high conductivity.

[0031] Fig 9A shows a well in which heating elements have been emplaced in the radials in a fashion generally similar to that seen in Fig 6C. In this instance, the well being operated in a huff-and-puff procedure. Water pumped downhole enters the radials, contacts the heating elements, turns to steam and proceeds to enter the reservoir. Fig 9B shows the well of Fig 9A during the production cycle, with the pump jack bringing oil to the surface.

DETAILED DESCRIPTION

[0032] This disclosure combines radial tunnels and certain innovative thermal stimulations treatments to improve oil recovery. This disclosure addresses shortcomings in how current thermal stimulations are applied and the efficiency with which oil is recovered from many such reservoirs.

[0033] This disclosure involves forming one or more radials in an oil-bearing reservoir by means of a whipstock and toolstring operated by a control-line such as a coiled tubing unit (CTU). The radials of this disclosure can be formed by one of several methods known to those in the radial drilling industry. For example, one can: 1) use a high-pressure fluid ejected from a nozzle in an attempt to jet drill a radial as described by Landers in 5,853,056; 2) eject acid from a nozzle to erode certain types of rock formations; 3) use lasers in an attempt to vaporize the rock; 4) apply extremely high levels of heat in an attempt to spall the rock; or 5) one can use a motor to rotate a flexible drive shaft and attached cutting head to mechanically drill the radial. Notably, this last category covers several genres of “drive shafts” or drill-strings to rotate a mechanical cutting head. For example, one may use: 1) a spring that circumscribes a hose; 2) a hose that is circumscribed by a counter-wound spring; or, 3) a series of segments or links that are pinned or nest together to transmit torque to the cutting head. Certain embodiments of the flexible drive shaft are described in PTC Application WO2014039078 A1, U.S. Patent Application 20120067647 A1 and U.S. Patent Application 13/226,489, all incorporated in their entirety herein by their reference.

[0034] Having discussed methods for forming the radials (or laterals), we now turn our discussion to the thermal stimulation. For clarity, it is worth reiterating that certain embodiments of this disclosure entail only the co-application of heat and radials, while other involve the co-application of hot water and radials, while yet other entail the co-application of steam and radials.

[0035] In embodiments involving only heat (and not the deliberate introduction of water), the heat can be generated downhole in the wellbore or in the radials, themselves. These solutions apply primarily to moderate to higher API oil reservoirs,

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where the added complications and costs of generating steam may not be necessary for satisfactory improvements in oil recovery rates. An example of such embodiments entails the placement of heating cables (described below) in the radials themselves. In these cases, the heat is used primarily to reduce the viscosity of the oil in the area immediately surrounding the radials. This solution is well-tailored to moderate to high permeability conventional reservoirs with permeability of over about 20mD and with moderate or low viscosity oils (e.g. over about 20 API).

[0036] While heat itself reduces the viscosity of oils it contacts, other embodiments of this disclosure deliberately introduces water in order to generate hot water or steam. Embodiments of this disclosure deliberately produce the vapor of steam due to its high latent heat carrying capacity, easier permeation into the reservoir and its ability to re-pressurize the reservoir. At the same time, one should not underestimate the efficacy of introducing hot water into oil reservoir, as water under pressure can range to very high temperatures (e.g. over 600F) before it flashing to steam. As such, hot water can have a very high absolute capacity to carry heat into the reservoir. Moreover, many heavy oils experience 3 or more orders of magnitude reduction in viscosity, when heated by a 200F to 300F.

[0037] SOURCES OF HEAT

[0038] In embodiments, this invention utilizes a series of resistive heating elements or “heating cables” as the heat source. These electrical heating elements can include a restive core surrounded by an insulation layer, such as magnesium oxide, and a sheathing, such as stainless steel. When a current is applied, the resistive elements (“heating cables”) heat up transferring heat to adjacent solids and fluids by means of convection and conduction. To minimize power loses in conveying the electrical current downhole, most embodiments employ three-phase electric power. Optionally, a timer can be used to prevent over-heating of the cables or a continuous computer controller can be used to assure proper and even heating along the heating cables. In addition, the heating elements in the heating cables can be placed and controlled in distinct arrays or in conjunction with distributed sensors, thereby allowing varying power and duty-cycles along various parts of the extended cables based on localized temperatures. In this fashion, optimal and uniform heating along the full length of the

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cables can be attained. To improve heat dissipation from the heating cables, the sheathing may incorporate fins or undulations that increase the surface area.

[0039] As the heating cables are cable of operating at elevated temperatures, water can be circulated across them to generate steam. An example of a heating cable suitable for this application is the PetroTrace™ mineral insulated heat cable that can generate over 650 watts per meter of length and operates to over 850°F. The high operating temperatures of these cables is noteworthy as they allow one to generate steam at depths well below the approximate 3,000 ft working depth limit of surface-generated steam solutions. For example, at 3,000 ft of water head pressure (approx. 1,500 psi), it only takes about 600°F to generate steam. Moreover, the solutions disclosed herein will typically be applied on older reservoirs, where the absolute bottom hole pressure is below the hydrostatic gradient. Basically, meaning that the water will flash to steam at significantly lower temperatures than otherwise suggested by the depth of the zone. Conversely, this also means that one can use these cables at even deeper depths and, yet, still generate steam or can produce superheated steam well above the flash point.

[0040] In certain embodiments, this disclosure uses an electrical resistance heating (“ERH”) process to generate heat in the reservoir. As with the heating cables, ERH can be used as a standalone process to merely generate heat in the reservoir; or, it can be used with the introduction of water to produce steam. In the ERH process, an electric current is passed between arrays of electrodes placed downhole or in the radials themselves. Water or brine serve as the conductive flow-path between the electrodes. The resistance that is encountered by the current when passing from electrode to electrode causes the brine and hence the reservoir to heat-up. A power delivery system helps control the flow of current between the electrodes and can thus be used to alter the current flow between individual sets of electrodes, assuring more even heating of the reservoir. To avoid the flashing of water to steam, one can operate the ERH at a reduced duty-cycle, allowing time for new brine to permeate into the spaces between the electrodes; or, one can pro-actively pump water between the opposite polarity sets of electrodes. As with the resistive heating elements above, if operated at high power levels and with a consistent water supply, hot water or steam can be generated. ERH

systems can be powered by A/C or D/C current.

[0041] Another aspect of this disclosure is to generate heat downhole using electromagnetic or radio frequency “RF” heating. In these systems, a signal generator produces a signal in the range of about 10khz to 400khz and powers a downhole antenna array. As the antenna emits RF energy, the energy is dissipated in the form of heat, with the area closest to the antenna being heated the most. When operated at high power levels, water in the formation turns to steam, which then moves toward lower pressure areas in the reservoir. The area of now-reduced water content has reduced electrical conductivity, which in turn results in the electromagnetic field penetrating further into the formation. This situation creates a sort of self-regulating system that helps avoid high localized temperatures. The RF source unit can have real-time monitoring capabilities allowing for modification of individual antenna power levels and/or cycle time. In this fashion one can control the location and quantity of heat being generated along the antenna array. An example of an RF heating system is offered by Harris under the HeatWave™ trade name and described in a typical deployment in US 8,646,527 B2, incorporated herein by reference.

[0042] In certain embodiments, the heat is generated by a combustion process involving burning a fuel source (whether a liquid or gaseous fuel) in the presence of an oxidizing material (i.e. an oxidant). For example, one can burn methane, butane or diesel in the presence of air, oxygen-enriched air, or oxygen. In yet other embodiments, the fuel and oxidant mixed are passed across a catalyst bed. To maximize the surface area of the catalyst bed and thereby assure complete oxidization, one can use a “honeycomb”, “waffle” pattern or similar large-surface area. Whether by combustion or catalyst, to assure full conversion of the fuel and oxidant, an optional ignition or pre-heater system can be employed. Naturally, both the combustion and the catalytic fuel oxidization processes could employ sensors and valves to measure and regulate the flow of the water, fuel and any consumable oxidizing material (e.g. enriched air). Again, these controllers will be useful to regulating combustion or catalyst bed temperatures and the quantity and quality of heat, hot water or steam that is generated. Discussed more fully below, the combustion or catalytic process can occur at the surface or downhole in the main wellbore.

[0043] In embodiments involving the generation of steam for shallow applications, to about 1,000 meters, the heat source and may be located at the surface near the wellhead or near the surface, in the actual well. Obviously, the hot water or steam would be generated in this proximity. These embodiments avoid the losses associated with central systems that distributing steam to individual wells.

[0044] In yet other embodiments the heat and steam is generated downhole in the main wellbore. If generated close to the reservoir, these embodiments can avoid most of the 5-20% heat loss that is typically lost in conveying the hot water or steam downhole. Embodiments where the heat, hot water or steam is generated downhole in the main wellbore apply to both the electrically-powered heat sources, as well as the fuel and oxidizer-based heat sources. Typically on electrically based solutions, the conductor line to supply power downhole would be strapped to the outside of production tubing. In embodiments involving a burner (combustion) or catalytic bed, the fuel, water and oxidant would be conveyed downhole by a flatpack with multiple conduits, a series of concentric tubing strings, or a multi-conductor line formed into a single round shape.

[0045] Another feature of embodiments of this invention is to generate the heat, hot water and steam in the radials themselves. While more difficult to deploy, this location has minimal heat losses, i.e. nearly 100% of the heat that is generated can be emplaced directly into the formation. In these embodiments, the heat can be created by means of flexible heating cables, RF arrays run on flexible lines, or by means of resistive heating elements (electrodes) conveyed on flexible cables. Because any of these heat sources are deployed on flexible lines or cables, they can be transitioned around the tight heel in the whipstock and inserted into a radial.

[0046] If only one radial is to have a flexible heating element placed within it, that element can be run through the whipstock that is used as part of the process to create the radial. If heating elements are to be emplaced in multiple radials an alternate method and apparatus can be used in order to “re-find” or “re-center” on a radial in order to then insert the heating elements. One such method employs a special landing nipple atop the anchor used to secure the whipstock during the radial forming process. In this approach, after the radials have been formed, the toolstring and whipstock would be removed, leaving in place the anchor and landing nipple. The operator

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would then lower a special kick-off or guide apparatus with multiple pre-arranged guide paths. The correct depth in the well is maintained by the unmoved anchor, while the correct azimuth can be dictated by mating features on the landing nipple and special guide apparatus. For example, the landing nipple may have a slide or taper that directs a mating feature on the special guide assembly into the pre-determined, specific azimuth. Whatever the exact mating profile between the landing nipple and special kick-off apparatus, the operator would lower the special guide apparatus until it fully seated into the landing nipple. At this point, the multiple guide paths would each be oriented toward a radial. The operator could now lower the multiple flexible heating elements through the special kick-off apparatus and emplace them in the radials. Ideally, the flexible heating elements would be powered by a common conductor running to the surface. This conductor could run through or be strapped to production tubing running to the surface, such as might be employed on a single well used in a huff-and-puff process. At the same time, if the well is to be used as a continuous steam injection well, one can eliminate the production tubing entirely and simply lower the conductor cable directly into the well.

[0047] In certain instances one may wish to find a radial produced in a prior drilling procedure wherein a downhole tool (e.g. landing nipple) has not been left as a reference point in a well. In this case one can “re-find” the radials by one of several methods. For example, one may employ a downhole imaging device and method similar to that described in US Patent 9,279,319 by Savage. Alternatively, one can run a special tool downhole that uses a pin and spring to locate upon a pre-existing radial. With the knowledge of where radials were previously emplaced, the operator could use the now-found reference location to place a special guide devices that is properly oriented toward other pre-existing radials.

[0048] In certain embodiments, the conductor cable used to power a downhole electrical element could also power a downhole electric submersible pump (ESP) used to pump oil to surface. This configuration could be used in a single well cyclic steam stimulation procedure, wherein the same supply-line powers both the electric heating elements and an ESP. The heating elements could be in the main wellbore with the ESP, or they could be emplaced into the radials.

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[0049] As a specific feature of this invention is to generate and efficiently emplace steam into the reservoir, we now turn to a discussion of how water is brought into contact with the thermal sources to generate steam. The answer depends partly upon the placement (location) of the heat source and whether it is near the surface, downhole in the main wellbore or in the lateral itself? In addition, the embodiments described herein would commonly be used with one or more isolation packer to optimize the placement of the steam into the radials or directly into the reservoir.

[0050] If the heat generation source is located near the wellhead, supply lines would be connected directly to appropriate supply sources and surface control equipment. Obviously, in the moving of the hot water or steam into the reservoir, back-pressures would be generated. Fortunately, because this invention can emplace the hot water or steam through the large surface-area of radials, the “choke” caused by the perforations is dramatically reduced. This is particularly important when emplacing steam into tight reservoirs or reservoirs with limited perforation contact area. Whatever the particular case, large quantities of steam can be efficiently emplaced into the reservoir with minimal pressure drop. Heat sources that comprise combustion or catalytic processes offer the further advantage that any nitrogen or produced CO² can also be placed into the reservoir; potentially further enhancing the oil recovery.

[0051] In embodiments where the heat source is positioned downhole in the main wellbore, the water used to generate hot water or steam would be pumped down a conduit. This conduit may be the production tubing, a separate tubing string or an annulus of the well. Optionally, the water flow could be divided by a manifold and regulated through a set of valves or orifices. In this fashion, appropriate quantities of water could be made to contact multiple downhole heating sources and/or be brought into contact with different parts of a single heating element. For example, if the heating source is a set of extended heating cables each in a different radial and each operated at the same power level, one can assure that each cable receives the appropriate amount of water based on how fast each is able to emplace steam into the reservoir. Furthermore, using this approach each part of each cable can receive the appropriate amount of water based upon the heat being generated along that part of the heating cable.

[0052] In yet other embodiments, where the heat source is in the radials themselves, the water can be pumped down the wellbore via a conduit and then out the radials. In some embodiments, the water entering the radial may simply travel in the annular space between the element and the borehole wall. One can assure water moves into the radials by applying adequate surface pumping pressure or otherwise assuring the head pressure of the vertical column of fluid in the well exceeds the back-pressure generated when creating and emplacing hot water or steam into the reservoir. In other embodiments, the water may be positioned in the radials by means of a flexible conduit that transitions from the main wellbore and into the radial. For example, in certain embodiments, heating elements defined by heating cables may circumscribe a perforated flexible conduit used for delivering water into the radials. In yet other embodiments, the flexible conduit may circumscribe the heat source placed in the radials. Whether a passive method (e.g. surface pumping only) or an active method (conduit that delivers fluid into the radials) is employed, the heat source and hence the hot water or steam would thus be generated in the radials themselves.

[0053] Various combinations of injection and production wells may be employed with the radials and thermal stimulations described herein. That is, the radials may be emplaced on the injection wells; on the production wells; or on both. Moreover, these wells may constitute various combinations of vertical, slant and horizontal wells. For example, in certain embodiments a vertical injection well with one or more radials can be used to efficiently emplace the heat, hot water or steam directly into the reservoir; with an offsetting vertical well then producing oil from the reservoir. In other cases, perhaps the well allows adequate emplacement of heat, hot water or steam without the need for an injection radial; but instead the production well has one or more radials that extend outward for improved recovery of oil from the reservoir. In other embodiments a horizontal well may subtend one or more vertical wells into which heat, hot water or steam has been emplaced with the aid of radials. In yet alternate embodiments a single well may be operated in a dual completion. In such instances, one or more isolation packers would be utilized to emplace heat or steam into the reservoir in one area of the wellbore and allow production of oil from another area of the same wellbore.

DETAILED DESCRIPTION OF DRAWINGS

[0054] The accompanying views of the drawing are incorporated into and form a part of the specification to illustrate several aspects and examples of the present disclosure, wherein like reference numbers refer to like parts throughout the figures of the drawing. These figures together with the description serve to explain the general principles of the disclosure. The figures are only for the purpose of illustrating preferred and alternative examples of how the various aspects of the disclosure can be made and used and are not to be construed as limiting the disclosure to only the illustrated and described examples. The various advantages and features of the various aspects of the present disclosure will be apparent from a consideration of the figures.

[0055] Fig. 1a illustrates a wellbore (7) in a heavy oil reservoir where one radial (9a) has been already formed in the oil zone (29) and a second radial (9b) is being created by a flexible mechanical drill-string (11), with attached cutting-head (13), powered by a mud motor (5). Positioned inside of the wellbore (7) is a bottom hole assembly (BHA) consisting of an anchor (17) and a whipstock (15) run on the end of tubing (19), in this case production tubing (19). The whipstock (15) sits upon a landing nipple (17b) located on the anchor (17), also a sealing mechanism (16) located on the anchor (17) seals against the wellbore (7). The flexible mechanical drill-string (11), with attached cutting-head (13), and the mud motor (5) are deployed inside of the production tubing (19) by coil tubing (3) which is controlled by a coil tubing unit (1). Also evident is a wellhead (21) located atop the wellbore (7).

[0056] Fig. 1b illustrates a wellbore (7) with insulated production tubing (23) and an isolation packer (25). Two radials (9) have been formed by the mechanical drilling system of Fig 1a. To minimize losses in conveying steam (27) from a central-steam facility to this well, an electrically-powered steam generator (22) consisting of resistive heating elements has been positioned in the wellbore (7) near the wellhead (21). A water supply (20) and power supply (24) are connected to the steam generator (22). A large volume of steam (27) is generated by the steam generator (22) and travels through the insulated production tubing (23) and exits into the wellbore (7) below the isolation packer (25). The radials (9) allow for the steam (27) to reach deep into the oil zone (29) and thus treating a great volume of the oil zone (29).

[0057] Fig 2 illustrates a wellbore (7) where two radials (9) have been made and very high temperature water (14) is being injected into the oil zone (29). A surface-based water pump unit (34), a compressor for the fuel (26), a compressor for the air/oxidant (114), and electric power supply (33), supply a catalytic heater system (32) positioned downhole. A supply line for the fuel (28), a supply line for the oxidant (113), along with a water supply line (20) and a conductor cable (30) are located at the surface. The water supply line (20), oxidizer supply line (113) and fuel supply line (28) each contain a check valve (18b, 18d and 18c) and another check valve (18) is located inside the insulated production tubing (23) to keep pressure from traveling up the lines. In this case, the catalytic heater (32) creates superheated 650°F water (14), but the bulk of the water (14) does not flash to or remain as steam, as the in-situ pressure at which this would occur is 750°F. The superheated hot water (14) moves through the insulated production tubing (23), which rests upon the landing nipple (25b) of the upper isolation packer (25), through the upper isolation packer (25), into the radials (9) and then deep into the oil zone (29) in a continuous flooding procedure. A lower isolation packer (25c) is also shown.

[0058] Fig. 3a illustrates a downhole steam generator (35) that employs a combustion system fed by a water supply line (41), a fuel supply line (39), an oxygen supply line (37) and a multi-conductor electrical supply line (36) run inside of production tubing (19) within a wellbore (7). In this system a burner combusts fuel and oxygen, with the aid of an electrical ignition system (51), after combustion water is introduced and steam (27) is created. In this case, the steam generator (35) has been positioned above an isolation packer (25). A check valve (38) is located in the tailstock (40) of the isolation packer (25) to prevent back-feeding of steam (27) from the reservoir, when the steam generator (35) is shut down. System heat losses are minimal due to the reservoir's immediate proximity to the location that the steam (27) is generated, that is to say the steam (27) is generated inside the wellbore (7) in close proximity to the oil zone (29). Massive amounts of steam (27) can be emplaced deep in the reservoir due to the large contact area provided by the radials (9) and thus a large volume of the oil zone (29) is treated. Evident at the surface are a water supply (47), a fuel supply (45), an oxygen supply (43) and an electric supply (49).

[0059] Fig. 3b illustrates a cross-sectional example of the oxygen supply line (37), fuel supply line (39), water supply line (41) and the multi-conductor electrical line (36) of Fig 3a in the form of a flat-pack assembly (53). Fig. 3c illustrates a cross-sectional view the water supply line (41), fuel supply line (39), oxygen supply line (37) and multi-conductor electrical line (36) of Fig 3a in the form of a concentric tubing assembly (55) with the multi-conductor electrical line (36) in the center. Fig. 3d illustrates a cross-sectional example of the water supply line (41), oxygen supply line (37), fuel supply line (39) and the multi-conductor electrical line (36) of Fig 3a, in the form of a round-pack, used to power the downhole steam generator (35) of Fig 3a. The multi-conductor electric line (36) of Figs 3a, 3b, 3c, and 3d is used to power the ignition system (51) and any downhole sensors of Fig 3a.

[0060] Fig. 4 illustrates a wellbore (7) where two radials (9) have been drilled into the oil zone (29) for continuous injection of steam (27) into the oil zone (29). An electrical conductor cable (58) has been strapped to the outside of tubing (19) and connected to heating elements (61), in this case “heating cables” (61) located inside of a heating apparatus (59), positioned downhole in the main wellbore (7). Water is being pumped down the tubing (19) by a surface pump (62) and is flashing to steam (27) on account of the fact that the heating cables (61) have been activated (turned on) via the electrical conductor cable (58) that is controlled by an electrical power control (64) at the surface. An isolation packer (25) placed above the radials (9) assures that the steam (27) does not travel back up the wellbore (7), but instead enters and reaches deep into the oil zone (29) via the large-contact area of the radials (9). Oil is heated and driven to an adjacent production well (not shown) by the steam (27).

[0061] Fig 5a illustrates an oil zone (29) in which radials (9) have been emplaced from a wellbore (7) and is being operated in a cyclic steam simulation procedure with an ESP (67). Electrically-powered heating elements (73) have been positioned downhole in the main wellbore (7) along a tubing string (19), which extends through an isolation packer (25). The heating elements (73), downhole valve (69) and ESP (67) are supplied power from a surface supply source (63) via a conductor line (62). Above the heating element (73) is a downhole valve (69) that allows one of three conditions. Condition one is the flow of fluid (water) down the tubing (19), through the passageway (71) located inside the apparatus (65), through the valve (69) and

through the heating elements (73), where steam (27) is generated and reaches deep into the oil zone (29) through the radials (9). In the second scenario the valve (69) allows for no flow whatsoever in either direction through the tubing (19). In the third scenario the valve (69) allows for flow from the wellbore (7) into the passageway (72), and into the ESP (67), discussed more in Fig 5b. As shown, the ESP (67) is turned off and the heating element (73) is turned on while the downhole valve (69) has been actuated, by the conductor line (62), to the position that allows the flow of water downhole through the production tubing (19) and the passageway (71). A pump (79) connected to a water supply source (not shown) is pumping water into the tubing (19), of notice is the valve (77) at the surface is open to allow the flow of water into the tubing (19). The water must move downhole as a valve (75) running from the tubing (19) to an oil tank battery (81) is closed. The water exits the downhole valve (69), contacts the heating elements (73), turns to steam (27) and proceeds to enter deep into the oil zone (29) via the radials (9). Of note is the tailstock (40) that drops below the isolation packer (25) for better injection of steam (27). While not shown in the figure, if one wished to perform maintenance or provide a soak period for the steam (27), the downhole valve (69) could be shifted to the no-flow position.

[0062] Fig. 5b illustrates the wellbore (7) of Fig 5a during the production phase (i.e. scenario 3). In this case, the heating elements (73) and surface water pump (79) have been turned off by the conductor line (62). The valve (77) to the pump (79) has also been closed while the valve (75) to the oil tank battery (81) has been opened allowing a path for produced oil to travel into the oil tank battery (81). The downhole valve (69) has been actuated by the conductor line (62), allowing for oil to enter the passageway (72) connected to the ESP (67). The ESP (67) has now been powered on and is lifting oil to the surface through the tubing (19) where it travels to the oil tank battery (81). The steam (27) from Fig 5a has heated a large area (58) of oil, thus lowering the viscosity of that oil which allows for better oil flow/production. The oil is pulled (shown by dotted arrows) from the oil zone (29), through the radials (9), up the tubing (19) and into the oil tank battery (81) by the ESP (67).

[0063] Fig. 6a illustrates a wellbore (7) in which two radials (9) have been emplaced. The whipstock (15), like that in Fig 1a, has been removed, but the anchor (17) and attached landing nipple (17b) have been left in place in the wellbore (7). A

special guide device (85) is being lowered toward the landing nipple (17b), on which the special guide device (85) will seat, on the end of a string of production tubing (19). The production tubing (19) has a seat (83) into which an electric submersible pump (ESP) can seat and form a seal. The reservoir in this case can be a conventional reservoir with medium API oil.

[0064] Fig. 6b illustrates the wellbore (7) of Fig 6a wherein a conductor line (89), connected at the surface to an electric power supply (90), is attached to an ESP (67) and flexible heating cables (87). At this time the conductor line (89) is being lowered inside the wellbore (7) inside of production tubing (19), the attached ESP (67) is being lowered toward its seat (83) and the flexible heating cables (87) are beginning to transition through special guide device (85). Said guide device (85) sits atop a landing nipple (17b) attached to an anchor (17), and directs the flexible heating cables (87) into radials (9) that have been emplaced in the oil zone (29). Also of note is that the apparatus (91) connected to the conductor line (89) and the flexible heating cable (87) serves to distribute the power from the conductor line (89) to both flexible heating cables (87).

[0065] Fig. 6c illustrates the wellbore (7) of Fig 6b with the flexible heating cables (87) emplaced into the radials (9) and generating heat (93) in the oil zone (29). The heat (93) radiates (shown by dotted lines) into the oil zone (29) around the wellbore (7) by conduction and convection, and reduces the viscosity of the oil in the oil zone (29). The lower viscosity oil flows (shown by dotted arrows) through the radials (9) and into the wellbore (7) where it is being pumped out of the wellbore (7), through the production tubing (19), by the ESP (67), which forms a leak-proof seal with the production tubing (19) at its seat (83). This system allows for continuous heating and producing of the oil zone (29) simultaneously.

[0066] Fig. 7 illustrates an RF based heat source used in conjunction with a gravity drainage configuration defined by radials (9c, 9d) emplaced in two different wellbores (7b, 7c). An RF antenna (95), connected, by a control line (94), to surfaced-based control equipment and a water supply (not shown), has been inserted through a whipstock (15) into an upper radial (9c) of one wellbore (7b). In this instance, positioned below this radial (9c) is another radial (9d) extending outward from an adjacent wellbore (7c). The RF antenna array (97) has been activated and is generating

heat in the area (98) of the oil zone (29) around and between the upper radial (9c) and lower radial (9d). The reduced viscosity oil is moving (shown by curved arrows) toward the lower radial (9d) and is aided by the benefit of gravity drainage. The oil is then produced from the wellbore (7c).

[0067] Fig. 8 illustrates an electric resistive heating system used in conjunction with radials (9e, 9f). In these systems, current (shown by dotted arrows) is passed from electrode (102a) to electrode (102b). Because alternating current (A/C) is used, an electrode (102) at one moment may be an anode (102), while at a later point in time it may be a cathode (102). The array of electrodes (102a, 102b) are connected to surface-based power control equipment (not shown) and in the heating phase cycle, water is pumped down the wellbore (7) to assure that the space between the sets of electrodes (102a, 102b) retain high conductivity. In this instance, we see two sets of radials (9e, 9f) extend outward from a single wellbore (7), but at different elevations. As the A/C current (shown by dotted arrows) moves between the each set of electrodes (102a, 102b) in the both radials (9e, 9f) the resistance of the intervening fluid generates the heat in the area (103). To more evenly heat the oil zone (29), certain electrodes (102c, 102d) have been turned off (shown by the absence of arrows) and so the current moves toward other electrodes (102a, 102b) and away from the area (103b) between the turned off electrodes (102c, 102d). By regulating the power to various electrodes (102a, 102b) one can more uniformly heat the oil within the oil zone (29) and drain it to the lower radial (9f). Water (not shown) can be pumped down the wellbore (7) and into the radials (9e and 9f), assuring conductivity between the electrodes (102a – 102d). Of note is the upper whipstock (105) that contains a passageway (105b) that allows for the lower set of electrodes (102a) to pass through it where they transfer through the lower whipstock (107) and into the lower radial (9f).

[0068] Fig 9a illustrates a wellbore (7) in which heating elements (87) have been emplaced in the radials (9) in a fashion generally similar to that seen in Fig 6C. There are however a couple of noteworthy differences. In this instance, the wellbore (7) is pumped by a pump-jack (86) and is being operated in a huff-and-puff procedure. The pump-jack (86) is shown turned off, and an optional downhole valve (82), which regulates the flow to the downhole sucker rod pump (88), has been closed. At this point, the surface-based water pump (100) has been engaged and is pumping water

down the annulus (shown by dotted arrows) of the wellbore (7). The heating elements (87) in the radials (9) have also been turned on and are operating. The water travels through a one-way check valve (92) positioned on an isolation packer (25) in the wellbore (7) above the radials (9). As the water enters the radials (9), it contacts the heating elements (87), turns to steam and proceeds to enter the oil zone (29). An extended soaking period now typically follows.

[0069] Fig 9b illustrates the wellbore (7) of Fig 9a during the production cycle. At this point, the water pump (not shown) and heating cables (87) have been turned off, the downhole valve (82) has been opened, by the conductor line (89), in order to allow flow into the downhole sucker rod pump (88). The steam that previously entered the reservoir is now driving reduced-viscosity oil (shown by dotted arrows) into the radials (9) and wellbore (7). As indicated by arrows the pump jack (86) is operating and is lifting oil to the surface through the sucker rod pump (88) which is connected to the sucker rods (84).

[0070] In embodiments, the invention defines a surface-based heat source that is used to generate hot water or steam that is conveyed downhole through a conduit where it enters an oil reservoir through one or more radials drilled into the reservoir by mechanical means. The hot water or steam reduces the viscosity of oil in the reservoir and then oil is produced from that reservoir.

[0071] In embodiments, the invention defines a surface-based heat source wherein hot water or steam is generated and pumped downhole through a conduit where it then enters an oil reservoir. The hot water or steam reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir through one or more radials drilled by mechanical means into the reservoir.

[0072] In embodiments, the invention defines a surface-based heat source wherein hot water or steam is generated and pumped downhole through a conduit where it enters an oil reservoir through one or more radials drilled by mechanical means into the reservoir. The steam reduces the viscosity of oil in the reservoir and oil is then produced from that reservoir through one or more other radials reaching into the reservoir, either the same or a different wellbore.

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[0073] In embodiments, the invention defines a heat source positioned inside of and near the top of a wellbore wherein hot water or steam is generated and conveyed downhole through a conduit where it enters an oil reservoir through one or more radials. The hot water or steam reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir.

[0074] In embodiments, the invention defines a heat source positioned inside of and near the top of a wellbore wherein hot water or steam is generated and conveyed downhole through a conduit where it enters an oil reservoir. The hot water or steam reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir through one or more radials.

[0075] In embodiments, the invention defines a heat source positioned inside of and near the top of a wellbore wherein hot water or steam is generated and conveyed downhole through a conduit where it enters a reservoir through one or more radials. The hot water or steam reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir through one or more radials.

[0076] The source of heat for the aforementioned embodiments, which define a surface or near-surface based heat source, being defined by one of the following:

- A burner for combusting a fuel and oxidant;
- A fuel that is oxidized with the aid of a catalyst; or
- An electrically-powered element that generated heat by means of resistive heating (“heating cables”), radio frequency, or electro resistive heating.

[0077] Moreover, in instances involving combustion or a catalytic process to generate heat, the fuel source may be liquid or gaseous. For example, it may be diesel, propane or methane. Moreover, the oxidizing material may be air, oxygen enriched air or pure oxygen. Furthermore, the heating source may define a pre-heater or ignition source to initiate and assure complete combustion of the fuel.

[0078] In embodiments, the invention defines a downhole heating source that generates heat, hot water or steam within the wellbore and which then moves into a reservoir through one or more radials.

[0079] In embodiments, the invention defines a downhole heating source that generates heat, hot water or steam within the wellbore and which then moves into a reservoir through perforations or an open-hole section. The heat, hot water or steam reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir through one or more radials.

[0080] In embodiments, the invention defines a downhole heating source that generates heat, hot water or steam within the wellbore and which then moves into a reservoir through one or more radials. The heat, hot water or steam reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir through one or more radials, whether in the same well or a different well.

[0081] The source of heat, hot water or steam for any of the aforementioned embodiments involving a downhole heating source being defined by one of the following:

- A burner for combusting fuel and an oxidizing material
- A fuel that is oxidized with the aid of a catalyst; or
- An electrically-powered element that generated heat by means of resistive heating (“heating cables”), radio frequency, or electro resistive heating.

[0082] Moreover, in instances involving combustion or a catalytic process to generate heat, the fuel source may be liquid or gaseous. For example, it may be diesel, propane or methane. Moreover, the oxidizing material may be air, oxygen enriched air or pure oxygen. Furthermore, the heating source may define a pre-heater or ignition source to initiate and assure complete combustion of the fuel.

[0083] In embodiments, the invention defines a heating source that generates heat, hot water or steam within a radial in an oil reservoir. The heat, hot water or steam

reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir from other wells in the reservoir.

[0084] In embodiments, the invention defines a heating source that generates heat, hot water or steam within a radial in an oil reservoir. The heat, hot water or steam reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir through the same radial.

[0085] In embodiments, the invention defines a heating source that generates heat, hot water or steam within a radial in an oil reservoir. The heat or steam reduces the viscosity of oil in the reservoir and oil is then produced from the reservoir through one or more different radials in another wellbore or in the same wellbore.

[0086] In embodiments the invention defines a wellbore emplaced with one or more radials into an oil reservoir; said radial(s) being used for the continuous or cyclical injection of hot water or steam that has been generated in the wellbore near the surface. In embodiments the invention defines a wellbore emplaced with one or more radials into an oil reservoir; said radial(s) being used for the continuous or cyclical injection of hot water or steam that has been generated downhole in the wellbore. In embodiments the invention defines a wellbore emplaced with one or more radials into an oil reservoir; said radial(s) being used for the continuous or cyclical emplacement of heat, hot water or steam that has been generated in one or more of said radials.

[0087] As evident in the attached figures and attendant descriptions, various embodiments of this disclosure involve isolation packers, landing nipples, special guide devices, water supply lines, conductor and multi-conductor cables, fuel supply lines and oxidant supply lines, pumping equipment, valves and controllers to regulate flow, controllers to regulate electrical power and one-way check valves. Moreover, in embodiments, the pumping equipment for bringing oil to the surface may comprise ESPs or rod pumps.

[0088] In embodiments, the radial and thermal stimulations disclosed herein may be used in conjunction with gravity drainage. That is the heat, hot water or steam may be emplaced at an upper portion of an oil reservoir and oil then recovered from a lower portion of the same reservoir. This gravity-assisted drainage feature maybe practiced

from one and the same wellbore; it may involve multiple vertical wellbores; or, it may involve combinations of vertical, slant and/or horizontal wellbores.

[0089] The various embodiments of the present disclosure can be joined in combination with other embodiments of the disclosure and the listed embodiments herein are not meant to limit the disclosure. All combinations of various embodiments of the disclosure are enabled, even if not given in a particular example herein.

[0090] While illustrative embodiments have been depicted and described, modifications thereof can be made by one skilled in the art without departing from the scope of the disclosure. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Moreover, the indefinite articles "a" or "an", as used in the claims, are defined herein to mean one or more than one of the element that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents, the definitions that are consistent with this specification should be adopted. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

[0091] Depending on the context, all references herein to the "disclosure" may in some cases refer to certain specific embodiments only. In other cases it may refer to subject matter recited in one or more, but not necessarily all, of the claims. While the foregoing is directed to embodiments, versions and examples of the present disclosure, which are included to enable a person of ordinary skill in the art to make and use the disclosures when the information in this patent is combined with available information and technology, the disclosures are not limited to only these particular embodiments, versions and examples.

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[0092] Numerous other modifications, equivalents, and alternatives, will become apparent to those skilled in the art once the above disclosure is fully appreciated. While embodiments of the disclosure have been shown and described, modifications thereof can be made by one skilled in the art without departing from the teachings of this disclosure. The embodiments described herein are exemplary only, and are not intended to be limiting. Many variations and modifications of the disclosure disclosed herein are possible and are within the scope of the disclosure.

[0093] Use of the term "optionally" with respect to any element of a claim is intended to mean that the subject element is required, or alternatively, is not required. Both alternatives are intended to be within the scope of the claim. It is intended that the following claims be interpreted to embrace all such modifications, equivalents, and alternatives where applicable. Other and further embodiments, versions and examples of the disclosure may be devised without departing from the basic scope thereof and the scope thereof is determined by the claims that follow.

CLAIMS

1. A method to enhance hydrocarbon production from a subsurface reservoir comprising:
 - forming at least one radial borehole that extend outward from a wellbore into a reservoir at least 5 feet at an angle of between 45 and about 90 degrees from the wellbore;
 - generating heated fluid;
 - conveying the heated fluid through the wellbore and into the reservoir;
 - reducing the viscosity of hydrocarbons in the reservoir; and
 - producing hydrocarbons from the reservoir.
2. The method of claim 1, further comprising:
 - forming the at least one radial borehole by using a mechanical toolstring to drill a borehole into the reservoir; and
 - removing the mechanical toolstring from the wellbore.
3. The method of claim 1, wherein the heated fluid comprises H₂O.
4. The method of claim 1, wherein the heated fluid comprises H₂O steam.
5. The method of claim 1, further comprising:
 - conveying the heated fluid through at least one radial borehole and into the reservoir.
6. The method of claim 1, further comprising:
 - producing hydrocarbons from the reservoir through at least one radial borehole.
7. The method of claim 1, further comprising:
 - conveying the heated fluid into the reservoir and producing hydrocarbons from the reservoir are both done through the same radial borehole.

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8. The method of claim 1, further comprising:
generating the heated fluid at a surface facility.
9. The method of claim 1, further comprising:
generating the heated fluid within the wellbore near a proximal end of the wellbore.
10. The method of claim 1, further comprising:
locating a heat source within the wellbore near a proximal end of the wellbore.
11. The method of claim 10, further comprising:
the heat source being in communication with a surface-based pumping equipment.
12. The method of claim 11, further comprising:
activating the surface-based pumping equipment and heat source to generate the heated fluid.
13. The method of claim 1, further comprising:
locating a heat source within at least one radial borehole.
14. The method of claim 13, further comprising:
the heat source being in communication with a surface-based pumping equipment.
15. The method of claim 14, further comprising:
activating the surface-based pumping equipment and heat source to generate the heated fluid within at least one radial borehole.
16. The method of claim 1, further comprising:
placing an isolation packer within the wellbore.

17. The method of claim 1, further comprising:
forming the at least one radial borehole extending outward from a wellbore into a reservoir at least 5 feet utilizing a method of borehole formation selected from the group consisting of: a jetting nozzle that erodes the formation; acid that dissolves the formation; a mechanical toolstring that drills the borehole with a cutting head; a laser that vaporizes the formation; heat that spalls the formation; and combinations thereof.
18. The method of claim 1, further comprising:
generating heated fluid utilizing an apparatus selected from the group consisting of: resistive heating elements; electrical resistive heating electrodes; an RF heating source; and combinations thereof.
19. The method of claim 1, further comprising:
generating heated fluid utilizing a method selected from the group consisting of: a combustion process involving a gas or liquid fuel and an oxidant; a catalytic process involving a fuel and an oxidant moving across a catalyst bed; and combinations thereof.
20. The method of claim 19, wherein the oxidant is selected from the group consisting of: oxygen; air; oxygen-enriched air; and combinations thereof.
21. The method of claim 1, further comprising:
providing a heat source selected from the group consisting of: a burner comprising an ignition source that can be activated by control equipment and a conductor cable; a catalyst bed comprising a preheater that can be activated by control equipment and a conductor cable.
22. The method of claim 13, wherein the heat source comprises flexible members located within at least one radial borehole.
23. The method of claim 13, further comprising:
introducing fluid into a radial borehole to contact the heat source or an area heated by the heat source and thereby generate heated fluid or steam.

24. The method of claim 22, further comprising:
 placing a guide device within the wellbore oriented toward a radial borehole;
 inserting a flexible heat source through the guide device and into at least one radial borehole.
25. The method of claim 24, wherein the guide device is a whipstock.
26. The method of claim 24, wherein the guide device comprises a landing nipple.
27. The method of claim 1, further comprising:
 inserting a conduit within the wellbore to convey fluid into a radial borehole.
28. The method of claim 1, further comprising:
 emplacement of heat, hot water or steam at an upper interval in the subsurface reservoir; and
 producing hydrocarbons from the reservoir at a lower interval.
29. An apparatus for placing a flexible heating element into a radial extending from a wellbore defined by a guide device having at least one guide path.
30. An apparatus for generating heat in a radial borehole extending from a wellbore comprising a flexible element connected to a power supply.
31. A system for increasing oil production from an oil reservoir comprising:
 a supply of fuel, oxidant and water;
 a means to regulate and pump downhole a quantity of fuel, oxidant and water;
 a burner positioned downhole in the reservoir and used to mix the fuel and oxidant;
 the fuel and oxidant generating heat upon combustion;
 water introduced into or near the burner to generate hot water or steam;
 an ignition system near the burner capable of instigating combustion;

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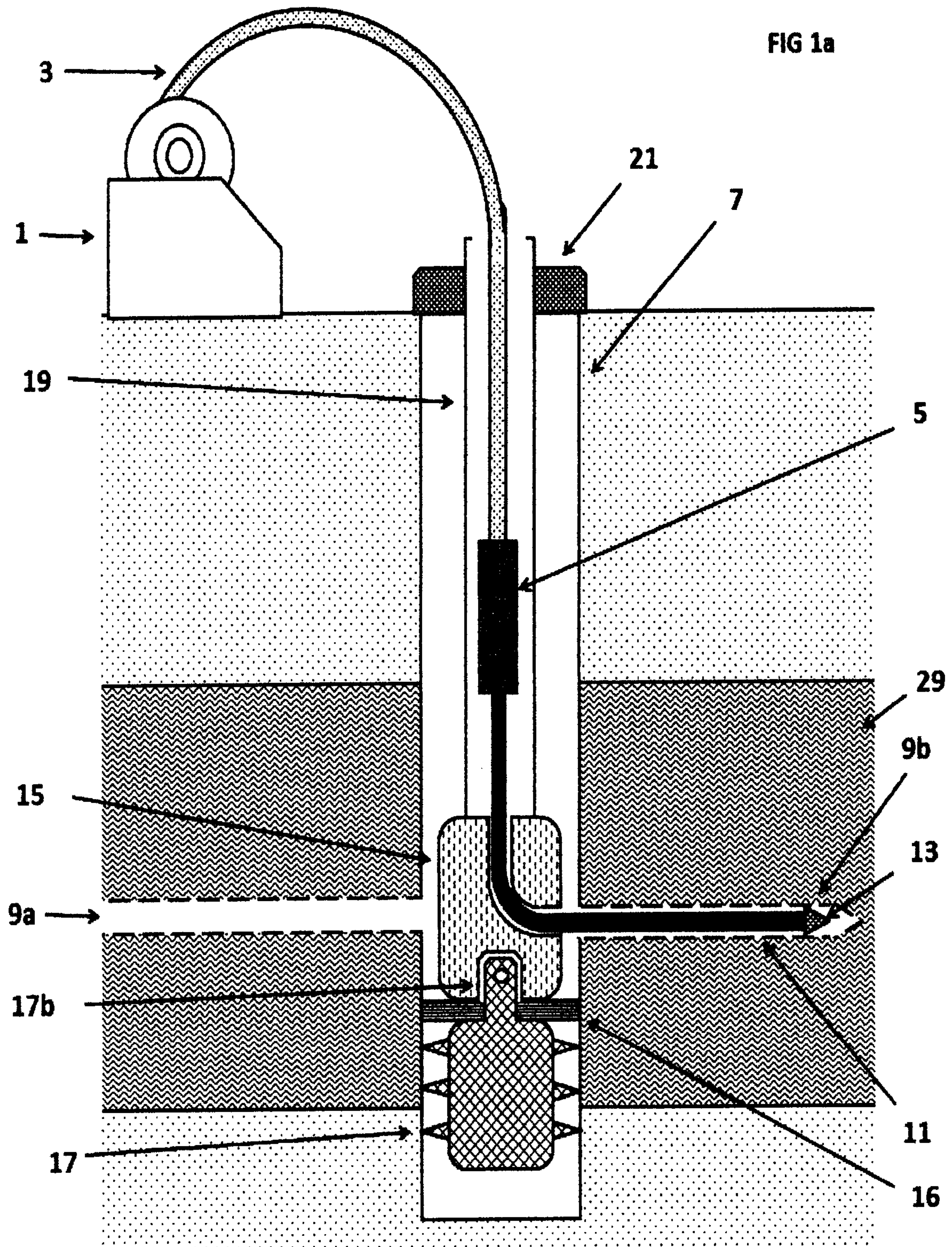
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emplacement of the hot water or steam into the reservoir through a radial borehole extending into the reservoir; and
producing oil from the reservoir.

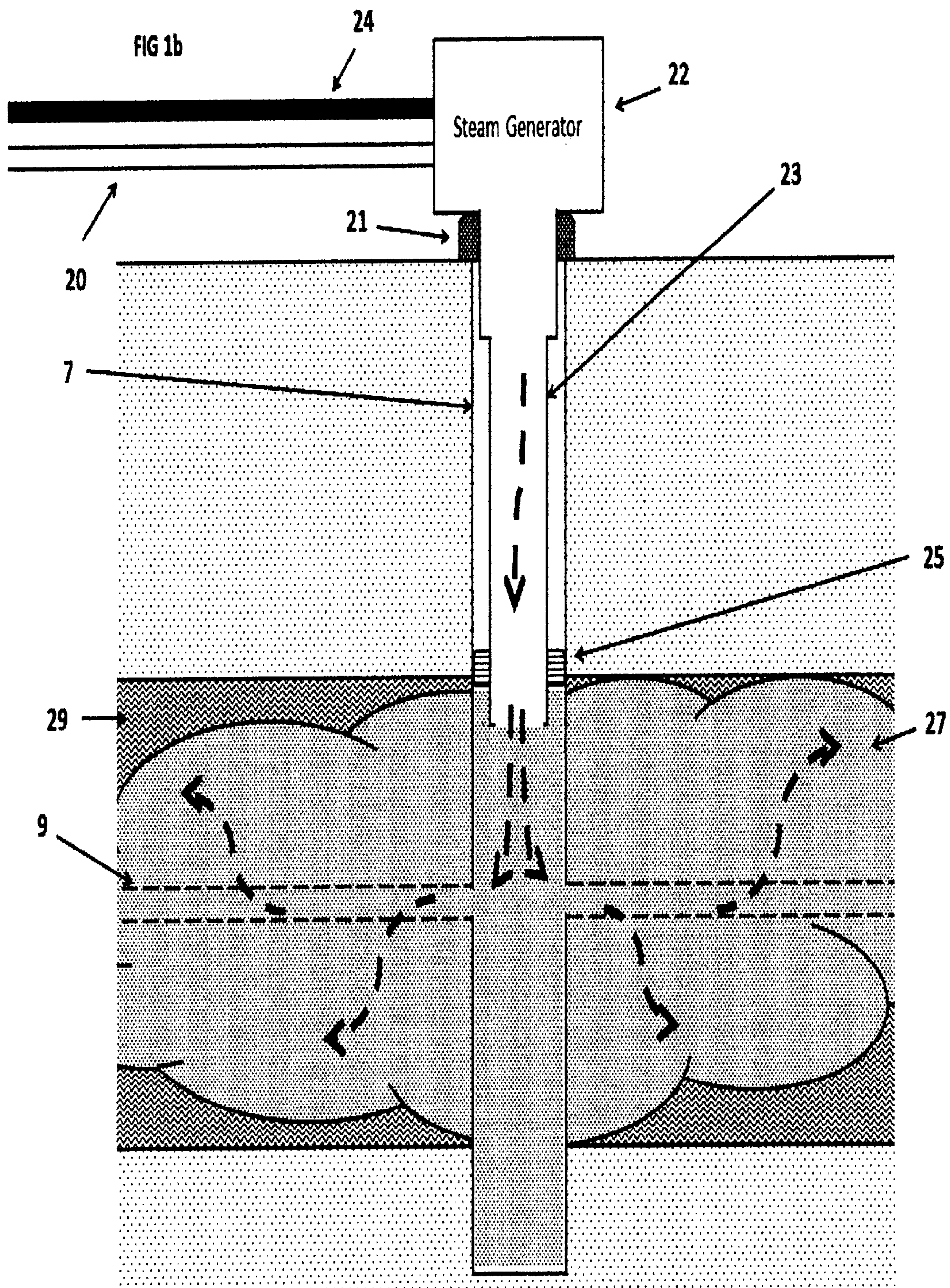
32. A system for increasing oil production from an oil reservoir comprising:
 - a supply of fuel, oxidant and water;
 - a means to regulate and pump downhole a quantity of fuel, oxidant and water;
 - a catalyst bed positioned in a wellbore in the reservoir and capable of oxidizing the fuel to generate heat;
 - the fuel and oxidant generating heat upon combustion;
 - water introduced into or near the burner to generate hot water or steam;
 - an ignition system near the burner capable of instigating combustion;
 - emplacement of the hot water or steam into the reservoir through a radial borehole extending into the reservoir; and
 - producing oil from the reservoir.
33. A system for increasing oil production from an oil reservoir comprising:
 - one or more radial boreholes emplaced into a reservoir extending from a well;
 - a tubing string in the well running to the surface;
 - a downhole pump positioned in the well;
 - an electrically-powered heat source positioned downhole in the well or in a radial;
 - an isolation packer positioned in the wellbore;
 - a conductor cable running from surface power control equipment to at least the downhole heat source;
 - a downhole valve system that can alternately allow the flow of water downhole toward the heat source or which can allow the flow of oil from the reservoir into the downhole pump.
34. The system of claim 33, wherein the downhole pump is chosen from the group consisting of: an ESP and a pump jack system.

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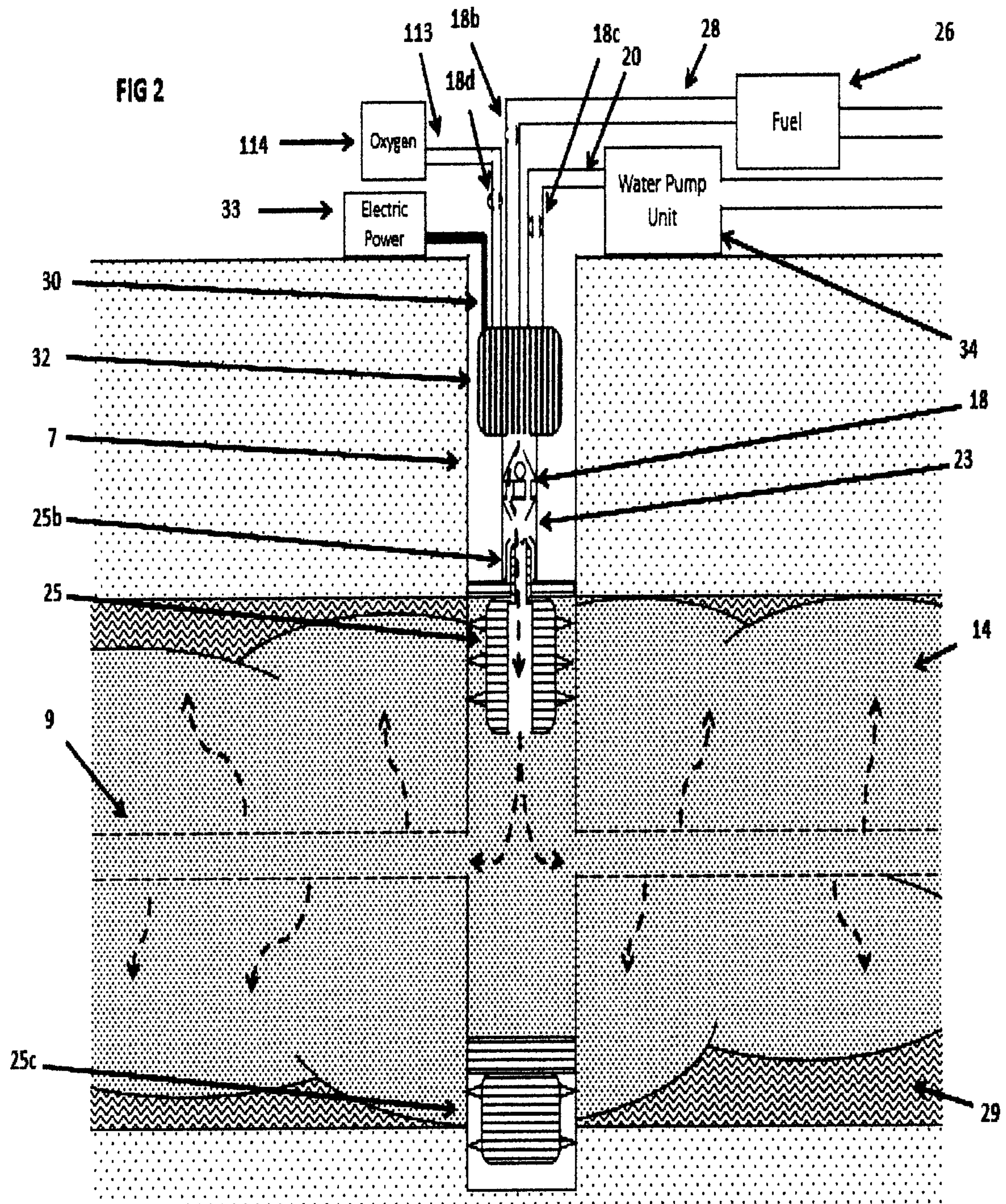
FIG 1a

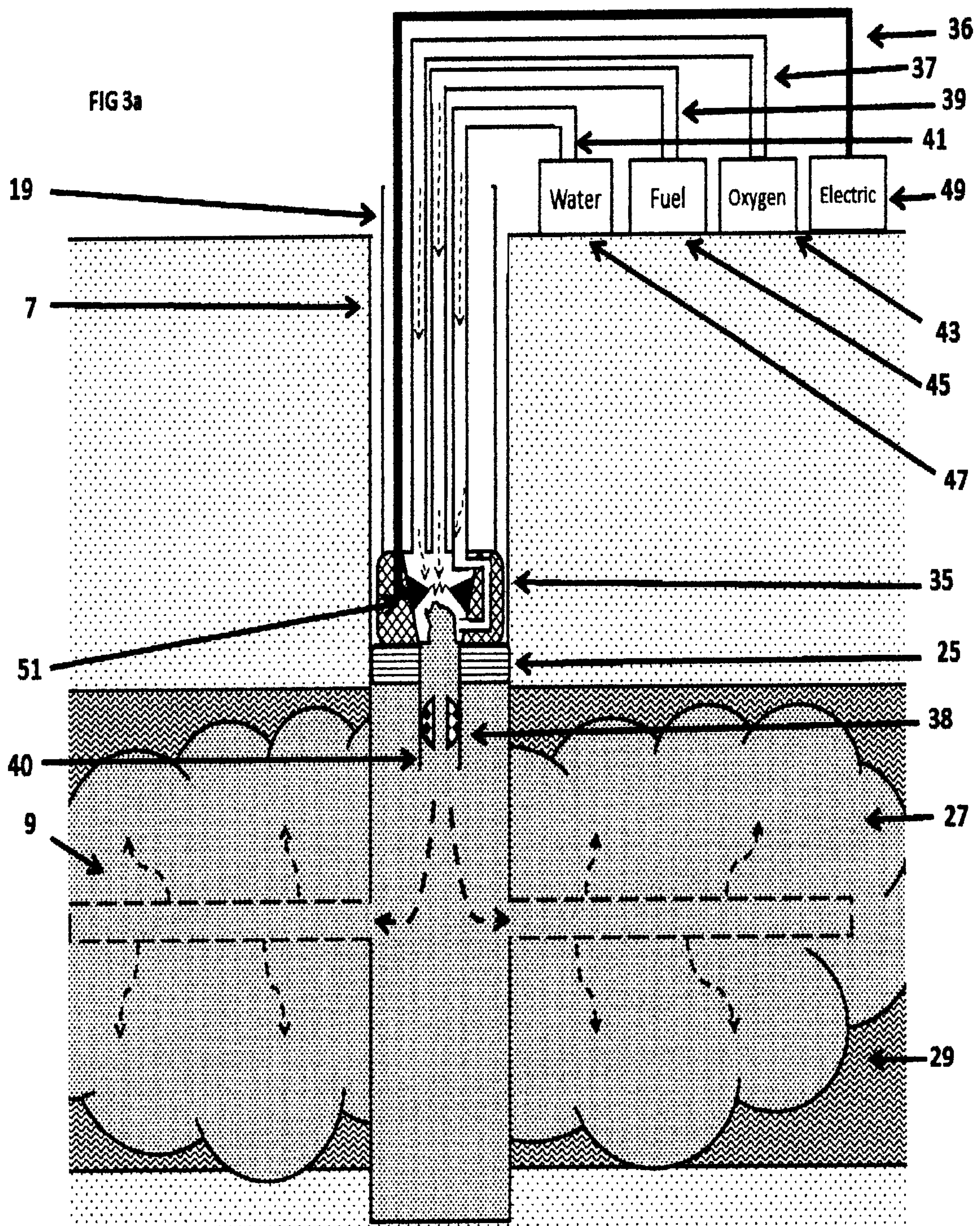


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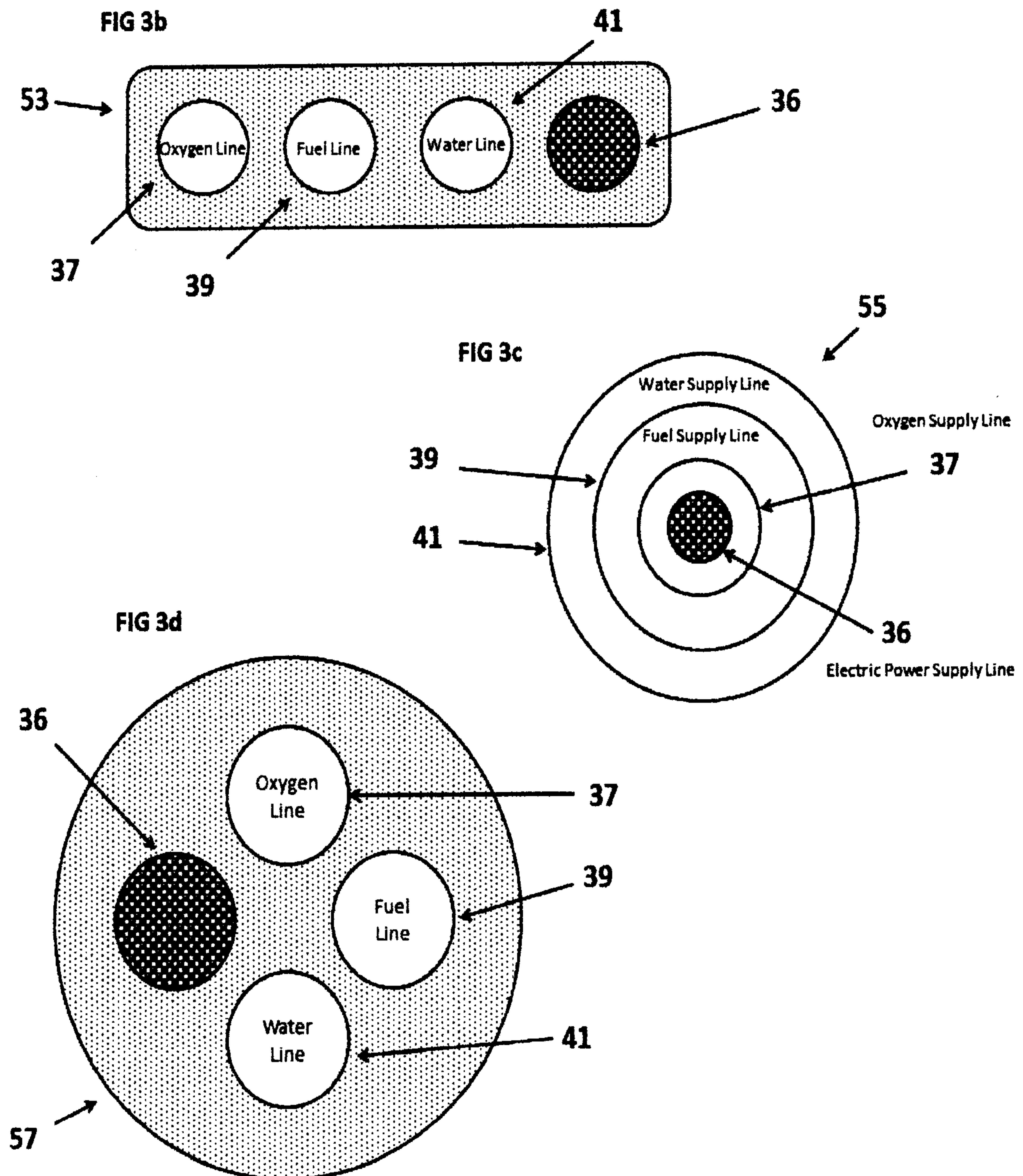


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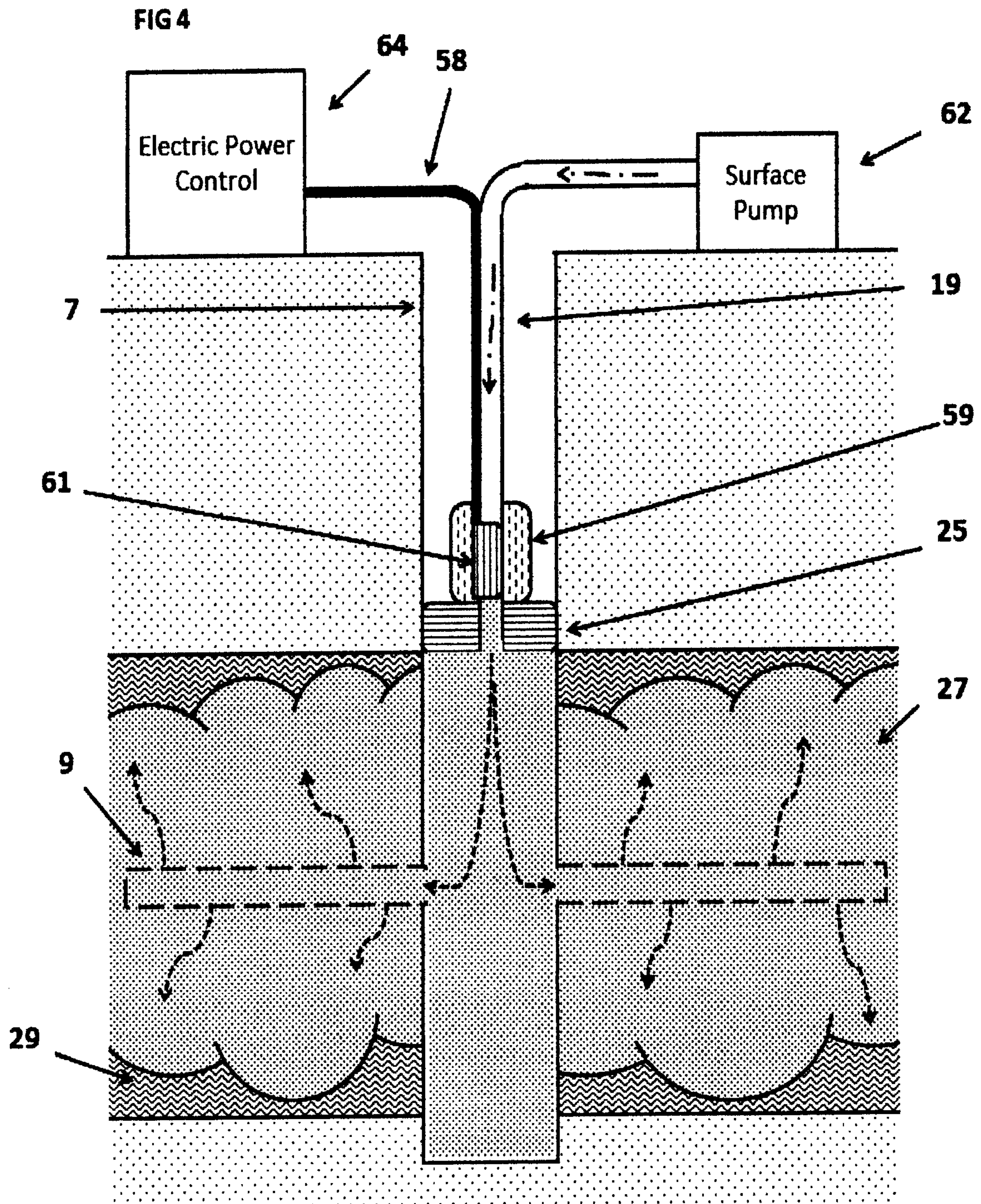




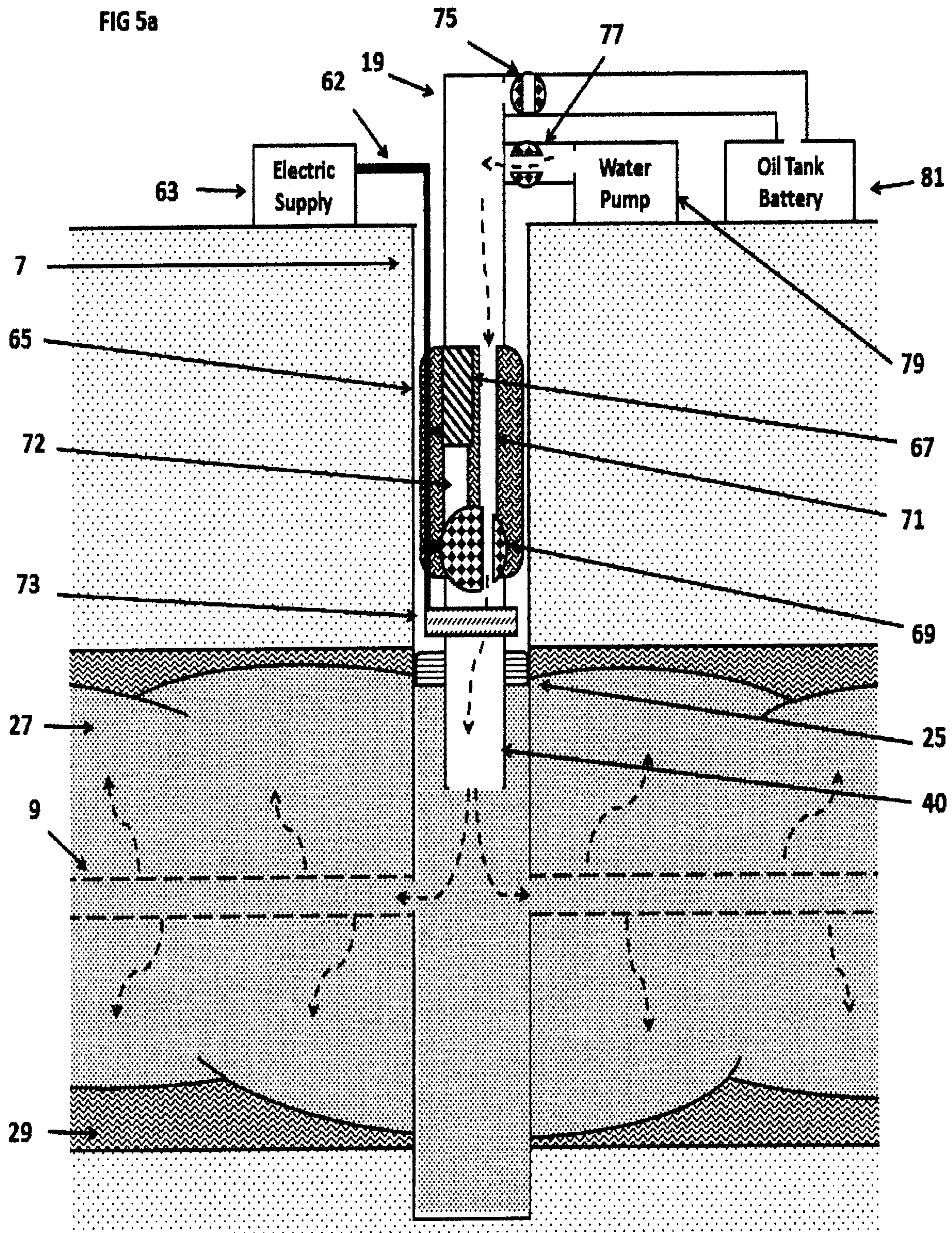
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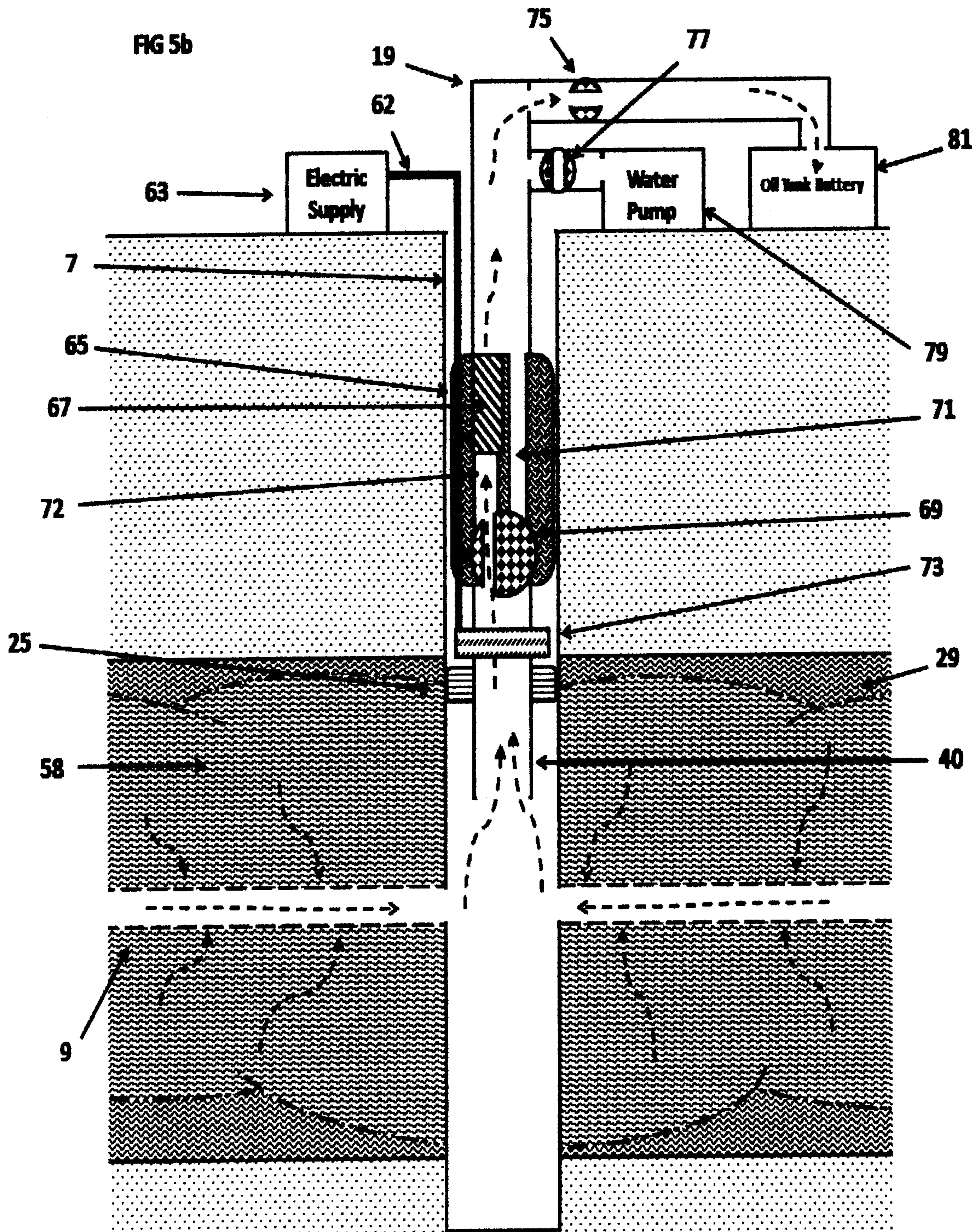
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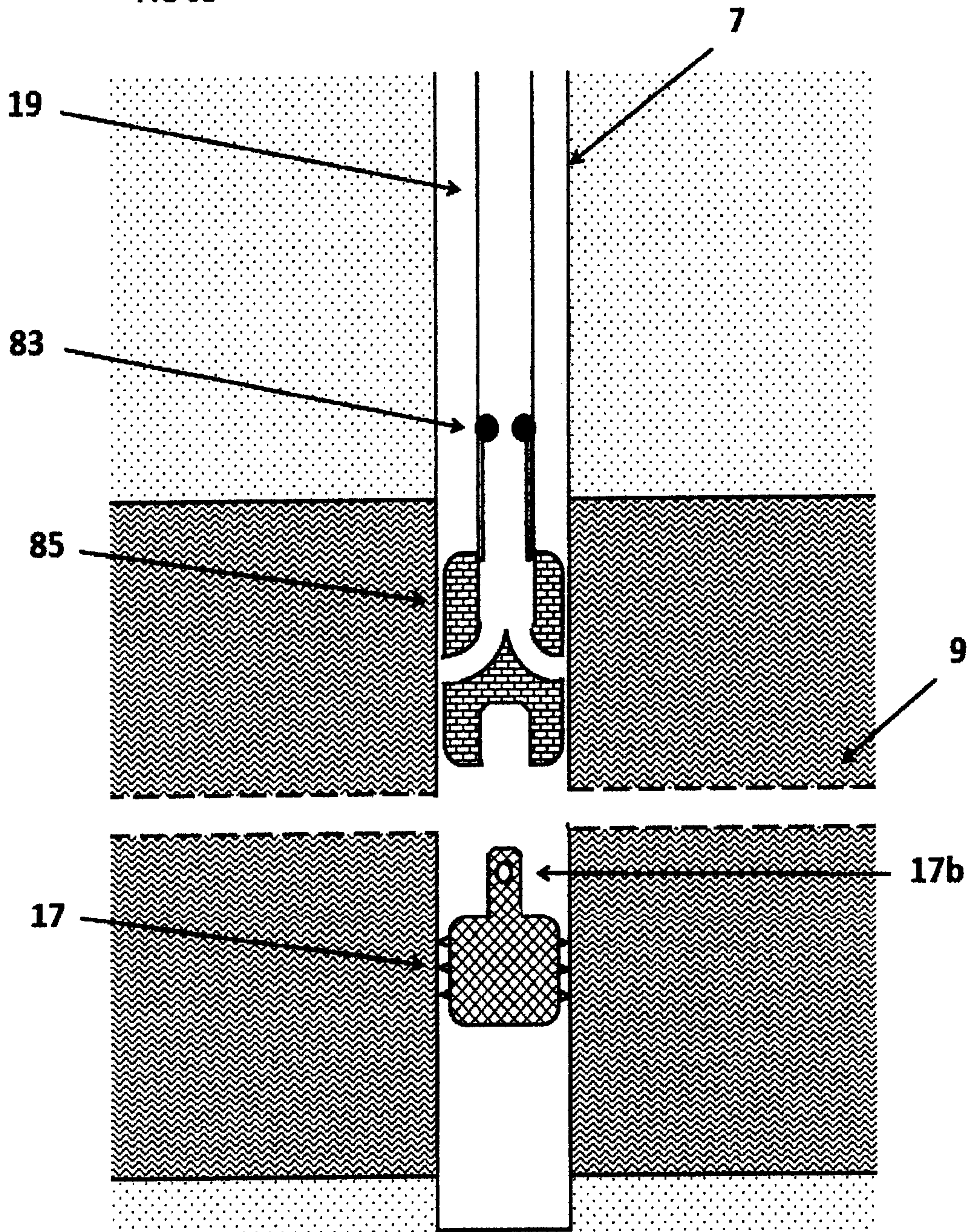


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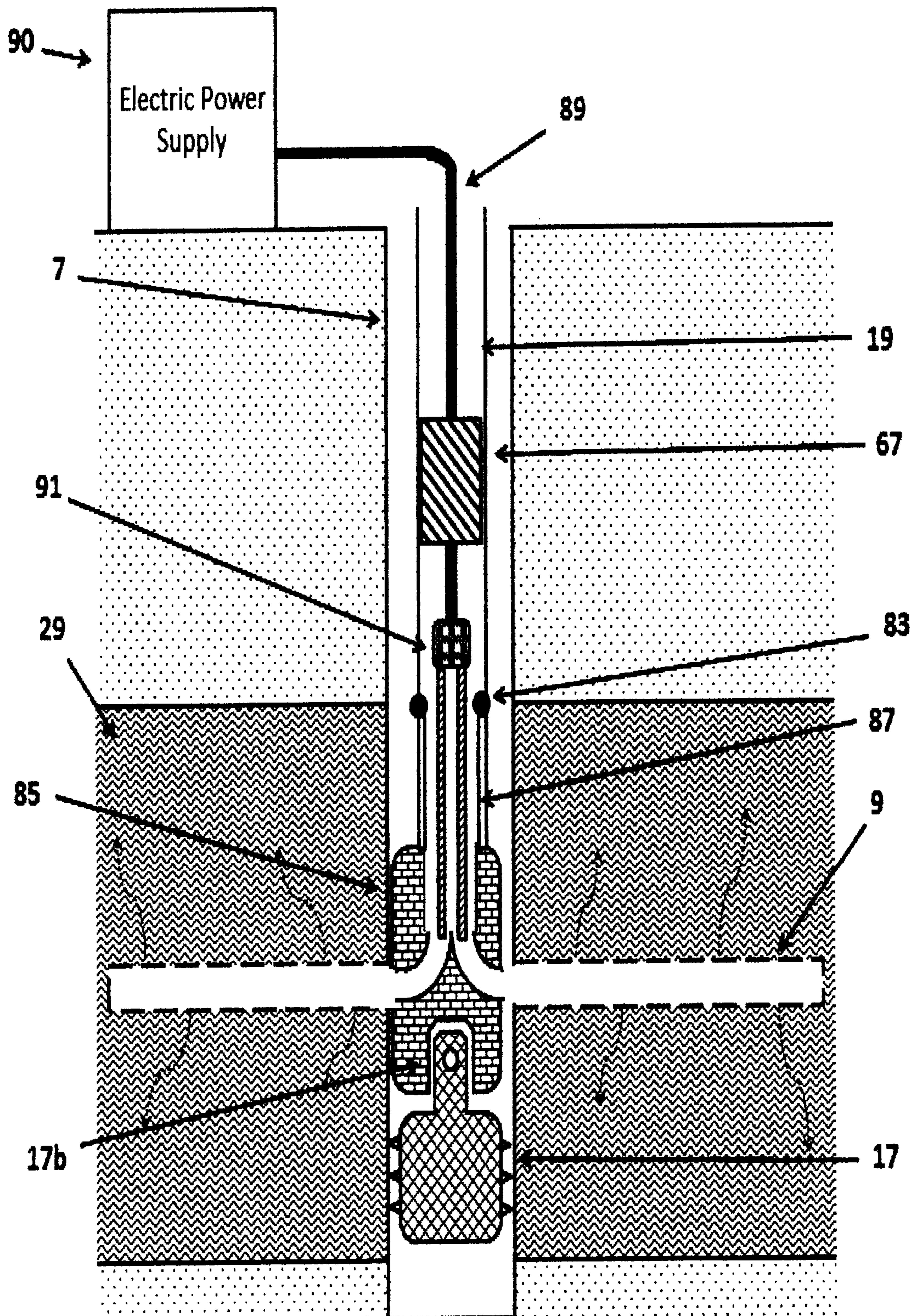
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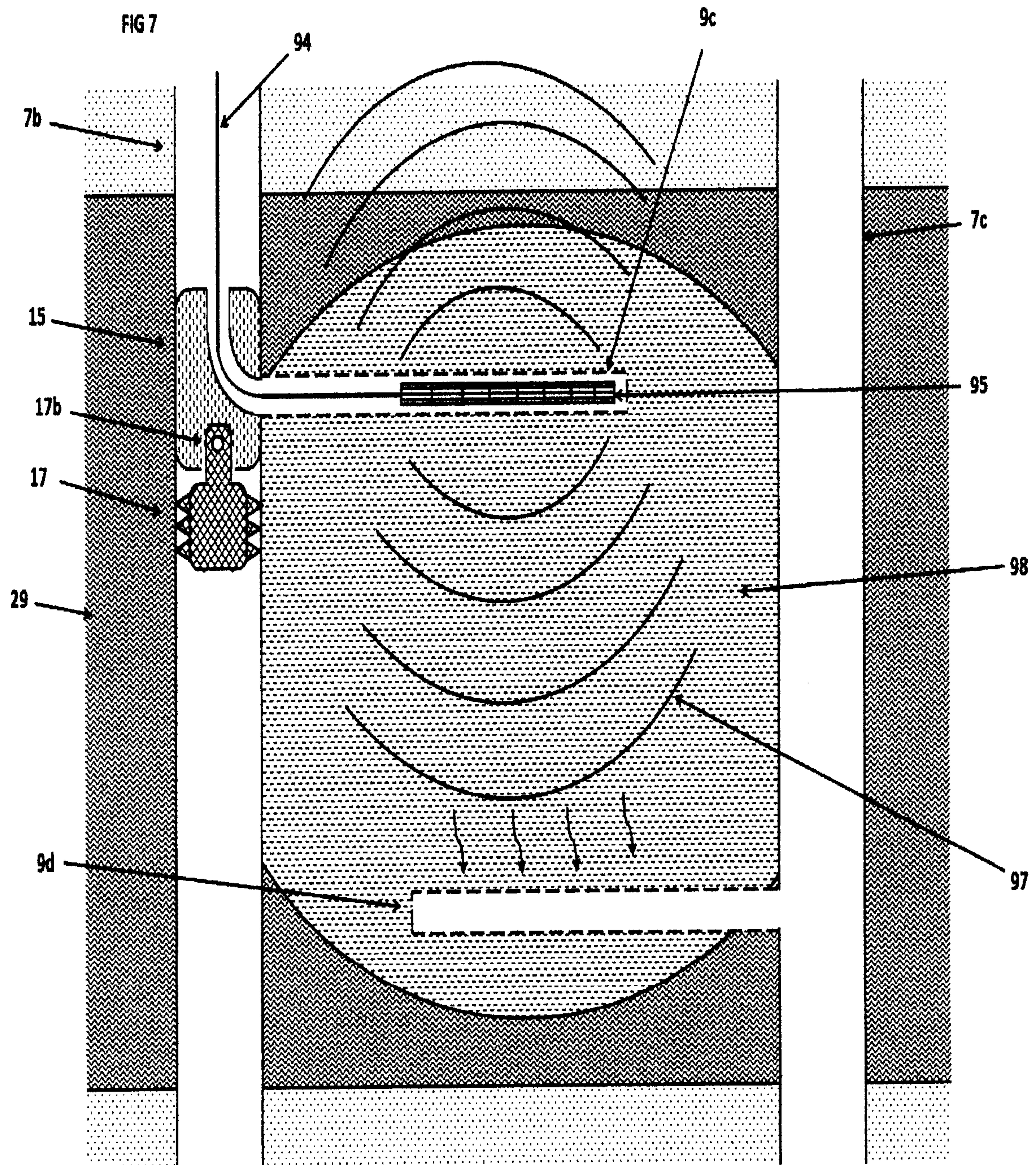
FIG 6a



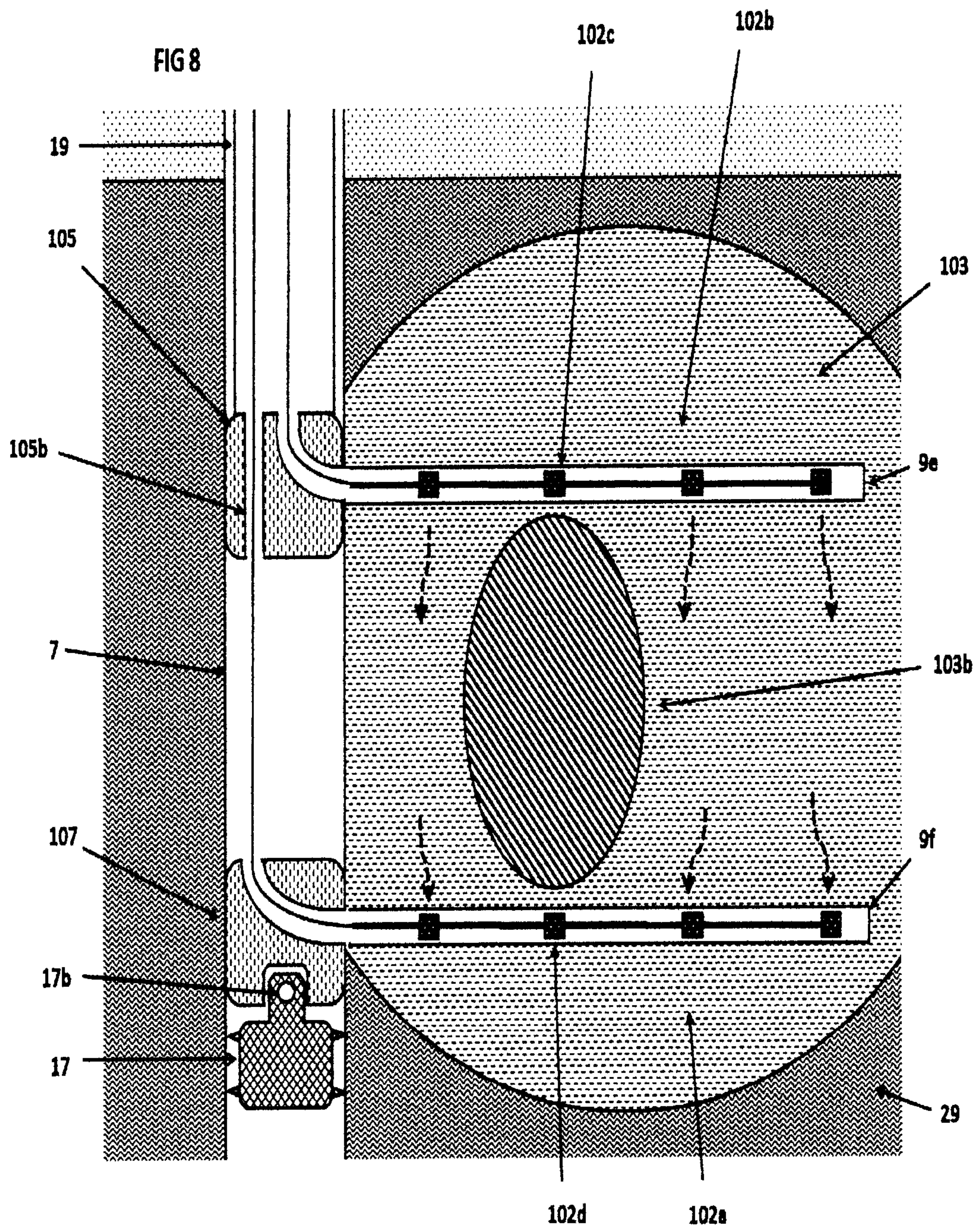
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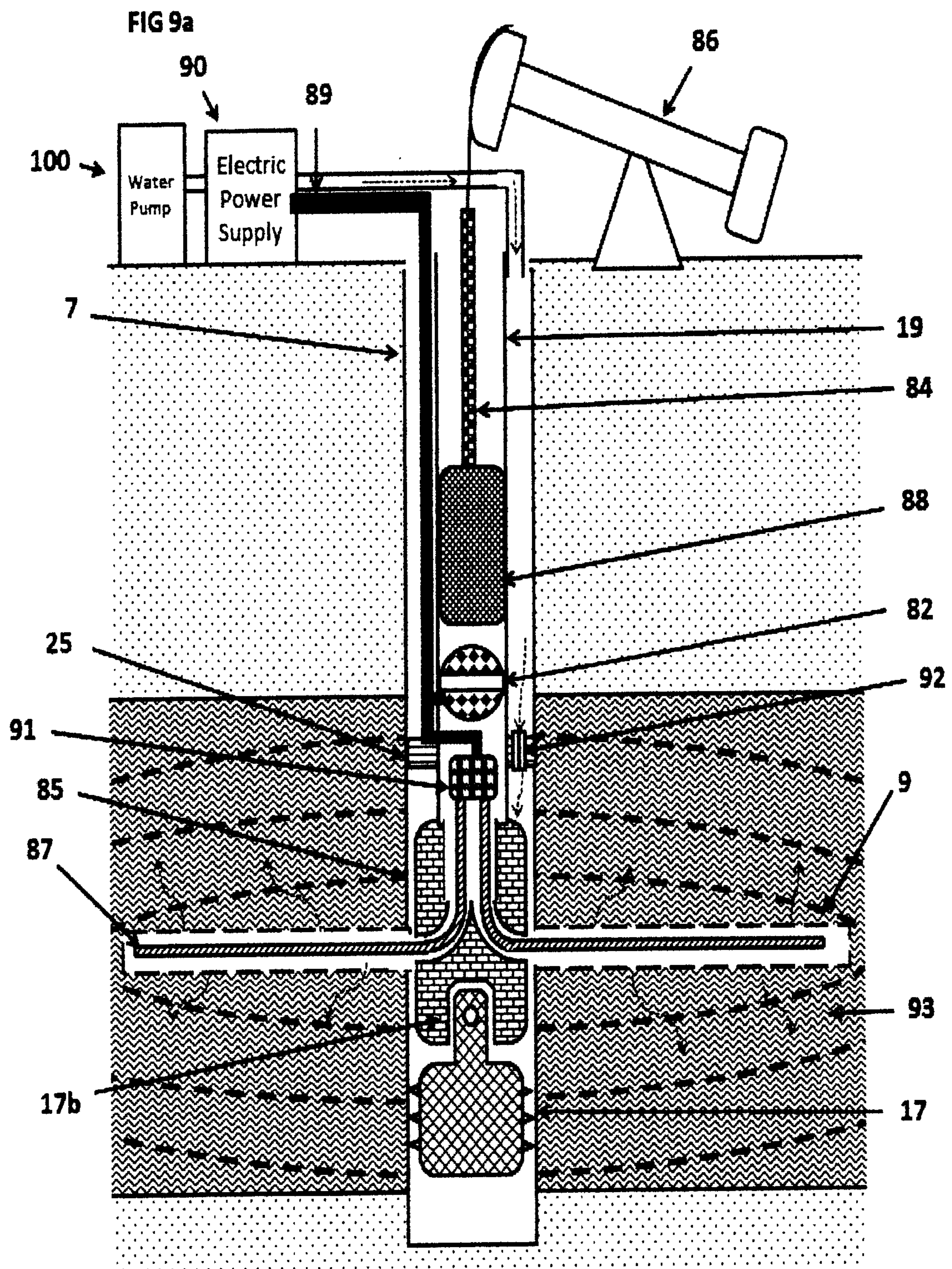
FIG 6b





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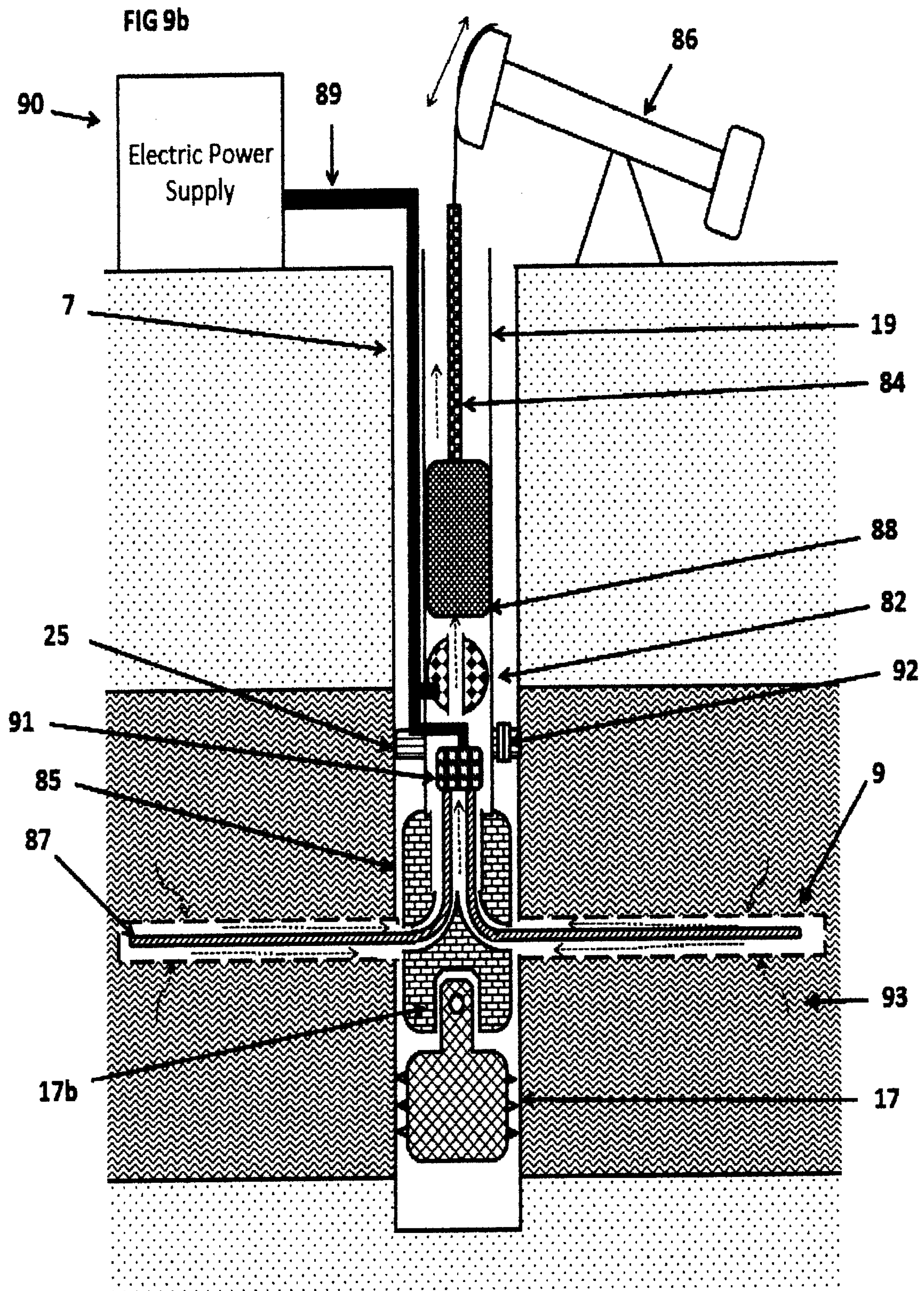


FIG 2

