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(54) **METHOD FOR UNDERGROUND RECOVERY OF HYDROCARBONS**

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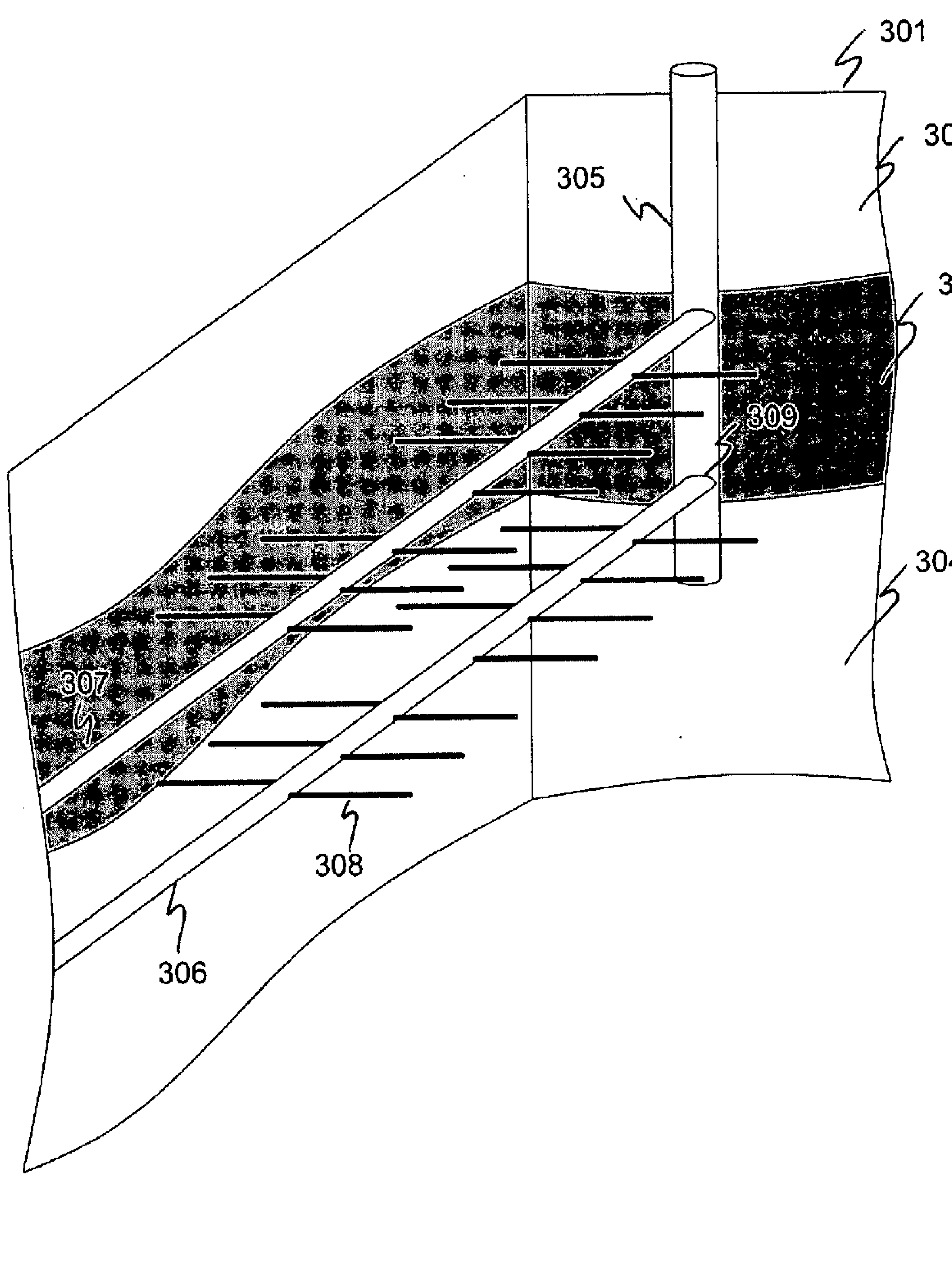
(57) **ABSTRACT**

The present invention discloses a method for installing, operating and servicing wells in a hydrocarbon deposit from a lined shaft and/or tunnel system that is installed above, into or under a hydrocarbon deposit. The entire process of installing the shafts and tunnels as well as drilling and operating the wells is carried out while maintaining isolation between the work space and the ground formation. In one aspect of the invention, well-head devices may be precast into the tunnel or shaft lining to facilitate well installation and operation in the presence of formation pressure and/or potential fluid in-flows. In another aspect of the invention, the tunnel itself can be used as a large diameter well for collecting hydrocarbons and, if required, for injecting steam or diluents into a formation to mobilize heavy hydrocarbons such as heavy crude and bitumen.



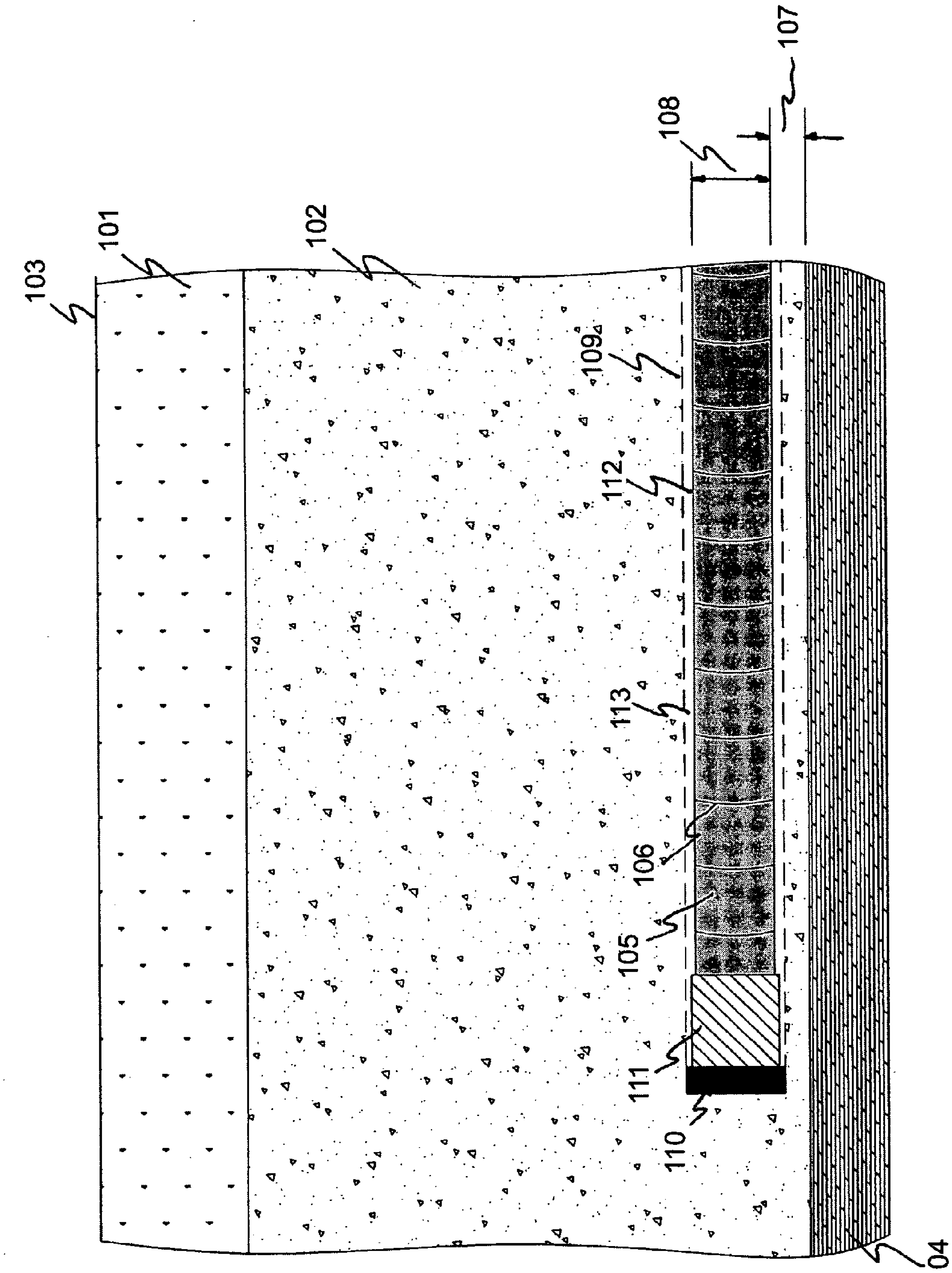


Figure 1

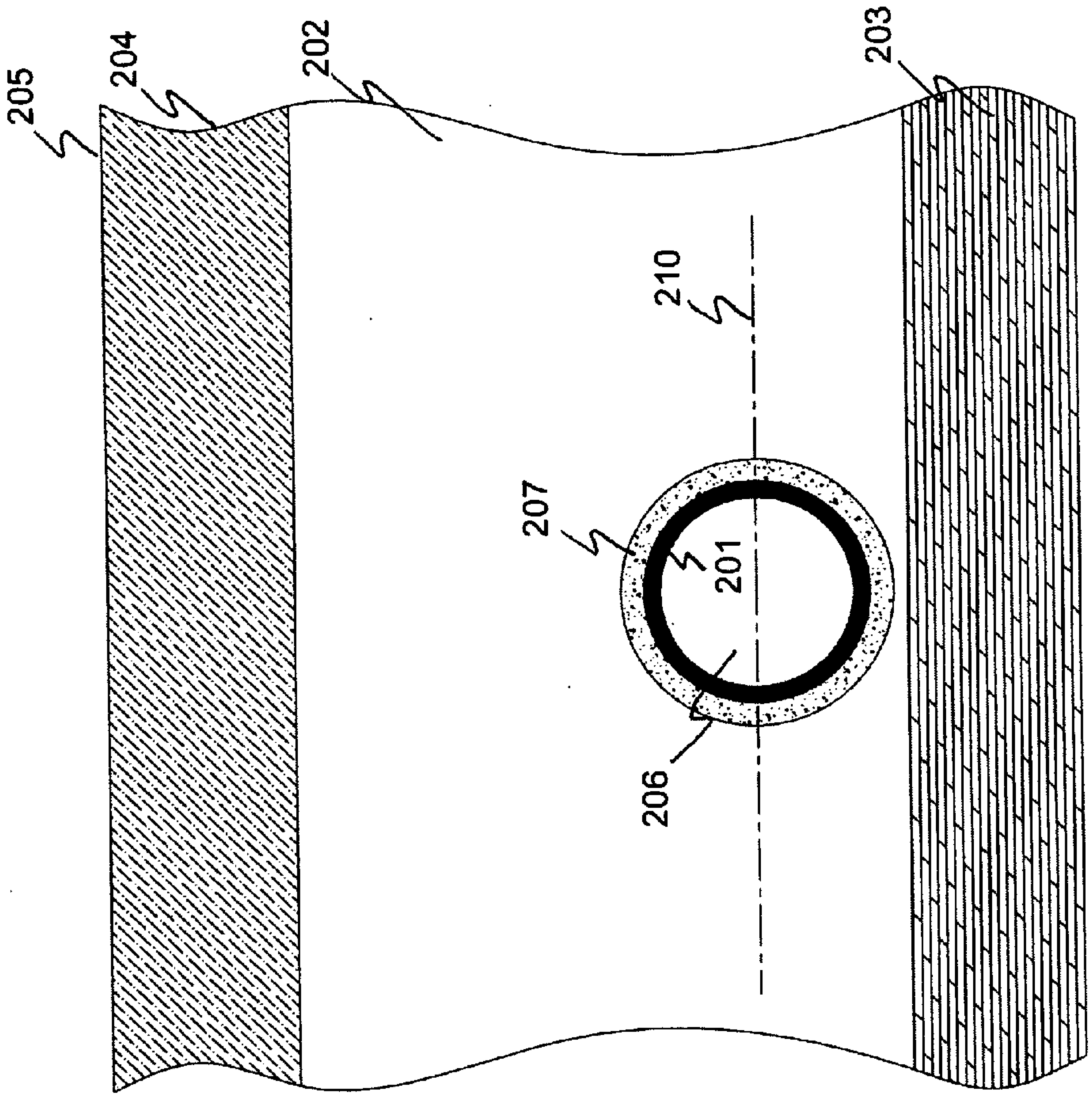
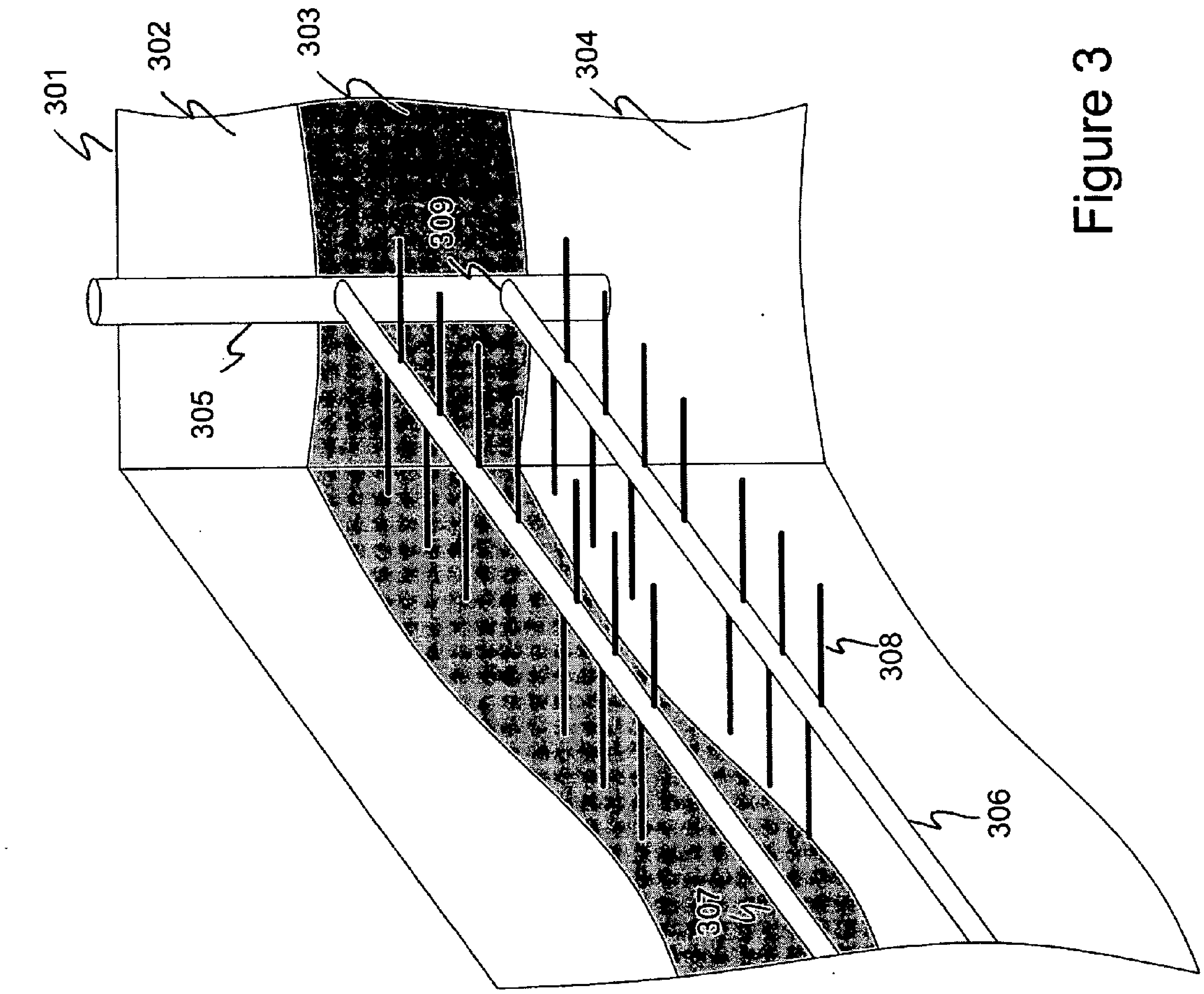


Figure 2



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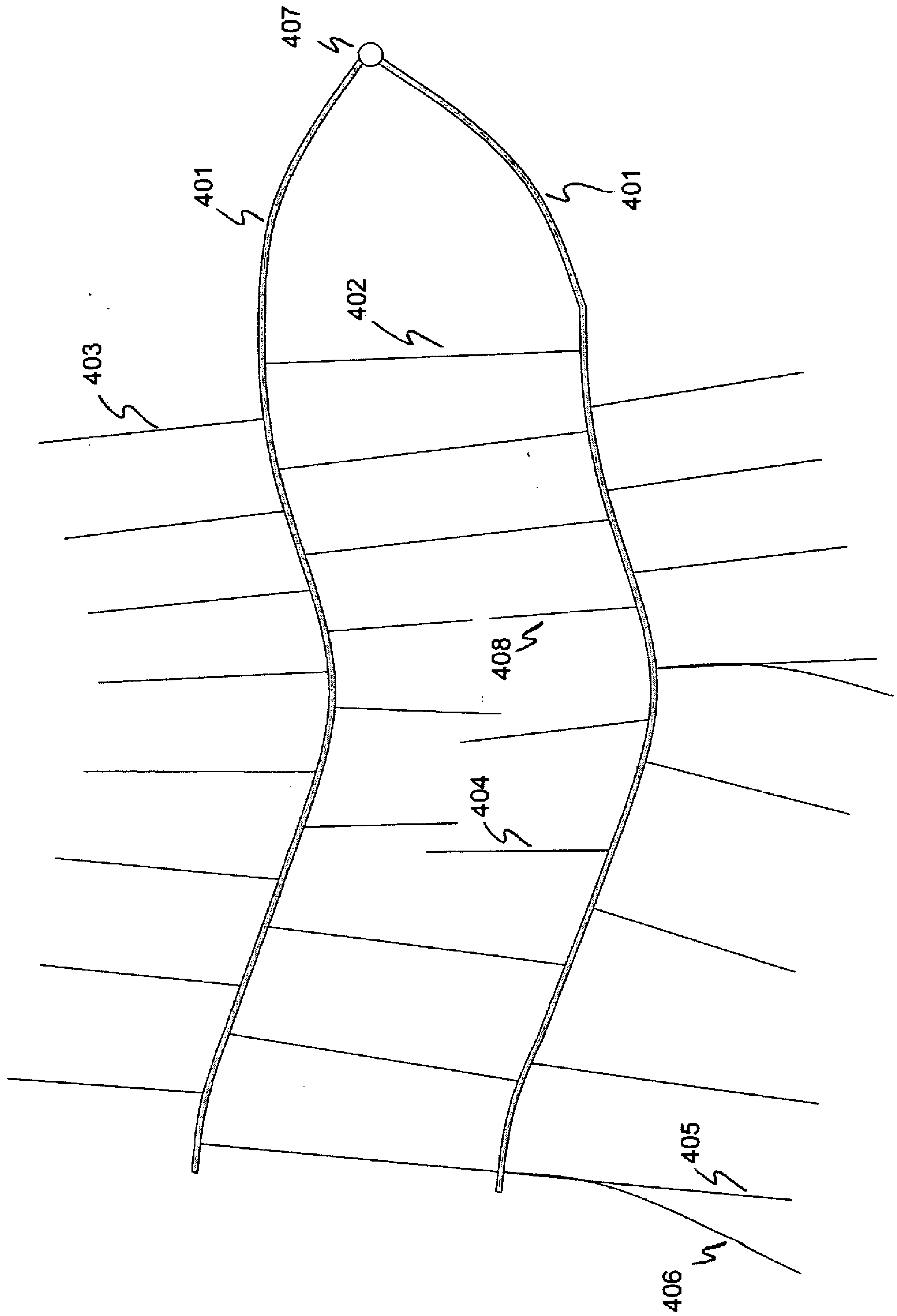

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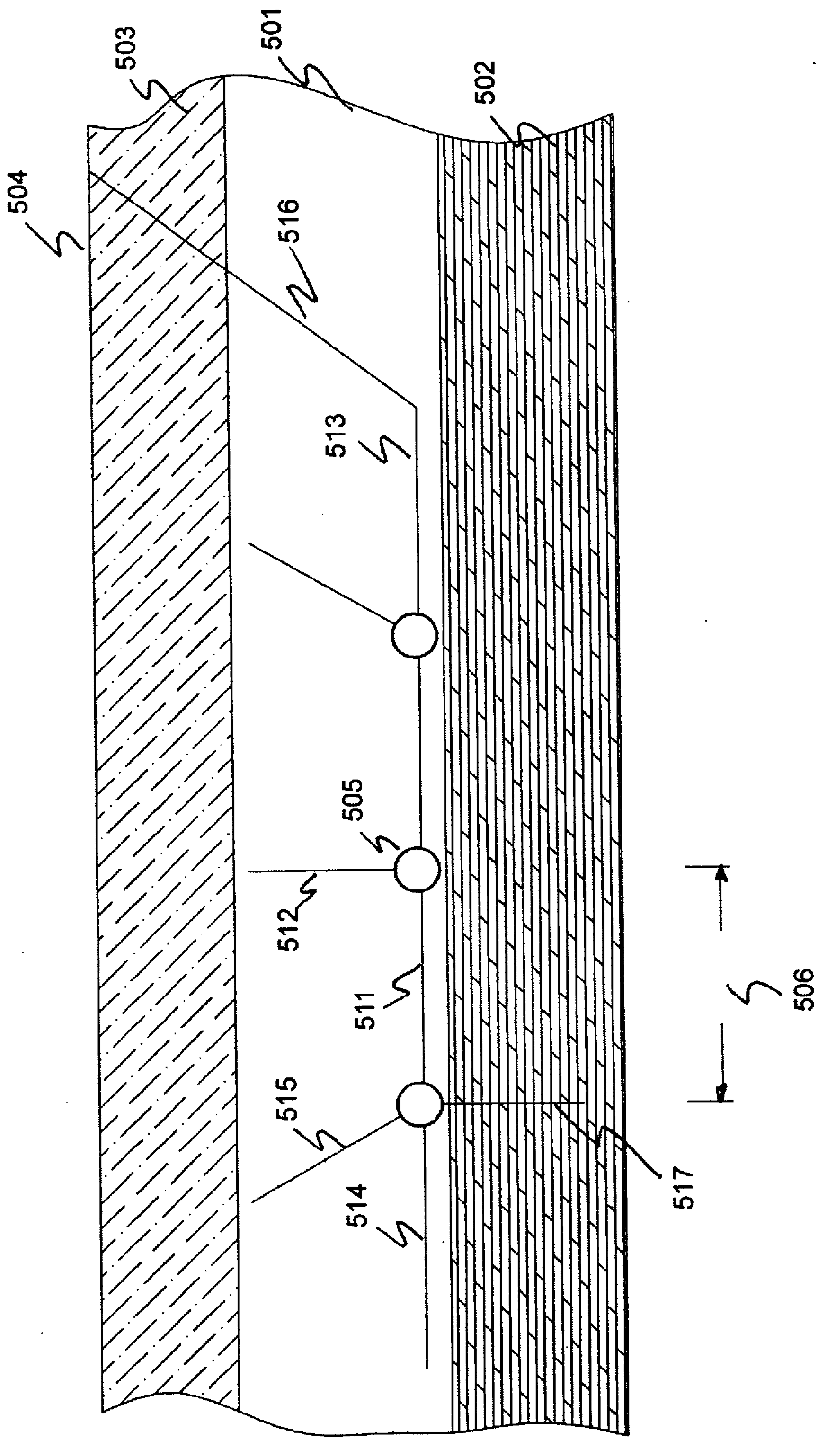

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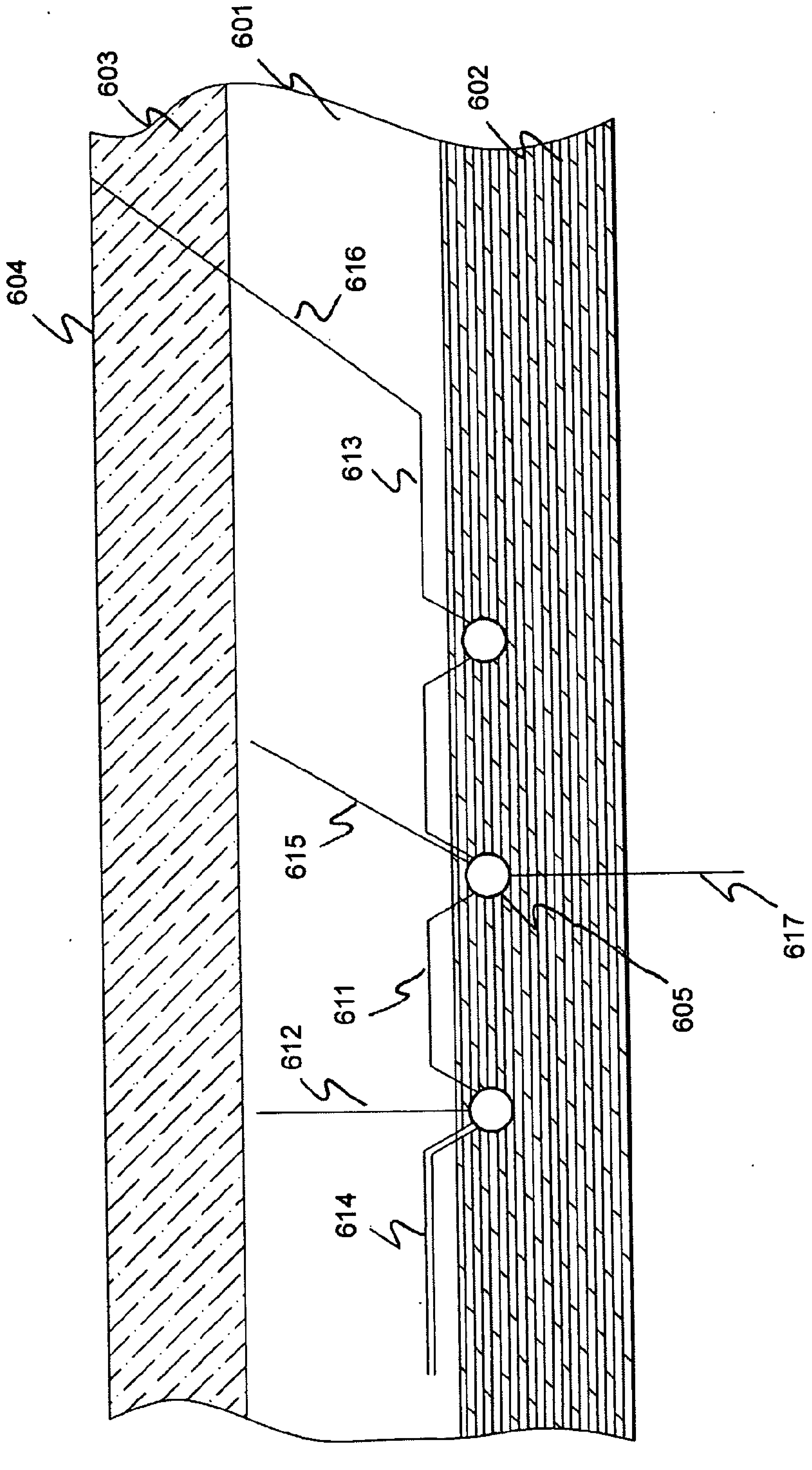

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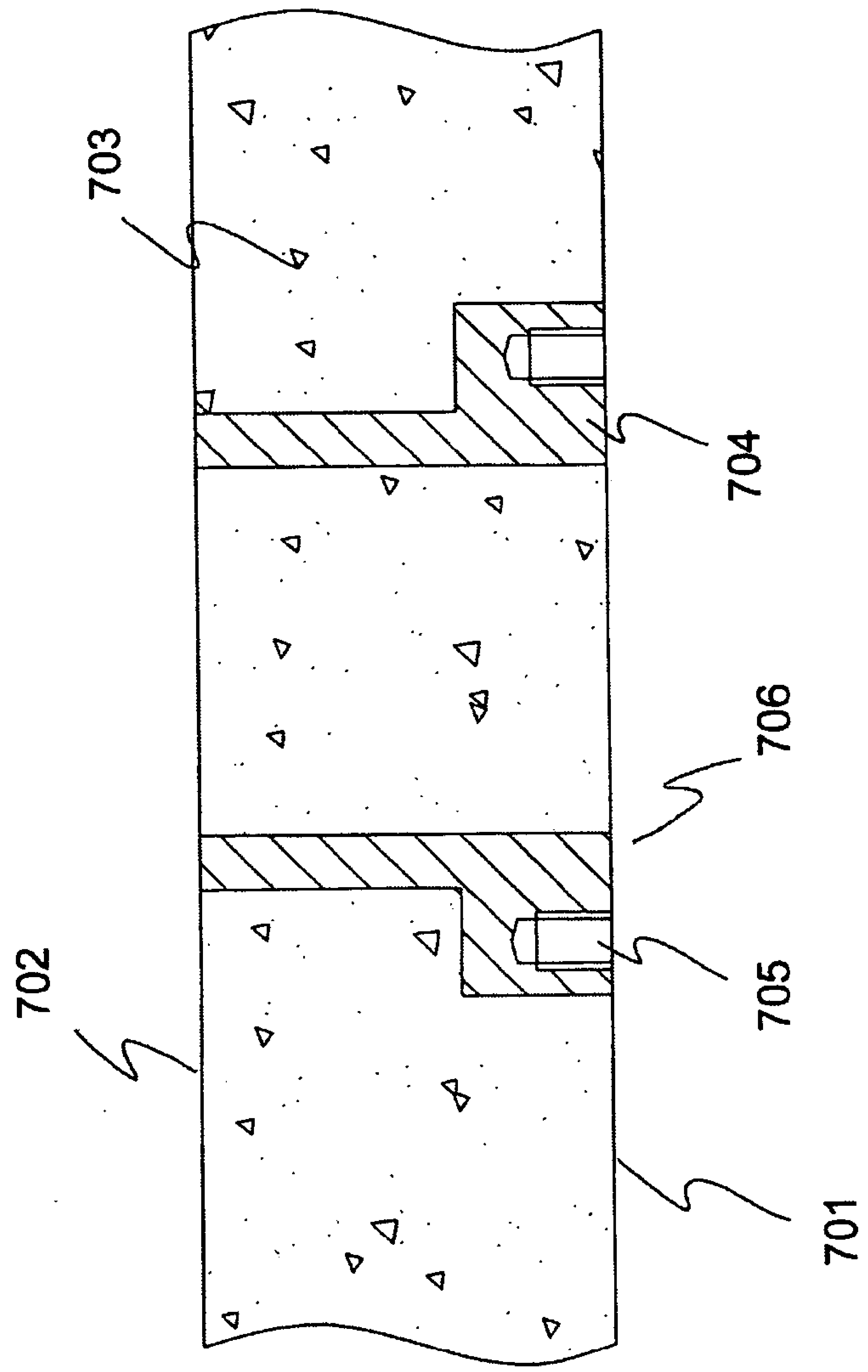

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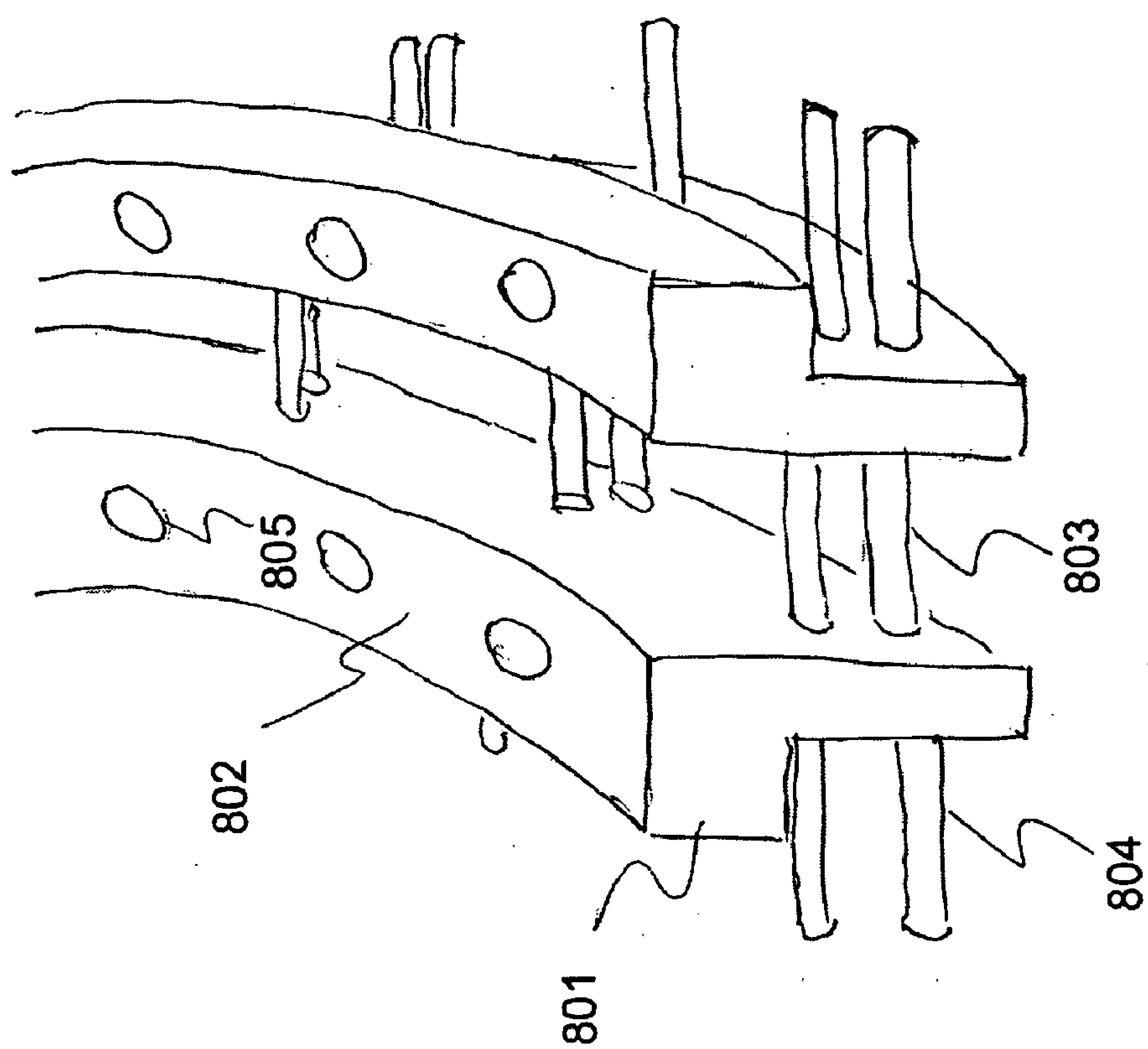
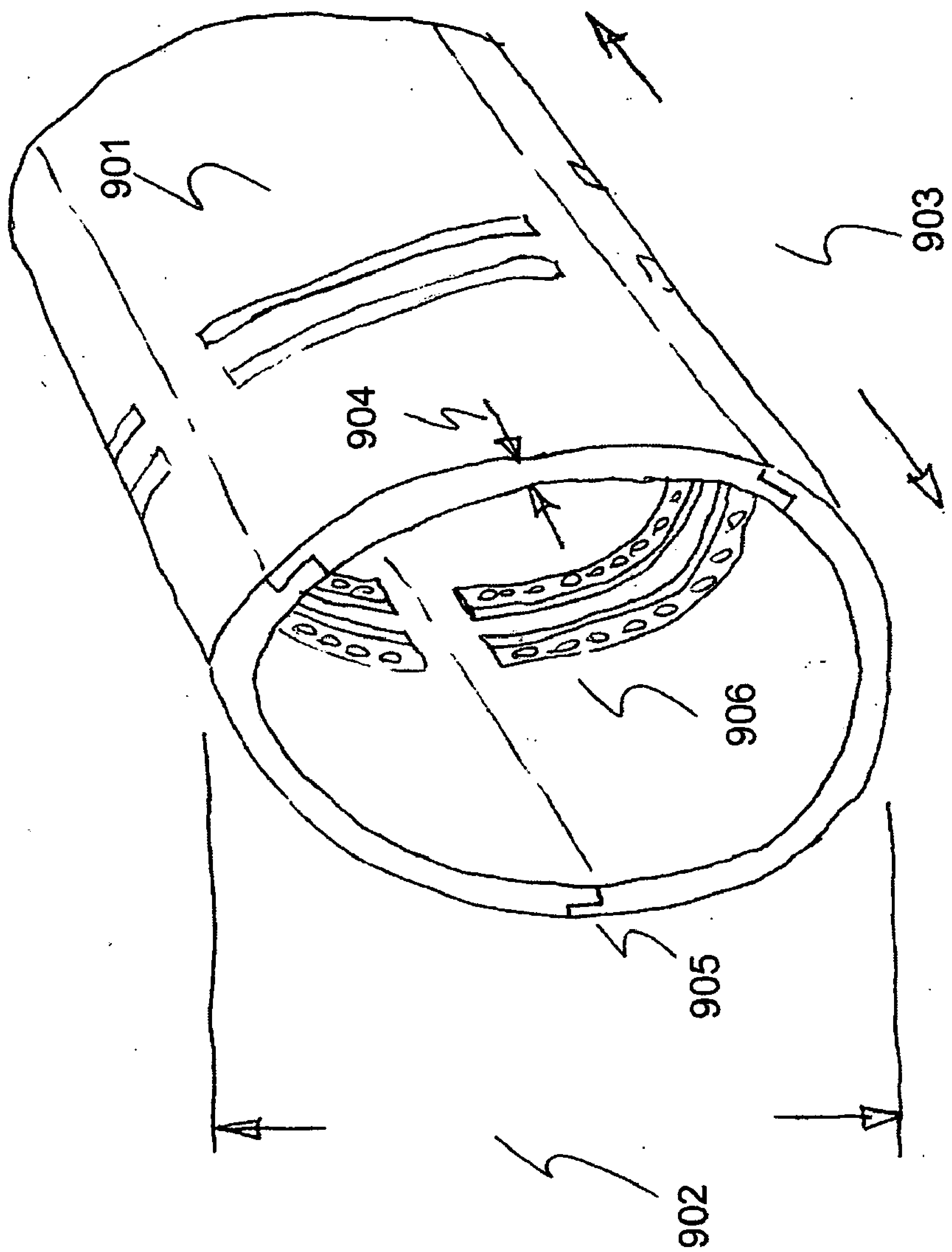
Figure 8





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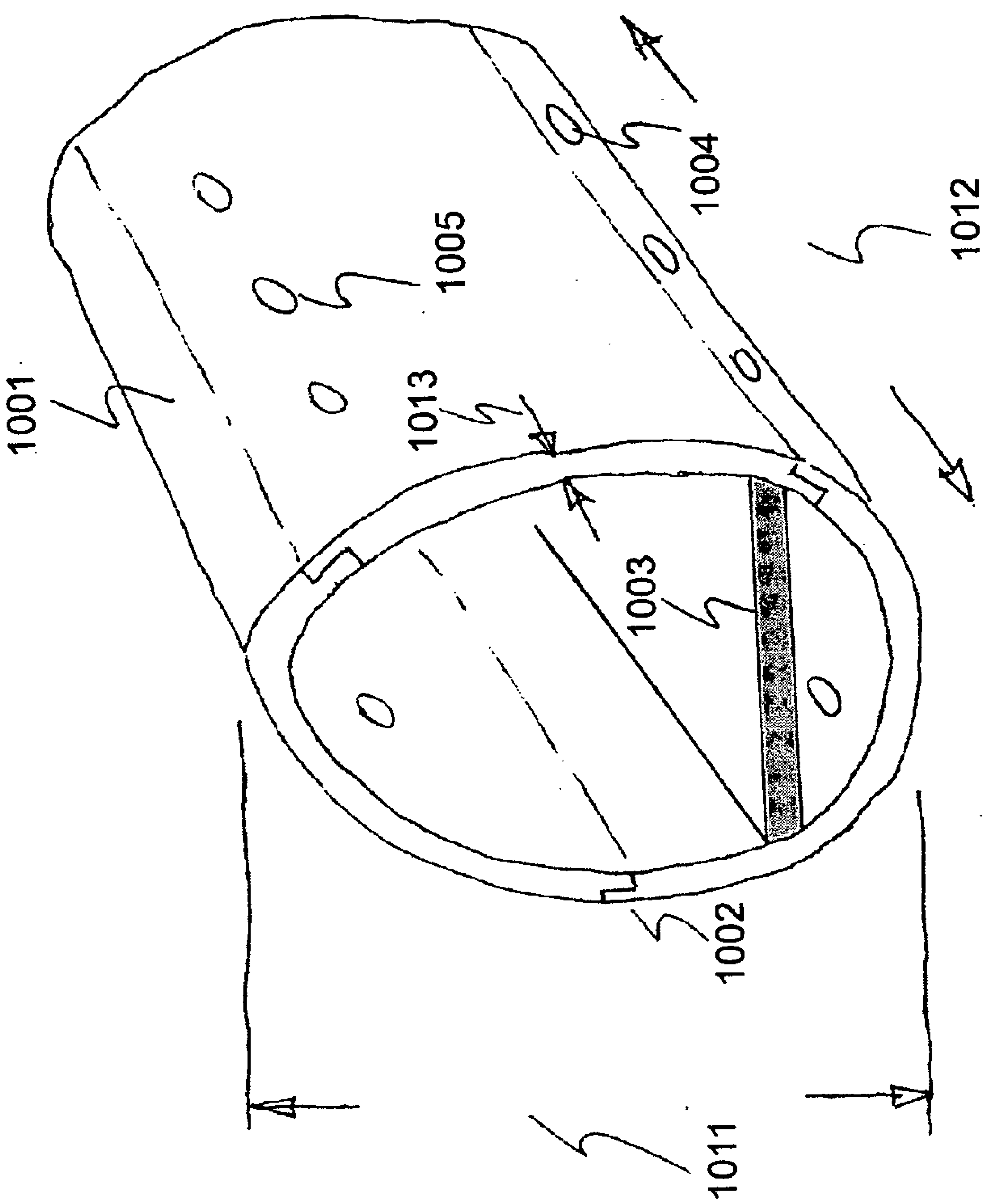

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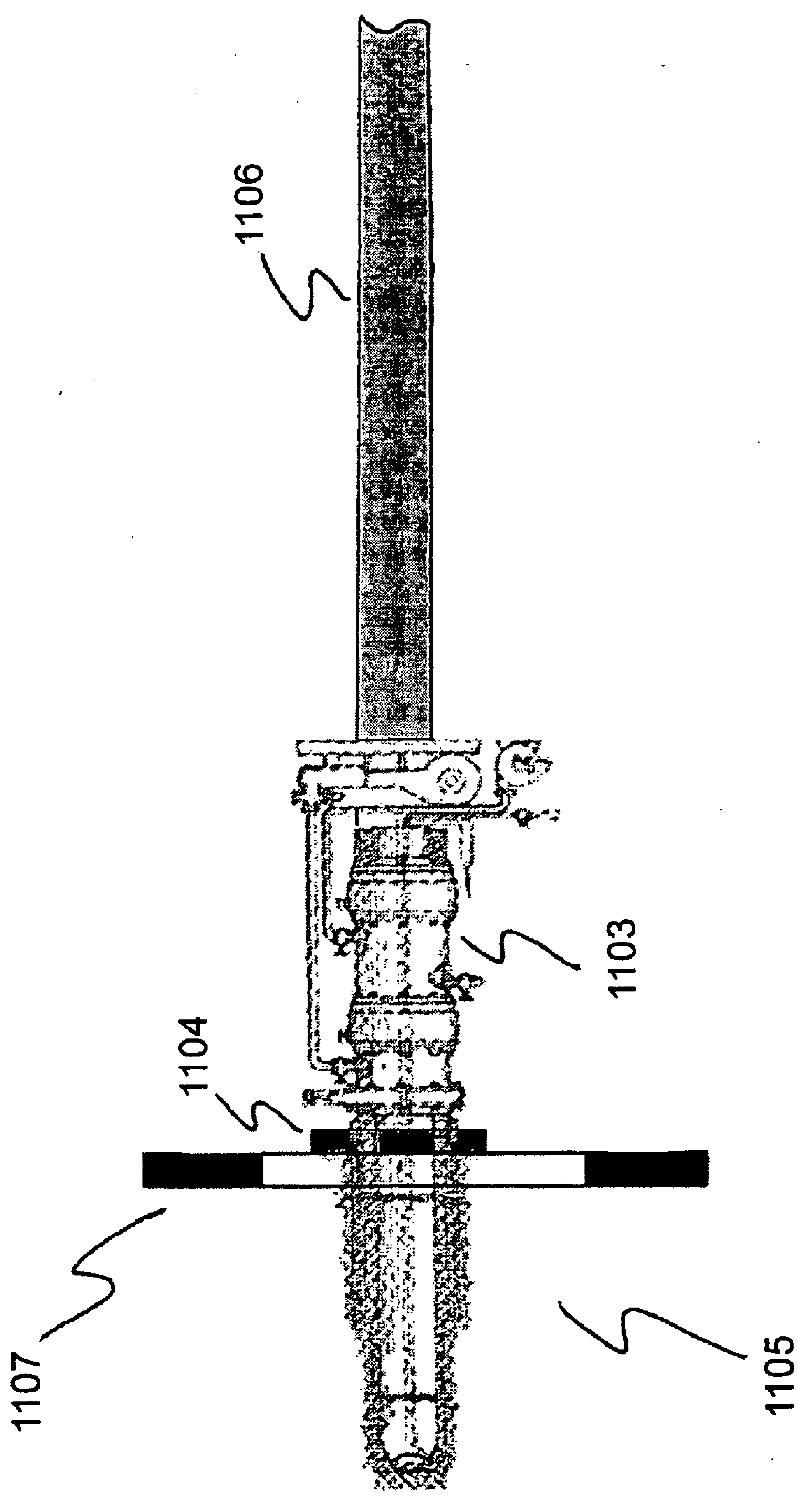

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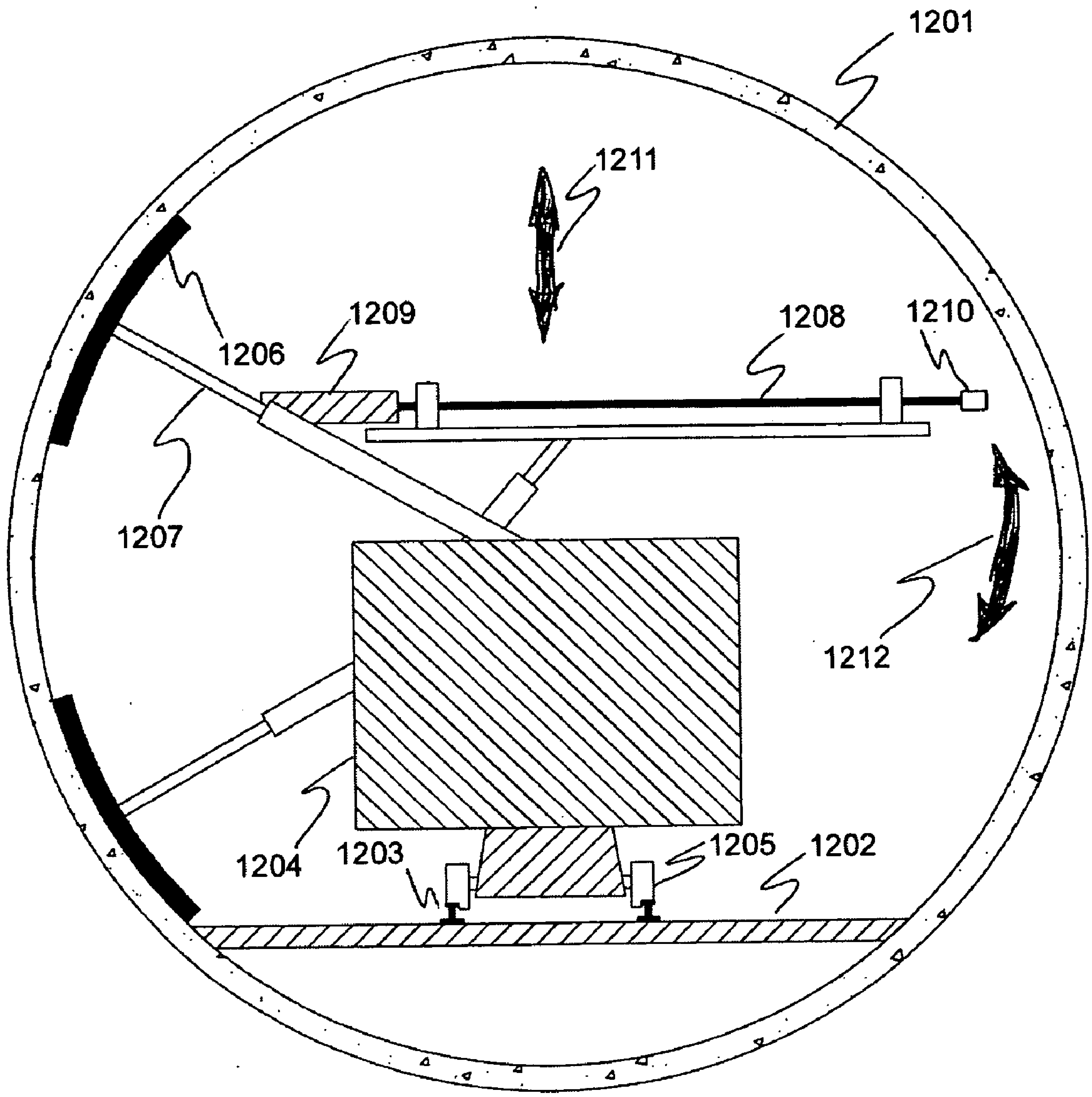

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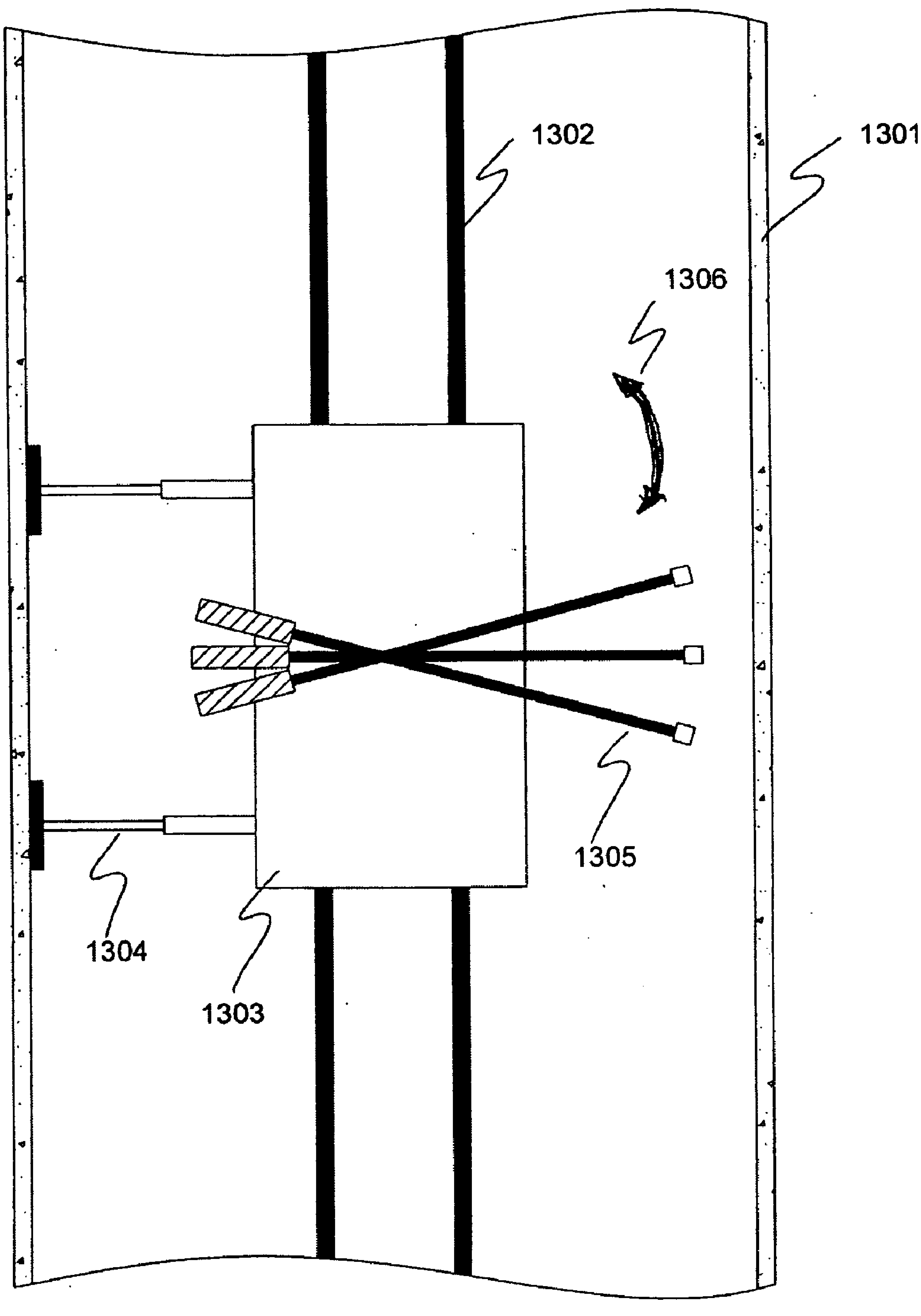

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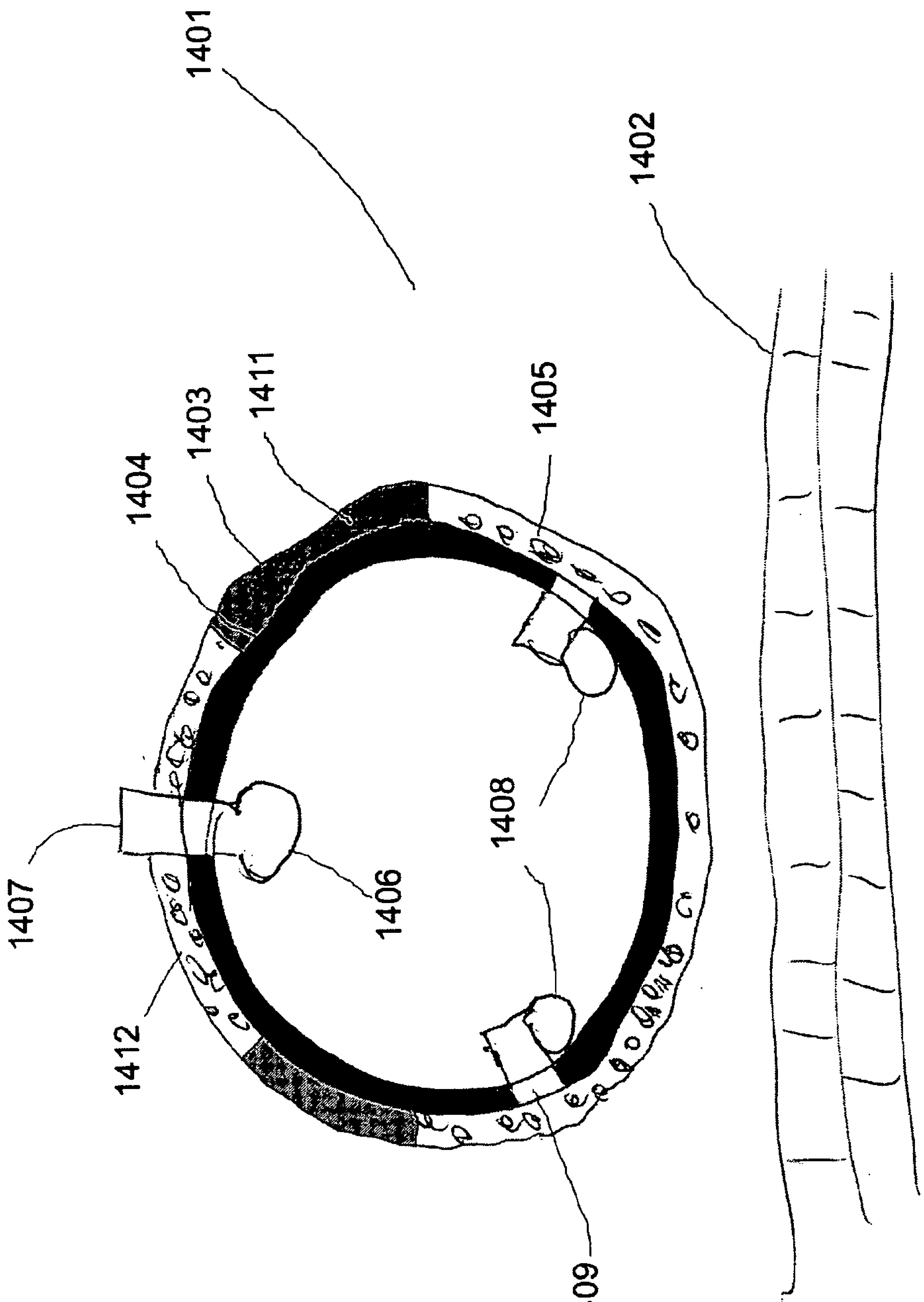

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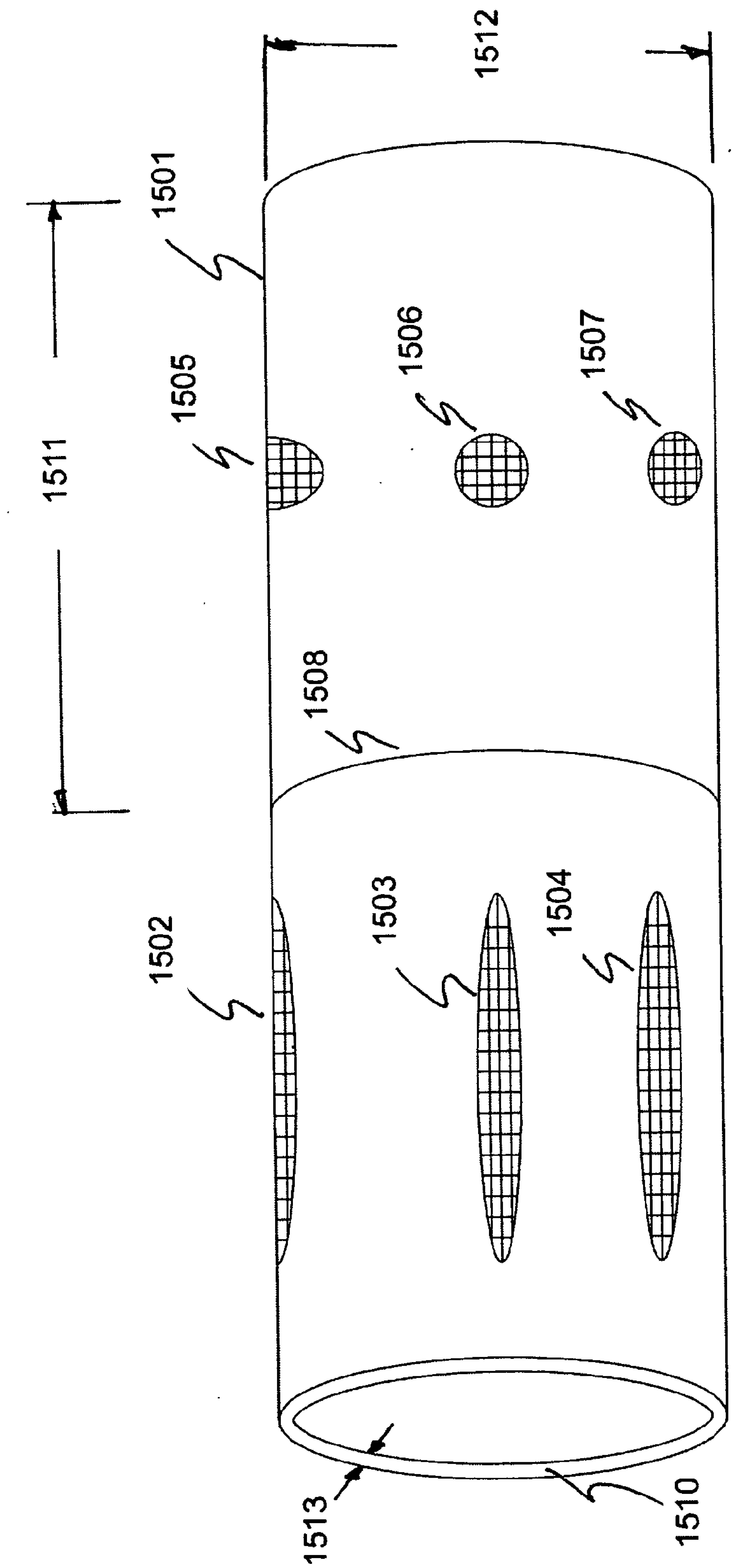

Figure 15

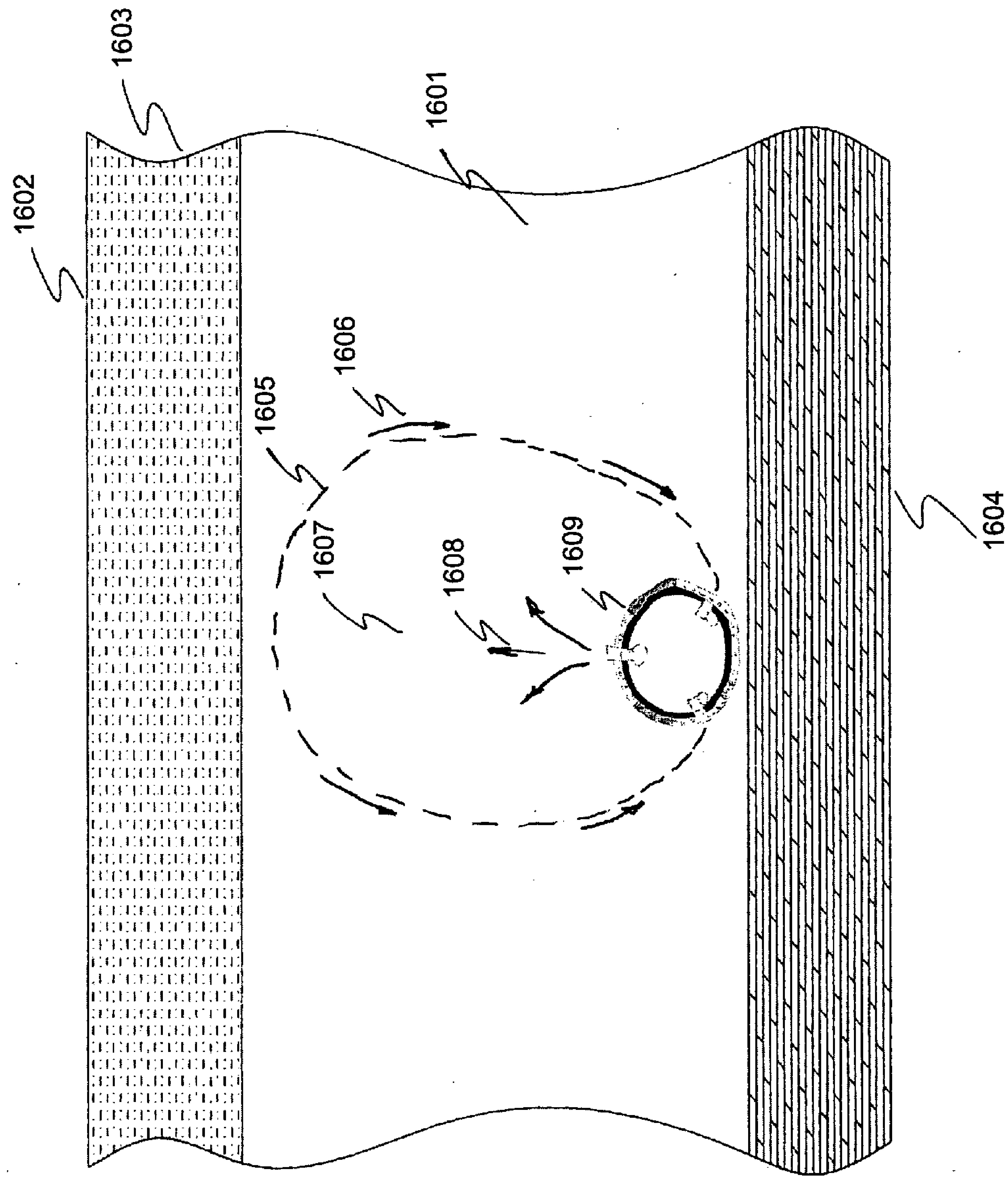

Figure 16

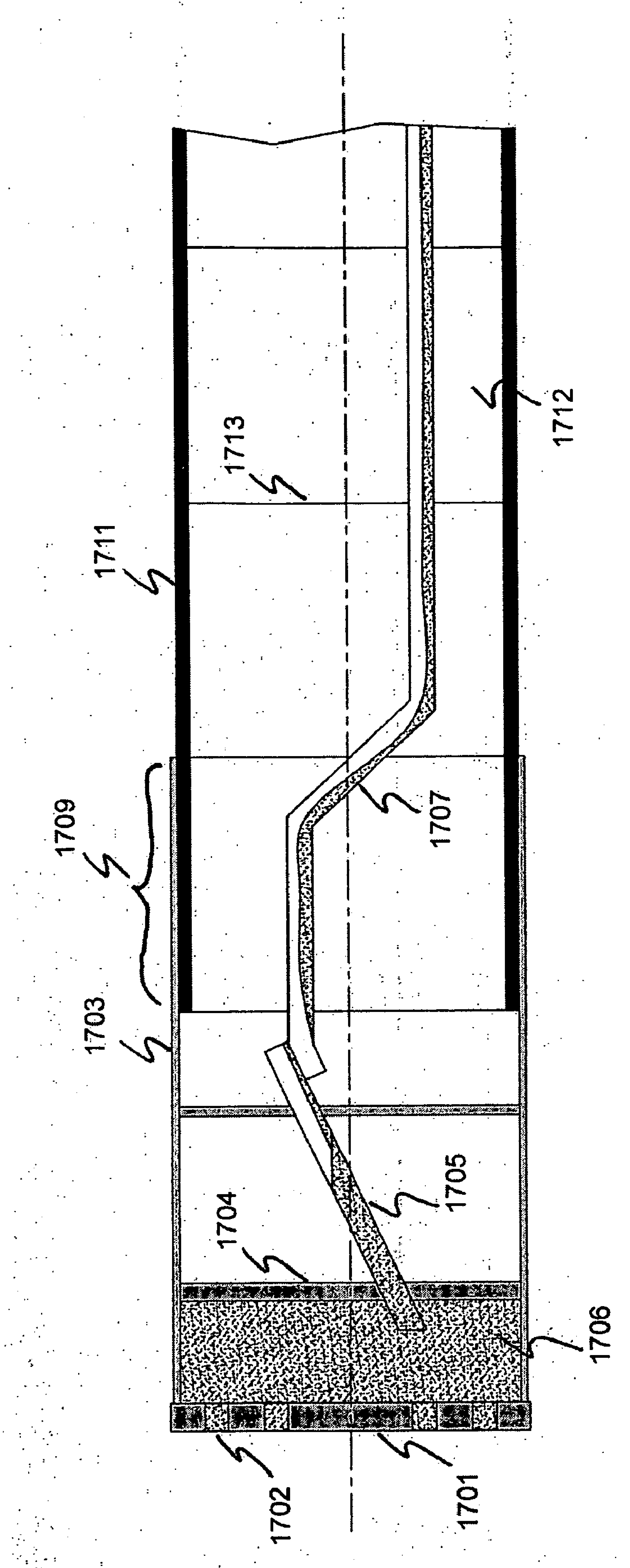

Figure 17

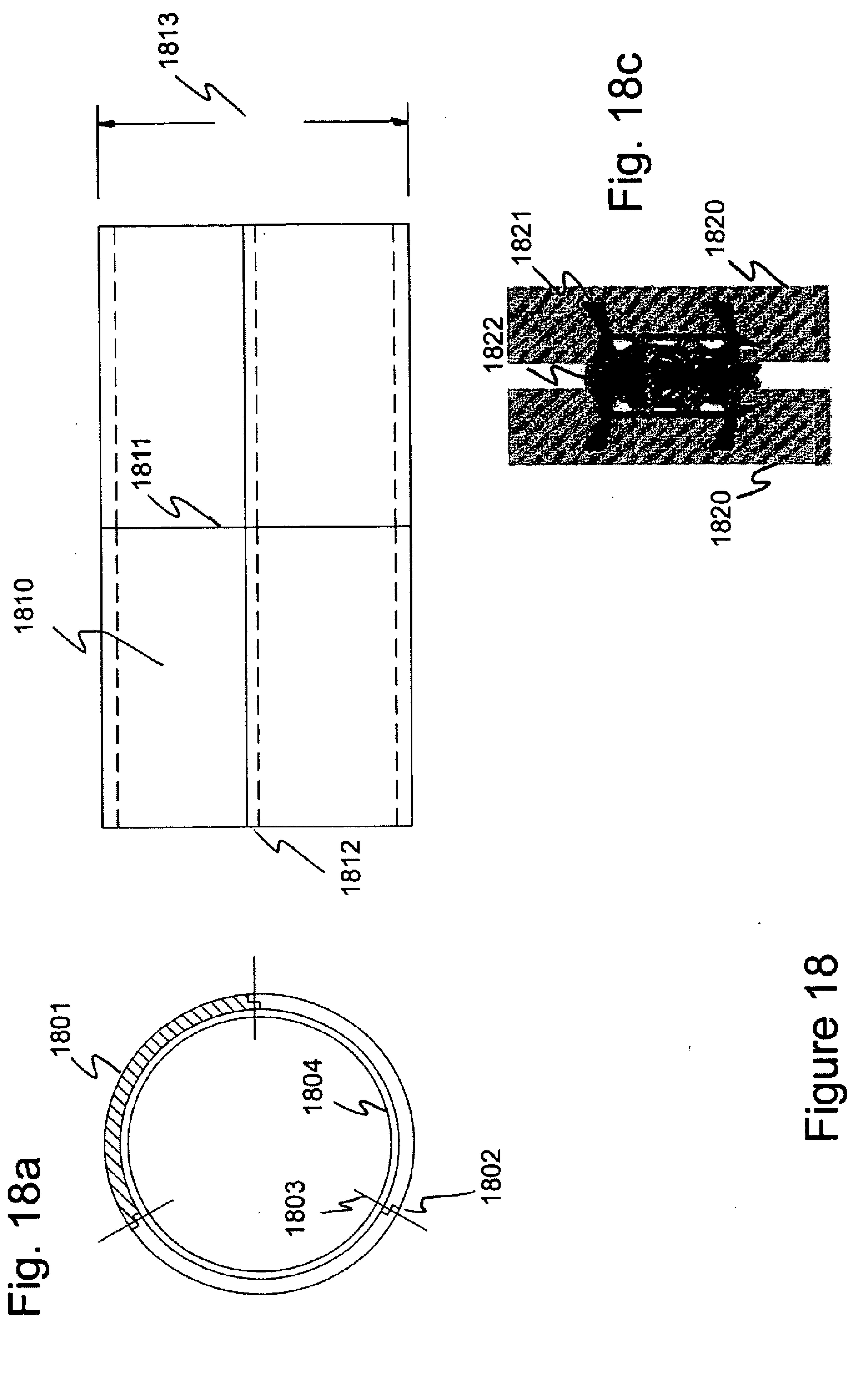

Fig. 18a
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Fig. 18b
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Fig. 18c
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Figure 18

METHOD FOR UNDERGROUND RECOVERY OF HYDROCARBONS

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application claims the benefits, under 35 U.S.C.§ 119(e), of U.S. Provisional Application Ser. No. 60/685,251 filed May 27, 2005, entitled “Method of Collecting Hydrocarbons from Tunnels” to Kobler and Watson; and U.S. Provisional Application Ser. No. 60/753,694, filed Dec. 23, 2005, entitled “Method of Recovering Bitumen” to Brock, Kobler and Watson; both of which are incorporated herein by these references.

FIELD

[0002] The present invention relates generally to a lined shaft and tunnel-based method and system for installing, operating and servicing wells for recovery of hydrocarbons, wherein the underground space is always isolated from the formation.

BACKGROUND

[0003] Oil is a nonrenewable natural resource having great importance to the industrialized world. The increased demand for and decreasing supplies of conventional oil has led to the development of alternative sources of crude oil such as oil sands containing bitumen or heavy oil and to a search for new techniques for more complete recovery of oil stranded in conventional oil deposits.

[0004] The Athabasca oil sands are a prime example of a huge alternative source of crude and is currently thought to have proven reserves of over 200 billion barrels recoverable by both surface mining and in-situ thermal recovery methods. There are also equally large untapped reserves of stranded light and heavy oil deposits from known reservoirs throughout North America which cannot be recovered by traditional surface drilling methods. These two sources of oil, bitumen and stranded oil, are more than enough to eliminate dependence on other sources of oil and, in addition, require no substantial exploration.

Recovering Bitumen

[0005] The current principal method of bitumen recovery, for example, in the Alberta oil sands is by conventional surface mining of shallower deposits using large power shovels and trucks to excavate the oil sand which is then delivered to a primary bitumen extraction facility.

[0006] Some of these bitumen deposits may be exploited by an appropriate underground mining technology. Although intensely studied in the 1970s and early 1980s, no economically viable underground mining concept has ever been developed for the oil sands. In 2001, an underground mining method was proposed based on the use of large, soft-ground tunneling machines designed to backfill most of the tailings behind the advancing machine. A description of this concept is included in U.S. Pat. No. 6,554,368 “Method and System for Mining Hydrocarbon-Containing Materials”.

[0007] When the oil sands deposits are too deep for economical surface mining, in-situ recovery methods are being used wherein the viscosity of the bitumen in the oil sand must first be reduced so that it can flow. These bitumen mobilization techniques include steam injection, solvent flooding, gas injection, and the like. The principal method currently being implemented on a large scale is Steam Assisted Gravity Drain (“SAGD”). Typically, SAGD wells or well pairs are drilled from the earth’s surface down to the bottom of the oil sand deposit and then horizontally along the bottom of the deposit and then used to inject steam and collect mobilized bitumen.

[0008] The SAGD process was first reduced to practice at the Underground Test Facility (“UTF”) in Alberta, Canada. This facility involved the construction of an access shaft through the overburden and oil sands into the underlying limestone. From this shaft, self-supported underground workings were developed in the underlying limestone from which horizontal well pairs were drilled up and then horizontally into the oil sands formation. The UTF is an example of “mining for access”, a technique that is also described below for recovery of stranded oil. With the advent of horizontal drilling techniques, it became possible to install SAGD well pairs by drilling from the surface and this is now the commonly used method of implementing the SAGD process.

Mining for Oil

[0009] Until recently, oil economics have precluded efforts to recover what is known as stranded oil. Most heavy and light oil reserves are recovered by drilling wells from the surface. Typically, these operations recover 5% to 30% of the oil-in-place. Additional oil (up to, in some cases, 50% of the original oil in place) can be recovered from the surface by secondary and tertiary methods (also known as Enhanced Oil Recovery or EOR methods) such as, for example, water flooding, gas flooding and hydraulic fracturing. Nevertheless, a substantial fraction of the oil remains in the ground and is not recovered and is deemed stranded. Much of this stranded oil is mobile and can be recovered by a combination of mining and/or drilling methods with known reservoir engineering practice. It is estimated that billions of barrels of recoverable light and heavy oil remains in known deposits in the US and Canada. Recovery awaits the right combination of economics and technology.

[0010] The literature describes three basic oil mining approaches:

[0011] (1) Surface extractive mining. Surface extractive mining is currently being implemented on a large scale in Alberta’s Athabasca oil sands as discussed above. This method is generally applicable to oil deposits that are within a few tens of meters of the surface.

[0012] (2) Underground extractive mining. Several methods of underground mining have been investigated especially in the past when oil prices have risen rapidly. For example, a number of studies were conducted in the 1980s for direct extraction of bitumen in oil sands and for direct mining of stranded light and heavy oil deposits in the US. These efforts were discontinued when oil prices subsequently fell. The economics of these methods were not competitive with conventional exploration and surface drilling at lower oil prices, and they were thought to be potential difficulties with safety and environmental issues using the underground technology available at the time.

[0013] (3) Mining for access. The 1980s studies referred to above also described methods of “mining for access” to oil deposits. For example, a method was described wherein shafts were sunk and tunnels driven from the shafts to the rock beneath an oil deposit. Rooms were then excavated on either side of the tunnels in the rock underlying the reservoir. These rooms were used for drilling rigs that could drill up into the oil deposit. The wells would collect oil driven by a combination of gravity, gas or water drive. The mining for access approach was considered the most promising technique for economially recovering oil using underground mining methods.

[0014] The principal mining method of interest for stranded oil continues to be mining for access. Some studies indicate that up to 80 percent of the oil remaining after primary and EOR techniques may be recovered using mining for access methods on deposits that are as deep as 1,500 meters. Mining for access can also be used to provide an underground platform for drilling rigs that can drill downward into a hydrocarbon formation below. Such a method could be applied, for example, to an offshore deposit. These mining methods, while well-known and feasible, do not adequately protect the underground workers from the gas, oil and water hazards associated with hydrocarbon reservoirs (both seepage of fluids and vapors as well as substantial inflows of water and gas, especially during installation of tunnels and drifts). An exemplary form of mining for access available during this time period is described in U.S. Pat. No. 4,458,945 entitled "Oil Recovery Mining Method" and U.S. Pat. No. 4,595,239 entitled "Oil Recovery Mining Apparatus" which describe how drainage wells may be drilled into the overlying roof of a tunnel cut into a competent rock zone below oil deposits containing unrecovered or stranded oil.

Heavy Civil Underground Technology

[0015] In recent years, there has been a substantial progress in heavy civil underground construction methods, especially in the area of soft-ground shaft sinking and tunneling.

[0016] Soft-ground shafts are commonly concrete lined shafts and are sunk by a variety of methods often in the presence of pressurized aquifers. These methods include drilling and boring techniques sometimes where the shaft is filled with water or drilling mud to counteract local ground pressures. There are also shaft sinking techniques for sinking shafts under water using robotic construction equipment.

[0017] Soft-ground tunnels can be driven through water saturated sands and clays or mixed ground environments using large slurry, Earth Pressure Balance (" EPB") or mixed shield systems. This new generation of soft-ground tunneling machines can now overcome water-saturated or gassy ground conditions and install tunnel liners to provide ground support and isolation from the ground formation for a variety of underground transportation and infrastructure applications

[0018] Developments in soft-ground tunneling led to the practice of micro-tunneling which is a process that uses a remotely controlled micro-tunnel boring machine combined with a pipe-jacking technique to install underground pipelines and small tunnels. Micro-tunneling has been used to install pipe from twelve inches to twelve feet in diameter and therefore, the definition for micro-tunneling does not necessarily include size. The definition has evolved to describe a tunneling process where the workforce does not routinely work in the tunnel.

[0019] Drilling technologies for soft and hard rock are also well known. Conventional rotary drilling and water jet drilling, for example, have been utilized in oil and gas well drilling, geothermal drilling, waste and groundwater control as well as for hard rock drilling.

[0020] To date, underground access to hydrocarbon reservoirs has relied principally on mining methods that have not yet provided a fully safe working environment for accessing and producing oil and gas from underground.

[0021] There therefore remains a need for safe and economical process of installing a network of hydrocarbon recovery wells from an underground work space while maintaining isolation between the work space and the ground formation. Such an invention would have the potential to develop inaccessible deposits such as those under rivers, increase hydrocarbon recovery factors, lower costs, result in less surface disturbance while providing a safe working environment.

SUMMARY

[0022] These and other needs are addressed by the present invention which is directed generally to removal of hydrocarbons, particularly flowable or fluid hydrocarbons, from hydrocarbon-containing formations using underground excavations.

[0023] In a first embodiment of the present invention, a method for extracting hydrocarbons from a hydrocarbon-containing deposit includes the steps of: (a) forming an underground excavation having a section extending through a hydrocarbon deposit; (b) forming a substantially fluid impermeable liner extending along the section of the excavation; and (c) from the section of the excavation, forming, through the liner, a plurality of wells extending into the hydrocarbon deposit, wherein the wells inject a fluid into the hydrocarbon deposit and/or extract a hydrocarbon from the deposit.

[0024] In a second embodiment, a method for recovering hydrocarbons includes the steps of: (a) forming an excavation in a hydrocarbon-containing formation; and (b) maintaining an interior of the excavation behind an excavation device substantially sealed from selected fluids in the formation. Typically, the excavation device is a tunnel boring machine.

[0025] A number of different seals are preferably maintained. A first seal is maintained between an excavation face and an interior of an excavating machine by modifying the excavated material so as to maintain the excavated material at a pressure that is approximately the pressure of the formation. A second seal at the interface between the tunnel boring machine and the excavation is formed by a moveable shield that is part of the tunnel boring machine. A third seal is formed between a rear edge of the shield and a surface of the liner using a brush seal assembly. A fourth seal is formed in the excavation behind the tunnel boring machine using a liner. A fifth seal is formed at the mating surfaces of tunnel liner segments and sections.

[0026] The maintenance of a sealed work space can provide a safe working environment for accessing, mobilizing and producing hydrocarbons from underground. The seals can prevent unacceptably high amounts of unwanted and dangerous gases from collecting in the excavation. It can

also allow the excavation to be located in hydrologically active formations, such as formations below a body of water or forming part of the water table. Prior art underground mining-for-oil methods require a competent rock formation underlying the hydrocarbon deposit. Thus, the present invention can enable development of hydrocarbon deposits from an underground workspace, such as those deposits overlying soft and/or fractured ground while always providing a safe working environment. The underground workspace of the present invention can therefore be installed below, inside or above the hydrocarbon reservoir.

[0027] In yet another embodiment, a method for extracting a hydrocarbon is provided that includes the steps of (a) forming a liner in an underground excavation; and (b) forming a plurality of wells passing through the liner and into a hydrocarbon-containing deposit. The liner, when formed, comprises a tool to facilitate at least one of well drilling, well completion, and hydrocarbon production from a well. The tool, for example, can be an anchor point for engaging a wellhead control assembly used in the at least one of well drilling, well completion, and hydrocarbon extraction, a sensor for measuring and/or monitoring fluid flow and/or formation pressure.

[0028] In yet another embodiment, a method for recovering hydrocarbons includes the steps of: (a) in an underground excavation, providing a lined excavation, the lined excavation extending through a hydrocarbon-containing formation, and a liner in the lined excavation including a plurality of fluid injection ports; (b) injecting a fluid, through the fluid injection ports, into the hydrocarbon-containing formation; and (c) collecting hydrocarbons mobilized by the injected fluid.

[0029] In one configuration, the lined tunnel has an impervious material positioned between at least first and second fluid permeable annular spaces positioned between the liner and a surface of the excavation, to inhibit the movement of the injected fluid from the first annular space to the second annular space. This configuration uses the liner as the fluid injection and collection mechanism in addition to or in lieu of wells drilled into the formation from the excavation. It therefore can provide substantial production increases relative to a tunnel configuration used only to install wells.

[0030] In another configuration, the fluid is steam or a diluent, and the method further includes the steps of transporting the fluid from the surface through the underground excavation to a set of injectors in communication with the injection ports and with the first and second annular spaces. If the fluid is steam, the temperature and/or pressure of the steam may be returned to a selected level during transportation.

[0031] The various embodiments can provide advantages relative to the prior art. For example, the use of underground excavations to recover hydrocarbons from many types of hydrocarbon-containing deposits, such as heavy oil and stranded oil deposits, can provide higher recovery rates and higher overall recovery factors at substantial cost savings relative to conventional surface-based techniques. Because hydrocarbon deposits and surrounding formations are typically soft and/or fractured rock, the invention can use tunnel boring machines to form the excavation. Tunnel boring machines are mature and highly robust continuous excavation technique. The location of the excavation in the hydrocarbon-containing formation itself can permit the liner to be used as the fluid injection and/or collection medium without the need to drill a large number of wells. Drilling a large number of wells from underground can be cost effective since each well does not have to traverse long distances of barren overburden such as is required by wells drilled from the surface. Finally, the use of liners can inhibit long-term surface subsidence above the excavation, thereby limiting the environmental impact of hydrocarbon recovery and enabling the recovery of hydrocarbons from deposits under, for example, developed farm lands, small towns, lakes, rivers and protected wildlife habitats.

[0032] The following definitions are used herein:

[0033] A hydrocarbon is an organic compound that includes primarily, if not exclusively, of the elements hydrogen and carbon. Hydrocarbons generally fall into two classes, namely aliphatic, or straight chain, hydrocarbons, cyclic, or closed ring, hydrocarbons, and cyclic terpenes. Examples of hydrocarbon-containing materials include any form of natural gas, oil, coal, and bitumen that can be used as a fuel or upgraded into a fuel. Hydrocarbons are principally derived from petroleum, coal, tar, and plant sources.

[0034] Hydrocarbon production or extraction refers to any activity associated with extracting hydrocarbons from a well or other opening. Hydrocarbon production normally refers to any activity conducted in or on the well after the well is completed. Accordingly, hydrocarbon production or extraction includes not only primary hydrocarbon extraction but also secondary and tertiary production techniques, such as injection of gas or liquid for increasing drive pressure, mobilizing the hydrocarbon or treating by, for example chemicals or hydraulic fracturing the well bore to promote increased flow, well servicing, well logging, and other well and wellbore treatments.

[0035] A liner as defined for the present invention is any artificial layer, membrane, or other type of structure installed inside or applied to the inside of an excavation to provide at least one of ground support, isolation from ground fluids (any liquid or gas in the ground), and thermal protection. As used in the present invention, a liner is typically installed to line a shaft or a tunnel, either having a circular or elliptical cross-section. Liners are commonly formed by pre-cast concrete segments and less commonly by pouring or extruding concrete into a form in which the concrete can solidify and attain the desired mechanical strength.

[0036] A liner tool is generally any feature in a tunnel or shaft liner that self-performs or facilitates the performance of work. Examples of such tools include access ports, injection ports, collection ports, attachment points (such as attachment flanges and attachment rings), and the like.

[0037] A mobilized hydrocarbon is a hydrocarbon that has been made flowable by some means. For example, some heavy oils and bitumen may be mobilized by heating them or mixing them with a diluent to reduce their viscosities and allow them to flow under the prevailing drive pressure. Most liquid hydrocarbons may be mobilized by increasing the drive pressure on them, for example by water or gas floods, so that they can overcome interfacial and/or surface tensions and begin to flow.

[0038] A seal is a device or substance used in a joint between two apparatuses where the device or substance makes the joint substantially impervious to or otherwise substantially inhibits, over a selected time period, the passage through the joint of a target material, e.g., a solid, liquid and/or gas. As used herein, a seal may reduce the in-flow of a liquid or gas over a selected period of time to an amount that can be readily controlled or is otherwise deemed acceptable. For example, a seal between a TBM shield and a tunnel liner that is being installed, may be sealed by brushes that will not allow large water in-flows but may allow water seepage which can be controlled by pumps. As another example, a seal between sections of a tunnel may be sealed so as to (1) not allow large water in-flows but may allow water seepage which can be controlled by pumps and (2) not allow large gas in-flows but may allow small gas leakages which can be controlled by a ventilation system.

[0039] A shaft is a long approximately vertical underground opening commonly having a circular cross-section that is large enough for personnel and/or large equipment. A shaft typically connects one underground level with another underground level or the ground surface.

[0040] A tunnel is a long approximately horizontal underground opening having a circular, elliptical or horseshoe-shaped cross-section that is large enough for personnel and/or vehicles. A tunnel typically connects one underground location with another.

[0041] An underground workspace as used in the present invention is any excavated opening that is effectively sealed from the formation pressure and/or fluids and has a connection to at least one entry point to the ground surface.

[0042] A well is a long underground opening commonly having a circular cross-section that is typically not large enough for personnel and/or vehicles and is commonly used to collect and transport liquids, gases or slurries from a ground formation to an accessible location and to inject liquids, gases or slurries into a ground formation from an accessible location.

[0043] Well drilling is the activity of collaring and drilling a well to a desired length or depth.

[0044] Well completion refers to any activity or operation that is used to place the drilled well in condition for production. Well completion, for example, includes the activities of open-hole well logging, casing, cementing the casing, cased hole logging, perforating the casing, measuring shut-in pressures and production rates, gas or hydraulic fracturing and other well and well bore treatments and any other commonly applied techniques to prepare a well for production.

[0045] Wellhead control assembly as used in the present invention joins the manned sections of the underground workspace with and isolates the manned sections of the workspace from the well installed in the formation. The wellhead control assembly can perform functions including: allowing well drilling, and well completion operations to be carried out under formation pressure; controlling the flow of fluids into or out of the well, including shutting off the flow; effecting a rapid shutdown of fluid flows commonly known as blow out prevention; and controlling hydrocarbon production operations.

[0046] It is to be understood that a reference to oil herein is intended to include low API hydrocarbons such as bitumen (API less than ~10°) and heavy crude oils (API from ~10° to ~20°) as well as higher API hydrocarbons such as medium crude oils (API from ~20° to ~35°) and light crude oils (API higher than ~35°) .

[0047] Primary production or recovery is the first stage of hydrocarbon production, in which natural reservoir energy, such as gasdrive, waterdrive or gravity drainage, displaces hydrocarbons from the reservoir, into the wellbore and up to surface. Production using an artificial lift system, such as a rod pump, an electrical submersible pump or a gas-lift installation is considered primary recovery. Secondary production or recovery methods frequently involve an artificial-lift system and/or reservoir injection for pressure maintenance. The purpose of secondary recovery is to maintain reservoir pressure and to displace hydrocarbons toward the wellbore. Tertiary production or recovery is the third stage of hydrocarbon production during which sophisticated techniques that alter the original properties of the oil are used. Enhanced oil recovery can begin after a secondary recovery process or at any time during the productive life of an oil reservoir. Its purpose is not only to restore formation pressure, but also to improve oil displacement or fluid flow in the reservoir. The three major types of enhanced oil recovery operations are chemical flooding, miscible displacement and thermal recovery.

[0048] As used herein, "at least one", "one or more", and "and/or" are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions "at least one of A, B and C", "at least one of A, B, or C", "one or more of A, B, and C", "one or more of A, B, or C" and "A, B, and/or C" means A alone, B alone, C alone, A and B together, A and C together, B and C together, or A, B and C together.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049] FIG. **1** is a schematic side view of the excavating process for installing a lined tunnel in a hydrocarbon formation under pressure.

[0050] FIG. **2** is a schematic end view of tunnel liner.

[0051] FIG. **3** is an isometric view of a shaft, tunnel and well complex installed in a hydrocarbon formation.

[0052] FIG. **4** is a plan view of a typical configuration of wells drilled from tunnels in a hydrocarbon formation.

[0053] FIG. **5** is an end view of multiple tunnels and wells installed near the bottom of a hydrocarbon formation.

[0054] FIG. **6** is an end view of multiple tunnels and wells installed from below a hydrocarbon formation.

[0055] FIG. **7** is a sectioned side view through a tunnel liner segment illustrating a ring assembly embedded in a liner segment.

[0056] FIG. **8** is an isometric view of a ring assembly such as shown in FIG. **8**.

[0057] FIG. **9** shows an isometric view of a tunnel liner section with a type of embedded assembly in each liner segment.

[0058] FIG. **10** shows an isometric view of a tunnel liner section with another type of embedded assembly in each segment.

[0059] FIG. **11** shows a schematic side view of wellhead control equipment installed in a tunnel or shaft liner.

[0060] FIG. **12** shows a schematic end view of drill rig in travel position mounted on a tunnel rail car.

[0061] FIG. **13** shows a schematic plan view drill rig in drilling position to drill a horizontal well through the side of the tunnel liner.

[0062] FIG. **14** shows a schematic end view of a method for recovery of hydrocarbons from a backfilled tunnel liner by SAGD.

[0063] FIG. **15** is an isometric view of tunnel liner sections showing two types of SAGD injector and collector ports.

[0064] FIG. **16** is an end view of a tunnel showing a SAGD steam chamber.

[0065] FIG. **17** is a side view schematic of a soft-ground TBM showing its principal sealing points.

[0066] FIG. **18** illustrates features of tunnel liner sealing.

DETAILED DESCRIPTION

[0067] As discussed in the BACKGROUND section, prior art "mining for access" methods are based on excavating tunnels, cross-connects and drilling caverns in competent rock above or below the target hydrocarbon formation. The competent rock provides ground support for the operation and, being relatively impermeable, to some extent protects the work space from fluid and gas seepages from the nearby hydrocarbon deposit. This approach cannot be applied when formation pressures are high; when the hydrocarbon reservoir is artificially pressurized for enhanced recovery operations ("EOR"); when the hydrocarbon formation is heated, for example, by injecting steam; or when the ground adjacent to the hydrocarbon reservoir is fractured, soft, unstable, gassy or saturated with ground fluids.

[0068] The present invention discloses a method for installing, operating and servicing wells in a hydrocarbon deposit from a lined shaft and/or tunnel system that is installed above, into or under a hydrocarbon deposit. The entire process of installing the shafts and tunnels as well as drilling and operating the wells is carried out while maintaining isolation between the work space and the ground formation. In one aspect of the invention, well-head devices may be precast into the tunnel or shaft liners to facilitate well installation and operation in the presence of formation pressure and/or potential fluid in-flows. In another aspect of the invention, the tunnel itself can be used as a large diameter well for collecting hydrocarbons and, if required, for injecting steam or diluents into a formation to mobilize heavy hydrocarbons such as heavy crude and bitumen.

[0069] In certain embodiments, the present invention discloses a method for installing an underground workspace suitable for drilling wells into a hydrocarbon formation wherein the underground workspace is fully lined in order to provide ground support and isolation from formation pressures, excessive temperatures, fluids and gases. The lining also provides anchor points for various apparatuses or liner tools that allow drilling wells, installing casing for injection of fluids into the formation, measuring and monitoring the formation, and collection of fluids from the formation, all while maintaining a seal between the interior working space and the formation. The process of maintaining isolation of the underground work space from the formation includes the phases of (**1**) installation of underground workspace and wells and (**2**) all production and maintenance operations from the underground workspace. The underground work space is provided principally by lined shafts and lined tunnels. The shafts and tunnels themselves may also serve as large injection and collection "wells" when they are installed in the hydrocarbon formation. Because the underground workspace is installed and operated in full isolation from the formation pressures and fluids, the workspace can be installed above, inside or below the hydrocarbon formation in soft or mixed ground.

[0070] In the descriptions below, it is understood that the functions described for tunnel liners also apply to shaft liners.

Development of Sealed Underground Workspace

[0071] FIG. **1** is an idealized schematic side view of one aspect of the present invention. A hydrocarbon formation **102** is shown under an overlying layer of rock and earth **101** which has a surface **103**. The hydrocarbon deposit **102** lays on top of a basement rock **104**. A soft-ground tunnel boring machine ("TBM") is shown near the bottom of the hydrocarbon formation **102**. In the example of FIG. **1**, the TBM is moving from right to left. The TBM is comprised of a rotating cutter head **110** and a moveable shield **111**. A tunnel liner **112** is erected by sections **105** inside the shield **111** as the TBM advances. The tunnel liner **112** may be formed by sections **105** which are joined together at joints **106** inside the shield **111** during the tunneling process. The sections **105** are preferably precast concrete segments but may be fabricated from other structural materials such as, for example, structural steel or composites of structural steel and concrete. The sections are preferably formed from a high temperature concrete mix and well-cured before installation. The bottom of the finished tunnel is located as shown by separation **107** above the basement formation **104**. When placed at the bottom of the hydrocarbon formation **102**, the bottom of the tunnel liner **112** would typically be located within about 0 to 5 meters of the basement formation **104** depending on geologic conditions such as for example a zone of water or water saturated sand lying on the basement formation **104**. The liner **112** remains in place and provides ground support as the cutting head **110** and shield **111** are moved forward. Most soft-ground tunnel liners are installed by slurry or earth-pressure balance ("EPB") tunnel boring machines ("TBMs"). These machines make it possible to excavate and remove material ("muck") in isolation from the workers and operators in the TBM and tunnel as the tunnel is being installed. The material is excavated in a forward chamber of the TBM where it may be formed into a slurry or paste and removed to the surface. In this configuration, the excavating and muck removal processes are isolated from the tunnel interior and are often carried out at a different pressure (usually higher) than that of the interior of the tunnel. The pressure in the interior of the tunnel is often at or near atmospheric pressure as it is connected to surface ambient pressure by other tunnels, drifts and shafts. Typically, a soft-ground tunnel liner **112** is formed from 3 or 4 segments which are bolted and gasketed together to form a short cylindrical section **105** of tunnel liner. As the tunnel is excavated, short liner sections **105** are assembled and positioned within a shield that is part of the excavating machine, in such a way as to maintain a continuous seal between the working area and the formation being excavated. Installing the tunnel liner while sealed against the formation, controls the seepage of fluids and vapors from the hydrocarbon deposit into the tunnels and drifts of underground working space. The liner also allows the TBM crew to control more substantial water and/or gas inflows encountered during excavation by well-known methods such as water pumps and ventilation air flows. Thus the inside of the tunnels of the present invention are sealed and isolated from the formation at all times during installation of the tunnel network. This ability to seal the tunnel interior from the formation during installation makes it possible to install the tunnel network in the hydrocarbon deposit itself.

[0072] The tunnel diameters envisioned by the present invention are in the range of about 3 meters to about 12 meters. The tunnel liner thicknesses are typically in the range of about 75 millimeters to about 600 millimeters. The liners may be formed from concrete or other low-cost structural materials and may contain layers of plastic or rubber materials to provide additional sealing. The liner may be formed by erecting segments or by continuously extruding concrete into a form.

[0073] The diameter of the cutter head **110** is typically slightly larger than the diameter of the shield. The TBM is used to install a fixed tunnel liner **112** which is shown as having a slightly smaller diameter than the TBM shield **111**. As the TBM advances, it creates an excavation whose inside diameter is denoted by **109**. A gap **113** is therefore formed between the inner diameter of the excavation **109** and the outer diameter of the tunnel liner **112**. The width of the gap **113** may be controlled and backfilled with a suitable material to serve several functions as will be discussed later. The gap **113** is typically in the range of 25 millimeters to about 300 millimeters and may be back-filled with an appropriate material such as grout, gravel or not be backfilled, depending on the application and ground situation. The tunnel liner **112** is preferably installed by using a slurry or Earth Pressure Balance ("EPB") tunnel boring machine ("TBM") and conventional tunnel liner installation technology. This tunneling method allows a liner to be installed while following the desired trajectory through the hydrocarbon deposit **102**. This trajectory may be designed to follow the deposit which may have been formed by a river or estuary for example. The length of the tunnel is dependent on the geology of the hydrocarbon deposit **102** and may be in the approximate range of 500 meters to 10,000 meters or longer if the deposit persists and/or if a number of deposits are separated by short sections of barren ground. The installation of the tunnel liner **112** may be initiated from a portal developed at the surface or by assembling the TBM and its equipment using an access shaft excavated from the surface **103** through the overburden **101** to the bottom of the hydrocarbon deposit **102**. With currently available tunneling technology, a tunnel liner **112** can be installed to within a few millimeters of its desired design location. If the tunnel is used in a thermal recovery operation, this capability therefore places a desirable low limit on the variance of placement of injection and collection points that is considerably more precise than is currently possible with horizontal drilling methods operated from the ground surface **103**. In current practice, soft-ground tunneling machines are limited to formation fluid pressures of about 10 to 12 bars. This limitation is currently dictated by seal design for fluid seals between the TBM shield **111** and the section of tunnel liner **105** erected under the shield **111**. This pressure limitation can be increased by improved seal design. For now, the present invention is limited to hydrocarbon deposits where ambient formation fluid pressures do not exceed about 15 bars. It is also possible, using known tunneling techniques, to locally drain fluids (dewatering and degassing). If the formation is relatively impermeable, then this can reduce local formation fluid pressures and inflow rates to allow the tunneling machine to proceed without exceeding the pressure limits on its seals. Once the tunnel liner is installed, the pressure limitation can be considerably higher than 10 bars as the pressure limit is now dictated by the structural integrity of the liner and/or the sealing technology used to form gaskets between liner segments (unless extruded liner technology, which does not require gaskets, is used). The tunnel liner serves a number of purposes. These include isolating the interior of the tunnel from the formation fluids and vapors, protecting the formation from activities in the tunnel including sparks and the like which can cause ignition of hydrocarbon vapors and materials; serving as a base for attaching fluid cutting and control assemblies used for drilling, logging, operating and servicing wells drilled through the liner; insulating the interior of the tunnel from high temperatures if steam injection is used; and serving as a base for installing drains for collecting oil around the tunnel itself. The tunnel liner **112** can also be installed in the basement formation **104** if desired. If the basement formation is soft or mixed ground, the tunnel would be formed from liner sections such as described above. If the basement formation is hard rock, the tunnel can be excavated by a hard rock TBM and the tunnel walls can be grouted or by other means to provide a seal. If necessary, the tunnel can be formed by using soft-ground techniques-(including installing a liner) but with a hard rock TBM cutter head. This latter method may be preferable, for example, if there were substantial in-flows of water or gas anticipated, as might be the case for basement formations underlying many hydrocarbon deposits.

[0074] FIG. **2** is a schematic end section view of a tunnel liner such as may be installed over, in or under a hydrocarbon reservoir. This view shows a tunnel liner **201** installed in a hydrocarbon formation **202**. The hydrocarbon formation **202** sits atop an underlying basement formation **203** and is overlain by a non-hydrocarbon bearing formation **204** which reaches to the surface **205**. The tunnel liner **201** isolates the interior of the tunnel **206** from the hydrocarbon deposit **202**. The tunnel liner may have an optional backfill zone **207** around the liner. The backfill zone is typically formed during the excavating process as part of the excavating and tunnel liner erection process. The backfill may include grout, concrete, sand, pebbles, small rock and the like and may provide additional sealing capability or drainage around the tunnel liner **201**. The backfill zone **207** is not necessarily circular in cross-section as shown but may be approximately elliptical in cross-section with much of the backfill material being above the spring-line **210** of the tunnel liner cross-section. It is also possible in some hydrocarbon formations to not backfill the zone **207** but allow the ground to expand and fill in the zone **207**. This may be desirable for some applications, for example, in many oil sands formations.

[0075] FIG. **3** is an isometric view of a shaft, tunnel and well complex installed in a hydrocarbon formation. This figure shows a shaft **305** connecting the surface **301** with a hydrocarbon formation **303**. The hydrocarbon formation itself may be comprised of one or more zones of hydrocarbon, each separated by a thin permeable barrier. A shaft **305** penetrates the formations **302** overlaying the hydrocarbon formation **303** and terminating in a basement formation **304**. The shaft **305** may be sunk below the hydrocarbon formation **303** to accommodate shaft elevator equipment or provide a sump volume for the oil produced. In this example, the shaft **305** connects the surface with two tunnels **306** and **307**. The upper tunnel **307** may be used for example to install producer or injection wells into the top of the hydrocarbon formation **303**. The lower tunnel **306** may be used for example to install producer or injection wells into the bottom of the hydrocarbon formation **303**. In this figure, blind wells **308** are shown drilled horizontally into the hydrocarbon formation. As can be appreciated, wells can be drilled at any angle into the formation as will be described in subsequent figures. A key feature of this installation are the junctions **309** between the shaft **305** and the tunnels **306** and **307**. If these junctions are in a pressurized or gassy or fluid-saturated portion of the formation, they must be sealed junctions. The junctions are not necessarily sealed during installation as dewatering, degassing or other well known techniques can be applied during installation to cope with fluid or gas inflows. A method for maintaining a seal at such junctions **309** during installation is described in FIG. **18**. As can be appreciated, wells can be drilled into the formation from the tunnels or shafts at any time after the tunnels and shafts are installed. Thus, it is straightforward to drill additional wells between existing wells to in-fill the well network, creating a dense network of wells in the formation. When drilled from a tunnel of the present invention located inside or adjacent to the hydrocarbon formation, the well lengths are almost entirely in the hydrocarbon formation and there is no cost to drill through the overburden as would be the case with wells drilled from the surface. This is a substantial advantage of the present invention.

[0076] FIG. 4 is a schematic plan view of a typical configuration of wells drilled from tunnels in or adjacent to a hydrocarbon formation. The tunnels themselves may contain provisions for directly injecting steam and collecting fluids and therefore act as large wells themselves. One or more tunnels **401** are driven substantially horizontally into a hydrocarbon formation, approximately following the path of interest in the formation. In this embodiment, a plurality of wells **402**, **403**, **404**, **405** and **408** are drilled outwardly from each tunnel **401** into the hydrocarbon formation. These wells are drilled from the tunnel and are designed to remain substantially within the hydrocarbon deposit. If more than one tunnel is installed, then the tunnels are spaced apart by a distance in the range of approximately 200 to 1,000 meters as indicated by well **402** which connects two tunnels **401**. As shown in FIG. **4**, wells **403**, **404**, **405** and **408** are drilled from the tunnels **401** and terminate in the hydrocarbon formation as blind wells. The lengths of the wells **403**, **404**, **405** and **408** are approximately half the distance between adjacent tunnels. The lengths of wells are thus in the approximate range of about 100 to about 400 meters. If all the wells are drilled as blind wells, the spacing between tunnels may be as much as about 2,000 meters and the blind wells may be up to about 1,000 meters in length. Other wells **402** may be drilled from one tunnel to the other. Other wells **405** may be drilled into the hydrocarbon formation and then offshoot wells **406** can be additionally drilled. As can be appreciated any number of offshoot wells **406** can be drilled from the initial well **405**. The wells may be drilled from any location along the length of the tunnels **401** but are typically spaced in the range of approximately 25 to approximately 150 meters apart. Wells originating from adjacent tunnels may or may not overlap in lateral extent as shown by examples **408** (non-overlapping) and **404** (overlapping). As can be appreciated, wells can be drilled as pairs with one well above the other to form a well pair such as used in SAGD operations. The tunnels **401** which can be curved if necessary to follow the meanderings of a hydrocarbon formation. As can be appreciated, there can be one two or more tunnels which may or may not be connected with cross drifts or wells. In the present invention, all the tunnels and cross drifts are lined; all the wells are sealed where they penetrate the tunnel liners; and when in production, all the wells are connected to a closed piping system such that the produced oil is never exposed to the inside of the tunnel and shaft network.

[0077] FIG. **5** is a schematic end section view of multiple tunnels and wells installed near the bottom of a hydrocarbon formation **501** showing a surface **504**, an overburden **503** and an underlying basement formation **502**. It is understood that the hydrocarbon formation **501** may be comprised of multiple producing zones, each zone being separated by a thin permeability barrier. Each tunnel **505** provides an underground workspace for drilling and operating wells in the hydrocarbon formation **501**. The tunnels **505** are driven roughly parallel to each other with a spacing **506**. The spacing **506** between adjacent tunnels **505** is typically in the range of about 100 to about 2,000 meters. The tunnel is formed by a structural liner (as illustrated, for example, in FIG. **2**) which is preferably constructed of approximately cylindrical sections that are gasketed and bolted together to form a workspace effectively sealed from the surrounding formation. The diameter of the tunnels **505** is preferably in the range of about 3 meters to 12 meters. Several types of wells may be drilled to connect with the tunnels **505**. Well **511** is drilled through the hydrocarbon formation **501** from tunnel to tunnel, the tunnels **501** being approximately in the range of about 200 meters to about 1,000 meters apart in this case. Well **514** is drilled out into the hydrocarbon formation **501** and terminates as a blind well in the hydrocarbon formation **510**. A blind well **514** is typically in the length range of approximately 100 to 1,000 meters but may be longer as blind drilling techniques are improved. Inclined well **515** is drilled to various desired locations in the hydrocarbon formation **510** and may be used, for example, to inject fluids for enhanced oil recovery ("EOR"). Well **516** is drilled down from the surface to connect with a tunnel. Well **516** may have a horizontal section **513** in the hydrocarbon formation **501** as shown. The horizontal section **513** of well **516** is typically in the length range of approximately 100 to 1,000 meters but may be longer as surface drilling techniques are improved. Well **517** is drilled vertically down and terminates as blind well in the basement formation **502**. Well **517** may be used, for example to sequester carbon dioxide or other gases or fluids that may be sequestered in the underlying formation. The diameters of the wells, the lengths of the wells and the spacing of the wells around the tunnels and along the length of the tunnels are controlled by the instructions of the reservoir engineer. The well lengths are limited by the drilling technology employed but are at least in the range of about 100 to 1,000 meters in length. The well diameters are in the range of about 50 mm to 1,000 millimeters, depending on the instructions of the reservoir engineer. The wells may be drilled as single wells, as well pairs such as commonly used in SAGD thermal recovery operations or as three well stacks such as used in some advanced SAGD thermal recovery operations. The methods of drilling from within the tunnels **505** may include, for example, conventional soft ground drilling methods using rotary or augur bits attached to lengths of drill pipe which are lengthened by adding additional drill pipe sections as drilling proceeds. Drilling methods may also include, for example, water jet drilling methods. Drilling methods may also include, for example, micro-tunneling techniques where a slurry excavation head is used and is advanced into the deposit by pipe-jacking methods. Forms of directional drilling may be used from within a tunnel. More conventional directional drilling methods may be used for wells or well pairs drilled from the surface to intercept a tunnel such as described in subsequent discussions. Although not shown, wells may be drilled upwards at an inclination such as well **515** and then be directionally changed to be a horizontal well at a new elevation within the formation.

[**0078**] FIG. **6** is and end view of multiple tunnels and wells installed, for example, in a basement formation **602** just below a hydrocarbon formation **601**. This figure also shows a surface **604** and an overburden **603** formation **602**. FIG. **6** is similar to FIG. **5** except the tunnels **605** are driven into an underlying basement formation **602** and the wells **611**, **612**, **614** and **615** must be drilled upwards out of the basement formation **602** and then horizontally at or near the bottom of the hydrocarbon formation **601**. The range of tunnel diameters and spacings and well pair diameters and spacings are the same as those described in FIG. **5**. In the case of the blind well pairs **614**, the techniques for drilling such well pairs from basement formation **602** into the hydrocarbon formation **601** has been established previously during the original development of the SAGD method at the Underground Test Facility ("UTF") in Alberta, Canada. In this case, the drilling of well pairs was conducted from underground workings drilled & blasted into limestone underlying an oil sands deposit. If the wells or well pairs are drilled from tunnels installed into hard ground, then it is possible to drill & blast small caverns at each drilling location to provide additional working space for the well drilling equipment. Each tunnel **605** provides an underground workspace for drilling and operating wells in the hydrocarbon formation **601**. Even if the basement formation is rock, the tunnel may formed by a structural liner (as illustrated in FIG. **2**) which is preferably constructed of approximately cylindrical sections that are gasketed and bolted together to form a workspace effectively sealed from the surrounding formation. Several types of wells may be drilled to connect with the tunnels **605**. In the case of the well **611** drilled between adjacent tunnels **605**, the well can be drilled from one tunnel and ultimately intercept the adjacent tunnel. This will require an innovation to presently available drilling technology. One way that this may be accomplished, for example, is to drill upwards from one tunnel out of the basement layer **602** and then horizontally at or near the bottom of the hydrocarbon deposit **601** until the horizontal well passes over the adjacent tunnel. It then is possible to drill upwards from the adjacent tunnel to intercept the horizontal portion of the well **611** in the hydrocarbon deposit **601**. Well pair **614** is drilled out into the hydrocarbon formation **601** and terminates as a blind well pair in the hydrocarbon formation **610**. A blind well pair **614** is typically in the length range of approximately 100 to 1,000 meters but may be longer as blind drilling techniques are improved. Inclined well **615** is drilled to various desired locations in the hydrocarbon formation **610** and may be used, for example, to inject fluids for enhanced oil recovery ("EOR"). Well **616** is drilled down from the surface to connect with a tunnel. Well **616** may have a horizontal section **613** in the hydrocarbon formation **601** as shown. The horizontal section **613** of well **616** is typically in the length range of approximately 100 to 1,000 meters but may be longer as surface drilling techniques are improved. Well **616** can be connected to tunnel **605** in the same way well **611** is connected. An example of this procedure was described previously. Well **617** is drilled vertically down and terminates as blind well in the basement formation **602**. Well **617** may be used, for example to sequester gases or fluids. Although not shown, wells may be drilled upwards at an inclination such as well **615** and then be directionally changed to be a horizontal well at a new elevation within the formation. The diameters of the wells, the lengths of the wells and the spacing of the wells around the tunnels and along the length of the tunnels are controlled by the instructions of the reservoir engineer. The wells may be drilled as single wells, as well pairs such as commonly used in SAGD thermal recovery operations or as three well stacks such as used in some advanced SAGD thermal recovery operations. If the basement formation is soft or mixed ground the tunnel would be formed from liner segments such as described previously. If the basement formation is hard rock, the tunnel can be excavated by a hard rock TBM and the tunnel walls can be grouted or lined by other means to provide a seal unless the basement rock is impermeable. If necessary, the tunnel can be formed by using soft-ground techniques but with a hard rock TBM cutter head. This latter method may be preferable, for example, if there were substantial in-flows of water or gas anticipated, as might be the case for basement formations underlying many hydrocarbon deposits. Access to the basement formation is typically by vertical shafts sunk from the surface **604** through the overburden layer **603** and hydrocarbon formation **601** and terminating in the basement formation **602**. The shafts are of a sufficient diameter to accommodate ventilation, access, and the large components of the tunneling machines.

Utilizing Liners to Maintain Sealing While Drilling

[**0079**] FIG. **7** is a side view through a liner segment illustrating a section through a ring assembly embedded in the liner segment. As will be shown subsequently, this type of ring assembly may serve as a mounting device for a fluid cutting and control assembly including blow-out preventers and allows drilling, logging, casing and servicing of wells to be carried out while the interior workspace is fully sealed from the formation. This ring assembly also allows drilling to be initiated from discrete orientations around the circumference of the tunnel. Threaded holes **705** are shown in each half **704** of the ring assembly. The holes **705** are on the inside **701** of the liner segment. The liner segment is commonly made as a precast concrete **703** component having an inside surface **701** and an outside surface **702**. The ring assembly is preferably made from steel but may be fabricated using other structural materials such as aluminum, high strength plastics or the like. A wellhead control assembly (such as shown in FIG. **12**) can then be mounted against the liner ring assembly with a gasket (not shown) forming a seal with surface **706**. This example is meant to illustrate how well-head equipment can be mounted using mounting assemblies cast into the tunnel liner. As can be appreciated, other types of mounting hardware can be cast into the tunnel liner.

[0080] FIG. **8** is an isometric view of the ring assembly shown in FIG. **7**. This view shows two ring halves **801** of the assembly. Threaded holes **805** are shown on the inside (concave surface) of the ring halves. Connectors **803** made for example from re-bar hold the two ring halves together. The connectors **803** and rods **804** also serve to maintain the ring assembly in position when the concrete segment is fabricated. The threaded holes **805** are spaced at equal angles around the ring halves and allow the wellhead control assembly to be positioned at any of a number of discrete angles around the finished tunnel liner. For example, the wellhead control assembly can be mounted at angular spacings of from about 5° to about 15°. This allows wells to be drilled through the tunnel liner walls at any angle since a well's final inclination angle can be adjusted by directional drilling techniques with drilling angle adjusted through small angles as the well is being drilled. Once the wellhead control assembly is positioned and secured to the ring assembly, a drill can penetrate the liner wall by drilling through the precast concrete in between the connector bars **803** and, using well known techniques can maintain a seal between the formation and the interior work space.

[0081] FIG. **9** shows an isometric view of three liner segments, each segment with a ring assembly **906** such as described in FIGS. **7** and **8** cast into the liner wall. The liner segments are bolted and gasketed together at overlapping joints **905** to form a short cylindrical section **901** of tunnel liner. The liner section **901** has a diameter **902**, a length **903** and a wall thickness **904**. The ring assemblies **906** are shown cast into the precast concrete segments. The ring assemblies are preferably located about halfway along the length of the segments. As can be appreciated, more than one ring assembly may be cast into the liner segments and they may be located anywhere along the length of the segments consistent with segment structural integrity.

[0082] FIG. **10** shows a liner section **1001** with rows of drain ports **1004** and **1005** installed in the tunnel liner. The tunnel liner **1001** is comprised of segments joined lengthwise as denoted by joint **1002**. A bottom platform **1003** may be used to provide a flat surface for laying tracks or rails along the tunnel for transportation. In this example, drain ports **1004** are shown located along both sides of the tunnel liner **1001** under platform **1003**. This is a preferred location for drain ports since they can be plumbed into an oil/gas collection piping system installed inside the liner **1001** at the bottom for removing oil/gas that is collected as it drains around the outside of the tunnel liner **1001**. Additional drain ports **1005** are shown located along both sides of the upper portion of the tunnel liner **1001**. This is also a good location for drain ports is since they can be plumbed into an oil collection piping system for removing oil that is collected as it drains around the outside of the tunnel liner **1001** by a piping system hung inside the liner **1001** near the crown of the tunnel liner **1001** and therefore above the traffic lanes and drilling sites within the tunnel. These drain ports may be pre-cast into the liner during fabrication of liner segments or they may be installed in the liner after the liner itself has been installed in the ground. If pre-cast into the liner during fabrication of liner segments, the drain ports may be initially plugged by, for example, a threaded pipe plug compatible with connections to a piping system for oil/gas removal. If installed in the liner after the liner itself has been installed, the drain ports may be installed in a manner similar to that used to install the fluid cutting and control assemblies described in FIG. **11**.

[0083] FIG. **11** is a close up cutaway side view of a tunnel liner wall **1107** with well-head equipment **1103** installed. The well-head equipment **1103** is attached and sealed to the tunnel liner **1107**. Well-head equipment **1103** is secured, for example, to a flange **1104** pre-cast into the tunnel liner wall **1107**. A portion of the well-head equipment **1103** is set into the formation **1105**. As shown, that portion is typical of well-production operations and collects hydrocarbons and delivers them to a piping system **1106**. The equipment shown is a wellhead control assembly which includes blow-out preventers. Equipment such as this allows drilling, logging, casing and servicing of wells to be carried out while the interior workspace is fully sealed from the formation.

[0084] FIG. **12** shows a drill rig in travel position mounted on a tunnel rail car. A platform **1202** is installed inside a tunnel liner **1201**. Narrow gage rail tracks **1203** are installed along the platform **1202**. These tracks are used for small tunnel locomotives and rail cars used to move men, materials, supplies and the like throughout the tunnel and, during tunnel driving operations, to supply, for example, backfilling material to the advancing face and to remove excavated material from the tunnel. A drill rig car **1204** with wheels **1205** is shown in a drilling position. Bearing pads **1206** are shown engaged with the liner walls by hydraulic cylinders **1207** and act to stabilize the drill rig during drilling, casing and other operations. This illustrates another advantage of a tunnel liner which is that it has a predictably smooth bearing surface on which the drill rig can stabilize itself and it can do so in almost any angular orientation. The wheels **1205** can also be designed to grip the rails **1203** when in drilling position to further stabilize the drill rig during drilling and casing operations. A drill with drill motor **1209**, drill rod **1208** and drill bit **1210** is shown mounted on a movable mount. The drill can be oriented as indicated by arrow **1212** to drill in any angular orientation around the tunnel liner. The drill can also be moved up or down as indicated by arrow **1211**. As can be appreciated, the drill can be a mechanical drill such as a rotary or percussive drill; or a water jet drill; or a micro-tunnel machine; or a combination mechanical and water jet drill. The drill rig can be used with well-head equipment such as shown in FIG. **11** to initiate and complete a well while maintaining a seal between the interior workspace and the formation. The drill rigs used in the present invention are designed to quickly add additional lengths of drill rod either by well-designed hand operations or by automatic addition of drill rod lengths such as practiced in petroleum drilling.

[0085] FIG. **13** shows a plan view of a drill rig **1303** in drilling position to drill a horizontal well through the side of the tunnel liner **1301**. Rail tracks **1302** are shown along the platform that forms the tunnel floor. Bearing pads are shown engaged with the liner walls by hydraulic cylinders **1304**. A drill **1305** is shown in a number of positions viewed from above with an approximate range of drilling positions indicated by arrow **1306**. The drill rig shown in FIG. **13** can be raised and lowered from the tunnel centerline through a distance of approximately about ¼ of a tunnel diameter. The drill rig can also be rotated to allow wells to be drilled at any angular orientation (pitch angle). The drill rig can also be rotated laterally to direct the drill line at an angle with respect to normal to the tunnel liner wall (yaw angle).

Utilizing Tunnels for Thermal Recovery

[0086] FIG. **14** shows an end view illustrating a method for using the tunnel liner for thermal recovery of heavy oil or bitumen. A backfilled tunnel liner **1404** illustrates a means of isolating steam from mobilized fluids. An end view of a tunnel is shown here embedded in an oil sands deposit **1401** just above the underlying basement rock **1402**. A tunnel structural liner **1404** provides ground support for an excavated bore **1403**. As described previously in FIG. **2**, the liner **1404** is preferably fabricated using a high-strength, high-temperature concrete to form short liner segments that can be installed, gasketed and bolted together as part of the tunneling process. The excavated tunnel bore and tunnel liner installation are preferably implemented using a soft-ground tunnel boring machine and well-known liner segment installation techniques. The annular spaces **1405**, **1411** and **1412** between the liner **1404** and the inner surface of the excavated bore **1403** are backfilled. In the bottom portion of the annular space **1405** backfill is provided by a low cost, readily available material such as, for example, pea gravel, coarse sand, small rocks and/or the like or combinations of these materials. For a liner diameter in the range of about 3 meters to about 12 meters, the annular gap **1405**, **1411** and **1412** is preferably in the range of about 25 millimeters to about 300 millimeters wide. The portion of the annular space **1411** above the previously mentioned annular space **1405** is thereupon backfilled with a high-temperature grout shown as a solid grey filler. The portion of the annular space **1412** above the previously mentioned annular space **1411** is then backfilled with a low cost, readily available material such as used in annular space **1405**. The grout in annular space **1411** serves to form a seal between the filler material in annular spaces **1405** and **1412**. This feature can prevent injected steam from communicating or short-circuiting from injector ports **1407** to collector ports **1409**. Steam may be injected through both ports **1407** and **1409** so as to heat up the oil sand formation surrounding the tunnel. Steam is not allowed past the grout in annular space **1411** and cannot go around the grout because of the un-mobilized bitumen in the formation. The steam mobilizes the bitumen around the top and bottom portions of the tunnel. At some point, steam injection through ports **1409** is stopped and the mobilized bitumen is allowed to remain in place while steam continues to be injected through injection ports **1407**. As bitumen is drained from around the tunnel through ports **1409**, volume is created for steam to be further injected into the formation through ports **1407**. In this figure, steam is piped down the tunnel and a portion is injected at each injection port **1407**. The steam pipes may be wrapped with a common insulating material to minimize heat loss before injection into the formation. This is a significant advantage that the present invention has over SAGD using well pairs drilled from the surface. An injection port or ports **1407** are located preferably in at least every tunnel liner segment as shown for example in FIG. **15**. The steam injection port **1407** can inject the steam at the outside surface of the liner **1404** or more preferably just beyond the annular layer **1412** directly into the oil sand **1401** as shown in the present figure. Since the steam, generated on the surface or in the tunnel itself, is transported from its point of origin down the inside of the tunnel liner **1404** by a piping system **1406**, its pressure and temperature can be readily monitored. If the steam conditions degrade with length down the tunnel, they can be returned to their desired levels by heater and compressor apparatuses located at intervals along the tunnel. This later capability can be an important advantage over injector wells installed by directional drilling and allows the tunnel-based steam injection system to be as long as required by the oil sands deposit being drained. The fluids are collected through ports **1409** located near the bottom of the tunnel. In this figure, two ports are shown at each cross-sectional location, although there may be any number of ports from one to many at each cross-sectional location. Along the length of the tunnel, collection ports **1409** are located preferably in at least every tunnel liner segment as shown for example in FIG. **15**. The collection ports **1409** feed into a piping system **1408** which allows the collected fluids to be transported through the tunnel and eventually pumped to the surface for further processing. As can be appreciated the tunnel liner also serves to insulate the interior workspace of the tunnel from the steam-heated formation. It does so by limiting the rate of heat flow through the liner (which is commonly made of concrete which has a low thermal conductivity) and by allowing the tunnel ventilation system to rapidly remove heated air so conducted into the tunnel. The ability to over-cut a tunnel bore **1403**, install an undersized liner **1404** and fill the resulting annular space with a number of different materials serving a number of functions, is an example of how modern tunneling technology can be used to enhance implementation of a SAGD process.

[0087] FIG. **15** is an isometric view of a tunnel segment **1501** showing an example of a possible layout for slotted or circular injector and collector ports. This illustrates how a tunnel can be used, for example, as a large diameter SAGD well. In SAGD as currently practiced, the injector well is typically made from a steel tubing with long narrow slots formed into the tubing wall. The slots are approximately 150 millimeters long and 0.3 millimeters wide. The narrow width of these slots is dictated by the requirement to prevent sand from entering into the slot when steam is not being injected and hot fluids (principally mobilized bitumen and condensed steam) are collected. An injector port slot **1502** of the present invention is shown on top of a tunnel segment **1501**. The injector port **1502** is a long slot through which steam is injected into the formation. The slot can be made during the fabrication of the tunnel liner segment **1501**. It can be covered by a screen or screens that allow steam to be injected while sand is prevented from entering the slot when steam is not being injected. The screen mesh is of a size that allows as much or more injection area while having openings approximately in the range of the slot widths used in conventional SAGD well pipe. The collector port slots **1503** and **1504** can be made in the same way as the injector port slot **1502**. The injector port slot **1502** is typically placed at or near the top of the segment **1501**. One of more collector port slots are typically located in the bottom half of the segment **1501** as shown for example by the location of slots **1503** and **1504**. The circumferential strength of the liner segment **1501** can be maintained for example by embedding reinforcing bar in the concrete liners across the slots in the circumferential direction. The injection and collection port slots can be made as long slots that can be almost as long as the tunnel liner segments but, if necessary, substantially wider than the slots used in conventional SAGD well tubing.

FIG. **15** also shows injector ports **1505** and collector ports **1506** and **1507**. These ports are circular in section and it is possible to locate one to three circumferential rows of ports embedded in the liner **1501**. These ports can be in the range of 100 mm to 400 mm in diameter. The length of the tunnel **1500** may be in the approximate range of 500 meters to 10,000 meters. The length **1511** of an individual tunnel liner segment **1501** is typically in the approximate range of 1 to 12 meters. If each tunnel segment **1501** has an injection port **1502** and collection ports **1504**, the injection of steam and the collection of fluids, in effect, occurs along a line which corresponds to the length of the tunnel. Thus the tunnel, which need not be straight but can be sinuous as shown in FIG. **4**, acts as a single long horizontal well pair such as used in conventional SAGD. Because the tunnel can have a diameter in the range of about 3 meters to about 12 meters, the collection area is substantially greater than the collection area of a collector well typically used in conventional SAGD. Since the rate of fluid production is proportional to the pressure and gravity gradients and to the natural logarithm of the effective diameter of the collector, the production rate per unit length of the present invention should be higher by a factor of about 2 to 4 than the production rate of a conventional SAGD collector well.

[0088] FIG. **16** is an end view of a tunnel as represented by a tunnel liner **1609** showing a SAGD steam chamber as represented by its outwardly moving condensation front **1605**. FIG. **16** also shows a ground surface **1602**, an overburden layer **1603**, an oil sand deposit **1601** and an underlying basement rock **1604**. The steam chamber is formed by steam injected **1608** through ports embedded in the tunnel liner **1609** and spaced along the length of the tunnel liner. The fluids which are comprised of mobilized bitumen and condensed steam, drain **1606** around the condensation front **1605** of the steam chamber and are collected through the collector ports spaced along either or both sides of the bottom half of the tunnel liner **1609** as also described in FIG. **15**. Since the characteristic size of a fully developed steam chamber is on the order of the thickness of the oil sand deposit **1601**, the collector ports are effectively along a line located at precise vertical and horizontal distances from the line formed by the injector ports. This geometry is therefore, in effect, a steam injection well with a large collector well spaced appropriately beneath the injector well.

Sealing the Underground Workspace

[0089] The present invention is a method of recovering hydrocarbons by developing an underground workspace that is isolated from the formation both during installation and operations. This requires means of sealing the excavating machines, drilling machines, and working spaces at all times. The principal points of sealing are:

[0090] 1. between the shaft walls and the formation

[0091] 2. between the shaft walls and the tunneling machine

[0092] 3. between the shaft walls and the tunnel liner

[0093] 4. between the tunneling machine and the tunnel liner during installation

[0094] 5. between the tunnel liner sections and segments during installation and operation

[0095] 6. between the tunnel liner and the wells drilled to or from the tunnel

[0096] 1. Lined shafts can be sunk in soft ground in the presence of formation pressure and fluids by well-known methods. For example, drilling mud can be used in conjunction with a large diameter drill bit to excavate the shaft and thick concrete walls can be installed before the mud is pumped out. Often, the surrounding ground can be dewatered and degassed by various well-known means to reduce formation pressures and fluid in-flows sufficiently so the shaft can be installed in short sections by a sequence of alternately excavating and pouring liner walls without drilling muds.

[0097] 2. Beginning a tunnel from a shaft is known practice. The shaft wall must be thick enough that the TBM can be sealed into place before it actually starts to bore. For example, if the shaft wall is, say 1.5 meters thick at the penetration point, the inside 1 meter may be recessed into the wall so the curvature of the shaft would be eliminated and the cutting face of the boring machine can bear squarely on a boring surface (fibre reinforced concrete for example) over its entire circumference. The outer shaft wall remaining would be thick enough to maintain a rigid seal under formation pressure but would be a boreable material such as for example by a fiber-reinforced concrete. Specially configured, very short tunnel liner sections would be bolted into the recess. Then the TBM machine can bore out of the wall and into the formation as sealed as it would be for each additional liner section.

[0098] 3. As can be appreciated, the above tunnel started from inside a shaft results in a tunnel liner section being installed and grouted in the hole bored through the shaft wall. As can be appreciated, this joint can be further sealed by additional grouting the joint and/or by reinforcing it with a structural sealing ring system.

[0099] 4. The seal between the tunnel boring machine and tunnel liner as it being installed is described in some detail below by FIG. **17**.

[0100] 5. The seals between the tunnel liner segments and liner sections are described in some detail below by FIG. **18**.

[0101] 6. Once a lined shaft or lined tunnel is installed, wells can be drilled through the shaft or tunnel wall liners by first attaching a wellhead control assembly (used for drilling, logging, operating and servicing wells, for example, at the well-head of a surface-drilled well) and then using this assembly to drill through the liner wall while maintaining a seal between the formation from the inside of the shaft or tunnel liner as illustrated for example in FIG. **11**. This is also a well-known practice.

[0102] FIG. **17** is a side view schematic of a soft-ground TBM showing its principal sealing points during excavation. This figure illustrates how an Earth Pressure Balance ("EPB") machine is sealed against formation pressures and fluids. It is understood that the seals may not be perfect seals but will substantially reduce the in-flow of, for example, liquids to an amount that can be readily controlled by pumps. Similarly, in the case of gases, seals can substantially reduce the in flow of gas to amounts that can be readily controlled by ventilation systems. FIG. **17** shows a schematic of an EPB machine with a cutter head **1701** and muck ingestion ports **1702**. The excavated material or muck is ingested into a chamber **1706** which is maintained at about local formation pressure (hence the name earth pressure balance). The excavated material is mixed with a plasticizer that gives the muck cohesion. A screw auger **1705**, then transfers the plasticized muck to a conveyor system **1707**. The muck in the auger forms an effective seal between the chamber **1706** and the conveyor **1707**. The conveyor system **1707** may therefore be an open or closed system and may be operated at the ambient pressure in the manned working areas inside the TBM and tunnel. The cutter head **1701** rotates within a shield **1703** and is sealed by well-known mechanical rotating sealing means. A tunnel liner **1711** is assembled within the shield **1703**. As the TBM moves forward(towards the left in FIG. **17**), the shield **1703** moves with it and exposes newly formed liner sections **1712** to the formation. A series of brush seals between the overlapping portion **1709** of the shield **1703** and liner sections **1712** form a substantial seal between the formation and the interior of the TBM/tunnel liner. In current practice, these brush seals are limited to formation fluid pressures of about 10 to 12 bars. The tunnel liner **1711** is formed by joining sections of liner **1712** at joints such **1713**. These joints are sealed as described in the following figure. Once the tunnel liner is installed, the pressure limitation can be considerably higher than 10 bars as the pressure limit is now dictated by the structural integrity of the liner and/or the sealing technology used to form gaskets between liner sections and segments. A slurry TBM seals in a slightly different way during excavation. The slurry TBM cutting head excavates by forming the ground just ahead of it into a dense slurry. The slurried muck is ingested into a pressurized chamber and then formed into a transportable slurry by adding additional water. The slurry may be transported out of the tunnel at approximately formation pressure in a closed slurry system. Thus, like the EPB TBM, the excavation and muck removal can be carried out at or near formation pressure while the working areas in the TBM and tunnel can remain at ambient pressure and isolated from the slurried muck.

[0103] FIG. **18** illustrates features of tunnel liner sealing. A soft-ground tunnel liner is commonly comprised of short cylindrical liner sections. The sections are in turn comprised of segments. Alternately, a tunnel liner may be formed by continuously extruding a concrete liner, a newer method that does not require as much sealing as a liner assembled from segments and sections. An end view of a typical tunnel liner is shown in FIG. **18**a showing three segments **1801** joined together at joints **1802** which may include sealing gaskets (not shown) and may be bolted **1803**. The segments are typically pre-cast and made from a high strength material such as for example concrete or fibre-reinforced concrete. An additional optional sealing liner **1804** may be installed to provide additional sealing. This sealing liner may be made of rubber, urethane or another tough sealing material. A side view of the tunnel liner is shown in FIG. **18***b* illustrating two sections **1810** of outer diameter **1813** joined together by a joint **1811**. A longitudinal segment joint **1812** such as described in FIG. **18***a* is also shown. Once each section **1810** is assembled inside the TBM shield (described previously in FIG. **17**), it is compressed against the previously installed section by the action of the TBM propelling itself forward by its hydraulic rams against the end of the tunnel liner. A seal is formed at section joints **1811** by a sealing gasket such as shown in FIG. **18***c* which illustrates a close-up section view between two liner sections **1820** and their joint surfaces. Typically a sealing gasket mounting assembly **1821** is cast into the liner segments **1820**. A compressible sealing material **1822** is installed in at least one of the sealing gasket mounting assemblies **1821**. When the liner sections **1820** are compressed by the propelling action of the TBM, the sealing material **1822** is compressed forming a seal between adjacent tunnel liner sections.

[0104] There are other advantages of the present invention not discussed in the above figures. For example, if there are problems during the operation of the system after production operations have begun, it is possible to perform servicing and repair. This could include for example repair of down hole pumps, valves and other production equipment. If required, additional wells can be drilled to offset declining production. Wells can readily be cleaned and serviced in all weather conditions. Remotely operated robotic vehicles can be operated inside the tunnel and monitor or observe problem areas. This can be especially useful when the tunnel is for thermal production operations such as SAGD. Finally, much of the installed equipment (piping, pumps, sumps, diagnostics, heaters and the like) can be retrieved from the tunnel for use in other tunnel-based hydrocarbon recovery operations.

[0105] A number of variations and modifications of the invention can be used. As will be appreciated, it would be possible to provide for some features of the invention without providing others. The present invention, in various embodiments, includes components, methods, processes, systems and/or apparatus substantially as depicted and described herein, including various embodiments, sub-combinations, and subsets thereof. Those of skill in the art will understand how to make and use the present invention after understanding the present disclosure. The present invention, in various embodiments, includes providing devices and processes in the absence of items not depicted and/or described herein or in various embodiments hereof, including in the absence of such items as may have been used in previous devices or processes, for example for improving performance, achieving ease and\or reducing cost of implementation.

[0106] The foregoing discussion of the invention has been presented for purposes of illustration and description. The foregoing is not intended to limit the invention to the form or forms disclosed herein. In the foregoing Detailed Description for example, various features of the invention are grouped together in one or more embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the following claims are hereby incorporated into this Detailed Description, with each claim standing on its own as a separate preferred embodiment of the invention.

[0107] Moreover though the description of the invention has included description of one or more embodiments and certain variations and modifications, other variations and modifications are within the scope of the invention, e.g., as may be within the skill and knowledge of those in the art, after understanding the present disclosure. It is intended to obtain rights which include alternative embodiments to the extent permitted, including alternate, interchangeable and/or equivalent structures, functions, ranges or steps to those claimed, whether or not such alternate, interchangeable and/or equivalent structures, functions, ranges or steps are disclosed herein, and without intending to publicly dedicate any patentable subject matter.

What is claimed is:

1. A method for extracting hydrocarbons from a hydrocarbon-containing deposit, comprising:

(a) forming an underground excavation having a section extending through a hydrocarbon deposit;

(b) forming a substantially fluid impermeable liner extending along the section of the excavation; and

(c) from the section of the excavation, forming, through the liner, a plurality of wells extending into the hydrocarbon deposit, wherein the wells at least one of inject a fluid into the hydrocarbon deposit and extract a hydrocarbon from the deposit.

2. The method of claim 1, wherein the liner, as formed, comprises at least one tool to facilitate at least one of well drilling, well completion, and hydrocarbon extraction from the deposit.

3. The method of claim 1, wherein the at least some of the wells inject a fluid into the hydrocarbon deposit and at least some of the wells extract a hydrocarbon from the deposit, wherein the fluid mobilizes the hydrocarbon for extraction, wherein the fluid is at least one of steam, a diluent, water, carbon dioxide, nitrogen, and air and wherein the liner extends substantially around the periphery of the excavation.

4. The method of claim 2, wherein the tool comprises at least one of an anchor point for engaging a device used in the at least one of well drilling, well completion, and hydrocarbon extraction, and a sensor for measuring and/or monitoring fluid flow and/or formation pressure.

5. The method of claim 2, wherein, after completion, the interior of the excavation is at least substantially sealed from fluids in the well.

6. The method of claim 1, wherein, during formation of the underground excavation, the interior of the excavation behind an excavation device forming the excavation is at least substantially sealed from the hydrocarbon deposit, wherein excavating and muck removal by a cutter head of the excavation device is at a higher pressure than a pressure in the excavation behind the excavation device, and wherein the excavation device is a slurry or earth pressure balance tunnel boring machine.

7. The method of claim 1, wherein the liner is at least partially surrounded by a backfill material positioned between the wall of the excavation and the liner.

8. Hydrocarbon produced from the wells of claim 1.

9. A method for extracting a hydrocarbon, comprising:

(a) providing an underground excavation;

(b) forming a liner in the underground excavation; and

(c) forming a plurality of wells passing through the liner and into a hydrocarbon-containing deposit, wherein the liner, when formed, comprises at least one tool to facilitate at least one of well drilling, well completion, and hydrocarbon production from a well.

10. The method of claim 9, wherein the tool is at least one of:

an anchor point for engaging a wellhead control assembly used in the at least one of well drilling, well completion, and hydrocarbon extraction; and

a sensor for measuring and/or monitoring fluid flow and/or formation pressure.

11. The method of claim 9, wherein the tool is a ring assembly embedded in a liner section, the ring assembly engaging a mounting device for a wellhead control assembly and wherein the liner section comprises one or more ring assemblies positioned at selected intervals around the liner section.

12. The method of claim 11, wherein a gasket is positioned at the interface between the mounting device and the ring assembly to form a seal therebetween.

13. The method of claim 11, wherein ring assembly comprises first and second ring halves, each ring half comprising threaded holes spaced at substantially equal angles around the ring half to allow the wellhead control assembly to be positioned at any of a number of angles around the tunnel liner.

14. The method of claim 9, wherein the tool is at least one of an injection port for injecting fluids and a drain port for collecting fluids located between the liner and the adjacent wall of the excavation.

15. The method of claim 9, wherein the tool is a flange operable to engage well-head equipment in communication with a well in spatial proximity to the flange.

16. Hydrocarbon produced from the wells of claim 9.

17. A liner for an excavation, comprising:

(a) a liner section; and

(b) a tool embedded in the liner section at selected intervals along a length of the section, wherein the tool is at least one of an attachment point, an injection port for a fluid to be injected into a hydrocarbon-containing formation, and a collection port for collection of hydrocarbon-containing fluids from the formation.

18. The liner of claim 17, wherein the tool is an attachment point, wherein a wellhead control assembly is attached to the tool.

19. The liner of claim 18, wherein the tool comprises a ring positioned substantially around the periphery of the liner section and a plurality of connectors positioned at selected intervals along the length of the ring to engage the wellhead control assembly.

20. The liner of claim 19, wherein the ring comprises first and second interconnected ring halves, each half being positioned adjacent to one another and containing a subset of the connectors, and wherein the connectors are positioned at equal angles around the ring, thereby allowing the device to be positioned at any of a number of discrete angles along a length of the ring.

21. The liner of claim 18, wherein the tool comprises a gasket to form a seal between the wellhead control assembly and a surface of the liner.

22. The liner of claim 17, wherein the liner section further comprises a plurality of drain ports for collecting fluids located between the liner and the adjacent wall of the excavation, the plurality of drain ports being in communication with a fluid collection system.

23. The liner of claim 17, wherein the tool is the injection port.

24. The liner of claim 17, wherein the tool is the collection port.

25. The liner of claim 23, wherein injection ports are positioned in an upper portion of a first liner section.

26. The liner of claim 25, wherein a the first liner section comprises collection ports positioned in a lower portion of the liner section.

27. The liner of claim 25 wherein the injection ports are elongated and comprise a screen to inhibit particulate material from passing through the ports.

28. The liner of claim 26, wherein the collection ports are elongated and comprise a screen to inhibit particulate material from passing through the ports.

29. A method for recovering hydrocarbons, comprising:

(a) in an underground excavation providing a lined excavation, the lined excavation extending through a hydrocarbon-containing formation, and a liner in the lined excavation comprising a plurality of fluid injection ports;

(b) injecting a fluid, through the fluid injection ports, into the hydrocarbon-containing formation; and

(c) collecting hydrocarbons mobilized by the injected fluid.

30. The method of claim 29, wherein the lined tunnel has an impervious material positioned between at least first and second fluid permeable annular spaces positioned between the liner and a surface of the excavation to inhibit the movement of the injected fluid from the first annular space to the second annular space, wherein the fluid is one of steam and a diluent, and further comprising:

(d) transporting the fluid from the surface through the underground excavation to a set of injectors in communication with the injection ports and with the first and second annular spaces, wherein the temperature and/or pressure of the steam is returned to a selected level during transportation.

31. The method of claim 29, wherein the fluid is injected into at least one annular space defined by the liner and a wall of the excavation and in the absence of a well.

32. The method of claim 29, wherein the liner comprises a plurality of collection ports and wherein the hydrocarbons pass through the collection ports in the absence of a well casing.

33. Hydrocarbon produced from the wells of claim 29.

34. A method for recovering hydrocarbons, comprising:

(a) in an underground excavation providing a lined excavation, the lined excavation extending through a hydrocarbon-containing formation, and a liner in the lined excavation comprising a plurality of collection and injection ports;

(b) injecting a fluid into the hydrocarbon-containing formation; and

(c) collecting, at the collection ports, hydrocarbons mobilized by the injected fluid.

35. The method of claim 34, wherein the liner comprises a plurality of injection ports, wherein the lined tunnel has an impervious material positioned between at least first and second fluid permeable annular spaces positioned between the liner and a surface of the excavation to inhibit the movement of the injected fluid from the first annular space to the second annular space, wherein the fluid is steam, and further comprising:

(d) transporting the fluid from the surface through the underground excavation to a set of injectors in communication with the injection ports and with the first and second annular spaces, wherein the temperature and/or pressure of the steam is returned to a selected level during transportation.

36. The method of claim 34, wherein the fluid is injected into at least one annular space defined by the liner and a wall of the excavation and in the absence of a well.

37. The method of claim 34, wherein the hydrocarbons pass through the collection ports in the absence of a well casing.

38. Hydrocarbon produced from the wells of claim 34.

39. A method for recovering hydrocarbons, comprising:

(a) forming an excavation in a hydrocarbon-containing formation; and

(b) maintaining an interior of the excavation behind an excavation device substantially sealed from selected fluids in the formation.

40. The method of claim 39, wherein the excavation device is a tunnel boring machine, wherein a first seal is maintained between a cutter head and a muck removal system using a ground modifying material and maintaining the modified excavated material at a pressure that is approximately the pressure of the formation.

41. The method of claim 40, wherein a periphery of the tunnel boring machine shield forms a second seal with a liner section.

42. The method of claim 41, wherein a third seal is formed in the excavation behind the tunnel boring machine using a liner.

43. The method of claim 42, wherein a fourth seal is formed between all the joints of the liner.

44. The method of claim 42, wherein the liner comprises a plurality of interconnected sections and wherein a sealing gasket is positioned between adjacent interconnection sections.

45. The method of claim 42, wherein the liner comprises a plurality of interconnected sections and wherein step (b) comprises:

(i) positioning a sealing material between adjacent liner sections;

(ii) interconnecting the adjacent liner sections; and

(iii) the tunnel boring machine apply a force to the interconnected adjacent liner sections, thereby causing the sealing material to form a seal along a joint between the adjacent liner sections.

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