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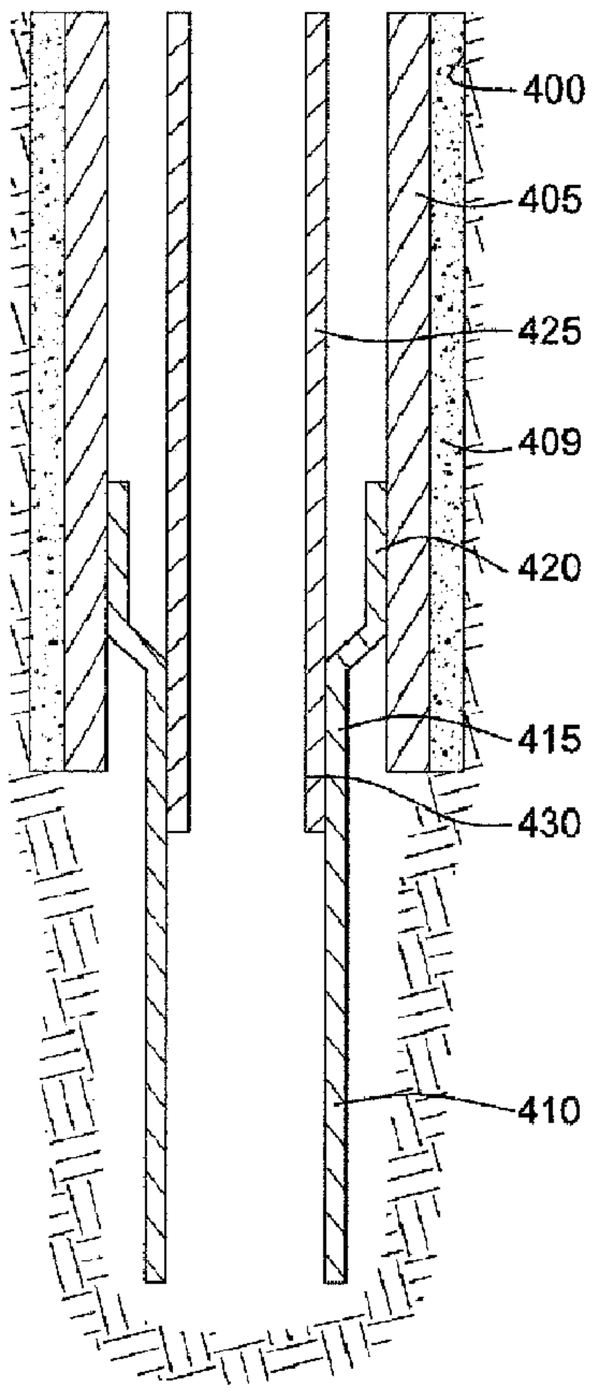
(54) **Titre : RACCORDEMENT PAR EXPANSION DE TIGES DE PRODUCTION DE FOND DE TROU**
(54) **Title: CONNECTION OF DOWNHOLE TUBULARS BY EXPANSION**



(57) **Abrégé/Abstract**:
The present invention provides apparatus and methods for completing a wellbore using expandable tubulars. Particularly, the invention relates to a system of completing a wellbore through the expansion of tubulars. More particularly, embodiments of the present invention relate to the concurrent expansion of a first and second tubular, wherein the first tubular contains a polished bore receptacle configured to sealingly receive a portion of the second tubular thereby providing a sealable connection therebetween.

ABSTRACT OF THE DISCLOSURE

The present invention provides apparatus and methods for completing a wellbore using expandable tubulars. Particularly, the invention relates to a system of completing a wellbore through the expansion of tubulars. More particularly, embodiments of the present invention relate to the concurrent expansion of a first and second tubular, wherein the first tubular contains a polished bore receptacle configured to sealingly receive a portion of the second tubular thereby providing a sealable connection therebetween.

CONNECTION OF DOWNHOLE TUBULARS BY EXPANSION

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to wellbore completion. More particularly, the invention relates to a system of completing a wellbore through the expansion of tubulars. More particularly still, the invention relates to the expansion of one tubular into another to provide a sealable connection therebetween. More particularly still, the invention relates to the concurrent expansion of a first and second tubular, wherein the first tubular contains a polished bore receptacle configured to sealingly receive a portion of the second tubular thereby providing a sealable connection therebetween.

Description of the Related Art

Wellbores are typically formed by drilling and thereafter lining a borehole with steel pipe called casing. The casing provides support to the wellbore and facilitates the isolation of certain areas of the wellbore adjacent hydrocarbon bearing formations. The casing typically extends down the wellbore from the surface of the well and the annular area between the outside of the casing and the borehole in the earth is filled with cement to permanently set the casing in the wellbore.

As the wellbore is drilled to a new depth, additional strings of pipe are run into the well to that depth whereby the upper portion of the string of pipe, or liner, is overlapping the lower portion of the casing. The liner string is then fixed or hung in the wellbore, usually by some mechanical slip means well known in the art.

In some instances wells are completed with the remote perforating of liner to provide a fluid path for hydrocarbons to enter the wellbore where they flow into a screened portion of another smaller tubular or production tubing. In these instances, the wellbore around the tubing is isolated with packers to close the annular area and urge the hydrocarbons into the production tubing. In other completions, the last string of liner extending into the wellbore is itself pre-slotted or perforated to receive and carry hydrocarbons upwards in the wellbore. In these instances, production tubing is usually connected to the top of the liner to serve as a conduit to the surface of the well. In this manner, the liner is "tied back" to the surface of the well. In order to complete these types of wells, the production tubing is inserted in the top of a liner in a sealing relationship usually accomplished by the use of a polish bore receptacle in the liner top. A polish bore receptacle has a smooth cylindrical inner bore designed to receive and seal a tubular having a seal assembly on its lower end. The polish bore receptacle and seal assembly combination allows the production tubing to be "stung" into the liner in a sealing relationship and be selectively removed therefrom.

Emerging technology permits wellbore tubulars to be expanded *in situ*. In addition to simply enlarging a tubular, the technology permits the physical attachment of a smaller tubular to a larger tubular by increasing the outer diameter of a smaller tubular with radial force from within. The expansion can be accomplished by a mandrel or a cone-shaped member urged through the tubular to be expanded or by an expander tool run in on a tubular string.

Figures 1 and 2 are perspective views of an exemplary expander tool **125** and Figure 3 is an exploded view thereof. However, it is understood that other means of expansion known to a person of ordinary skill in the art can be utilized to effectively expand tubulars. The expander tool **125** has a body **102**, which is hollow and generally

tubular with connectors **104** and **106** for connection to other components (not shown) of a downhole assembly. The connectors **104** and **106** are of a reduced diameter (compared to the outside diameter of the longitudinally central body part **108** of the tool **125**), and together with three longitudinal flutes **110** on the central body part **108**, allow the passage of fluids between the outside of the tool **125** and the interior of a tubular therearound (not shown). The central body part **108** has three lands **112** defined between the three flutes **110**, each land **112** being formed with a respective recess **114** to hold a respective roller **116**. Each of the recesses **114** has parallel sides and extends radially from the radially perforated tubular core **115** of the tool **125** to the exterior of the respective land **112**. Each of the mutually identical rollers **116** is near cylindrical and slightly barreled. Each of the rollers **116** is mounted by means of a bearing **118** at each end of the respective roller for rotation about a respective rotational axis, which is parallel to the longitudinal axis of the tool **125** and radially offset therefrom at 120-degree mutual circumferential separations around the central body **108**. The bearings **118** are formed as integral end members of radially slidable pistons **119**, one piston **119** being slidably sealed within each radially extended recess **114**. The inner end of each piston **119** (Figure 2) is exposed to the pressure of fluid within the hollow core of the tool **125** by way of the radial perforations in the tubular core **115**.

By utilizing an expander tool, such as the one described, the upper end of a liner can be expanded into the surrounding casing. In this manner, the conventional slip assembly and its related setting tools are eliminated. In one example, the liner is run into the wellbore on a run-in string with the expander tool disposed in the liner and connected thereto by a temporary connection. As the assembly reaches a predetermined depth whereby the top of the liner is adjacent a lower section of the casing, the expander tool is actuated and then, through rotational and/or axial movement of the actuated expander tool within the liner, the liner wall is expanded past its elastic limits and into contact with the wall of the casing. Rotation of the expander tool is performed by rotating the run-in string or by utilizing a mud motor in the run-in string to transfer fluid power to rotational movement, for example.

While the foregoing method successfully hangs a liner in a casing without the use of slips, there are problems arising with the use of this method where production tubing must be subsequently stung into the top of a liner. One such problem relates to the polish bore receptacle, which is formed in the inner surface of the liner. When the liner is expanded into the inner wall of the casing, the liner, because of the compliant rollers of the expander tool, tends to assume the shape of the casing wall. Because the casing is not perfectly round, the expanded liner is typically not a uniform inner circumference. Further, the inside surface of the liner is necessarily roughened by the movement of the rollers of the expander tool during expansion.

There is a need therefore for an improved method of expanding a first tubular within a wellbore while allowing the first tubular to sealingly engage a second tubular. Furthermore, there is a need for a method of concurrently expanding a first and a second tubular, wherein the first tubular contains a polished bore receptacle configured to sealingly receive a portion of the second tubular thereby providing a sealable connection therebetween.

SUMMARY OF THE INVENTION

The present invention provides apparatus and methods for completing a wellbore using expandable tubulars. According to one embodiment of the present invention, a method of completing a well includes first running a first tubular into a wellbore, wherein the wellbore includes a cased portion. The first tubular is suspended at a selected depth within the wellbore and at least a portion of the first tubular is expanded. A second tubular is run into the wellbore and a portion of the second tubular is located proximate the first tubular, thereby leaving an overlapping area therebetween. At least a portion of the second tubular is also expanded.

According to another embodiment of the present invention, a method of completing a well includes first running a first tubular into a wellbore, wherein the wellbore includes a cased portion. The first tubular is suspended at a selected depth within the wellbore. A second tubular is run into the wellbore and a portion of the second tubular is mated into a portion of the first tubular. The inner diameter of the

mated portion of the first tubular is configured to sealingly receive the outer diameter of the mated portion of the second tubular, thereby creating an overlapping area between the first and second tubulars. A substantial portion of the first and second tubulars including the overlapping area between the first and second tubulars is concurrently expanded.

According to another embodiment of the present invention, a method of completing a well includes first running a first tubular into a wellbore, wherein the wellbore comprises a cased portion. The first tubular is suspended at a selected depth below the cased portion of the wellbore and at least a portion of the first tubular is expanded against an inner surface of the wellbore below the cased portion. A second tubular is run into the wellbore and a portion of the second tubular is located proximate the first tubular, thereby leaving an overlapping area therebetween. At least a portion including the overlapping area of the second tubular is also expanded.

According to another embodiment of the present invention, a method of completing a well includes running a first tubular into a wellbore, wherein the wellbore comprises a cased portion. The first tubular is suspended at a selected depth within the cased portion. A second tubular is then run into the wellbore, wherein the second tubular includes a forming member proximate a lower end thereof. Thereafter, a portion of the first tubular is formed with the forming member, wherein the portion is configured to sealingly receive an outer diameter of the second tubular. The second tubular is subsequently positioned within the formed portion of the first tubular.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

Figure 1 is a perspective view of an expander tool.

Figure 2 is a perspective view of the expander tool.

Figure 3 is an exploded view of the expander tool.

Figures 4A-B provide section views of the present invention according to one embodiment.

Figures 5A-B show section views of the present invention according to another embodiment of the present invention.

Figures 6A-D provide section views of the present invention according to another embodiment of the present invention.

Figures 7A-D provide section views of the present invention according to another embodiment of the present invention.

Figure 8 illustrates another embodiment of the present invention as described in Figures 7A-D.

Figures 9A-D illustrate section views of another embodiment of the present invention.

Figures 10A-B show section views of the invention according to another embodiment.

Figures 11A-D provide section views of the invention according to another embodiment.

Figures 12A-B illustrate section views of the present invention according to another embodiment.

Figure 13A-B provide section views of the present invention according to another embodiment.

Figures 14A-D provide section views of another embodiment of the invention wherein more than one clad is employed within the wellbore.

Figures 15A-C provide section views of the invention according to another embodiment wherein more than one clad is employed within the wellbore.

Figures 16A-B show section views of the invention according to another embodiment wherein a clad is employed within the wellbore.

Figures 17A-B illustrate section views of the invention according to another embodiment wherein a clad is employed within the wellbore.

Figure 18 provides a section view of the invention according to another embodiment wherein more than one clad is employed within the wellbore.

Figures 19A-D provide section views of another embodiment of the invention wherein a PBR is formed by a tubular having an expansion cone at a lower end thereof.

Figures 20A-B provide section views of another embodiment of the invention wherein a PBR is formed by a tubular having an expansion cone at a lower end thereof.

Figures 21A-B provide section views of another embodiment of the invention wherein a PBR is formed by a tubular having an expansion cone at a lower end thereof.

Figures 22A-B provide section views of another embodiment of the invention wherein a tubular is removed from a wellbore and replaced with another tubular.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the present invention generally relate to methods and apparatus for completing a well. Particularly, the invention relates to a system of completing a wellbore through the expansion of tubulars. More particularly, embodiments of the present invention relate to the concurrent expansion of a first and

second tubular, wherein the first tubular contains a polished bore receptacle configured to sealingly receive a portion of the second tubular thereby providing a sealable connection therebetween. As herein defined, the term "polished bore receptacle" refers to a device that is used to locate and seal a first tubular in a second tubular. Additionally, the term "expander tool" is defined as any member that used to expand a tubular, such as the roller expander tool as discussed above, a cone member, hydraulic pressure or any other type of expansion member used in the oil and gas industry.

Embodiments of the invention are described below with terms designating orientation in reference to a vertical wellbore. These terms designating orientation should not be deemed to limit the scope of the invention. Embodiments of the invention can also be used in a non-vertical wellbore, such as a horizontal wellbore.

Figures 4A and 4B provide section views of the present invention according to one embodiment. Figure 4A is a section view of a wellbore **400** having casing **405** along a portion of the walls thereof and cement **409** filling an annular area between the casing **405** and the earth formation. Figure 4A particularly illustrates a section of the wellbore **400** where the casing **405** terminates. Also shown in Figure 4A is an upper portion **420** of a first tubular **410** that has been expanded into contact with the casing **405** by an expander tool (not shown), such as of the type previously described.

The first tubular **410** is set in the casing **405** by positioning the upper portion **420** of the first tubular in an overlapping relationship with the lower portion of the casing **405**, as illustrated in Figure 4A. Thereafter, the expansion tool (not shown) is employed to expand the first tubular **410** at an upper portion **420** towards the casing **405** and into engagement with the casing **405**. The expansion tool is then removed by any means as known to a person of ordinary skill in the art, such as a mechanical connection means that can be remotely disengaged after the expansion process is complete.

After the upper portion **420** of the first tubular **410** is attached to the casing **405**, the expander tool is removed and subsequently, a second tubular member **425** is run into the wellbore **400** with an expansion tool (not shown) disposed therein on a run-in string. A second portion **415** of the tubular **410** disposed below the expanded upper

portion **420** is configured to serve as a polished bore receptacle (PBR). The inner diameter of the PBR **415** is designed to allow the second tubular **425** to line the PBR **415**, wherein the outer diameter of the second tubular **425** is slightly smaller than the inner diameter of the PBR **415**. Accordingly, the second tubular member **425**, which can serve as production tubing, is run into the wellbore **400** until sealably engaging the PBR portion **415** of the first tubular **410**. As illustrated in Figure 4A, the second tubular member **425** has an outside diameter that easily fits within the PBR portion **415** of the first tubular **410**. Proper placement of the second tubular member **425** in the first tubular **410** can be ensured using a profile (not shown) formed on the member with a mating groove formed in the interior of the first tubular **410**. It is understood that a polished bore receptacle could be formed in any portion of the first tubular **410**.

A substantial portion of the second tubular **425** is expanded into contact with the wall of the first tubular **410**, whereby the weight of the second tubular **425** is transferred to the first tubular **410**, as shown in Figure 4B. The frictional force between the second tubular **425** and the PBR **415** is increased by the concurrent expansion of both a substantial portion of the second tubular **425** and the PBR portion **415** of the first tubular **410**. The tubulars **410** and **425** are expanded until the inner diameter of the expanded portion of the second tubular **425** is substantially equal to that of the first tubular **410** below its PBR portion **415**. The expansion of both tubulars **410** and **425** allows the second tubular **425** to be sealably engaged with the first tubular **400** while maintaining a substantially equivalent inner diameter throughout the tubulars **410** and **425**. In this manner, the first tubular **410** is tied back to the surface of the well and hydrocarbons can follow the fluid path formed in the first tubular **410** and in the second tubular member **425**.

As previously described, the tubulars **410** and **425** can be run in with an expander tool on a run in string. A temporary connection is included between the expander tool and the tubulars **410** and **425**, wherein the temporary connection can be a shearable connection or can be some other mechanical or hydraulic arrangement wherein the connection can bear the weight of the tubulars **410** and **425** but can later be remotely disconnected to permit the run in string and expander tool to move

independent of the tubulars **410** and **425**. In one embodiment, the temporary connection is a collet (not shown) with hydraulically actuated release means.

Figures 5A-B provide section views of the present invention according to another embodiment. As shown in Figure 5A, a first tubular **510** is hung along a lower portion of casing **505** by a conventional means, such as a slip mechanism **535**. However, it is understood that other hanging devices well known by a person of ordinary skill in the art can be employed to hang the first tubular. The first tubular **510** is located at a position wherein a portion of the first tubular **510** overlaps a portion of the casing **505**. The first tubular **510** includes a PBR **515** disposed at an upper portion thereof.

As shown in Figure 5A, the PBR **515** of the first tubular **510** is designed to receive a second tubular **525**, which as previously described can be used as production tubing. The outer diameter of the second tubular **525** is designed to line the inner diameter of the PBR **515**. The PBR **515** serves to sealably engage a lower portion **530** of the second tubular **525**. As described in Figures 4A-B, an expander tool (not shown) is used to concurrently expand a substantial portion of the second tubular **525** including the lower portion **530** and the PBR **515** of the first tubular **510**. The PBR **515** is expanded until contacting the inner surface of the casing **505**. The expansion of both tubulars **510** and **525** allows for a substantially constant inner diameter throughout the tubulars **510** and **525**, as shown in Figure 5B. In addition, the simultaneous expansion of tubulars **510** and **525** provides a greater frictional engagement force between the tubulars.

Figures 6A-D provide section views of the present invention according to another embodiment. As shown in Figure 6A, a first tubular or clad **610** is located below a string of casing **605**. In one embodiment, "clad" or "open hole clad" represents a patch or protective layer, such as a tubular, used to clad or cover a section within a wellbore. Accordingly, a clad is generally not attached to the existing casing and is disposed below an existing casing. Clads can be employed within a wellbore to relieve a multitude of adverse downhole conditions, such as to seal fractured reservoirs or perforated sections of the wellbore in which large quantities of water can be produced

from discrete zones. As will be described in further detail, more than one clad may be employed within a wellbore. The clads used in the following embodiments are described as tubular members that effectively cover the desired section; however, it is understood that other clad systems well known to a person of ordinary skill in the art may also be utilized. As described, the clad **610** serves to isolate a particular un-lined section of the wellbore **600**. The clad **610** includes a PBR portion **615** disposed at an upper portion thereof. As previously described, an expander tool (not shown) is used to suspend and expand a substantial portion of the clad **610** including the PBR **615** against the present formation, thereby frictionally engaging the clad **610** to the formation, as illustrated in Figure 6B.

Referring to Figure 6C, a tubular **625** is lowered into the wellbore **600** within the casing **605**. As in previously described embodiments of the invention, the outer diameter of the tubular **625** is designed to line the inner diameter of the PBR **615**. The PBR **615** overlaps a portion of the tubular **625**, thereby forming a seal between the tubular **625** and the clad **610**. As shown, an upper portion **640** of the tubular **625** overlaps but does not make contact with the casing **605**. In order to form a seal between the annular area surrounding the tubular **625** and the casing **605**, an expander tool (not shown) is again employed to expand the upper portion **640** of the tubular **625** into contact with the casing **605**, as shown in Figure 6D. The expanded portion **640** of the tubular **625** can also be designed to function as a PBR to receive subsequent tubing or liners. Since the tubular **625** is sealingly engaged to both the casing **605** and the clad **610**, the tubular **625** serves to isolate or "straddle" the area between the casing **605** and the clad **610**.

Figures 7A-D provide section views of the present invention according to another embodiment of the invention. As in the embodiment of the present invention described by Figures 6A-B, Figure 7A illustrates a first tubular or clad **710** disposed within the wellbore **700** below the casing **705**. An expansion tool (not shown), as previously described, can be used to suspend the clad **710** within the wellbore **700** and to then expand an upper portion **750** and a lower portion **745** of the clad **710** against the

surrounding wellbore **700**. The clad **710** is now frictionally engaged to the wellbore **700**, as shown in Figure 7B.

Referring to Figure 7C, a tubular **725** is run into the wellbore **700** and into a PBR portion **715** of the clad **710**. As in previously described embodiments, the tubular **725** is designed to line the PBR **715**, thereby becoming sealably engaged to the clad **710**. In order to form a seal between the annular area surrounding the tubular **725** and the casing **705**, an expander tool (not shown) is again employed to expand an upper portion **740** of the second tubular **725** into contact with the casing **705**, as shown in Figure 7D. The expanded upper portion **740** of the tubular **725** can also be designed to function as a PBR to receive subsequent tubing or liners. As previously described, the tubular **725** can be used to straddle or isolate the area between the existing clad **710** and the casing **705**.

In another embodiment, a substantial portion of the tubular **725** and the PBR **715** can be concurrently expanded until the PBR **715** of the tubular **725** contacts the wellbore **700**, as shown in Figure 8. As previously described, the simultaneous expansion of the tubular **725** and the PBR **715** serve to increase the frictional engagement between the two and to increase the inner diameter of the tubular **725**. An upper portion **740** of the tubular **725** is also expanded into contact with the casing **705** so as to create a sealed area between the wellbore **700** and the tubular **725**. The upper portion **740** of the tubular **725** can also be configured to function as a PBR.

Several additional embodiments of the present invention for expanding tubulars and/or clads within a wellbore are described in detail below. The following embodiments are only a selection of exemplary embodiments that can be adopted in accordance with aspects of the present invention. It is, therefore, understood, that other equally effective embodiments may be used in accordance with the present invention.

Figures 9A-D illustrate section views of another embodiment of the present invention. As shown in Figure 9A, a first tubular **910** is run into the wellbore **900** to a position wherein an upper portion **920** of the first tubular **910** overlaps a bottom portion of an existing casing **905**. As previously described, the first tubular **910** can be run into

the wellbore **900** using a run-in sting (not shown) having an expander tool disposed within the first tubular **910** and used to support the first tubular. The expander tool is then used to expand an upper portion **920** of the first tubular **910** into contact with the casing **905**. The expansion of the first tubular **910** allows the first tubular **910** to become frictionally engaged with the casing **905**, thereby transferring the weight of the first tubular **910** to the casing **905**, as shown in Figure 9B. The expander tool is then again employed to expand a second portion **915** of the first tubular **910**. As shown in Figure 9C, the second portion **915** is disposed below the previously expanded upper portion **920** and is not expanded into contact with casing **905**. More particularly, the second expanded portion **915** is expanded to receive a second tubular **925** of a substantially equal inner diameter to the unexpanded portion of the first tubular **910** below the first and second expanded portions, **920** and **915**, respectively. In one embodiment, the second expanded portion **915** is designed to function as a polished bore receptacle for sealably receiving the second tubular **925**, as shown in Figure 9D.

Another embodiment of the present invention is illustrated in Figures 10A-B. As in the embodiment described by Figures 9A-D, an upper portion **1020** of a first tubular **1010** is expanded into frictional engagement with an existing casing **1005**. Once the first tubular **1010** has been set within the wellbore **1000**, a second tubular **1025** is run into the wellbore **1000** and hung in a location wherein a bottom portion of the second tubular **1025** overlaps a portion of the expanded portion **1020** of the first tubular **1010**. Initially, the second tubular **1025** is not in contact with the casing **1005** or the first tubular **1010**, as shown in Figure 10A. A substantial portion of the second tubular **1010** is then expanded into contact with the expanded upper portion **1020** of the first tubular **1010**. In one embodiment, the expanded portion **1020** includes a PBR portion **1015** for sealingly receiving the second tubular **1025**, as shown in Figure 10B. The engagement of the second tubular **1025** with the expanded portion **1020** of the first tubular **1010** forms a substantially constant diameter throughout the two tubulars **1010**, **1025**.

Figures 11A-D provide section views of the invention according to another embodiment. As in Figure 9A, Figure 11A illustrates a first tubular **1110** being suspending in an overlapping position with casing **1105**. As previously described, the

first tubular **1110** may be suspended by a run in string or other means well known in the art. An expander tool (not shown) is disposed within the first tubular **1110** and is used to expand a substantial portion of the first tubular **1110** to a constant diameter wherein an upper portion **1120** of the first tubular **1110** is placed in contact with the casing **1105**, as shown in Figure 11B. The weight of the first tubular **1110** is now completely transferred to the casing **1105** and the frictional force between the casing **1105** and the upper portion **1120** of the first tubular **1110** provides the necessary force to effectively suspend the first tubular **1110** within the wellbore **1100**.

As shown in Figure 11C, a second tubular **1125** is run into the wellbore **1100** and suspended in an overlapping position with the first tubular **1110** and the casing **1105**. Initially, the second tubular **1125** is not in contact with the casing **1105** or the first tubular **1110.** An expander tool (not shown) is used to expand a substantial portion of the second tubular **1125**. The second tubular **1125** is expanded until a lower portion **1130** of the second tubular contacts the upper portion **1120** of the first tubular **1110**, as shown in Figure 11D. In one embodiment, the upper portion **1120** of the first tubular **1110** includes a PBR **1115** to effectively receive and seal a lower portion **1130** of the second tubular.

Figures 12A-B illustrate section views of the present invention according to another embodiment. As in Figures 6A-B, a clad **1210** has been frictionally engaged against an unlined portion of the wellbore **1200** below an existing casing **1205**. A tubular **1225** is then run into the wellbore **1200** and suspended in an overlapping position with both the casing **1205** and the clad **1210**. As shown in Figure 12A, the entire tubular **1225** is then expanded until a lower portion **1230** of the tubular **1225** contacts the inner diameter of the clad **1210**. In one embodiment, an upper portion of the clad **1210**, which is placed in contact with the lower portion **1230** of the tubular **1225**, includes a PBR **1215** to receive the tubular **1225** and form a seal between the tubular **1225** and the clad **1205**. An upper portion **1240** of the tubular **1225** is then expanded into contact with the casing **1205**. The tubular **1225** now functions as a straddle to isolate the unlined area between the clad **1210** and casing **1205**, as shown

in Figure 12B. The inner diameter of the expanded upper portion **1240** of the tubular **1225** can also be designed to function as a PBR to receive subsequent tubing or liners.

Figures 13A-B provide section views of the present invention according to another embodiment. As in Figures 7A-B, Figure 13A illustrates a clad **1310** having been expanded at an upper portion **1350** and a lower portion **1345** thereof against an unlined section of the wellbore **1300**. A tubular **1325** is then suspended in an overlapping position with both the casing **1305** and the clad **1310**. Initially, the tubular **1325** is not in contact with the casing **1305** or the clad **1310**. An expander tool (not shown) is used to expand a substantial portion of the tubular until a lower portion **1330** of the tubular **1325** is engaged against the non-expanded portion of the clad **1310**. In one embodiment, the non-expanded portion of the clad **1310** includes a PBR portion **1315** for effectively receiving the tubular **1325** and forming a seal between the tubular **1325** and the clad **1310**. An upper portion **1340** of the tubular **1325**, which overlaps a bottom portion of the casing **1305**, is expanded against the casing, as shown in Figure 13B. As previously described, the tubular **1305** functions as a straddle to isolate the unlined area between the casing **1325** and the clad **1310**. As in previous embodiments, the inner diameter of the expanded upper portion **1340** of the tubular **1325** can also be designed to function as a PBR to receive subsequent tubing or liners.

Figures 14A-D provide section views of another embodiment of the invention wherein more than one clad is employed within a wellbore. As shown in Figure 14A, a first clad **1410** has been inserted within the wellbore **1400** and expanded against an unlined portion of the wellbore **1400** below an existing casing **1405**. A second clad **1470** is then run into the wellbore **1400** passed the casing **1405** and suspended at a location below the first clad **1410**. As with the first clad **1410**, the second clad is expanded into frictional engagement with an unlined section of the wellbore **1400**, as shown in Figure 14B.

A tubular **1425** is run into the wellbore **1400** and suspended wherein an upper portion **1430** of the tubular **1425** overlaps a portion of the first clad **1410** and a lower portion **1480** of the tubular **1425** overlaps a portion of the second clad **1470**. As shown

in Figure 14C, the tubular **1425** is not initially in contact with either of the clads **1410**, **1470**. The entire length of the tubular **1425** is then expanded until the upper portion **1430** of the first tubular **1425** contacts the first clad **1410** and the lower portion **1480** of the tubular **1425** contacts the second clad **1470**. In one embodiment, the first clad **1410** includes a PBR portion **1415** disposed at a lower end thereof, and the second clad **1470** includes a PBR portion **1475** disposed at an upper end thereof. The polished bore receptacles **1415** and **1475** are designed to effectively receive and seal the upper and lower portions **1430** and **1480**, respectively, of the tubular **1425**. As shown in Figure 14D, the tubular **1425** functions to isolate the area between the two clads **1410**, **1470**. The tubular **1425** can include a PBR disposed on a portion of the inner diameter designed to receive subsequent tubulars or liners.

Figures 15A-C provide section views of the invention according to another embodiment. In a similar fashion as the embodiment described with respect to Figures 14A-D, the present embodiment involves the use of two or more clads. As shown in Figure 15A, a first clad **1510** is disposed below an existing casing **1505** and is frictionally engaged to an unlined section of the wellbore **1500**. A second clad **1570** is disposed below the first clad and expanded only at an upper portion **1550** and a lower portion **1545**, as shown in Figure 15A.

Referring to Figure 15B, a tubular **1525** is run into the wellbore **1500**. The second clad **1570** includes a PBR **1575** disposed between the expanded portions **1550**, **1545** of the second clad **1570**. As in previously described embodiments, the tubular **1525** is designed to line the PBR **1575**, thereby becoming sealably engaged to the clad **1510**. An expander tool (not shown) is again employed to expand an upper portion **1540** of the tubular **1525** into contact with a lower portion **1515** of the first clad **1510**, as shown in Figure 15C. A portion of the inner diameter of the tubular **1525** can also be designed to function as a PBR to receive subsequent tubing or liners. As previously described, the tubular **1525** functions to straddle or isolate the unlined area between the first clad **1510** and the second clad **1570**.

Figures 16A-B provide section views of the present invention according to another embodiment. As in Figures 6A-B, Figure 16A illustrates a first tubular or clad **1610** located below a string of casing **1605**. The clad **1610** includes a PBR portion **1615** disposed at an upper portion thereof. As previously described, an expander tool (not shown) is used to suspend and expand a substantial portion of the clad **1610** including the PBR **1615** against the present formation, thereby frictionally engaging the clad **1610** to the formation, as shown in Figure 16A. A tubular **1625** is lowered into the wellbore **1600** within the casing **1605**. As in previously described embodiments of the invention, the outer diameter of the tubular **1625** is designed to line the inner diameter of the PBR **1615**. The PBR **1615** overlaps a portion of the tubular **1625**, thereby forming a seal between the tubular **1625** and the clad **1610**. As shown, an upper portion **1640** of the tubular **1625** is hung along a lower portion of casing **1605** by a conventional means, such as a slip mechanism **1635**. However, it is understood that other hanging devices well known by a person of ordinary skill in the art can be employed to hang the tubular **1625**.

Figures 17A-B provide section views of the present invention according to another embodiment of the invention. As in the embodiment of the present invention described by Figures 7A-C, Figures 17A-B illustrate a first tubular or clad **1710** disposed within the wellbore **1700** below the casing **1705**. An expansion tool (not shown) is used to suspend the clad **1710** within the wellbore **1700** and to then expand an upper portion **1750** and a lower portion **1745** of the clad **1710** against the surrounding wellbore **1700**, as shown in Figure 17B. A tubular **1725** is then run into the wellbore **1700** and into a PBR portion **1715** of the clad **1710**. As in previously described embodiments, the tubular **1725** is designed to line the PBR **1715**, thereby becoming sealably engaged to the clad **1710**. As shown, an upper portion **1740** of the tubular **1725** is hung along a lower portion of casing **1705** by a conventional means, such as a slip mechanism **1735**. However, it is understood that other hanging devices well known by a person of ordinary skill in the art can be employed to hang the tubular **1725**.

Figure 18 provides a section view of the invention according to another embodiment. In a similar fashion as the embodiment described with respect to Figures

15A-B, the present embodiment involves the use of two or more clads. As shown in Figure 18, a first clad **1810** is disposed below an existing casing **1805** and is frictionally engaged to an unlined section of the wellbore **1800**. A second clad **1870** is disposed below the first clad and expanded only at an upper portion **1850** and a lower portion **1845**. A tubular **1825** is run into the wellbore **1800**. The second clad **1870** includes a PBR **1875** disposed between the expanded portions **1850**, **1845**. As in previously described embodiments, the tubular **1825** is designed to line the PBR **1815**, thereby becoming sealably engaged to the clad **1810**. An upper portion **1840** of the tubular **1825** is hung along a lower portion of casing **1805** by a conventional means, such as a slip mechanism **1835**, as shown in Figure 18. However, it is understood that other hanging devices well known by a person of ordinary skill in the art can be employed to hang the tubular **1825**.

The forgoing embodiments illustrated in Figures 7A-D, 12A-B, 13A-B, 14A-D, 15A-C, 16A-B, 17A-B and 18 may be employed in a monobore well type application, wherein the open hole diameter is drilled or under-reamed to a diameter greater than the nominal diameter of the casing string.

Several additional embodiments of the present invention for expanding tubulars with an expansion cone are described in detail below. The following embodiments are only a selection of exemplary embodiments that can be adopted in accordance with aspects of the present invention. It is, therefore, understood, that other equally effective embodiments may be used in accordance with the present invention.

Figures 19A-D provide section views of the present invention according to another embodiment. As shown in Figure 19A, a first tubular **1910** is hung along a lower portion of casing **1905** by a conventional means, such as a slip mechanism **1935** or an expandable hanger. However, it is understood that other hanging devices well known by a person of ordinary skill in the art can be employed to hang the first tubular **1910**. The first tubular **1910** is located at a position wherein a portion of the first tubular **1910** overlaps a portion of the casing **1905**.

As shown in Figure 19B, a second tubular **1925**, which as previously described can be used as a production tubular, is lowered into a wellbore **1900** in the direction indicated by arrow **1945** by a conventional means, such as on a run-in string (not shown). Proximate the lower end of the second tubular 1925 is a shaped forming member or an expansion cone **1950** which is used to form a PBR at the upper end of the first tubular **1910.** In one embodiment, the shaped expansion cone **1950** is designed to produce near-zero or negative surplus expansion as the second tubular **1925** is stabbed into the first tubular **1910.**

Positioned above the expansion cone **1950** is a plurality of seal sets **1955** which subsequently forms a sealing relationship between the first tubular **1910** and the second tubular **1925.** As further shown in Figure 19B, an anchor member **1960**, such as a ratchet, is disposed above the seal sets **1955** to secure the second tubular **1925** in the first tubular **1910**. It should be noted, however, the anchor member **1960** is an optional part of the second tubular **1925** and the second tubular **1925** may be employed without the use of the anchor member **1960** without departing from principles of the present invention. Additionally, it should be noted that the location of the seal sets **1955** in relation to the anchor member **1960** is not limited to the arrangement illustrated in this embodiment or any other embodiment. Rather, the seal sets **1955** may be disposed on the second tubular **1925** above and/or below the anchor member **1960** without departing from principles of the present invention. Further, the expansion cone **1950** may be a separate piece operatively attached to the second tubular **1925** or be formed integral with the second tubular **1925** without departing from principles of the present invention.

As illustrated in Figure 19C, a PBR **1915** is formed as the second tubular **1925** is stabbed into the first tubular **1910**. In a similar manner as previously discussed, the PBR 1915 is designed to allow the second tubular **1925** to line the PBR **1915** to form a sealing relationship with the first tubular **1910.** However, in this embodiment, the PBR **1915** is formed by the expansion cone **1950** as the second tubular **1925** is urged into the first tubular **1910** in the direction indicated by the arrow **1945**. As shown in

Figure 19D, the second tubular **1925** continues to be urged into the first tubular **1910** until the anchor member **1960** grips an inner diameter of the first tubular **1910**.

Figures 20A-B provide section views of the present invention according to another embodiment. As shown in Figure 20A, a first tubular **2010** is hung along a lower portion of casing **2005** by a conventional means, such as a slip mechanism **2035** or an expandable hanger. However, it is understood that other hanging devices well known by a person of ordinary skill in the art can be employed to hang the first tubular **2010**. The first tubular **2010** is located at a position wherein a portion of the first tubular **2010** overlaps a portion of the casing **2005**. The first tubular **2010** includes a modified portion **2030** at the upper end thereof, such as a flare or taper to accommodate a second tubular **2025**.

The second tubular **2025**, which as previously described can be used as a production tubular, is lowered into a wellbore **2000** in the direction indicated by arrow **2045** by a conventional means, such as on a run-in string (not shown). In a similar manner as in the embodiment described by Figures 19A-D, the second tubular **2025** includes an expansion cone **2050** to form a PBR proximate the upper end of the first tubular **2010.** The second tubular **2025** also includes a plurality of seal sets **2055** and an anchor member **2060**.

As illustrated in Figure 20B, a PBR **2015** is formed as the second tubular **2025** is stabbed into the first tubular **2010**. In a similar manner as previously discussed, the PBR **2015** is formed by the expansion cone **2050** as the second tubular **2025** is urged into the first tubular **2010**. However, in this embodiment, the PBR **2015** is formed to create a monobore tieback. The monobore tieback allows the first tubular **2010** and the second tubular **2025** to have approximately the same diameter along their length, causing the path for fluid flow through the tubulars **2010**, **2025** to remain substantially consistent along their length.

Figures 21A-B illustrate section views of another embodiment of the present invention. As shown in Figure 21A, a first tubular **2110** is run into the wellbore **2100** to a position wherein an upper portion **2120** of the first tubular **2110** overlaps a bottom

portion of an existing casing **2105**. As previously described, the first tubular **2110** can be run into the wellbore **2100** using a run-in sting (not shown) having an expander tool (not shown) disposed within the first tubular **2110** and used to support the first tubular **2110**. The expander tool is then used to expand an upper portion **2120** of the first tubular **2110** into contact with the casing **2105**. The expansion of the first tubular **2110** allows the first tubular **2110** to become frictionally engaged with the casing **2105**, thereby transferring the weight of the first tubular **2110** to the casing **2105**. Thereafter, a second tubular **2125**, which as previously described can be used as a production tubular, is lowered into a wellbore **2100** in the direction indicated by arrow **2145** by a conventional means, such as on a run-in string (not shown). In a similar manner as in the embodiment described by Figures 19A-D, the second tubular **2125** includes an expansion cone **2150,** a plurality of seal sets **2155** and an anchor member **2160**. The PBR **2015** is formed by the expansion cone **2050** as the second tubular **2025** is urged into the first tubular **2010,** as illustrated in Figure 21B. It should be further noted, that this embodiment may also be configured to form monobore tieback in a similar manner as discussed in Figures 20A-B.

Figures 22A-B illustrate section views of another embodiment of the present invention. As shown in Figure 22A, a first tubular **2210** is hung along a lower portion of casing **2205** by a conventional means, such as a slip mechanism **2235** or an expandable hanger. The first tubular **2210** is located at a position wherein a portion of the first tubular **2210** overlaps a portion of the casing **2205**. Thereafter, a second tubular **2225**, which as previously described can be used as a production tubular, is lowered into a wellbore **2200** by a conventional means, such as on a run-in string (not shown). Similar to other embodiments, the second tubular **2225** includes an expansion cone **2250**, a plurality of seal sets **2255** and an anchor member **2260**. Subsequently, a first PBR **2215** is formed by the expansion cone **2250** as the second tubular **2225** is urged into the first tubular **2210**. The second tubular **2225** remains in contact with the first tubular **2210** until the second tubular **2225** is to be removed from the wellbore **2200**. At that point, the second tubular **2225** is pulled upward in the direction indicated by arrow **2245**. The movement of the second tubular **2225** releases the anchor member **2260** and subsequently the second tubular **2225** is pulled from the wellbore **2200**.

Thereafter, a third tubular **2275** having an expansion cone **2280,** a plurality of seal sets **2285** and an anchor member **2290** may be introduced into the wellbore **2200** in the direction indicated by arrow **2270**. In a similar manner as previously discussed the third tubular **2275** forms a second PBR **2295** proximate the lower end of the first PBR **2215**. In this respect, the tubular member **2225** may be removed from the PBR **2215** and replaced with another tubular member **2275** that forms another PBR **2295** without necessitating the installation of an intermediate packer or a straddle to ensure a seal between the first tubular **2210** and the new tubular **2275**. It is within the scope of the present invention that this sequence of steps may be repeated as many times as required.

While the tubular members and clads are described as being run into the wellbore on a run in string of tubulars, it will be understood that the apparatus of the invention can be transported into the wellbore using any number of means including coiled tubing and electrical wire as well as any other means as known by a person of ordinary skill in the art.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims:

1. A method of completing a well comprising:

running a first tubular into a wellbore, wherein the wellbore comprises a cased portion;

suspending the first tubular at a selected depth within the wellbore;

expanding at least a portion of the first tubular;

running a second tubular into the wellbore;

locating a portion of the second tubular proximate the first tubular, leaving an overlapping area therebetween; and

expanding at least a portion of the second tubular; and

wherein the overlapping portion of the first tubular includes a polished bore receptacle.

2. The method of claim 1, wherein a portion of the second tubular is mated into a portion of the first tubular, the inner diameter of the mated portion of the first tubular being configured to sealingly receive the outer diameter of the second tubular.

3. The method of claim 2, wherein a substantial portion of the first and second tubulars are concurrently expanded including the overlapping area between the first and second tubulars.

4. The method of claim 1, wherein the second tubular is production tubing.

5. The method of claim 1, wherein the first and second tubulars are expanded by an outward radial force applied on an inner wall thereof.

6. The method of claim 1, wherein the first and second tubulars are expanded with an expander tool having at least one outwardly actuatable, member disposed thereon.

7. The method of claim 1, wherein the first tubular is suspended within the cased portion of the wellbore by expanding an upper portion of the first tubular into contact

with the cased portion, thereby frictionally engaging the first tubular within the cased portion of the wellbore.

8. The method of claim 1, wherein the first tubular is suspended within the cased wellbore by the use of slips.

9. The method of claim 1, wherein the first tubular is suspended below the cased portion of the wellbore by expanding at least a portion of the first tubular into contact with an unlined portion of the wellbore.

10. The method of claim 9, wherein the overlapping portion of the first tubular is expanded against an unlined portion of the wellbore.

11. The method of claim 10, wherein the first tubular is a clad.

12. The method of claim 3, wherein an expanded portion of the second tubular is expanded until the inner diameter of the second tubular is substantially equal to the inner diameter of an unexpanded portion of the first tubular.

13. The method of claim 9, wherein an upper portion of the second tubular overlaps and is expanded against the cased portion of the wellbore, thereby isolating an unlined portion of the wellbore between the first tubular and the cased portion of the wellbore.

14. A method of completing a well comprising:

running a first tubular into a wellbore, wherein the wellbore comprises a cased portion;

suspending the first tubular at a selected depth within the wellbore;

running a second tubular into the wellbore;

mating a portion of the second tubular into a portion of the first tubular, the inner diameter of the mated portion of the first tubular being configured to sealingly receive

the outer diameter of the second tubular, thereby creating an overlapping area between the first and second tubulars; and

concurrently expanding a substantial portion of the first and second tubulars including the overlapping area between the first and second tubulars.

15. The method of claim 14, wherein the second tubular is production tubing.

16. The method of claim 14, wherein the first tubular is suspended within the cased portion of the wellbore by expanding the upper portion of the first tubular into contact with the cased portion, thereby frictionally engaging the first tubular within the cased portion of the wellbore.

17. The method of claim 14, wherein the first tubular is suspended within the cased wellbore by the use of slips.

18. The method of claim 14, wherein the first tubular is suspended below the cased portion of the wellbore by expanding at least a portion of the first tubular into contact with an unlined portion of the wellbore.

19. The method of claim 18, wherein the overlapping portion of the first tubular is expanded against an unlined portion of the wellbore.

20. The method of claim 19, wherein the first tubular is a clad.

21. The method of claim 14, wherein an expanded portion of the second tubular is expanded until the inner diameter of the second tubular is substantially equal to the inner diameter of an unexpanded portion of the first tubular.

22. The method of claim 14, wherein the overlapping portion of the first tubular includes a polished bore receptacle.

23. The method of claim 18, wherein an upper portion of the second tubular overlaps and is expanded against the cased portion of the wellbore, thereby isolating an unlined portion of the wellbore between the first tubular and the cased portion of the wellbore.

24. A method of completing a well comprising:

running a first tubular into a wellbore, wherein the wellbore comprises a cased portion;

suspending the first tubular at a selected depth below the cased portion of the wellbore;

expanding at least a portion of the first tubular against an inner surface of the wellbore below the cased portion;

running a second tubular into the wellbore; and

locating a portion of the second tubular proximate the first tubular, leaving an overlapping area therebetween.

25. The method of claim 24, wherein at least a portion of the second tubular is expanded.

26. The method of claim 25, wherein a portion of the second tubular is mated into a portion of the first tubular, the inner diameter of the mated portion of the first tubular being configured to sealingly receive the outer diameter of the second tubular.

27. The method of claim 26, wherein a substantial portion of the first and second tubulars are concurrently expanded including the overlapping area between the first and second tubulars.

28. The method of claim 24, wherein the first tubular is a clad.

29. The method of claim 25, wherein an expanded portion of the second tubular is expanded until the inner diameter of the second tubular is substantially equal to the inner diameter of an unexpanded portion of the first tubular.

30. The method of claim 26, wherein the overlapping portion of the first tubular includes a polished bore receptacle.

31. The method of claim 25, wherein an upper portion of the second tubular overlaps and is expanded against the cased portion of the wellbore, thereby isolating an unlined portion of the wellbore between the first tubular and the cased portion of the wellbore.

32. The method of claim 25, wherein a third tubular is run into the wellbore and disposed between the cased portion of the wellbore and the second tubular.

33. The method of claim 32, wherein at least a portion of the third tubular is expanded against the unlined portion of the wellbore.

34. The method of claim 33, wherein an upper portion of the second tubular overlaps and is expanded against a portion of the third tubular, thereby isolating an unlined portion of the wellbore between the first tubular and the third tubular.

35. The method of claim 34, wherein the third tubular is a clad.

36. The method of claim 24, wherein the second tubular is suspended within the cased wellbore by the use of a slip mechanism.

37. The method of claim 34, wherein the second tubular is hung from the third tubular by the use of a slip mechanism.

38. A method of completing a well comprising:

running a first tubular into a wellbore, wherein the wellbore comprises a preinstalled cased portion;

suspending the first tubular at a selected depth within the wellbore;

expanding at least a first portion of the first tubular against an inner surface of the preinstalled cased portion of the wellbore;

running a second tubular into the wellbore; and

mating a portion of the second tubular into an expanded portion of the first tubular, the inner diameter of the expanded portion of the first tubular being configured to sealingly receive the outer diameter of the second tubular, thereby creating an overlapping area between the first and second tubulars and the cased portion.

39. The method of claim 38, wherein a second portion of the first tubular is expanded below the first portion until the inner diameter of the second portion of the first tubular is substantially equal to the outer diameter of an unexpanded portion of the first tubular.

40. A method of completing a well comprising:

running a first tubular into a wellbore, wherein the wellbore comprises a cased portion;

suspending the first tubular at a selected depth within the cased portion;

running a second tubular into the wellbore, the second tubular having a forming member proximate a lower end thereof;

then, forming a portion of the first tubular with the forming member, the portion configured to sealingly receive an outer diameter of the second tubular; and

positioning the second tubular into the formed portion of the first tubular.

41. The method of claim 40, further including sealing an overlapping portion between the first tubular and the second tubular.

42. The method of claim 40, further including anchoring the second tubular in the first tubular.

43. The method of claim 40, wherein the forming member is an expansion cone.

44. The method of claim 40, further including removing the second tubular from the formed portion of the first tubular.

45. The method of claim 44, further including running a third tubular into the wellbore.

46. The method of claim 45, further including forming a second portion of the first tubular, the second portion is configured to sealingly receive an outer diameter of the third tubular.

47. The method of claim 46, further including positioning the third tubular into the second formed portion of the first tubular.

48. The method of claim 40, wherein an inner diameter of the second tubular is substantially equal to an inner diameter of the first tubular.

49. A tubular assembly for forming an anchor and/or seal receiving surface in a downhole tubular, the tubular assembly comprising:

a tubular member;

a cone member disposed on the tubular member proximate a lower end thereof, the cone member constructed and arranged to radially expand the downhole tubular to form the anchor and/or seal receiving surface in the downhole tubular; and

a seal member disposed on the tubular member.

50. The tubular assembly of claim 49, further including an anchor member to secure the tubular assembly in the downhole tubular.

51. The tubular assembly of claim 49, wherein the upper portion of the tubular is configured to receive a second cone member of a substantially identical tubular.

52. The tubular assembly of claim 49, wherein a hanging member is used to hang a tubular to a portion of casing.

53. The tubular assembly of claim 51, wherein the substantially identical tubular is dimensionally similar to the first tubular assembly.

54. The tubular assembly of claim 49, wherein the seal receiving surface comprises a polished bore receptacle.

55. The tubular assembly of claim 49, wherein the cone member comprises a radius.

56. The tubular assembly of claim 52, wherein the hanging member is a slip mechanism or an expandable hanger.

57. The tubular assembly of claim 51, wherein the configuration of the tubular to receive a second tubular comprises a flare or taper.

58. A method of completing a well comprising:

running a first tubular into a wellbore, wherein the wellbore comprises a cased portion;

suspending the first tubular at a selected depth within the cased portion;

running a second tubular into the wellbore, the second tubular having a forming member proximate a lower end thereof;

forming a portion of the first tubular with the forming member while the forming member is coupled to the second tubular member, the portion configured to sealingly receive an outer diameter of the second tubular; and

positioning the second tubular into the formed portion of the first tubular.

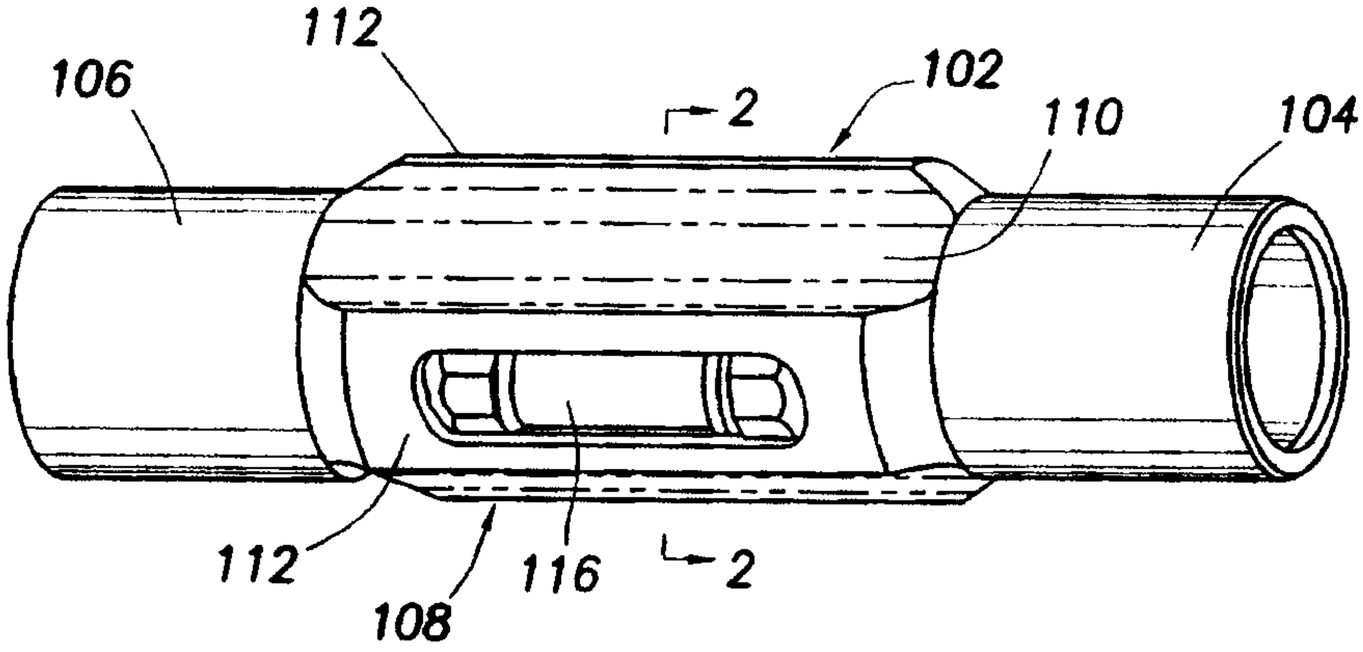


FIG. 1
(PRIOR ART)

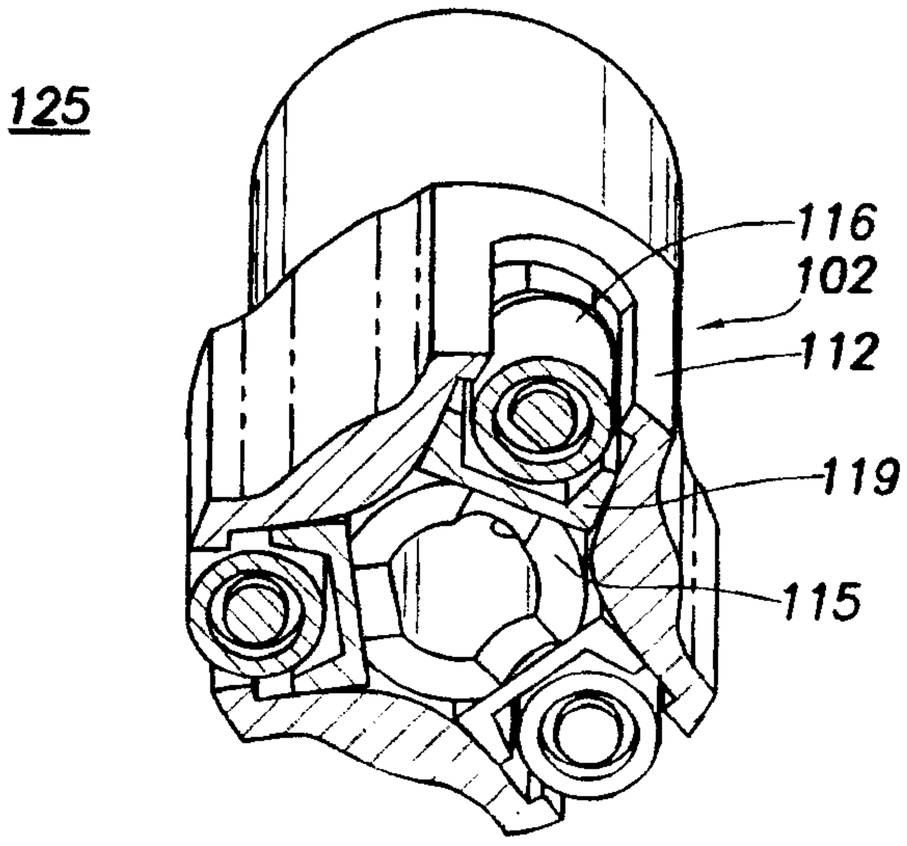


FIG. 2
(PRIOR ART)

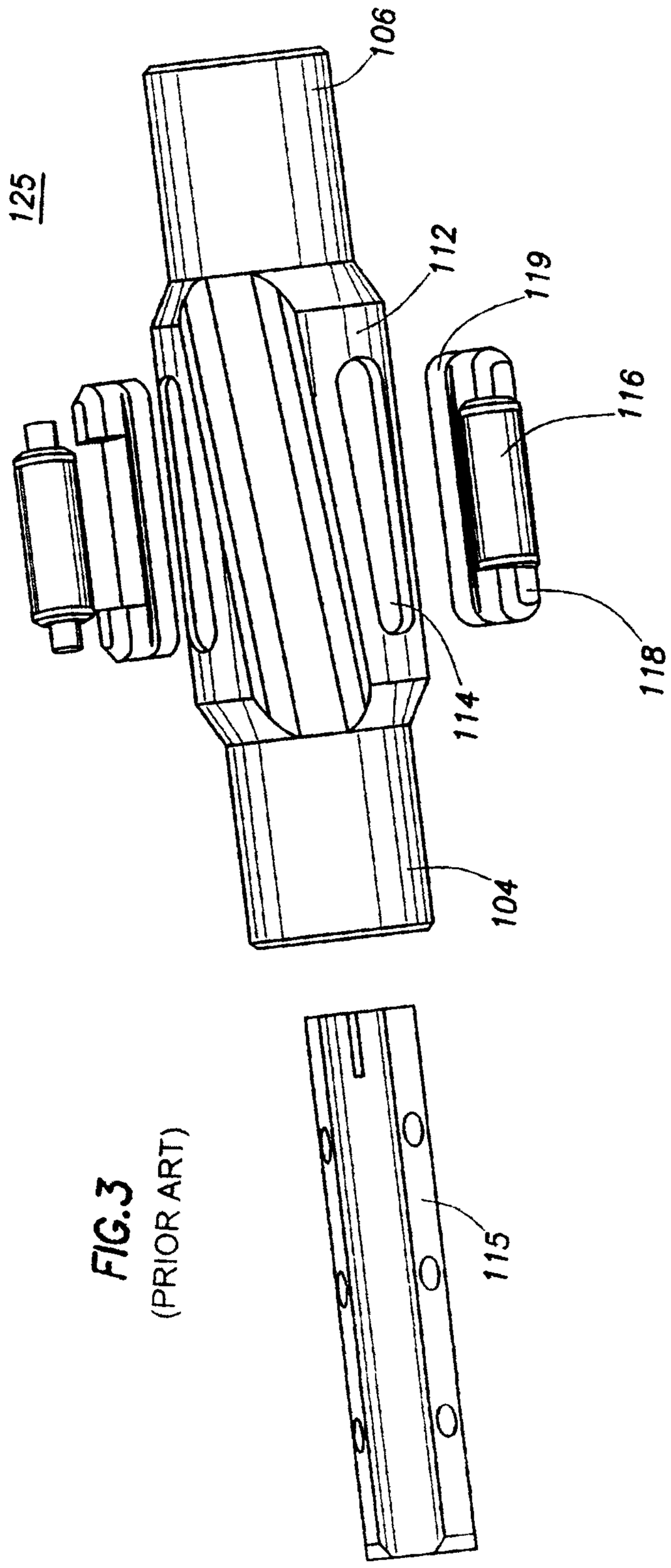


FIG.3
(PRIOR ART)

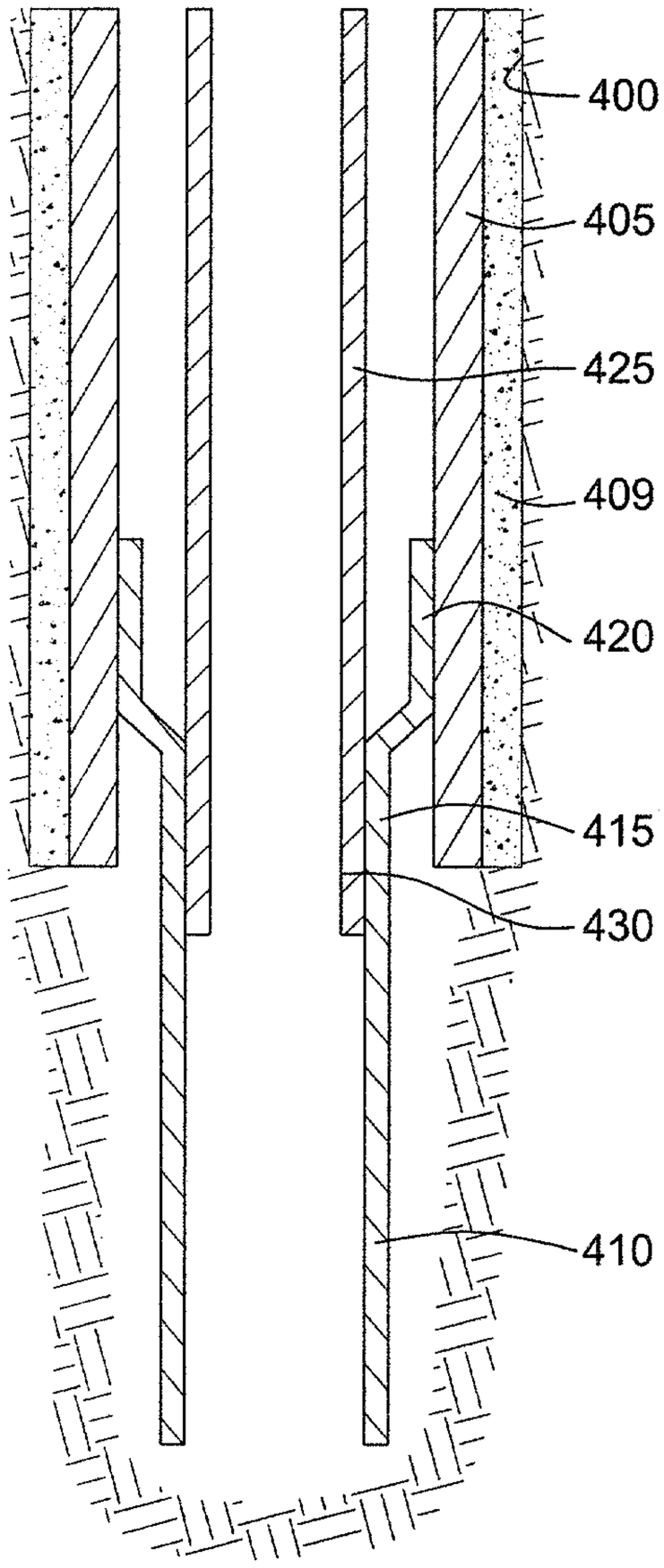


FIG. 4A

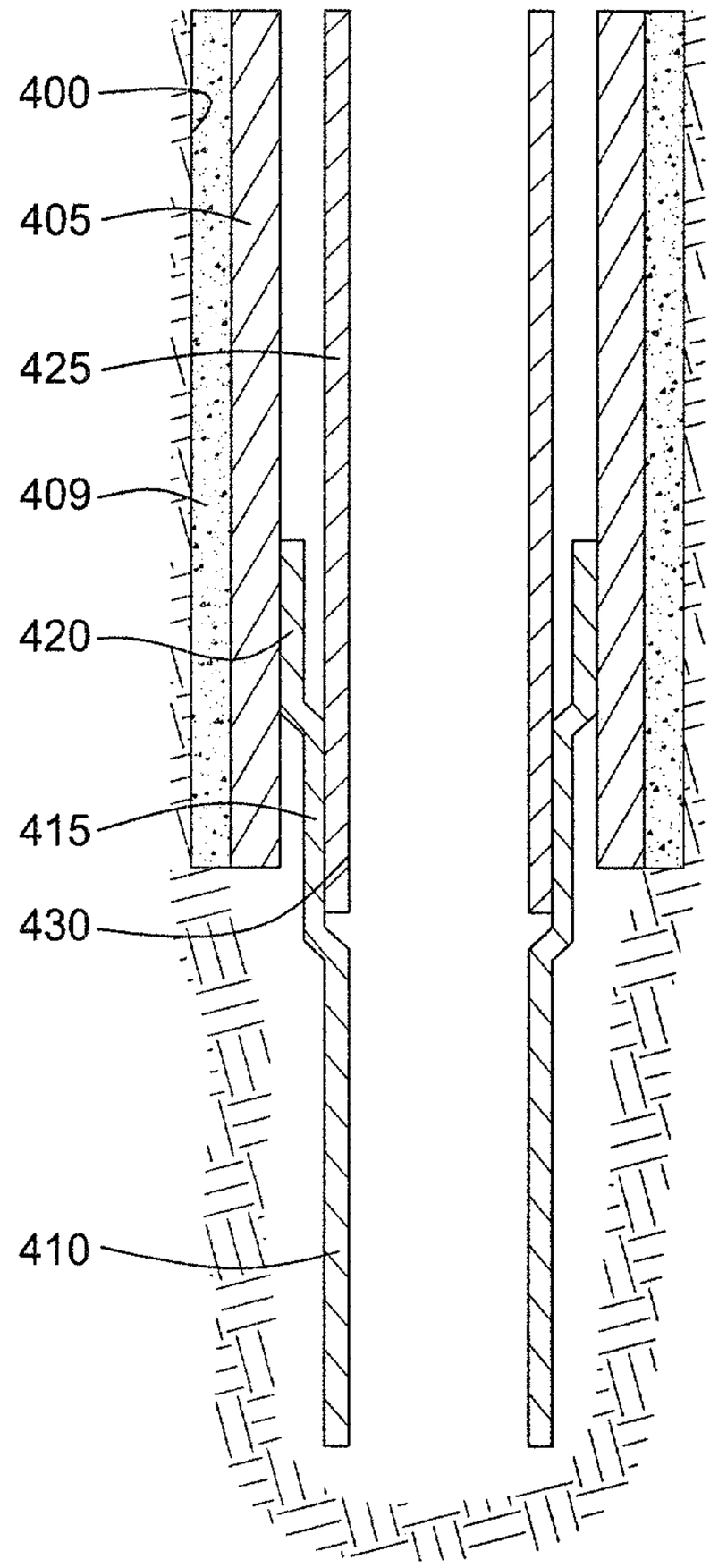


FIG. 4B

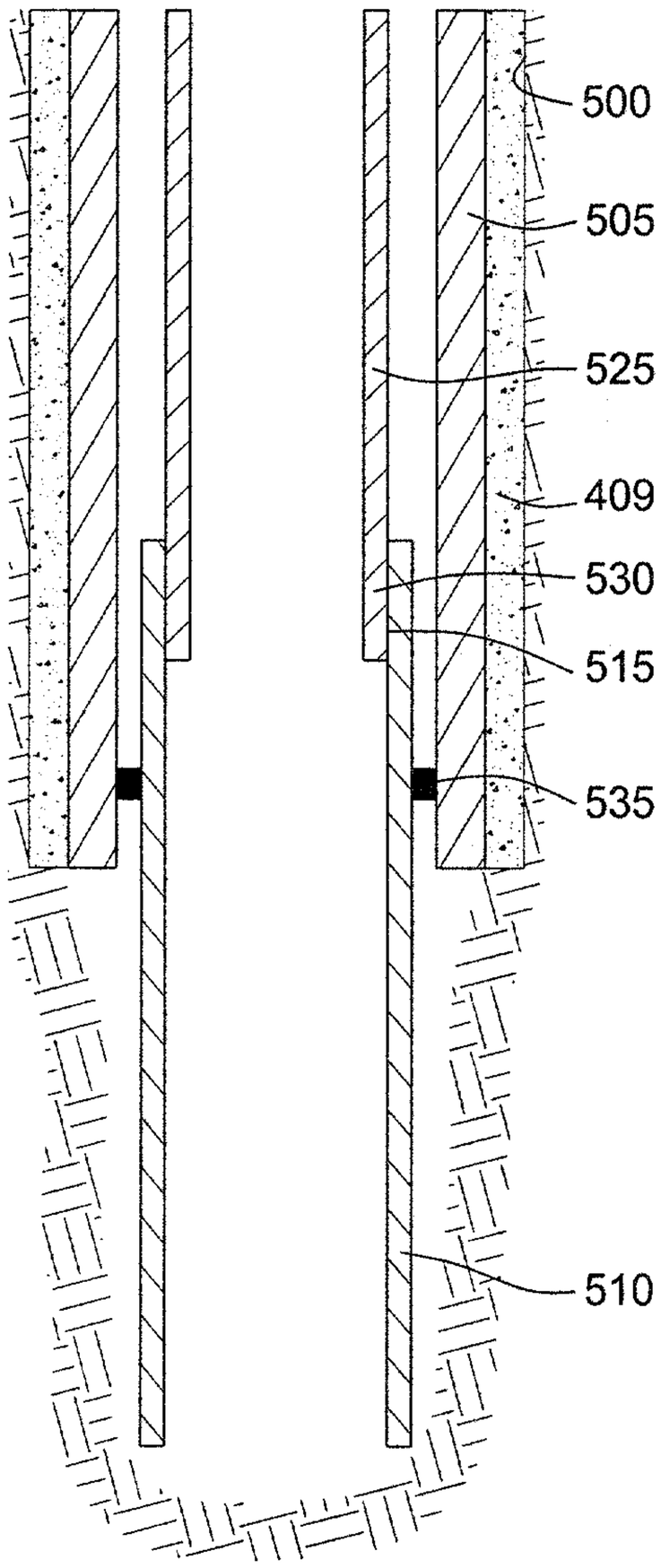


FIG. 5A

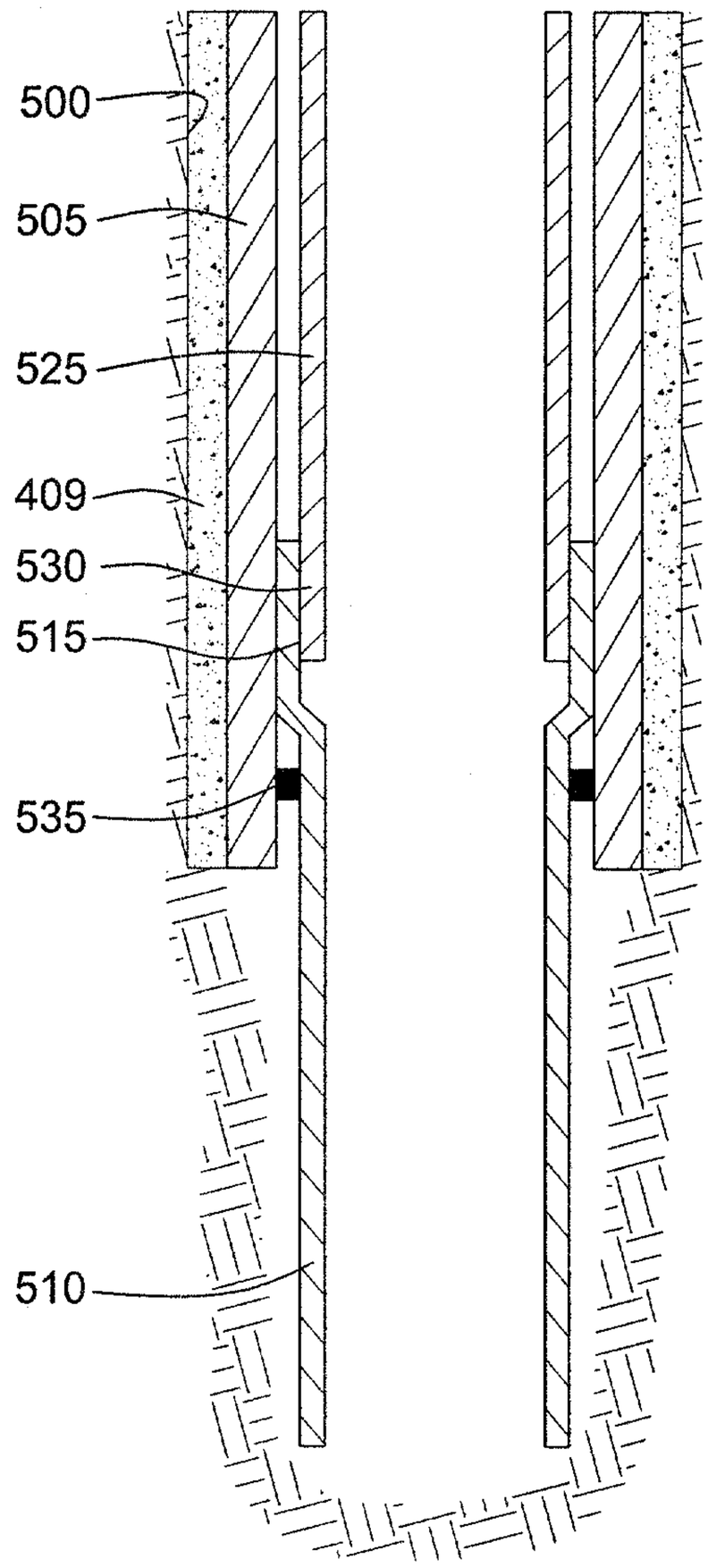


FIG. 5B

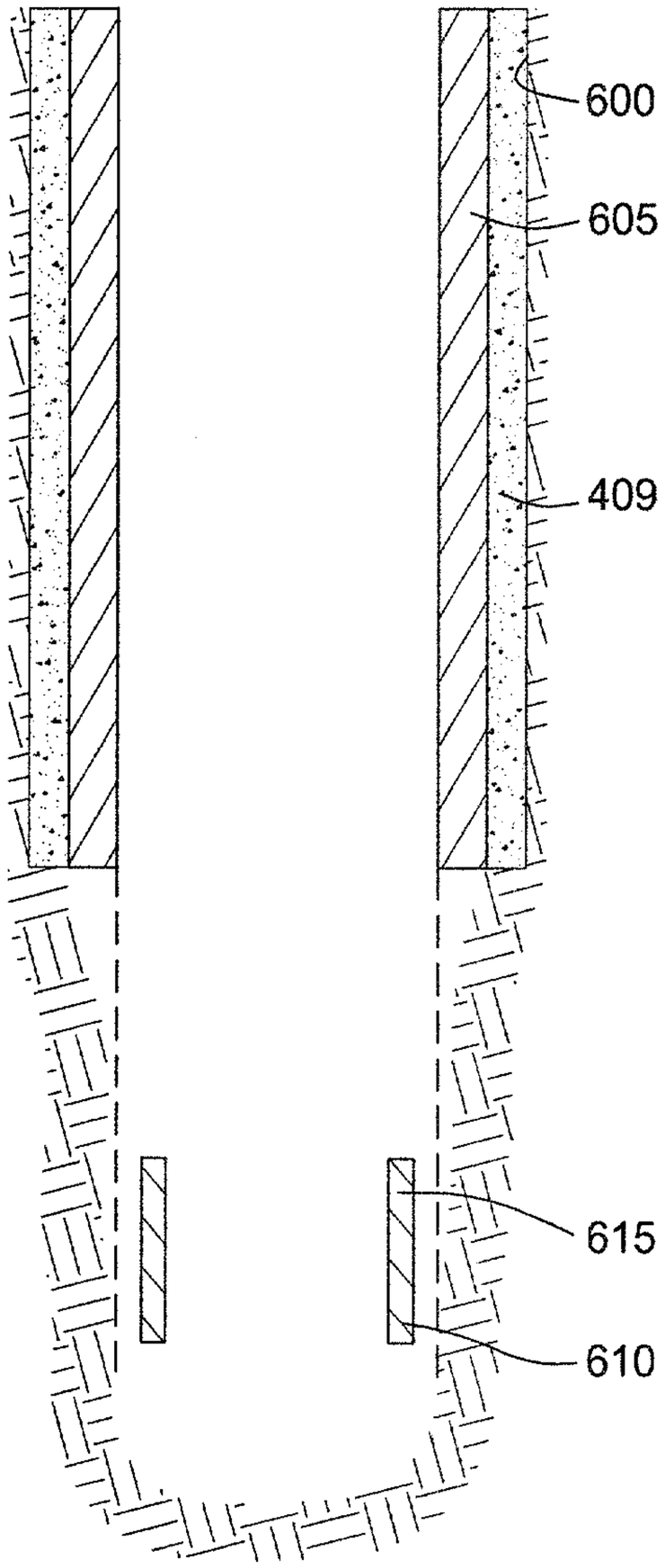


FIG. 6A

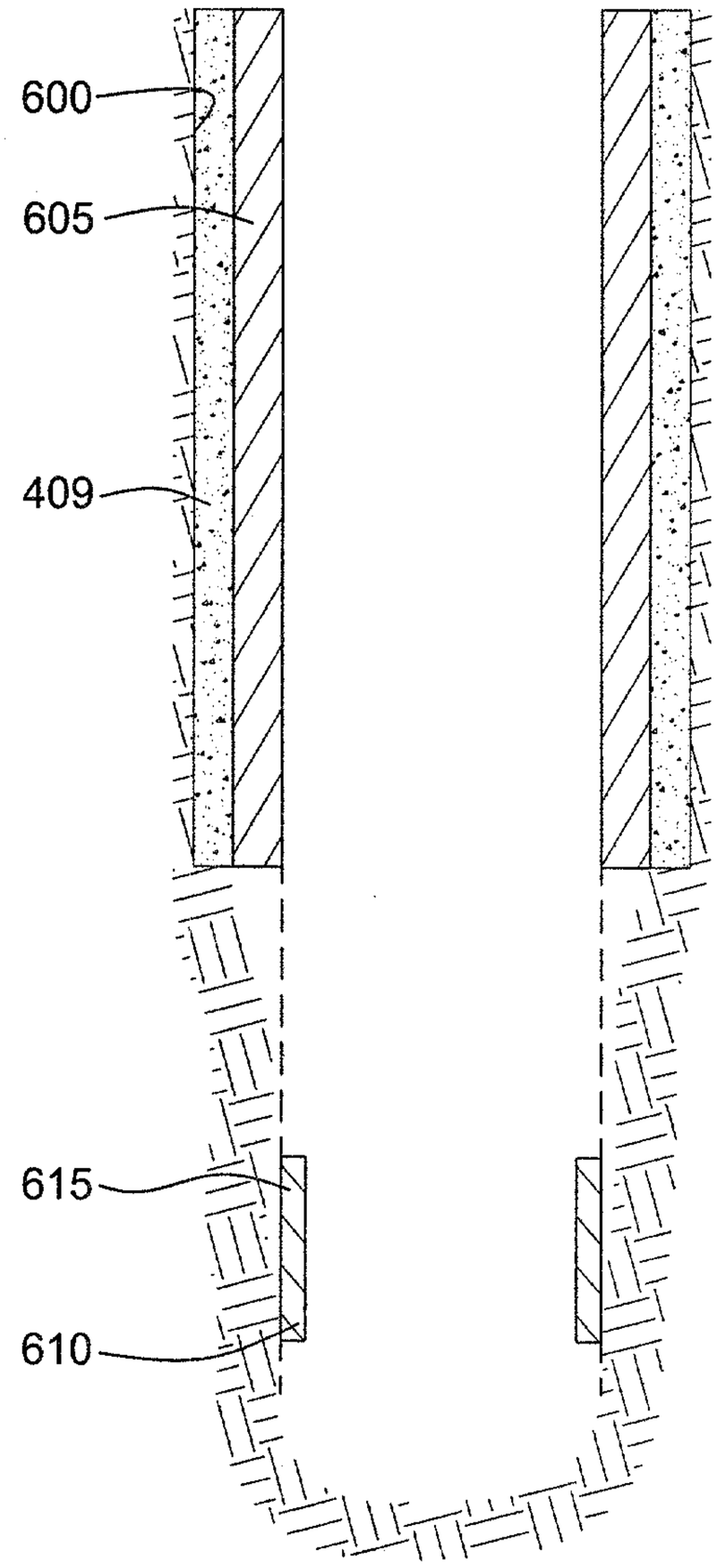


FIG. 6B

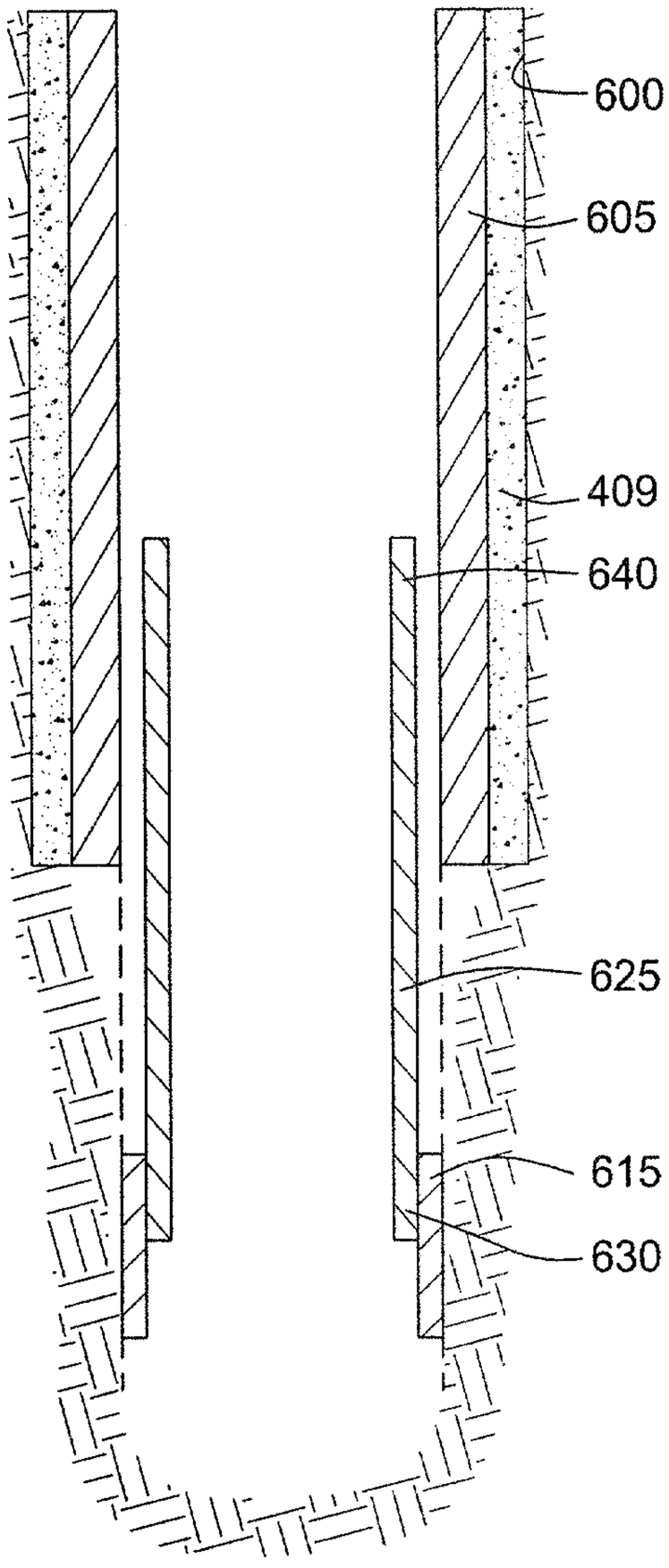


FIG. 6C

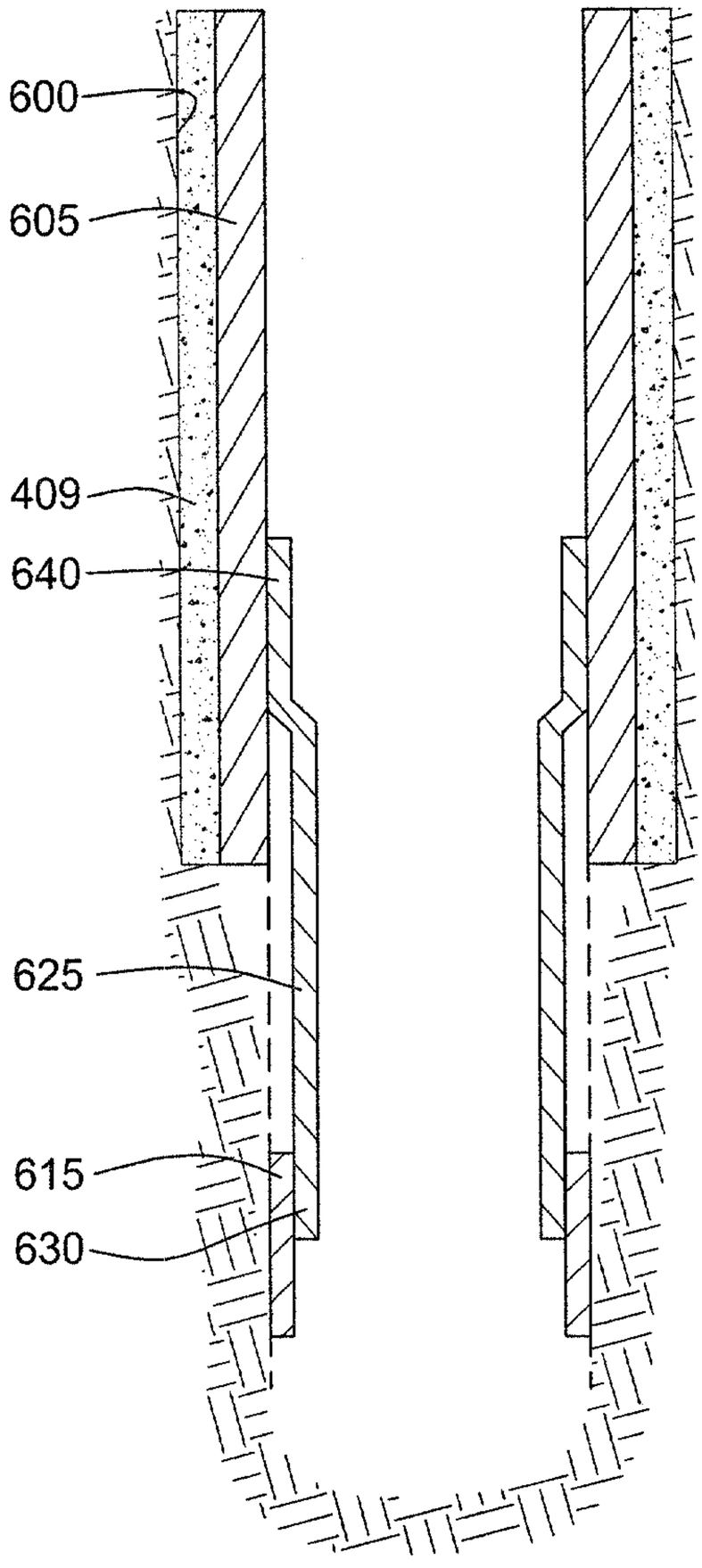


FIG. 6D

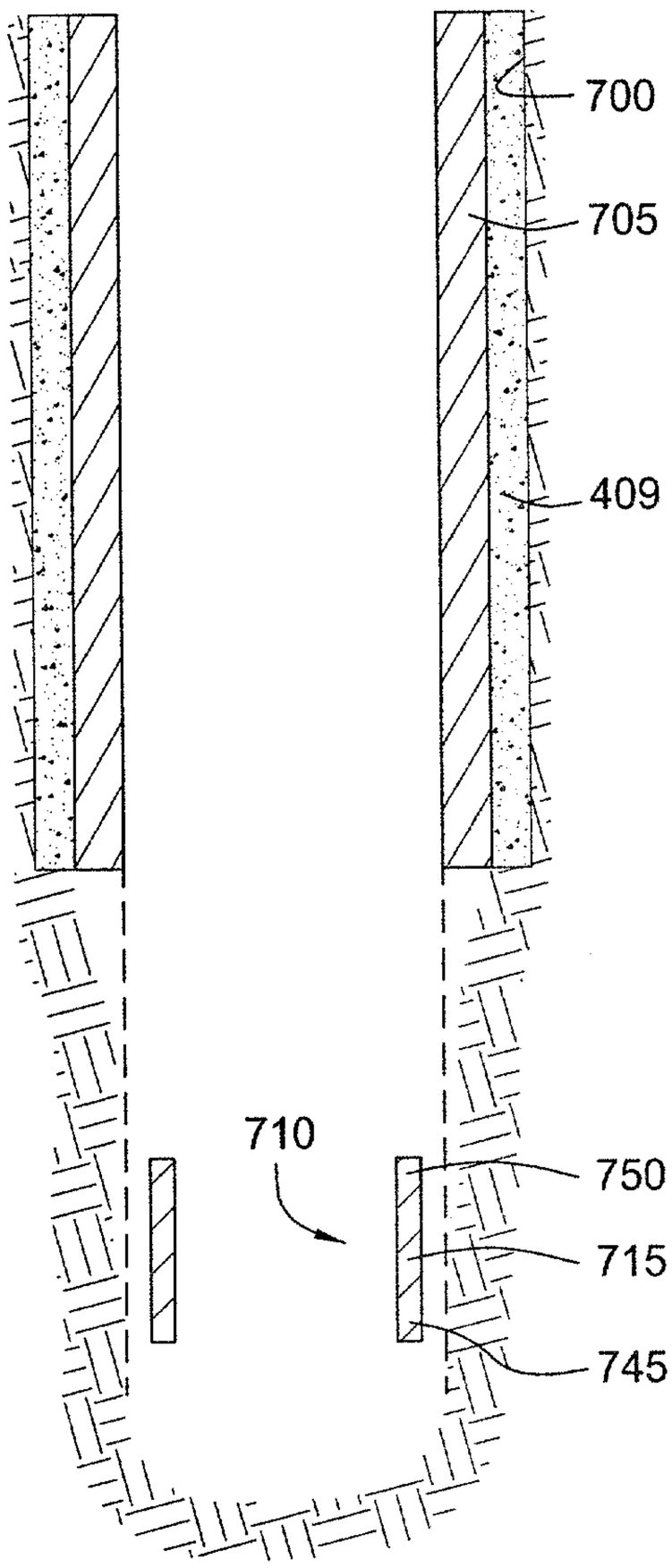


FIG. 7A

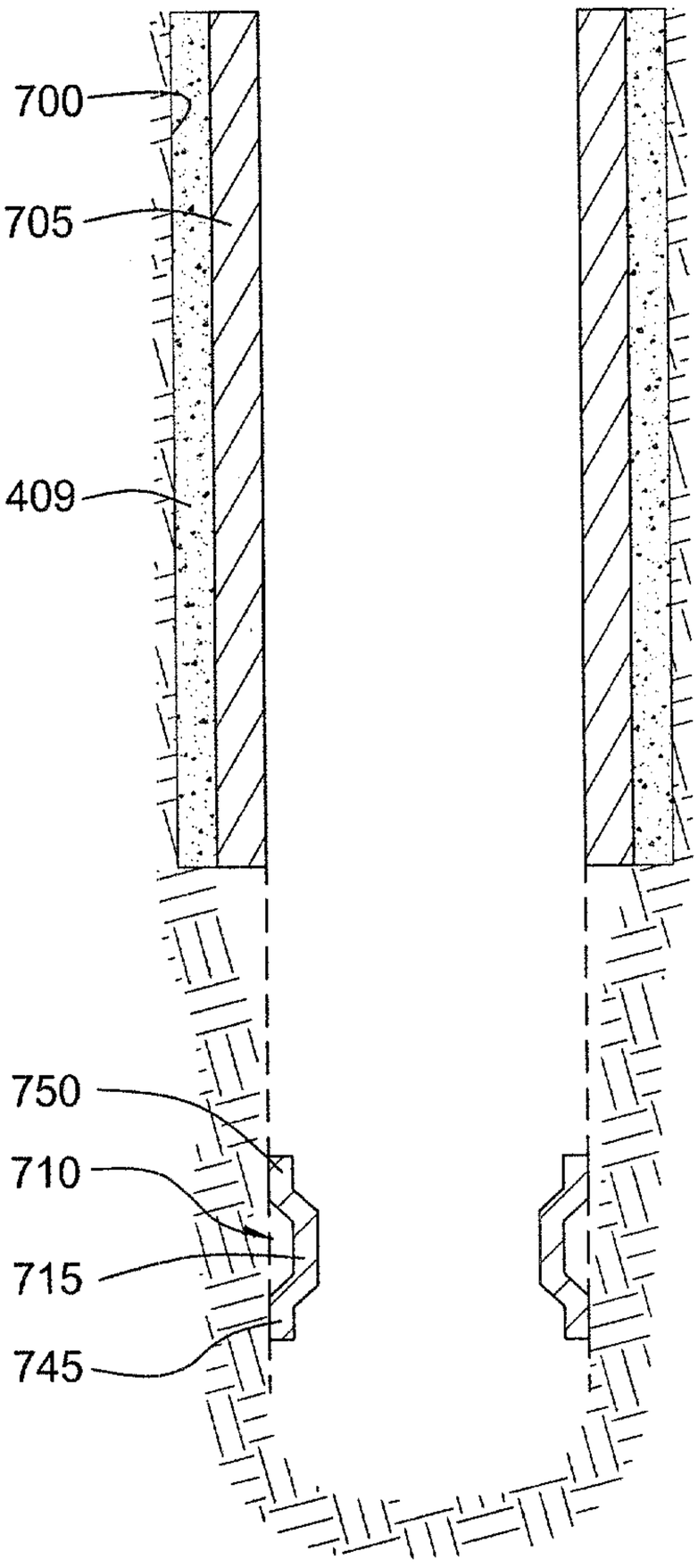


FIG. 7B

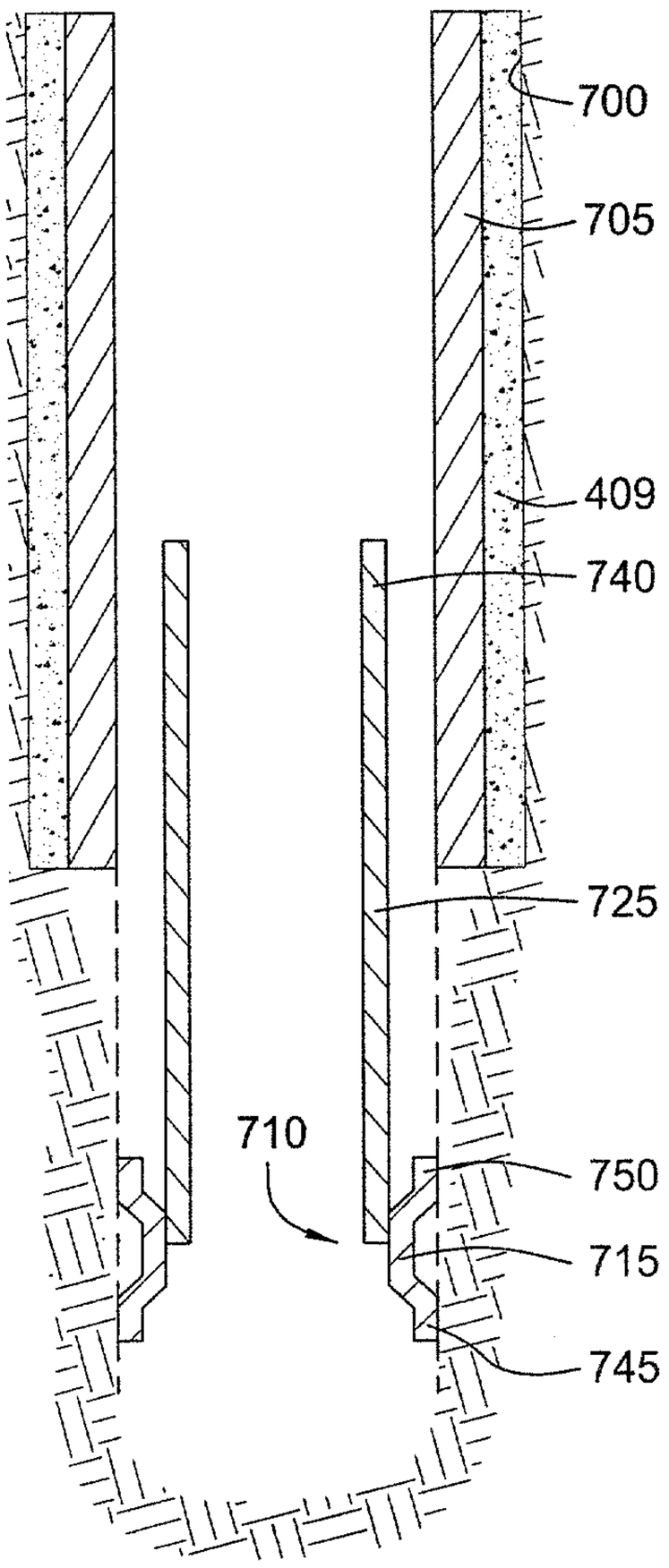

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FIG. 7C

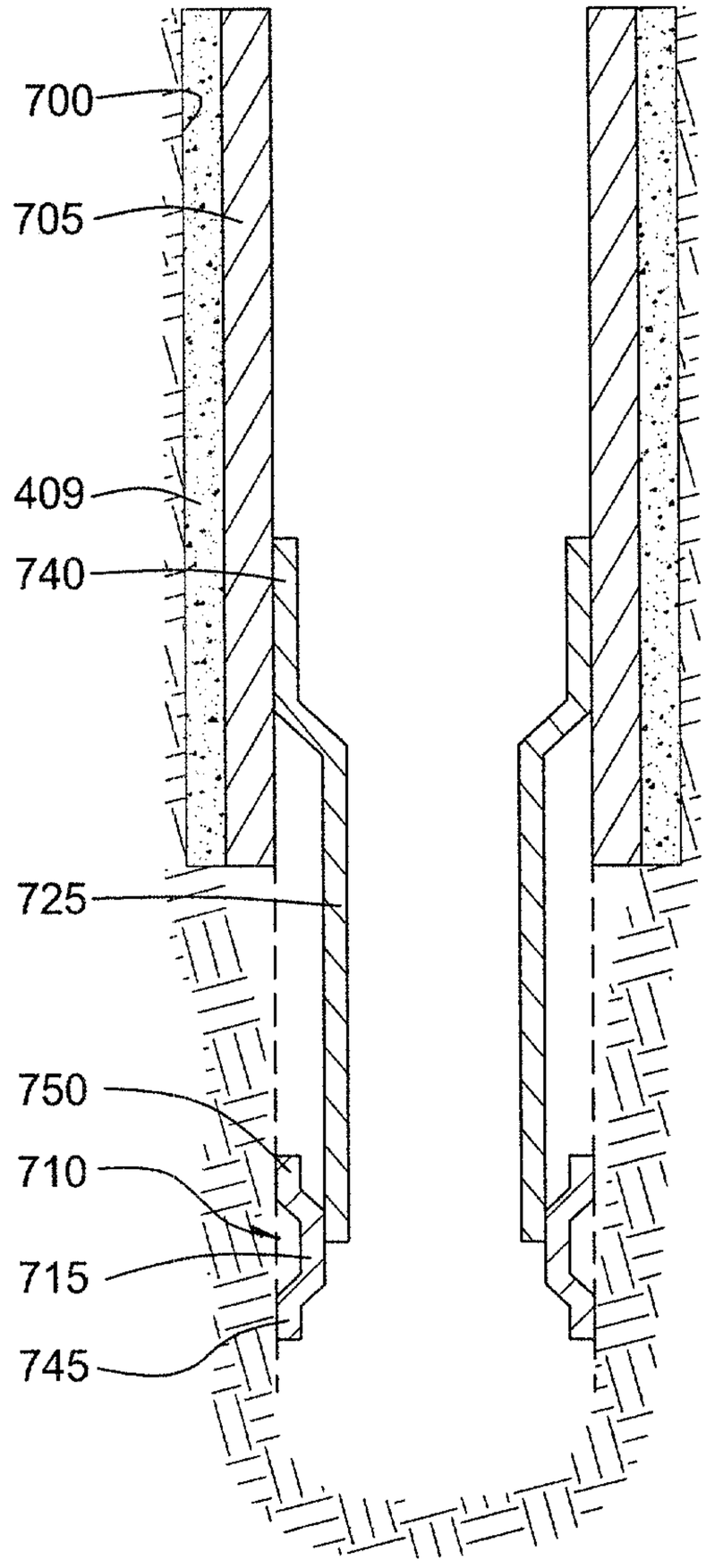
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FIG. 7D

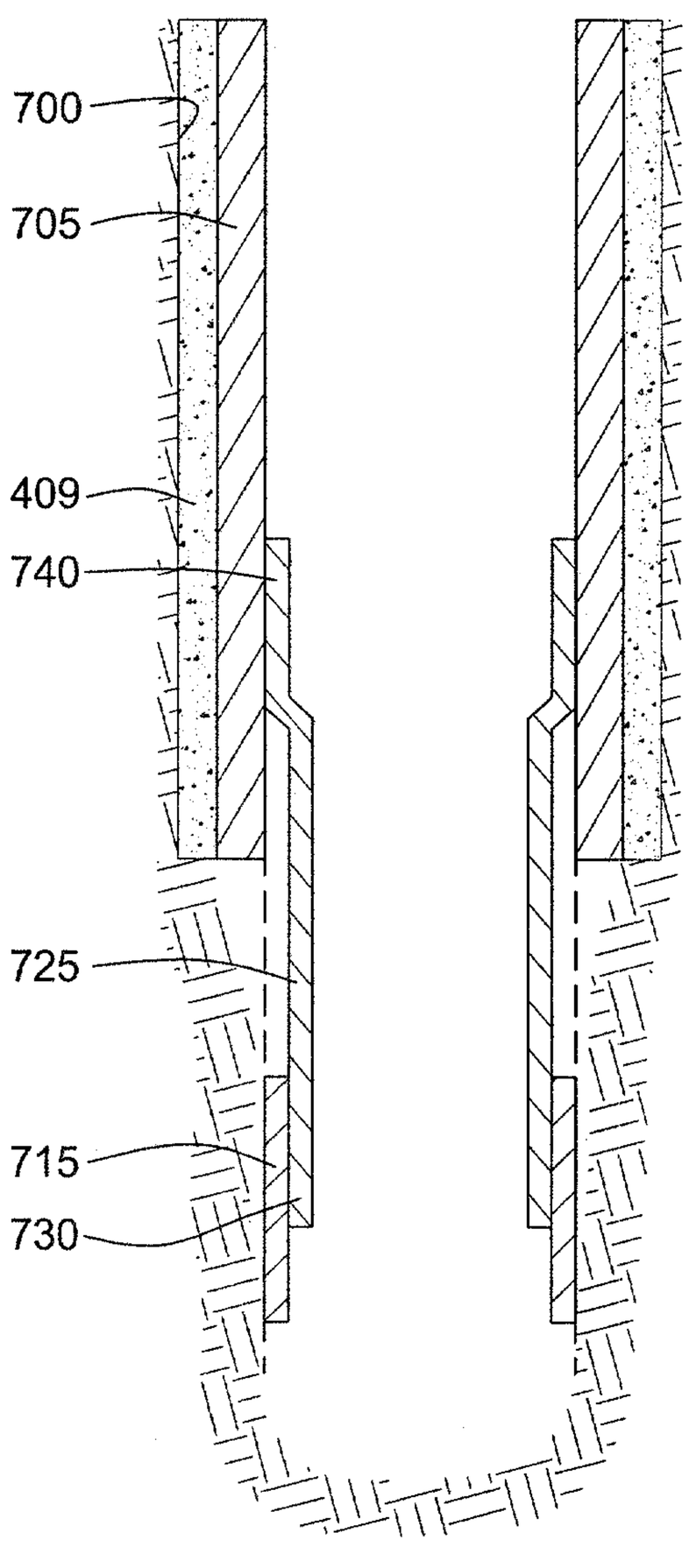


FIG. 8

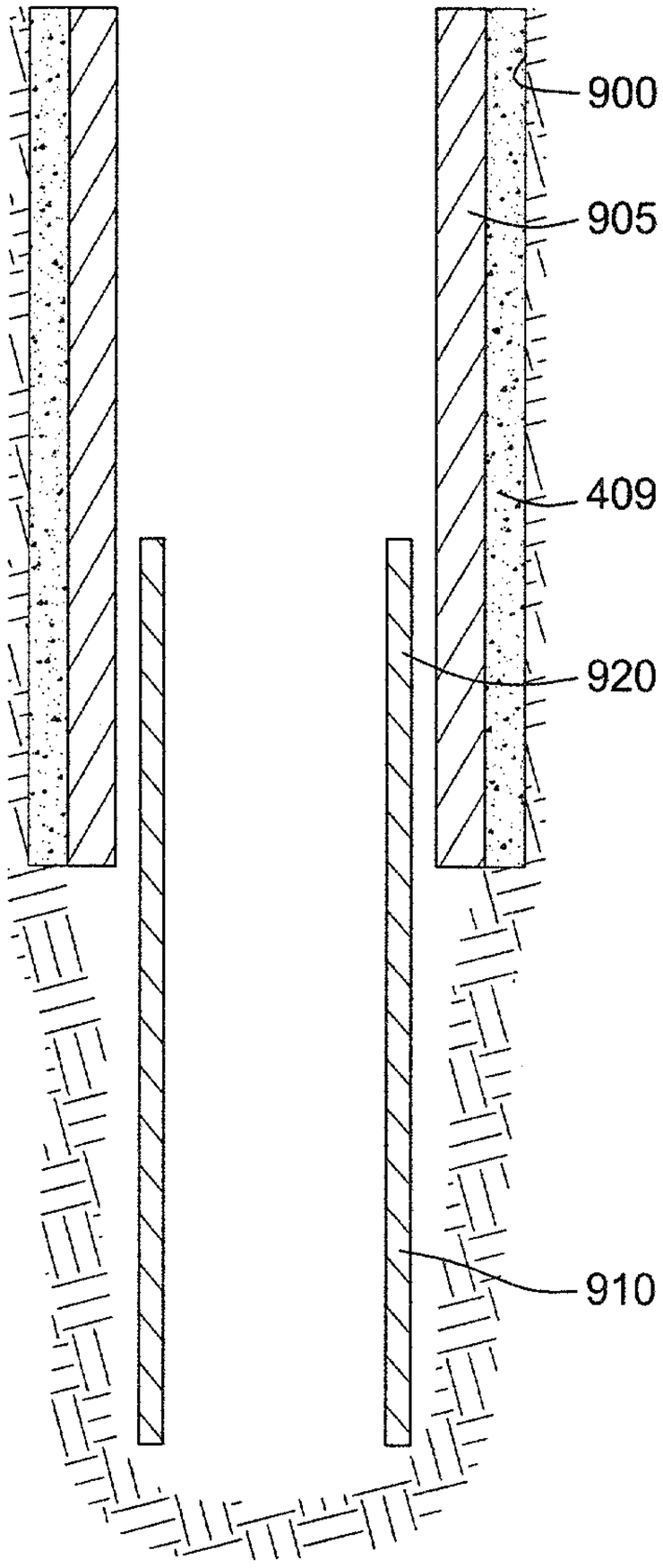


FIG. 9A

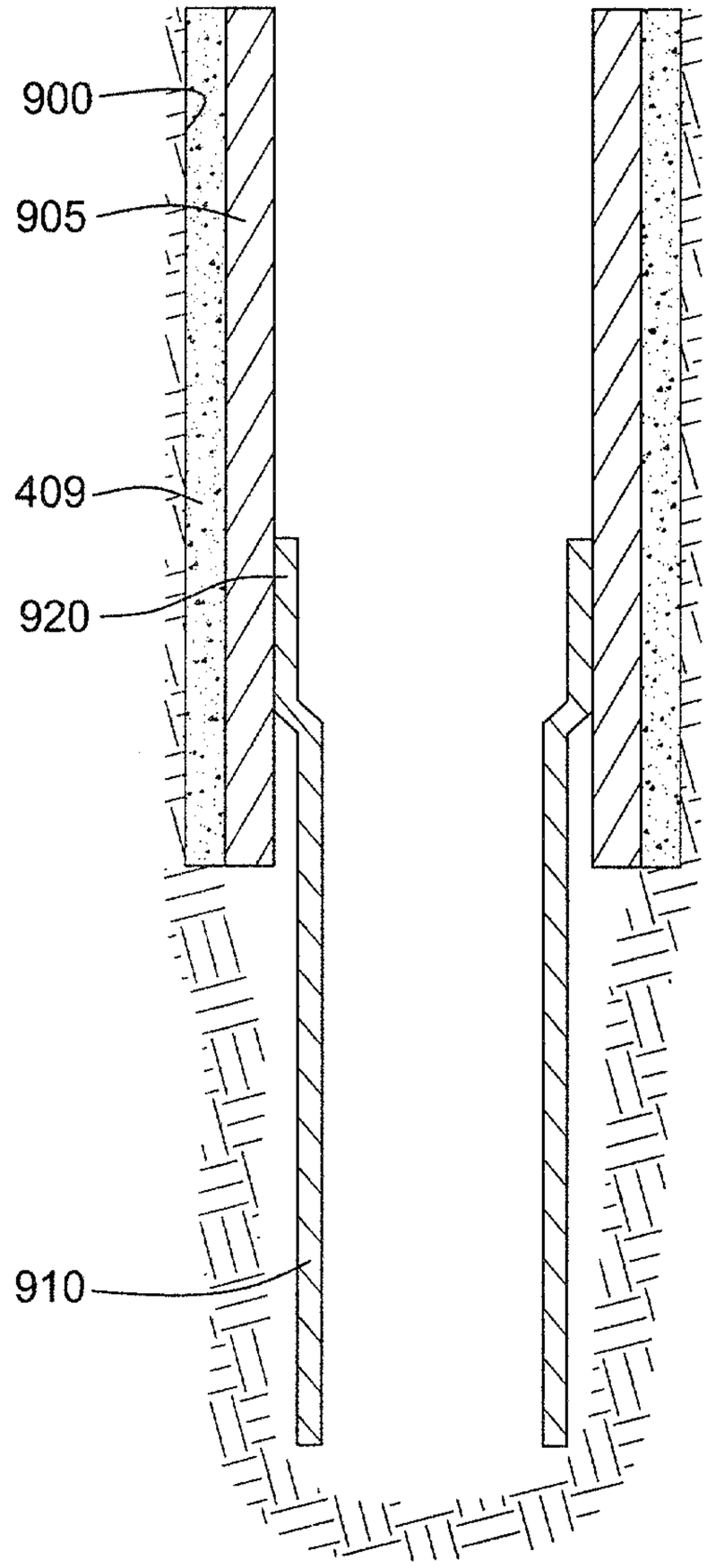


FIG. 9B

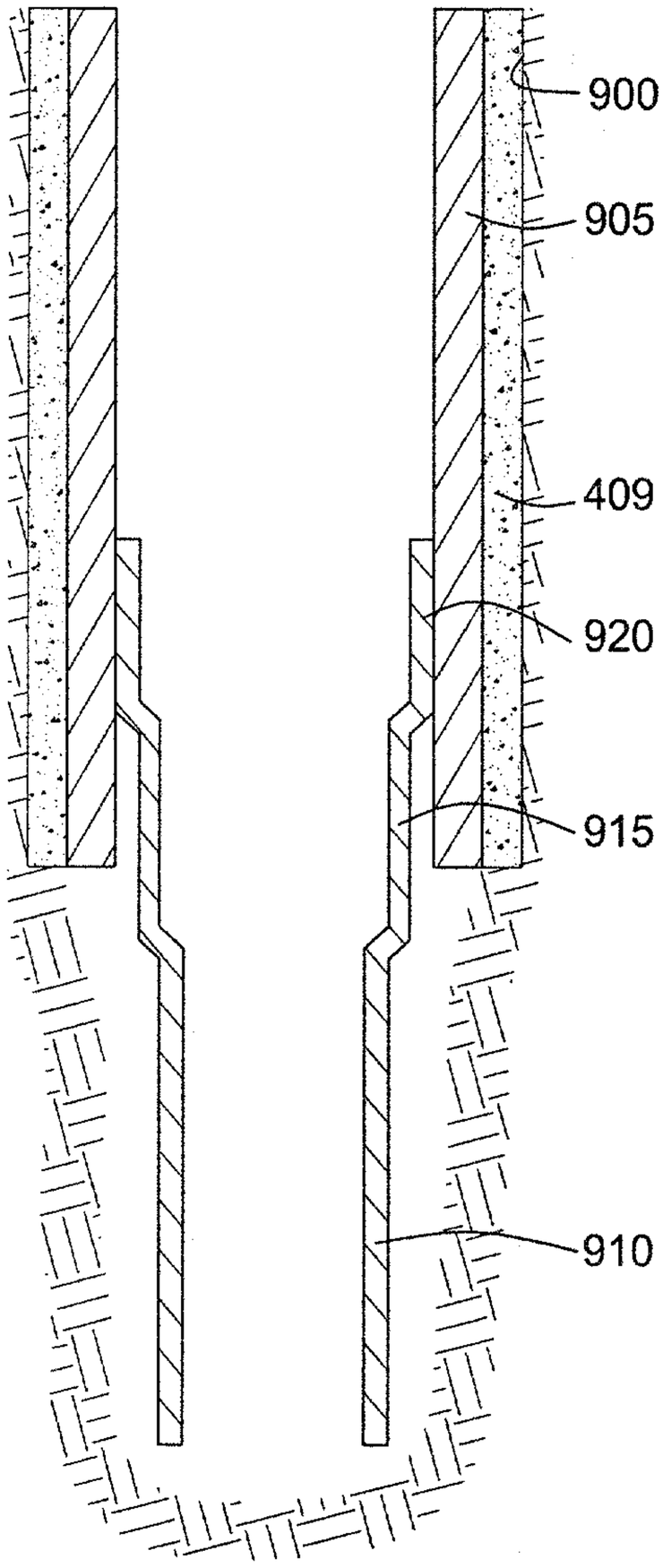


FIG. 9C

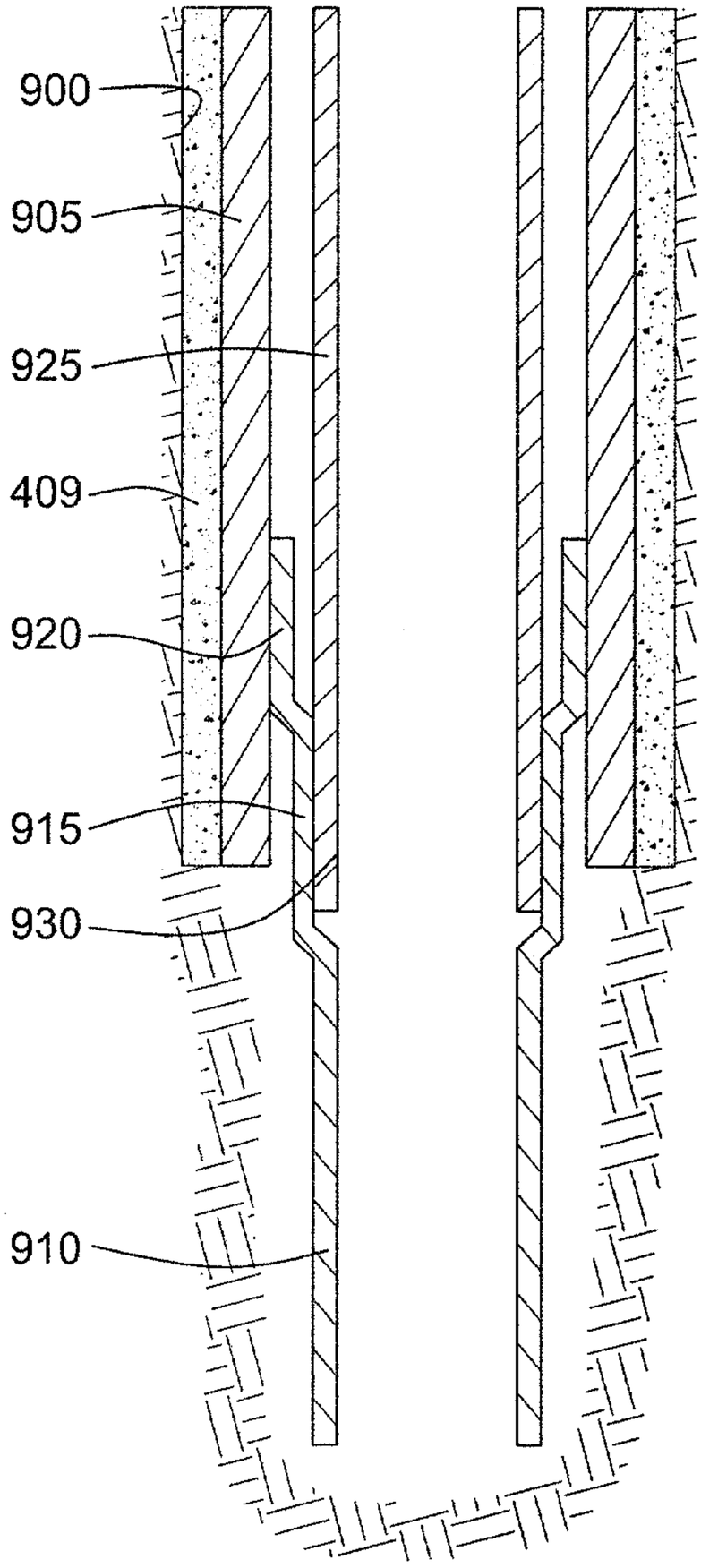


FIG. 9D

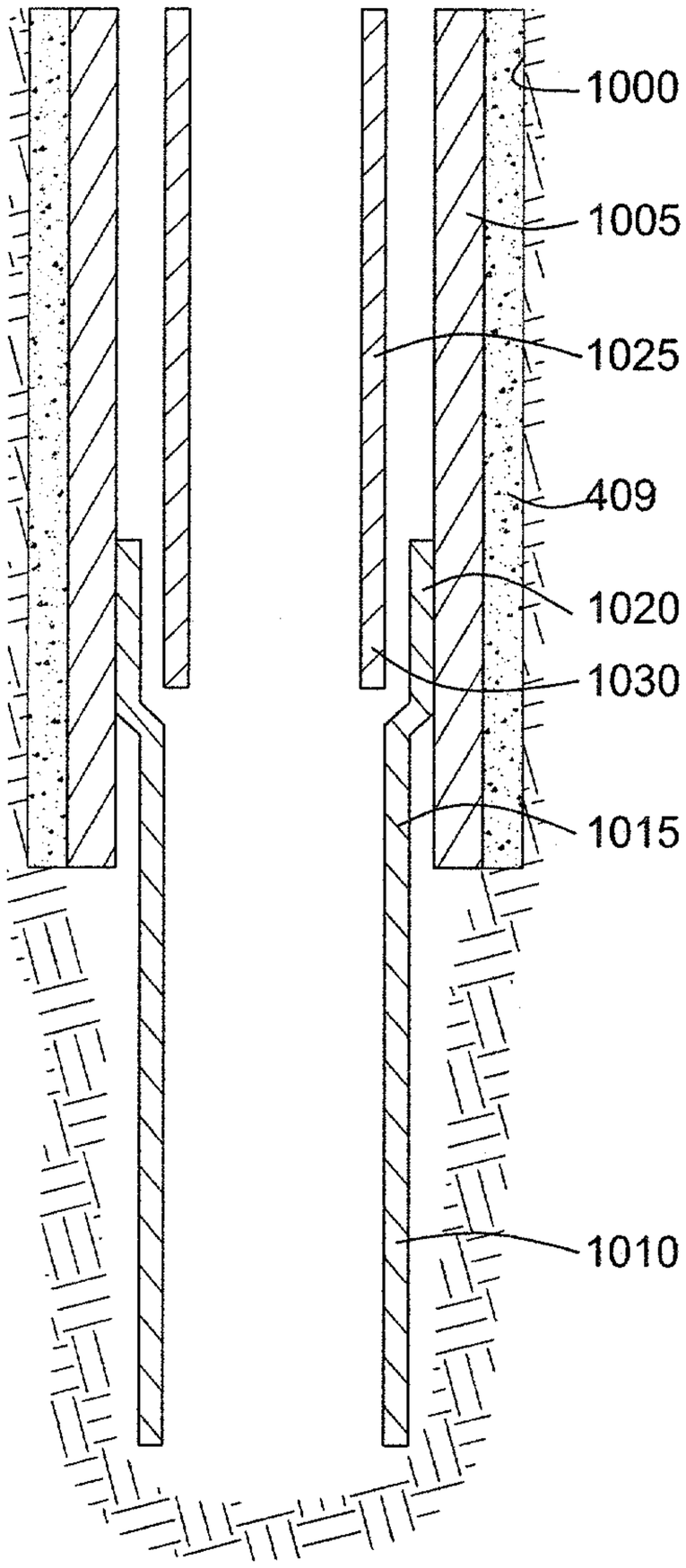


FIG. 10A

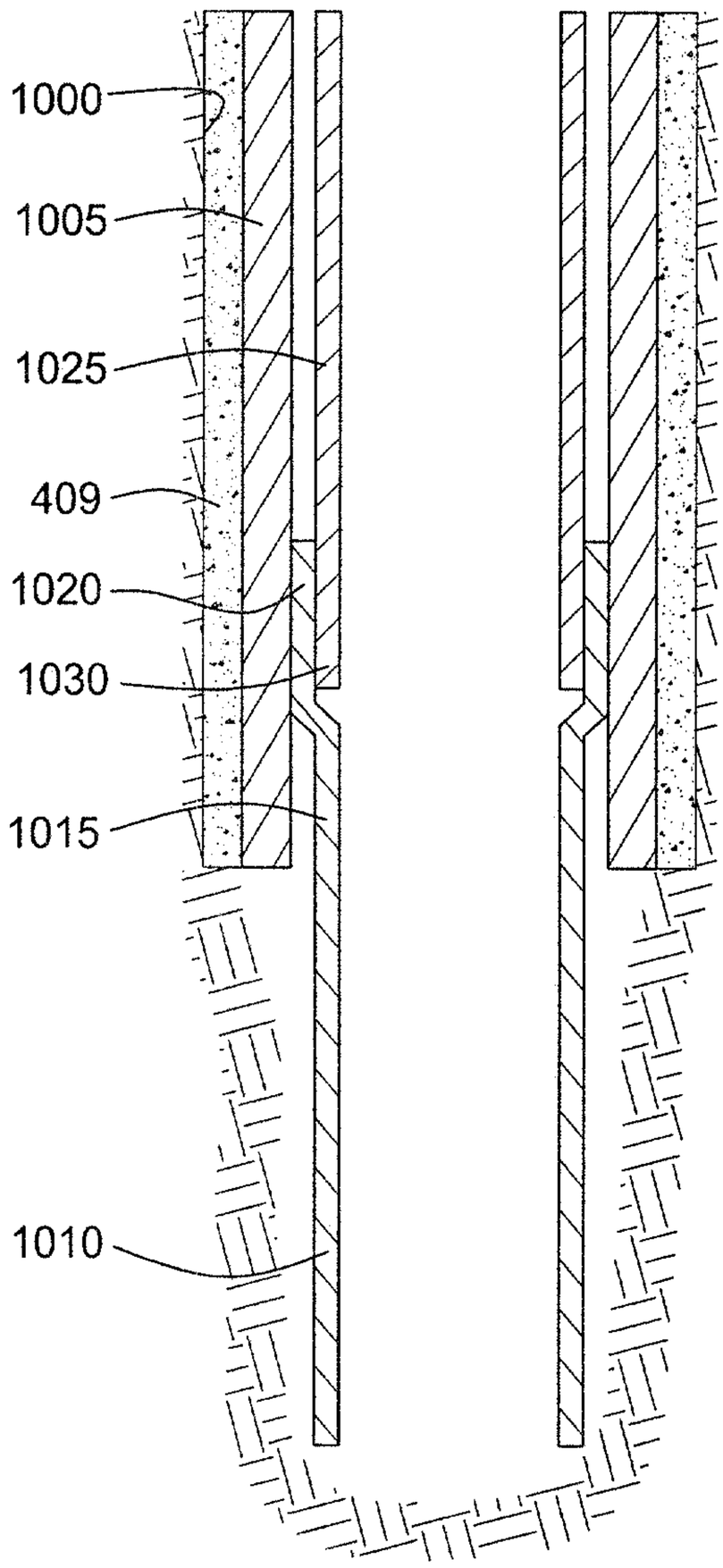


FIG. 10B

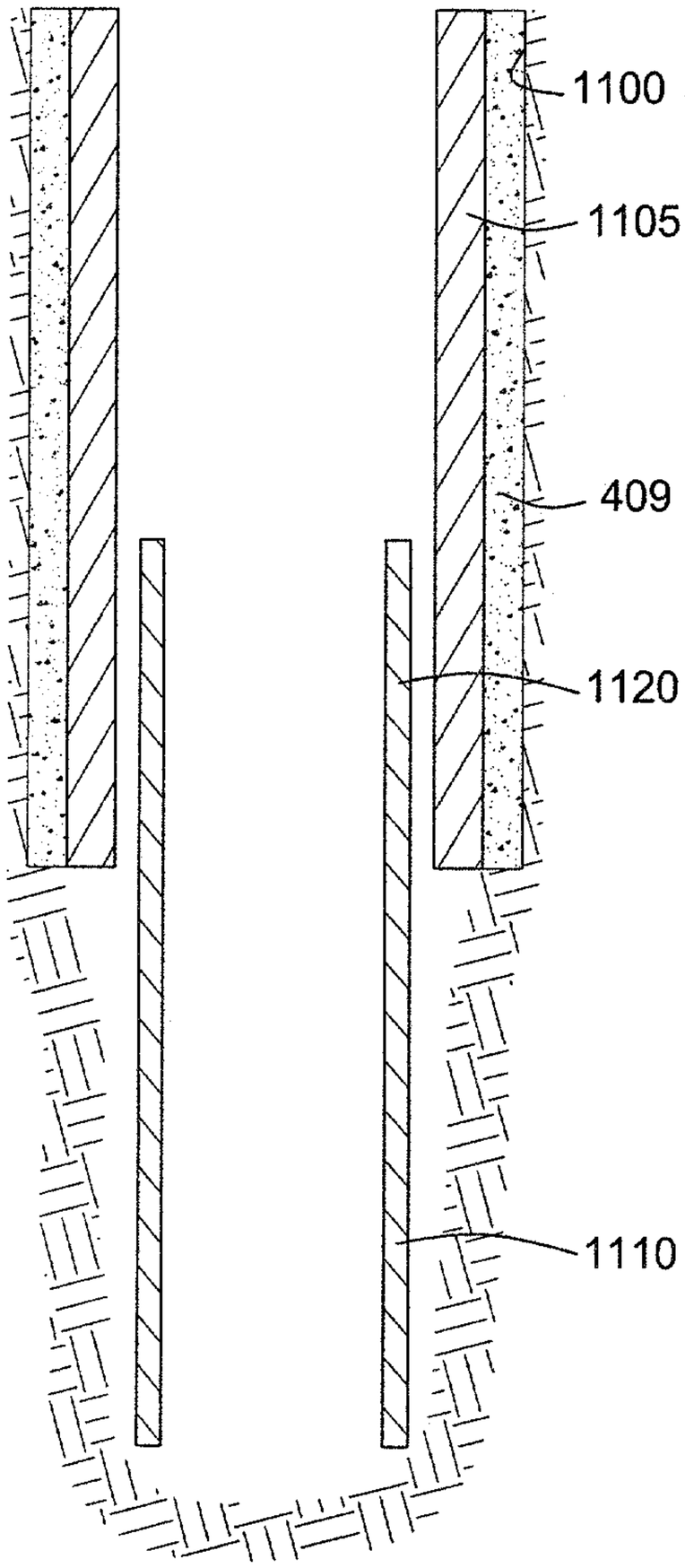


FIG. 11A

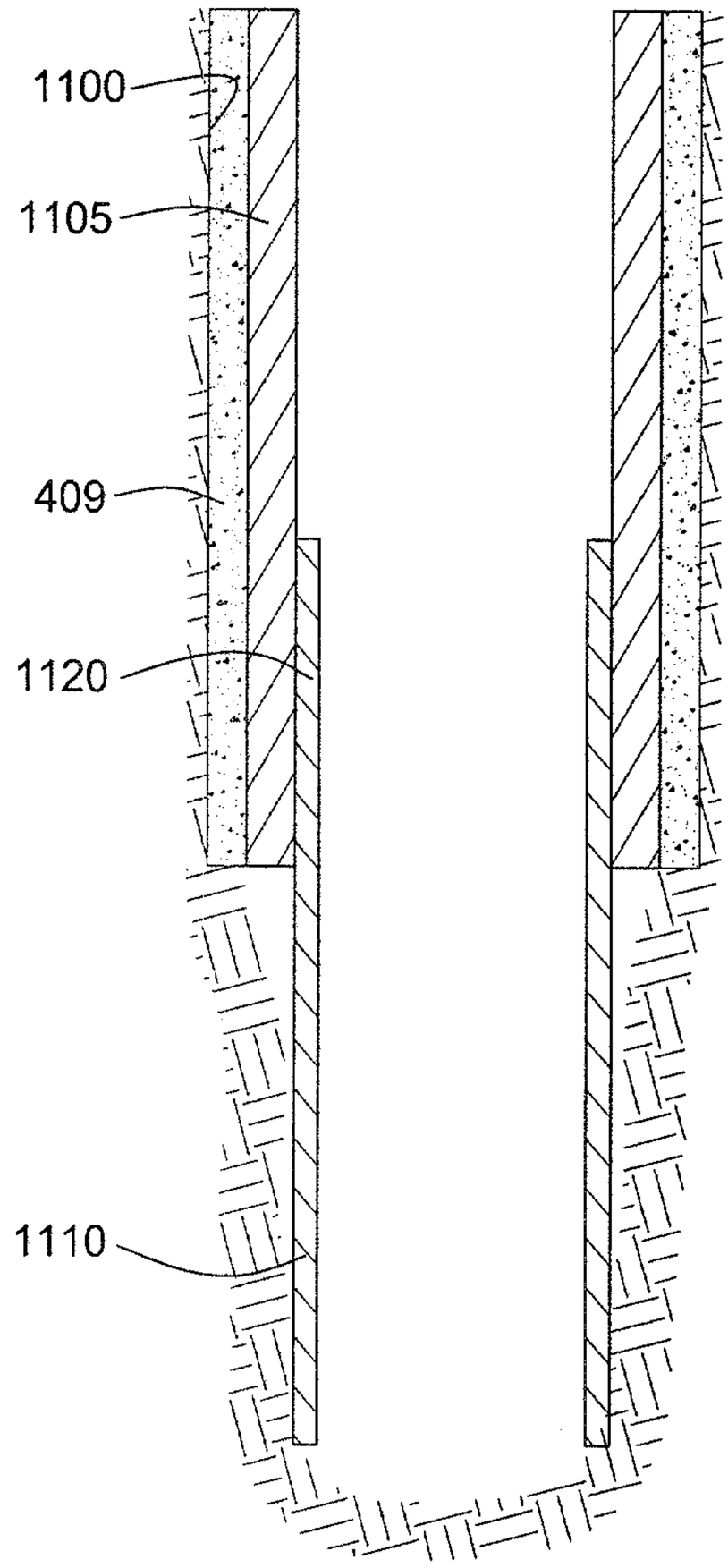


FIG. 11B

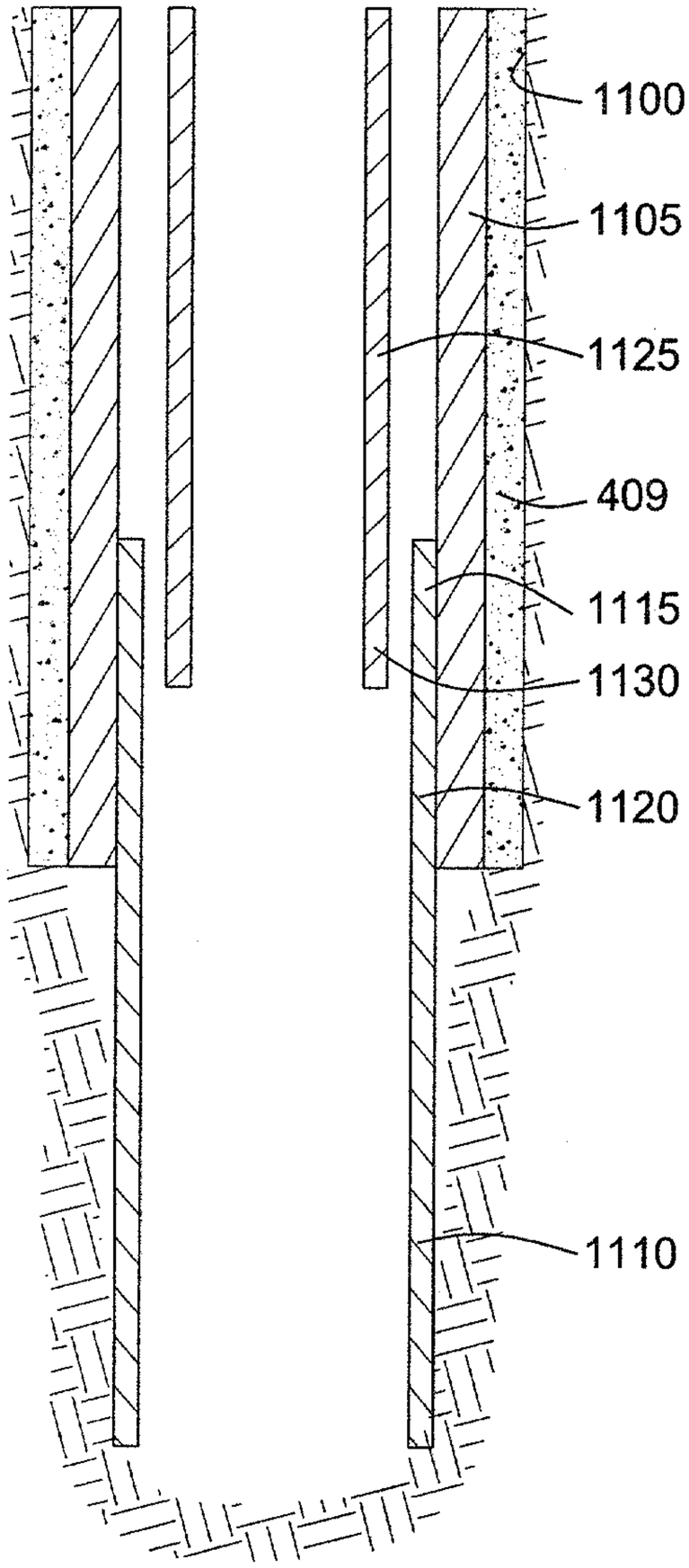


FIG. 11C

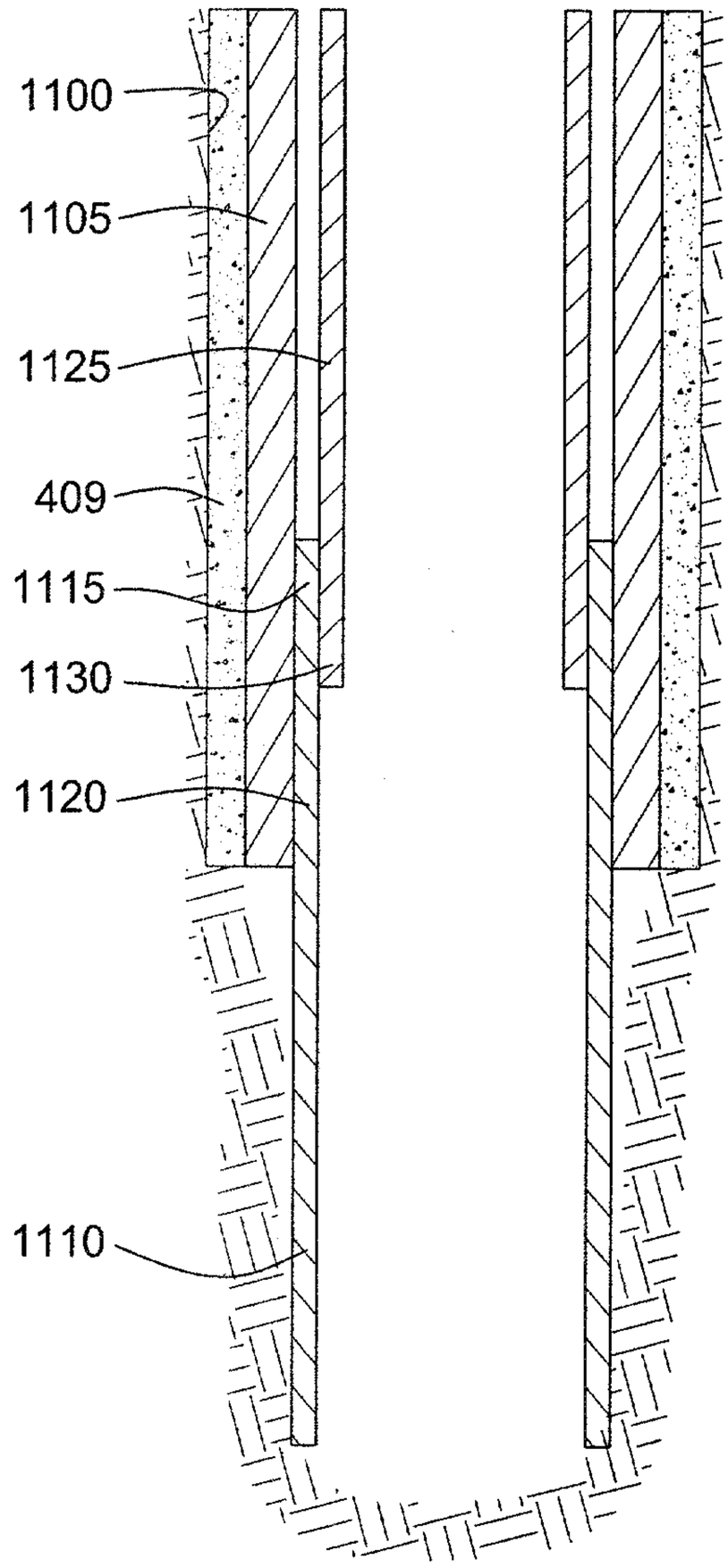


FIG. 11D

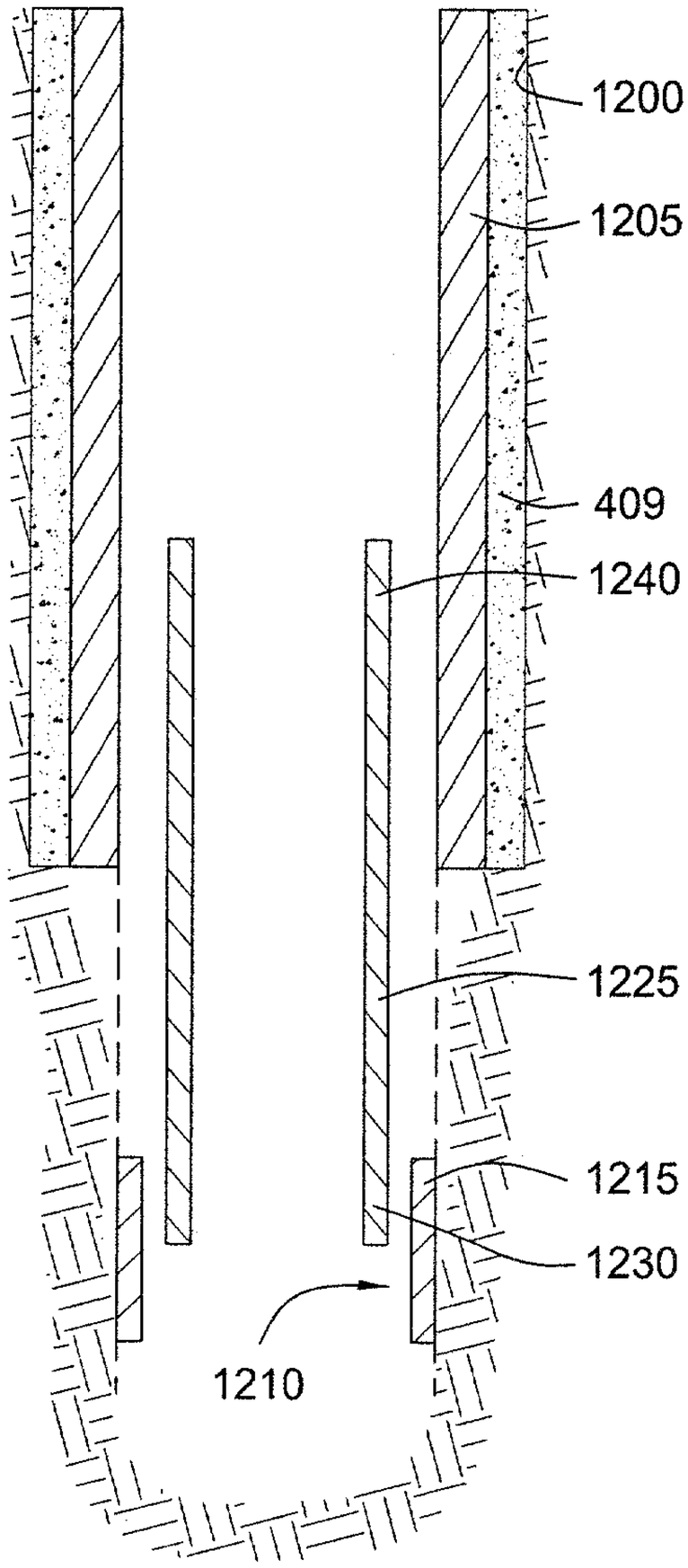


FIG. 12A

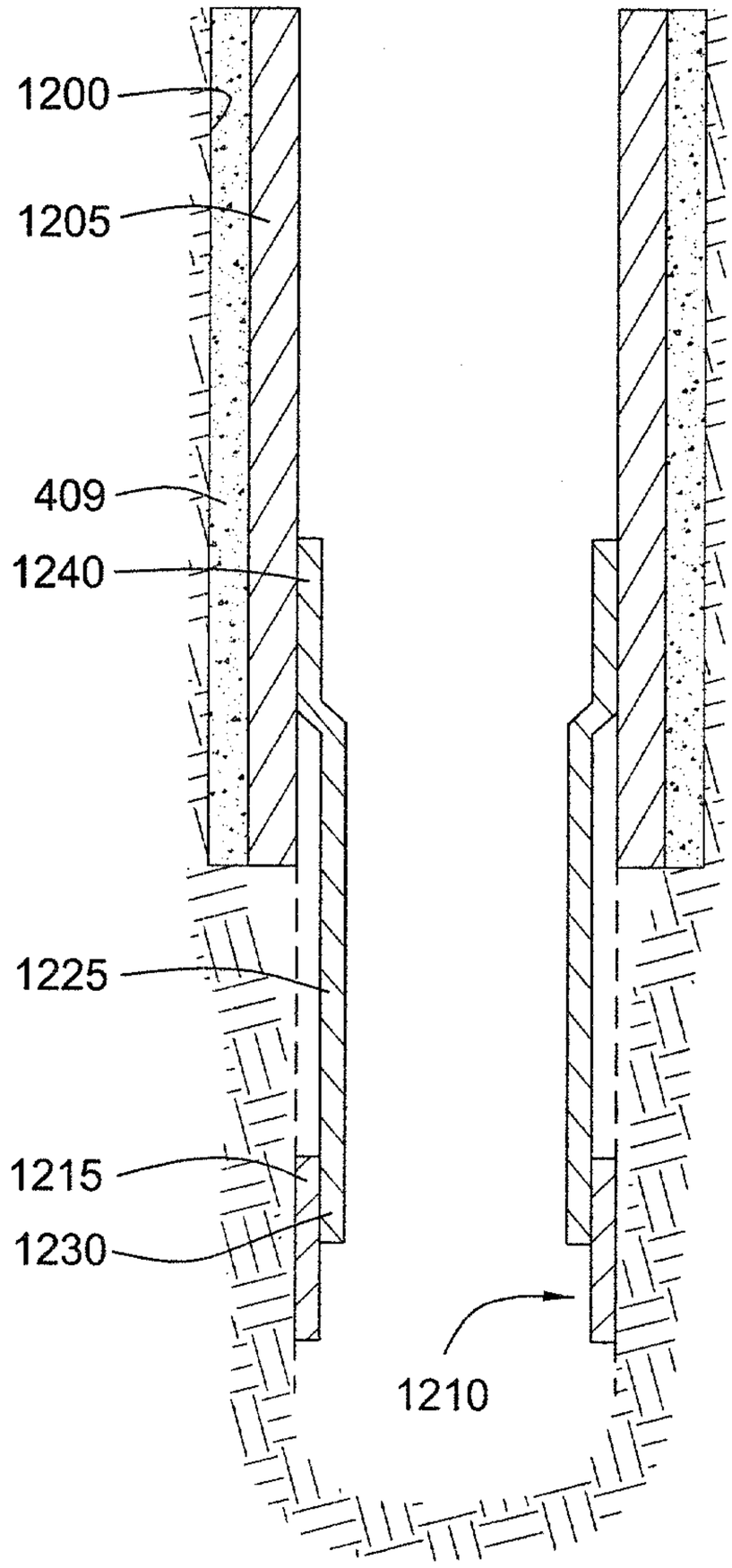


FIG. 12B

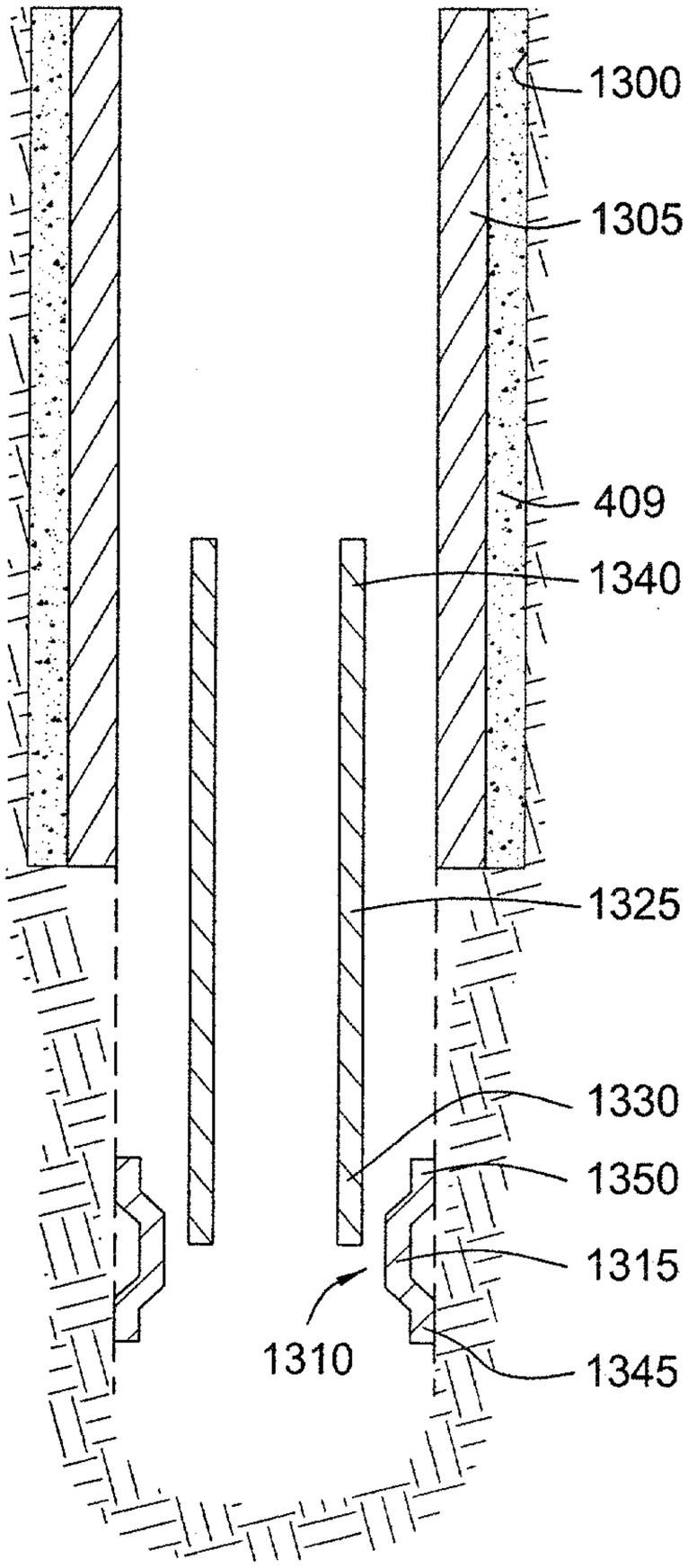


FIG. 13A

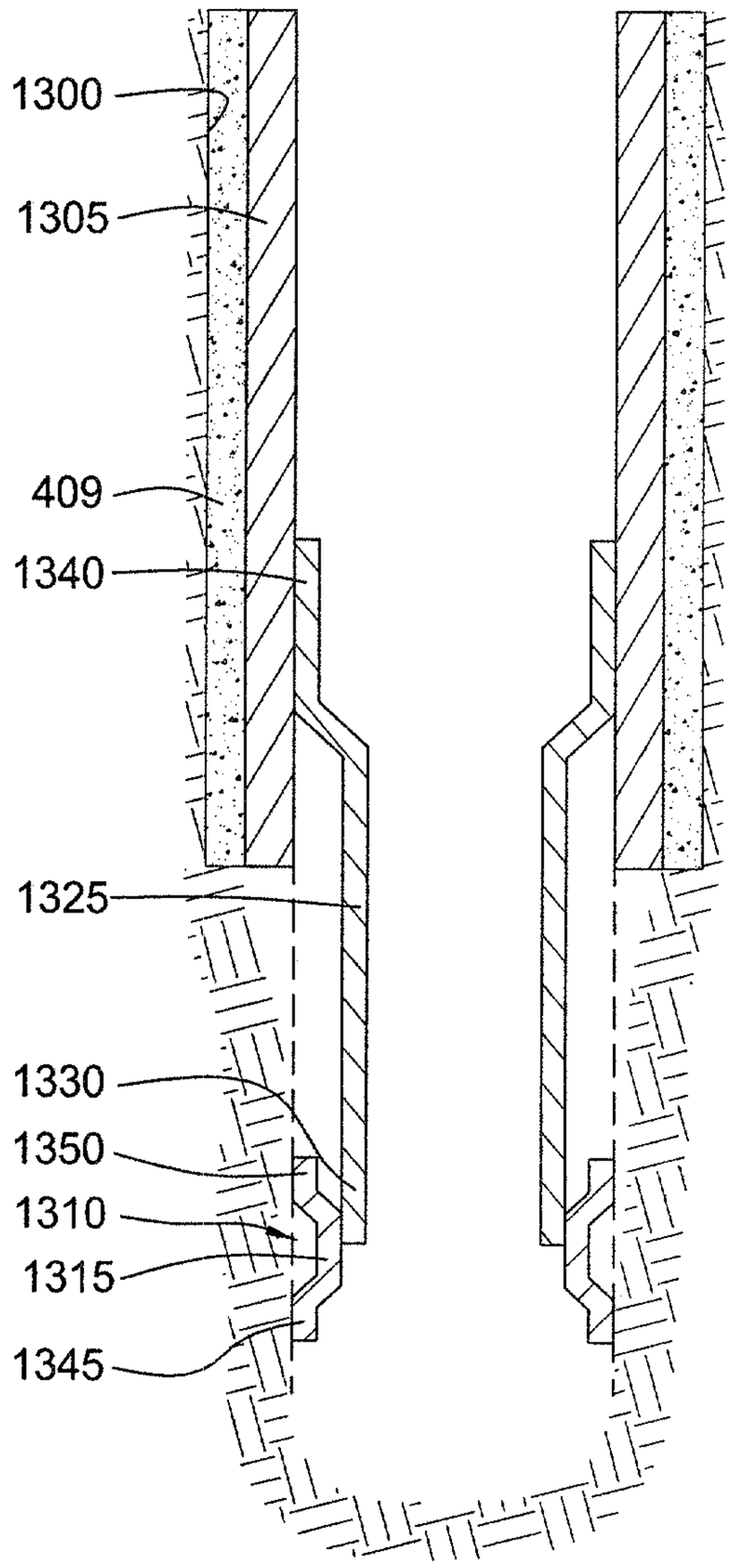


FIG. 13B

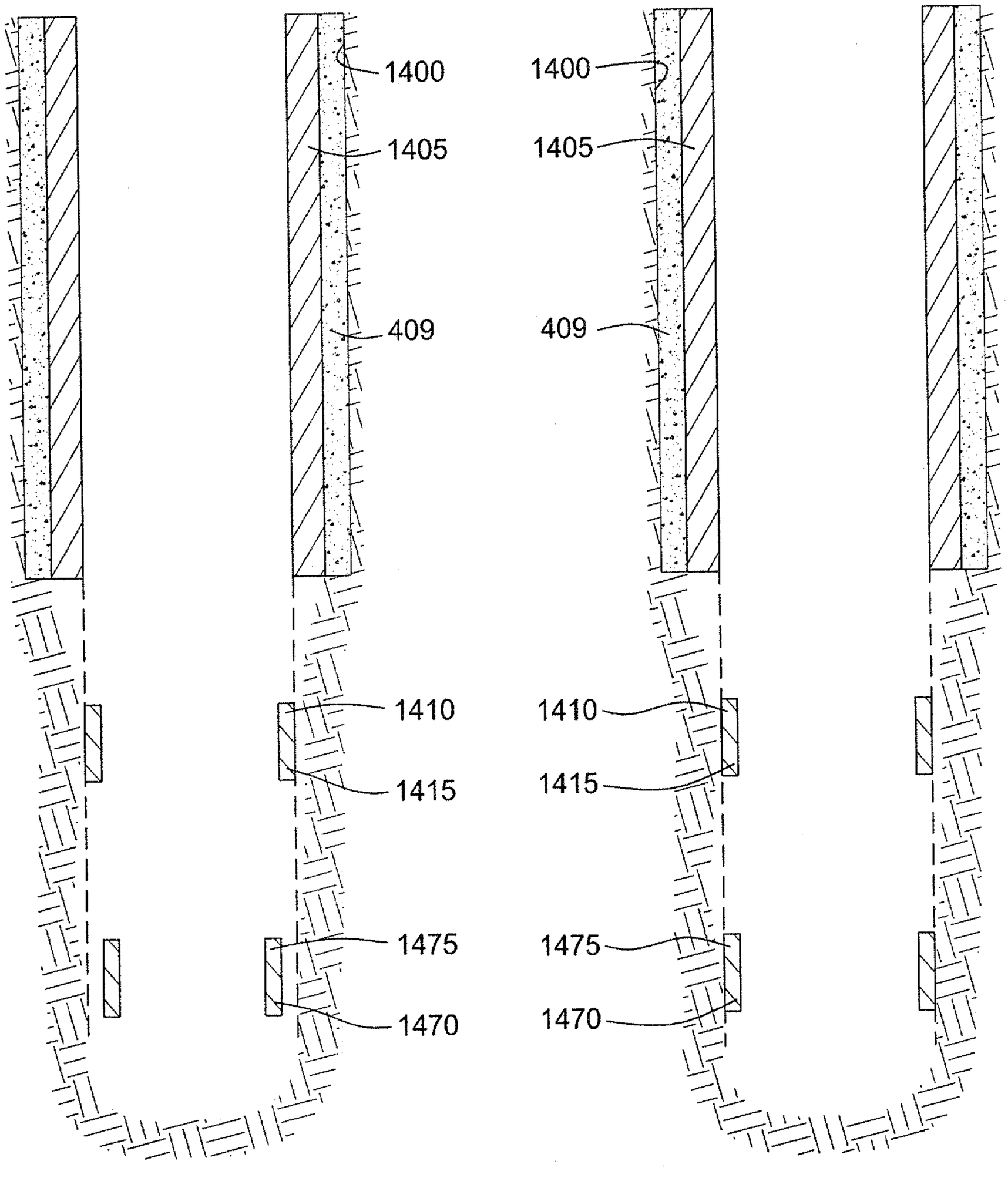


FIG. 14A

FIG. 14B

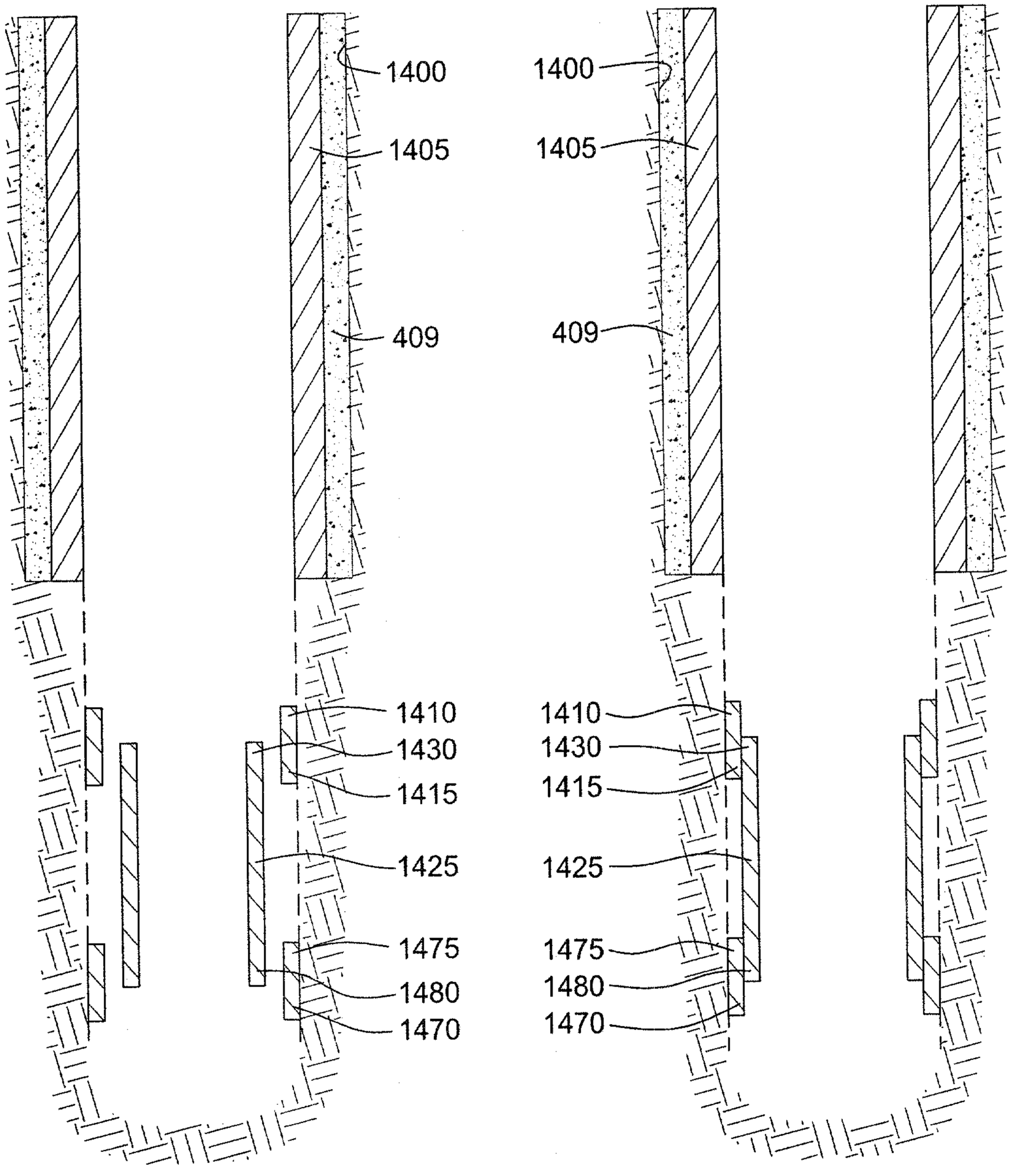


FIG. 14C

FIG. 14D

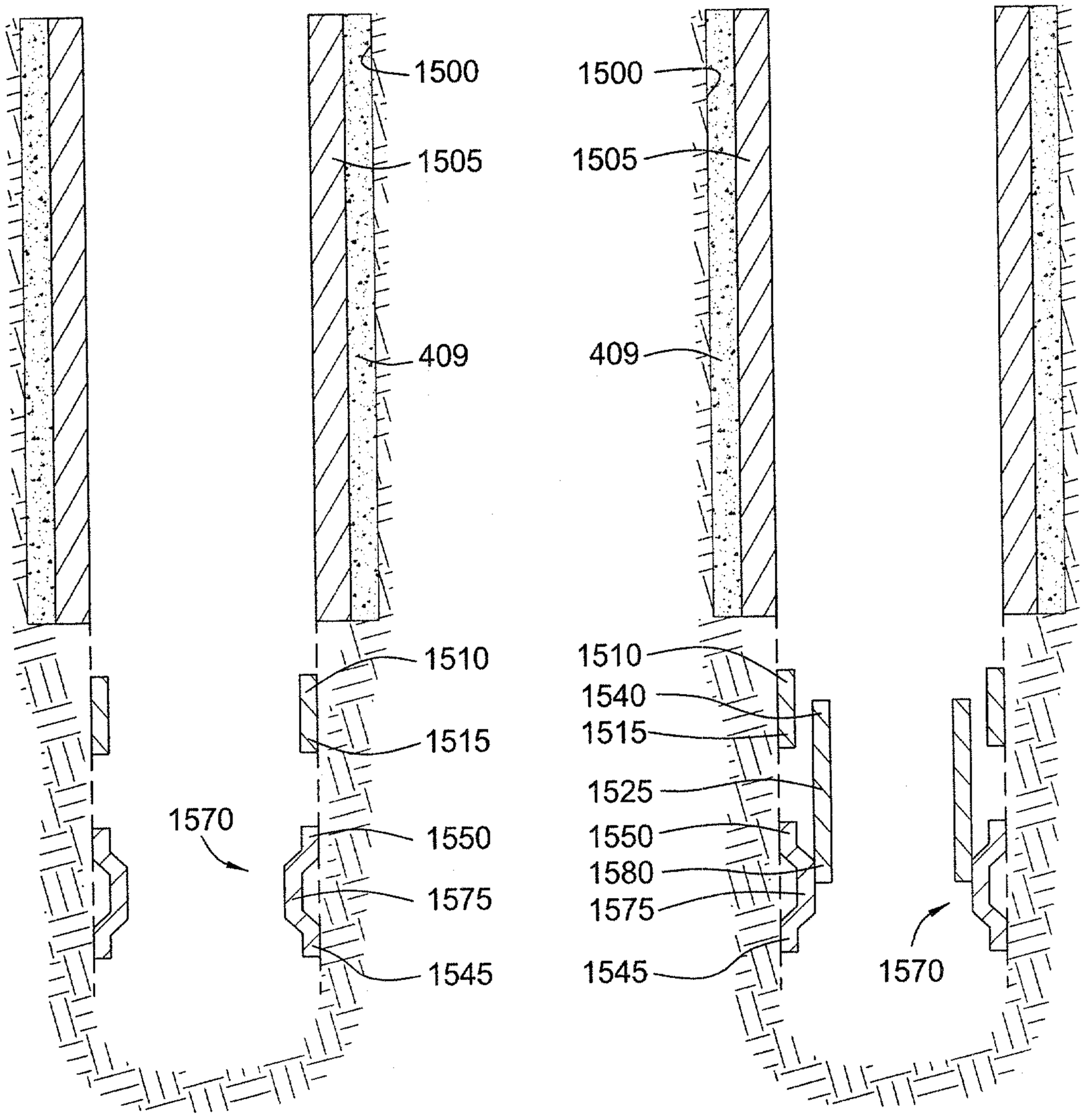


FIG. 15A

FIG. 15B

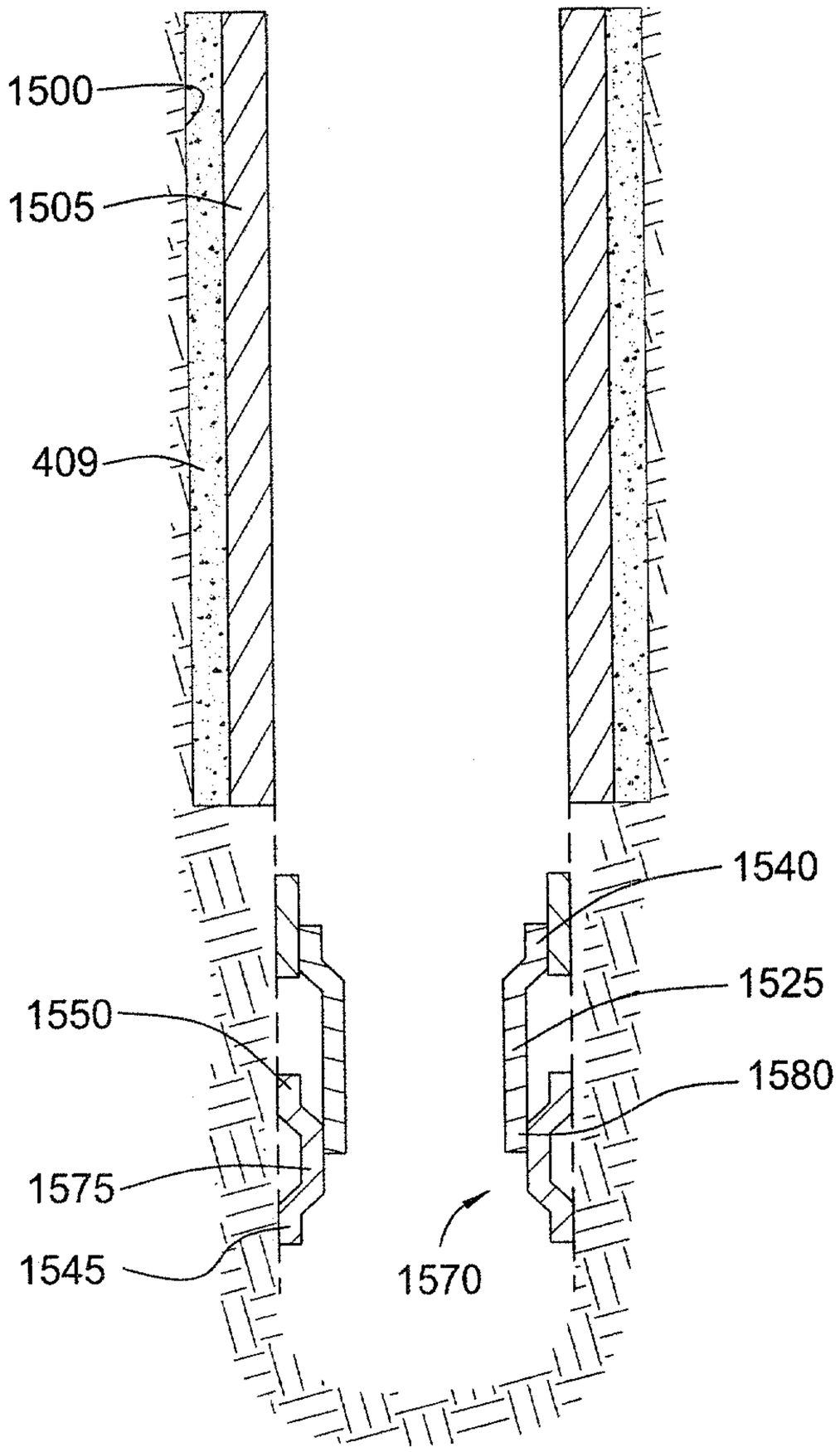


FIG. 15C

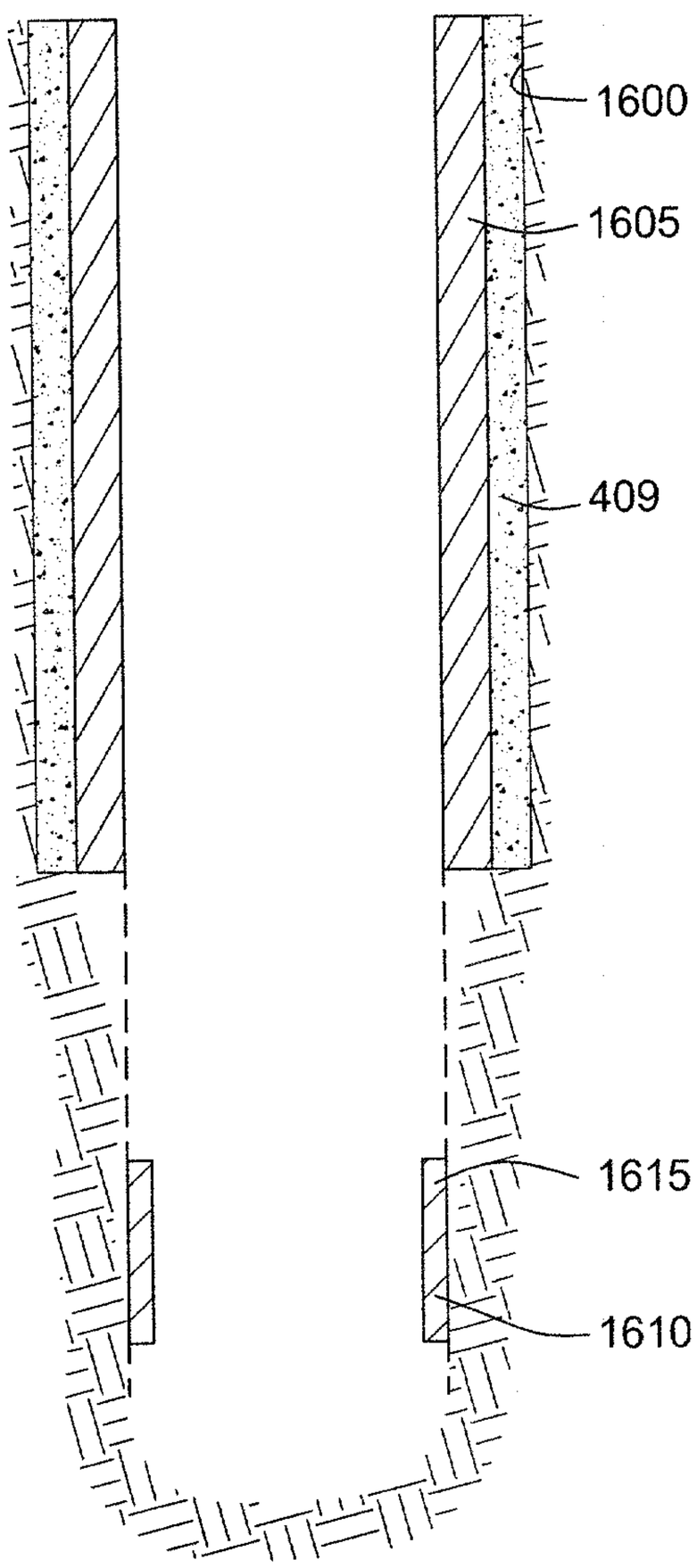


FIG. 16A

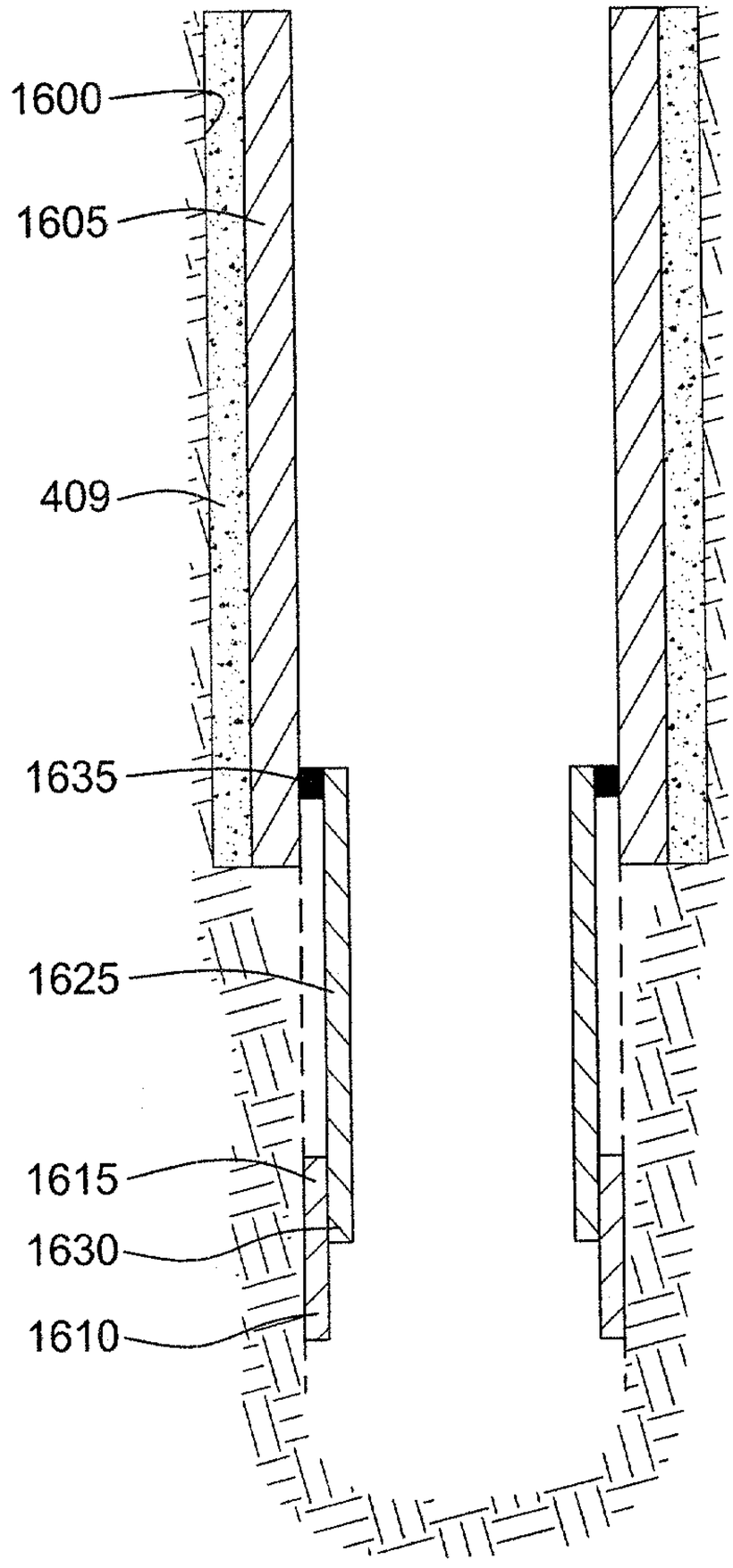


FIG. 16B

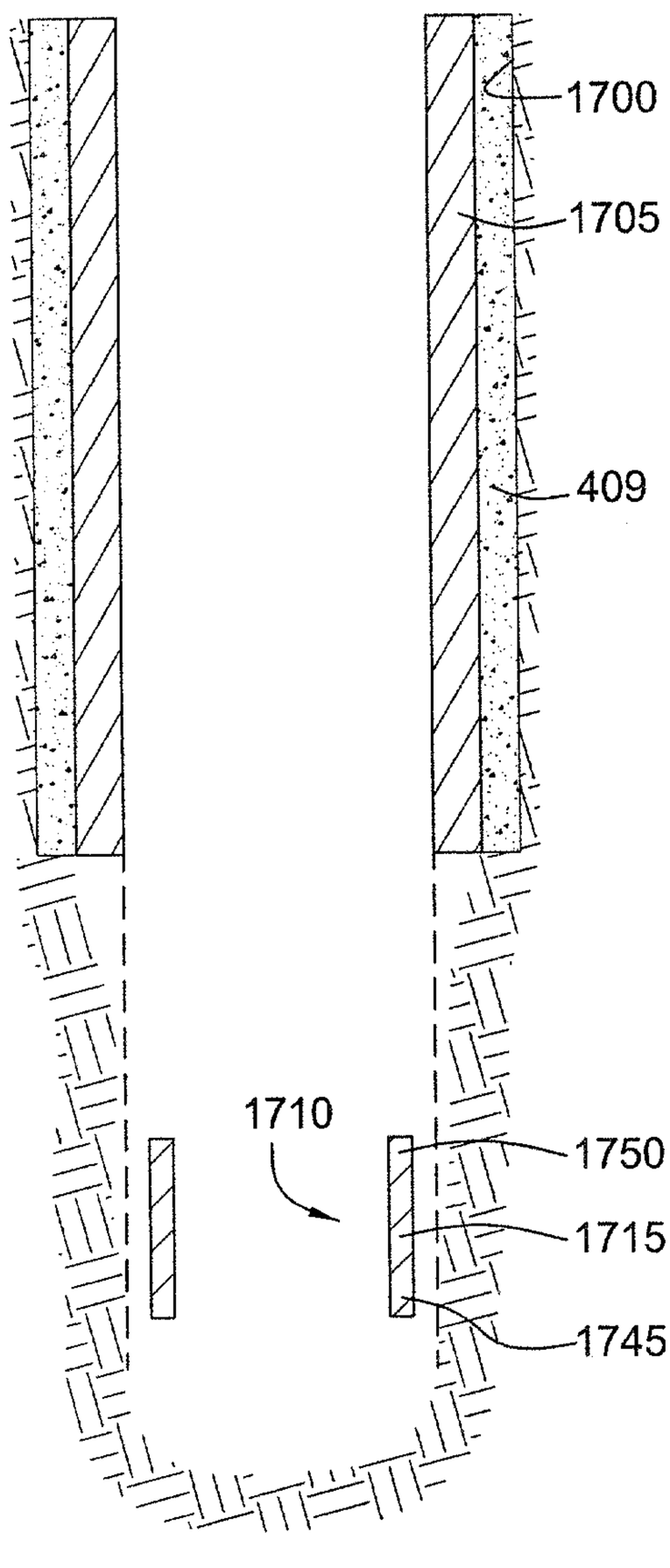


FIG. 17A

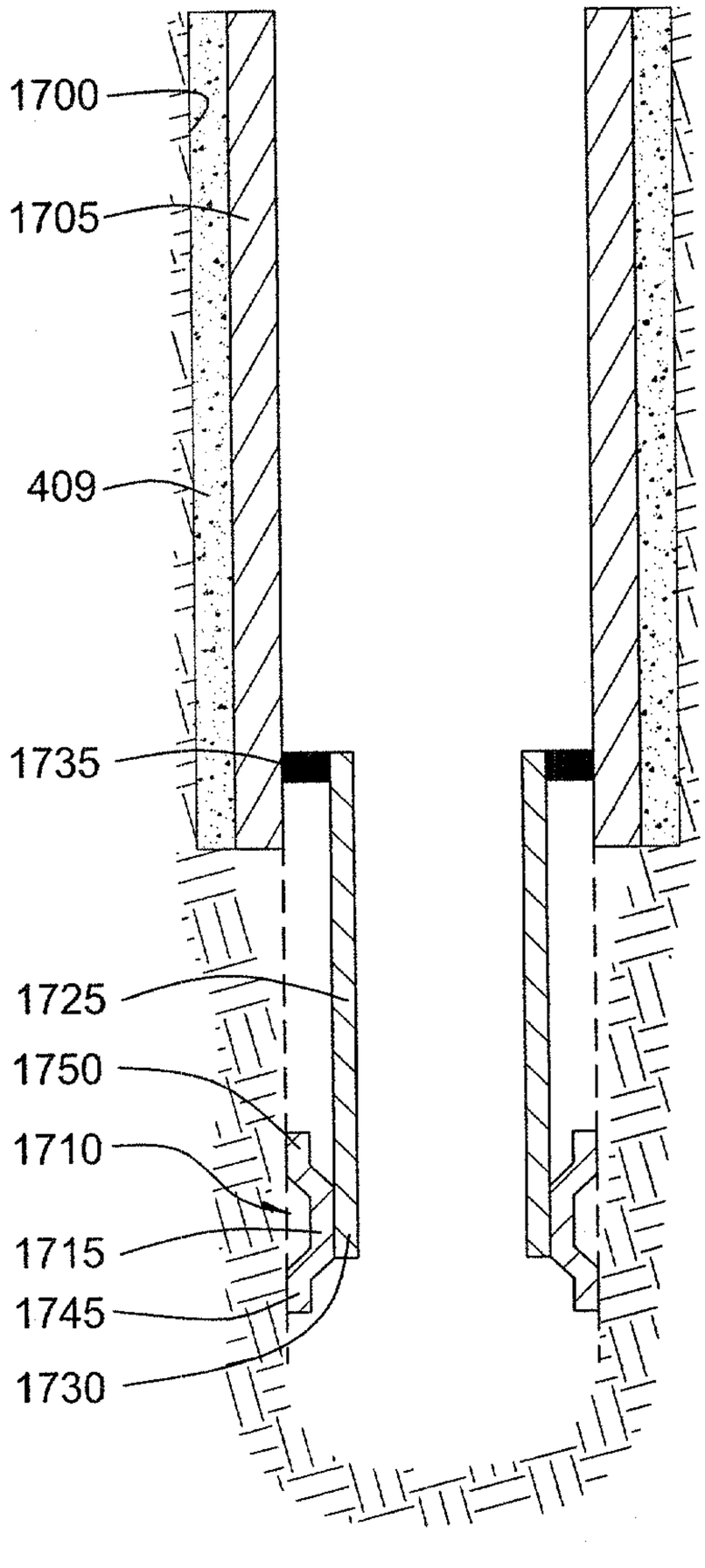


FIG. 17B

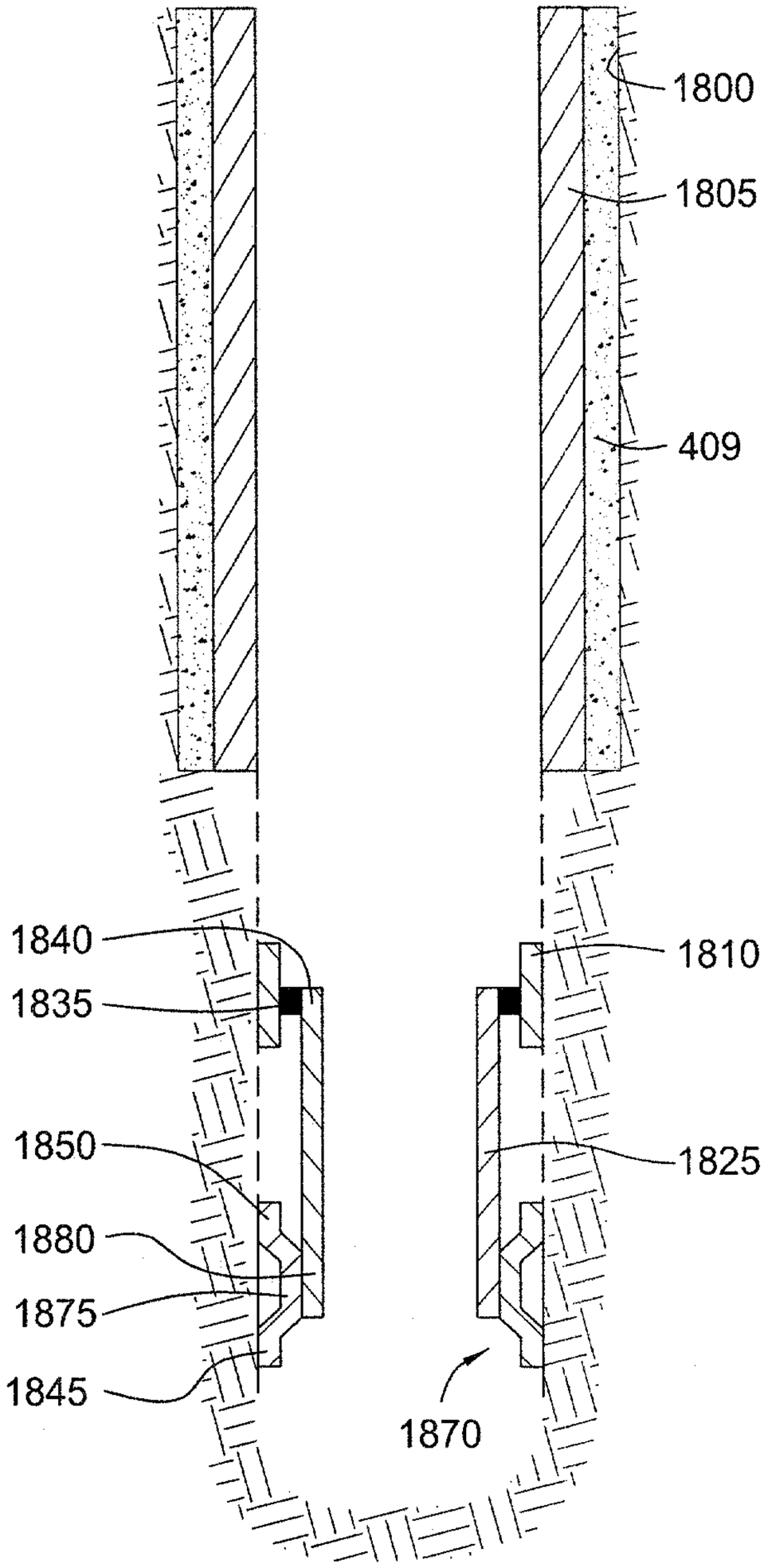


FIG. 18

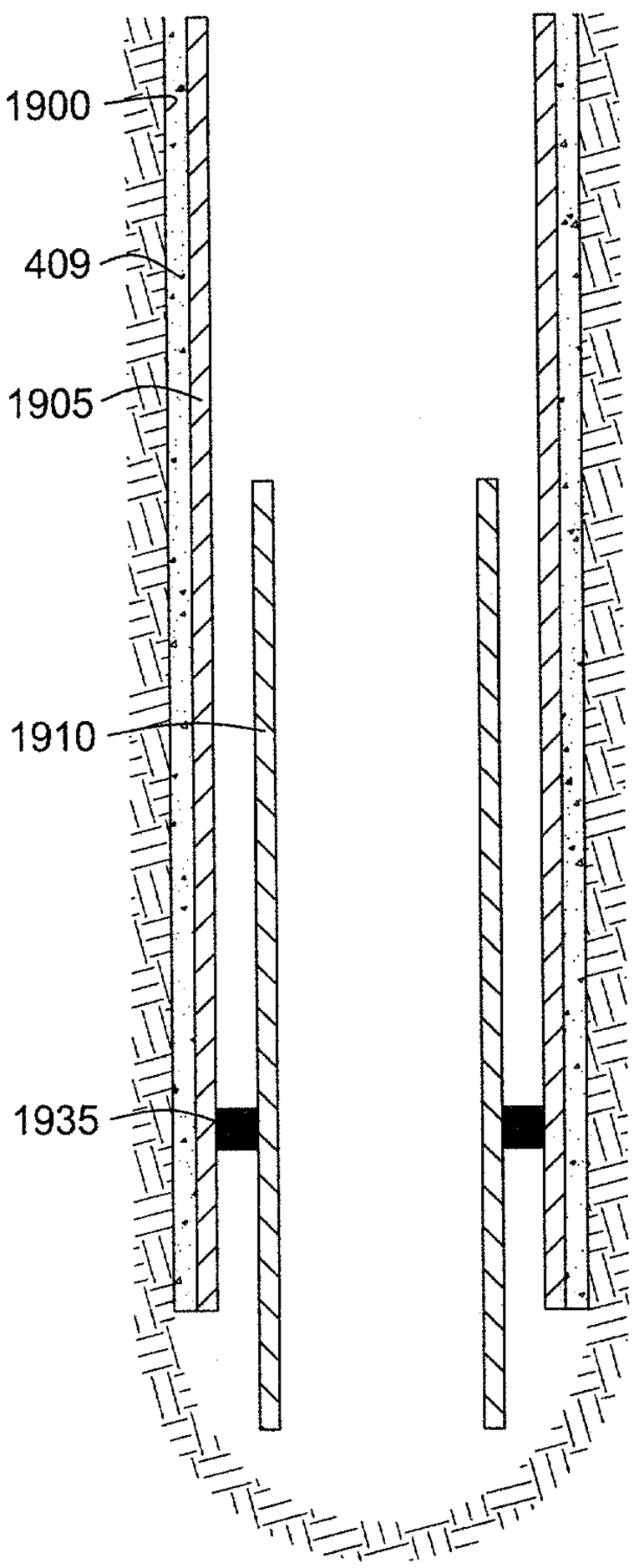


FIG. 19A

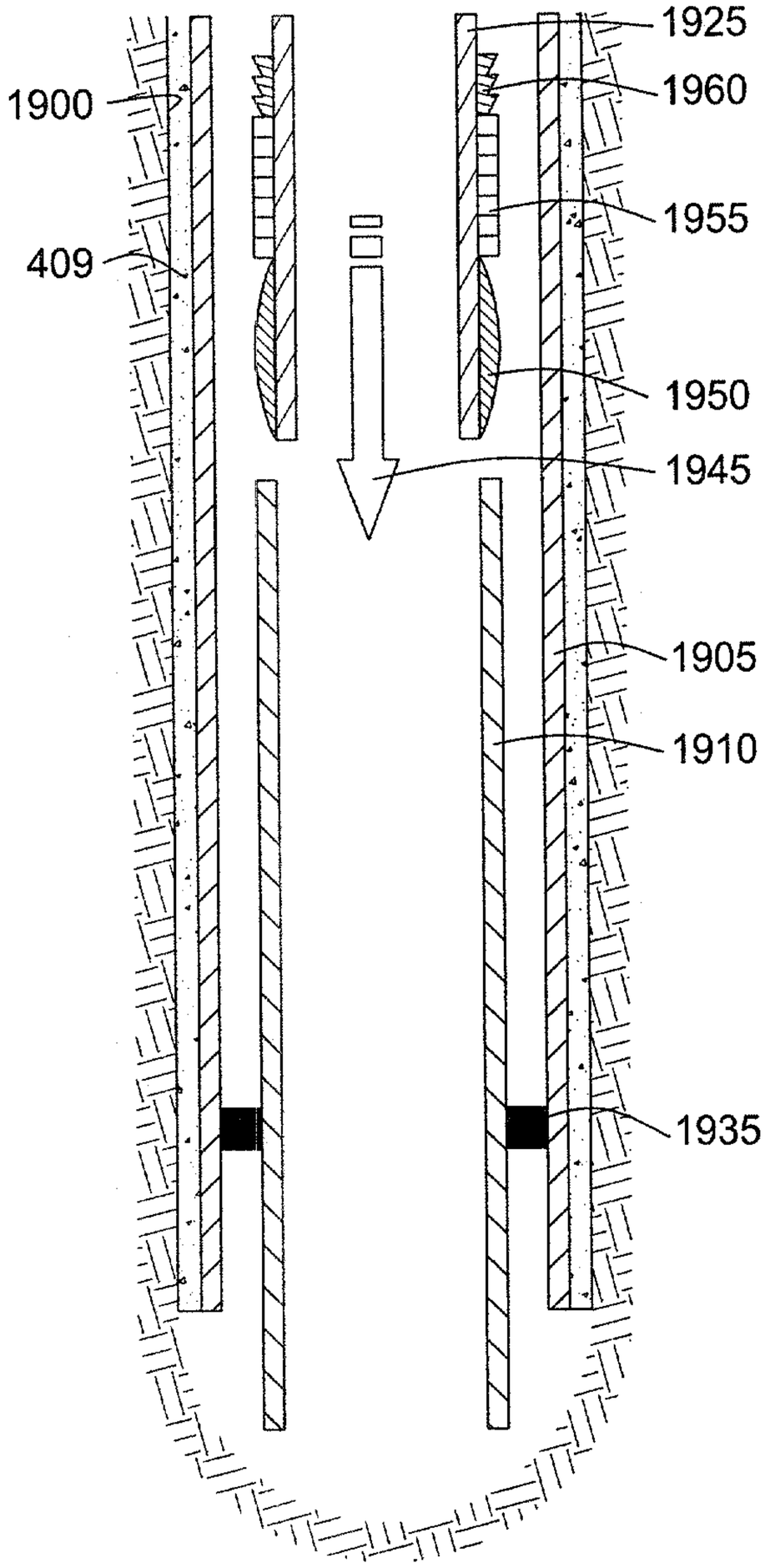


FIG. 19B

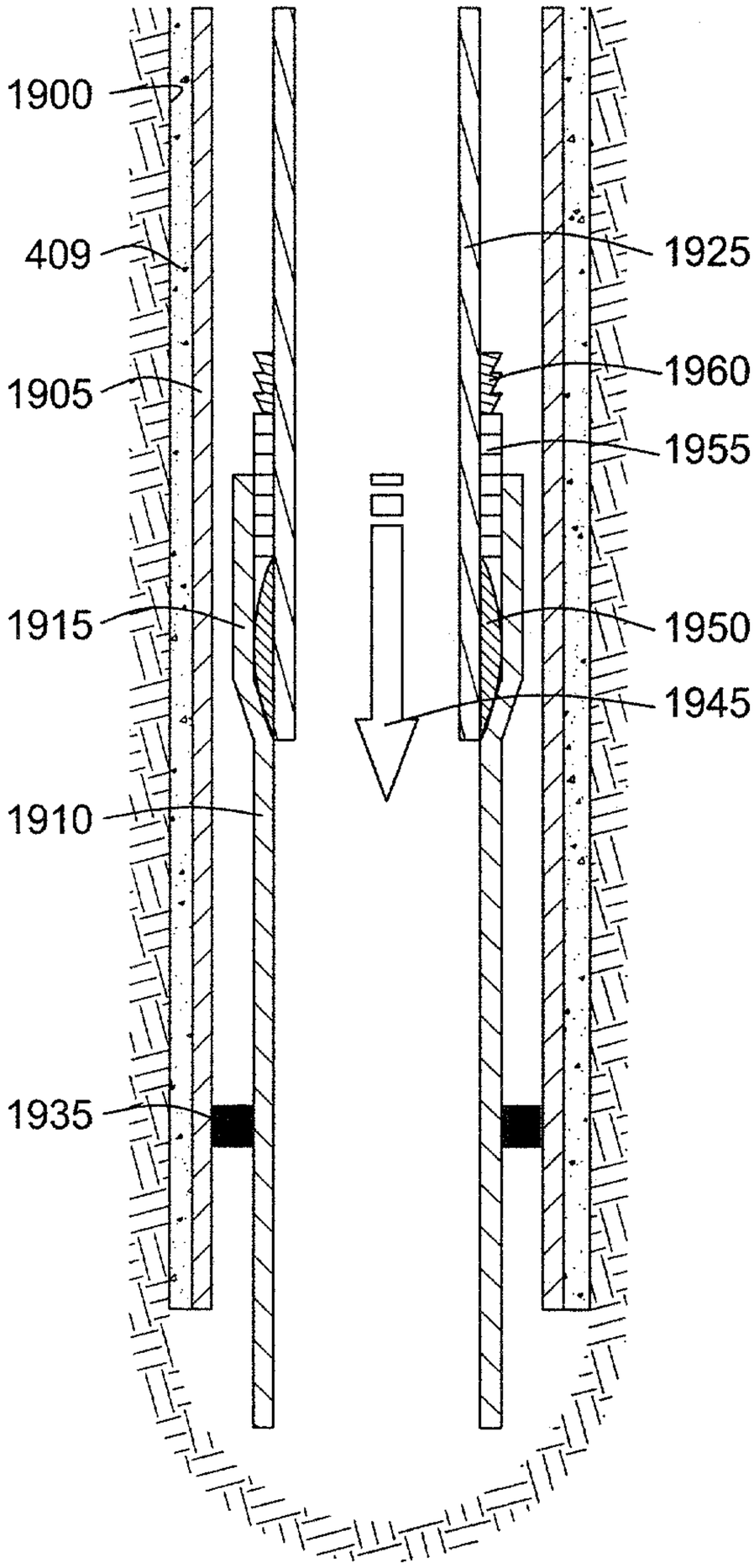


FIG. 19C

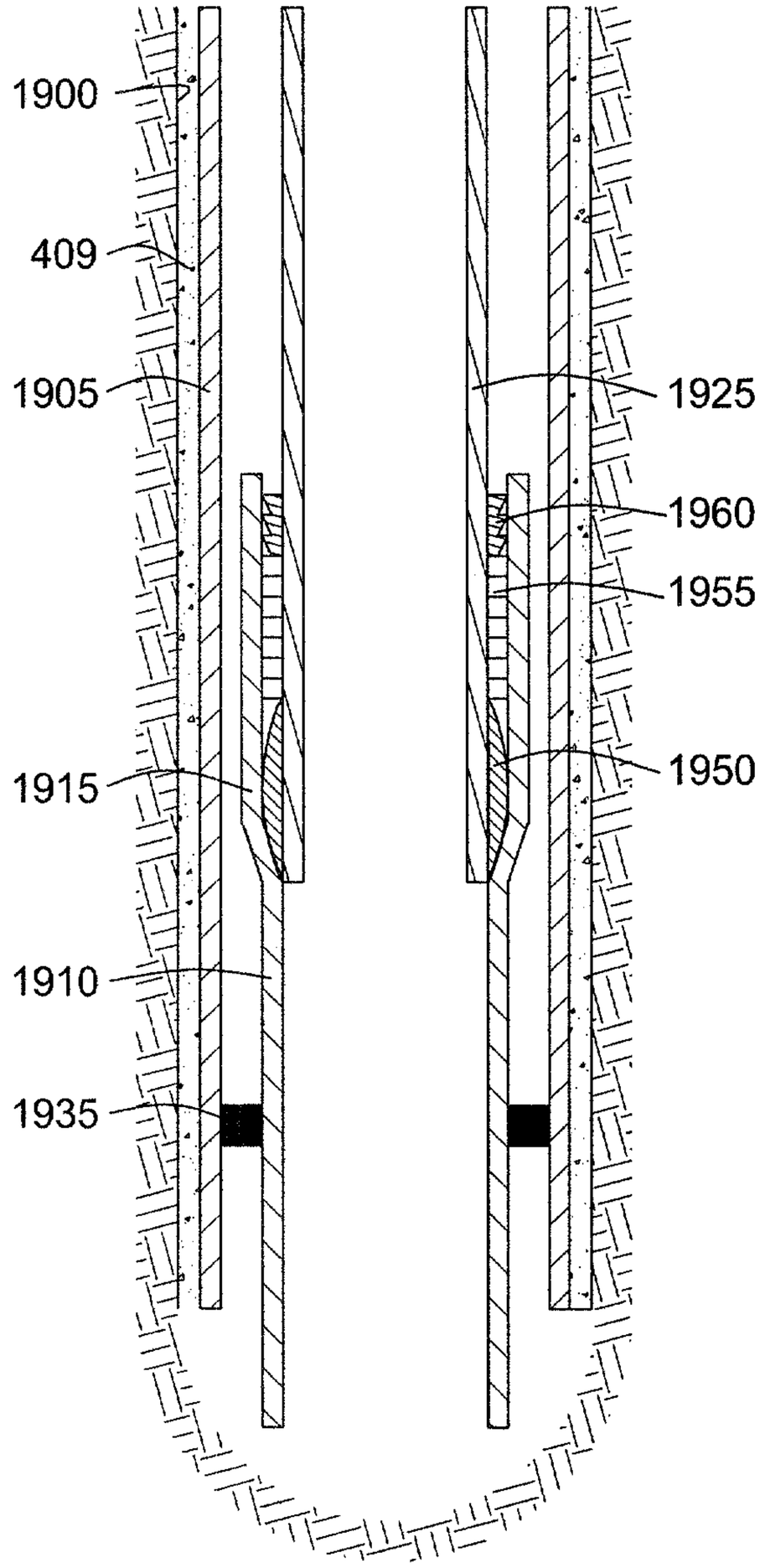


FIG. 19D

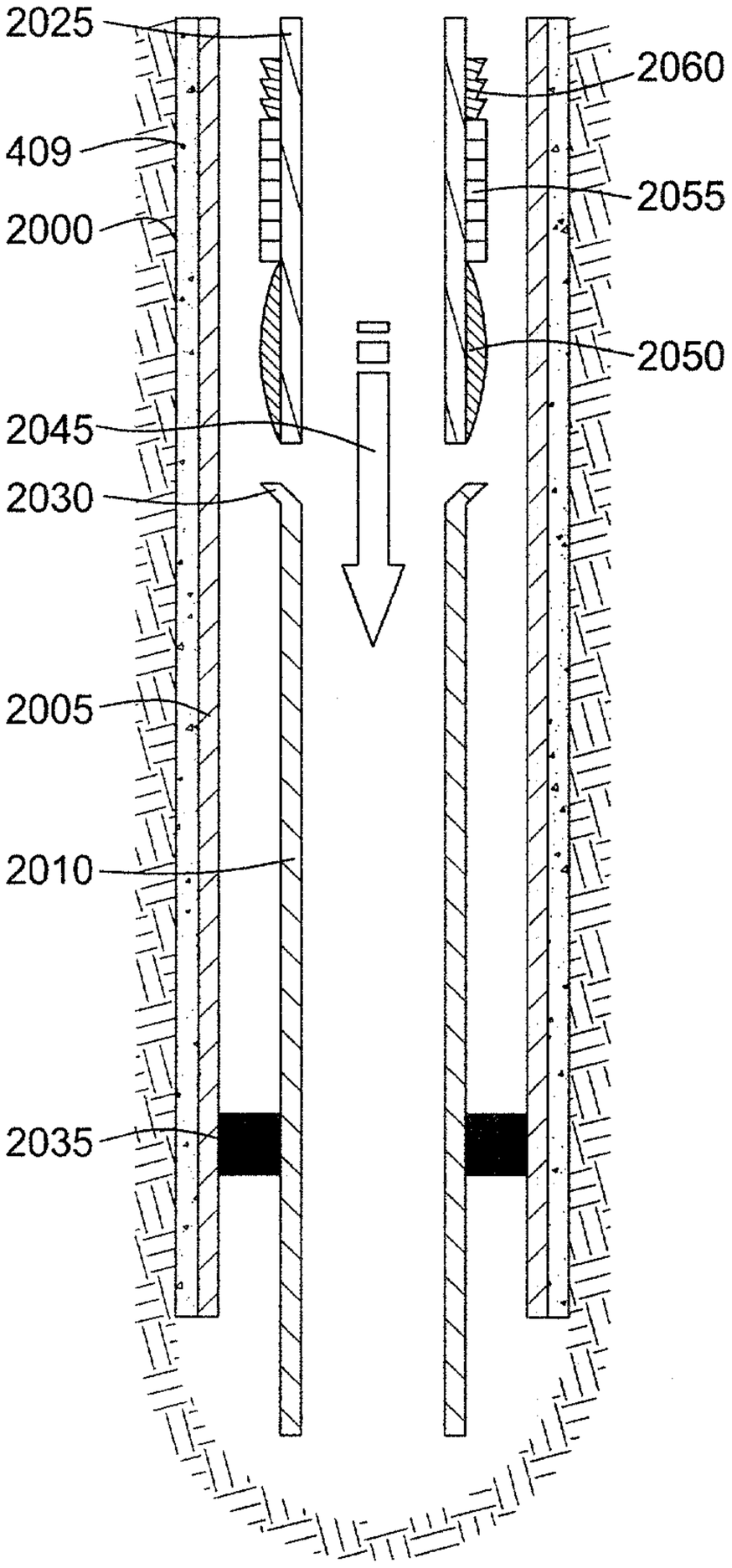


FIG. 20A

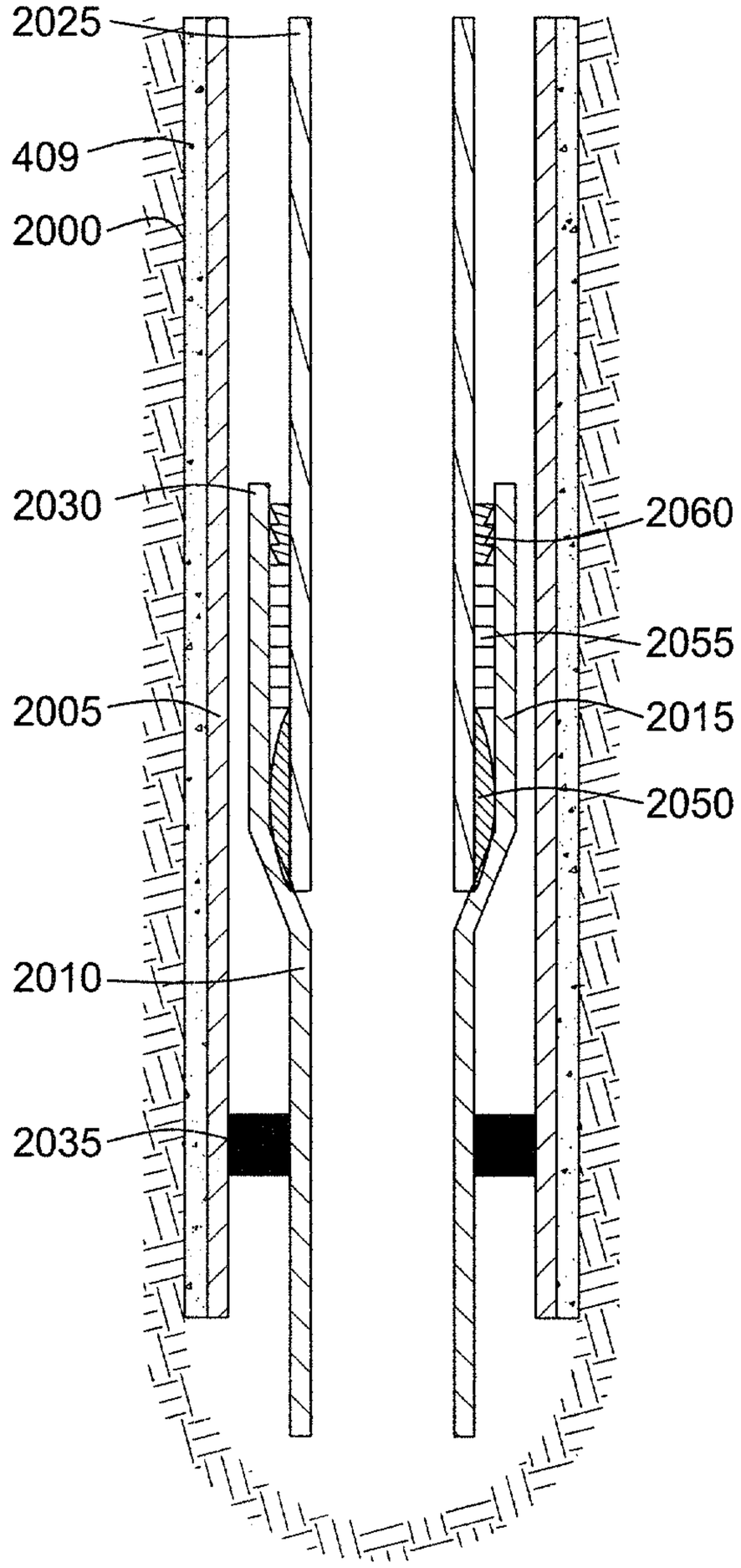


FIG. 20B

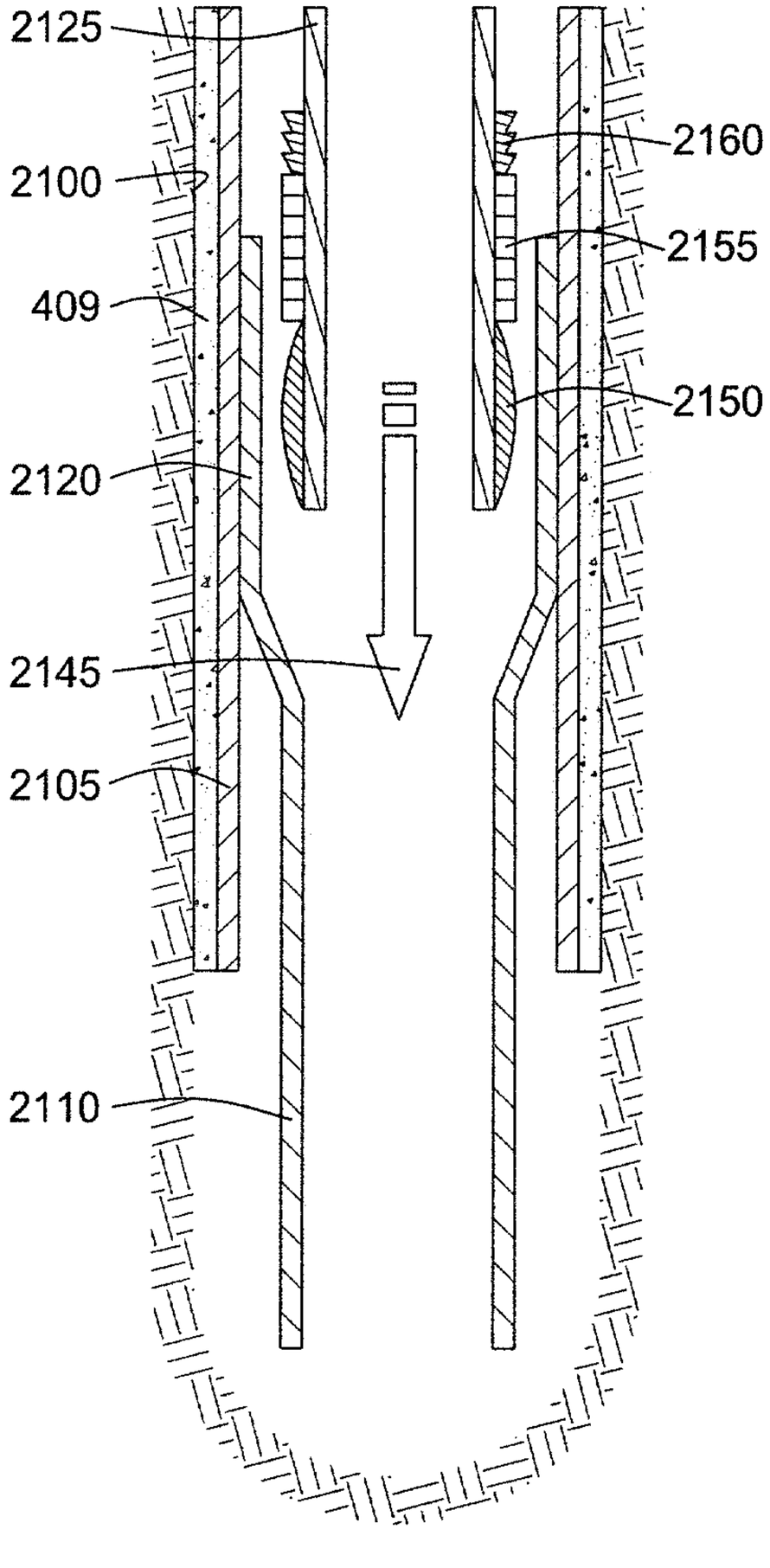


FIG. 21A

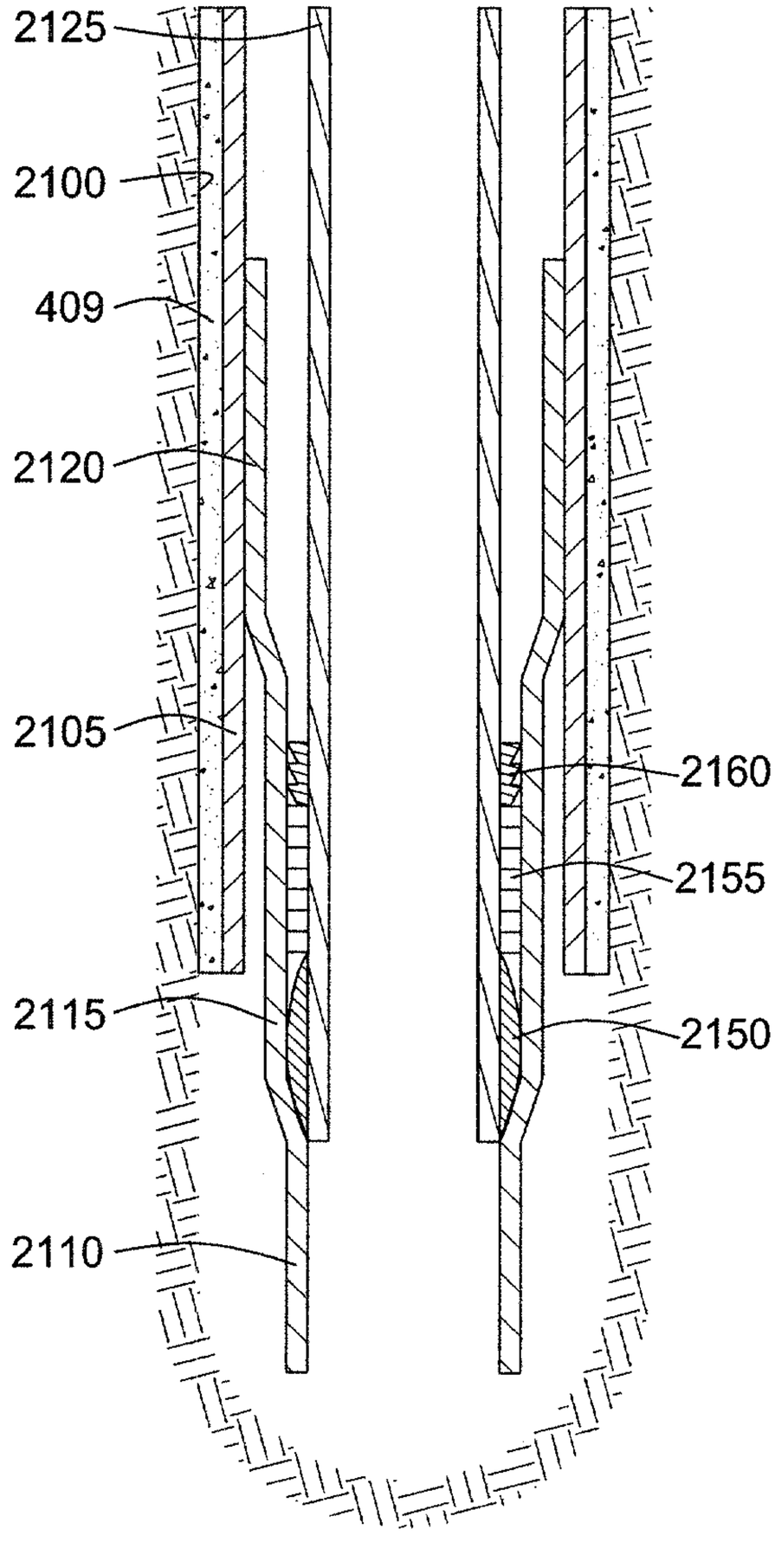


FIG. 21B

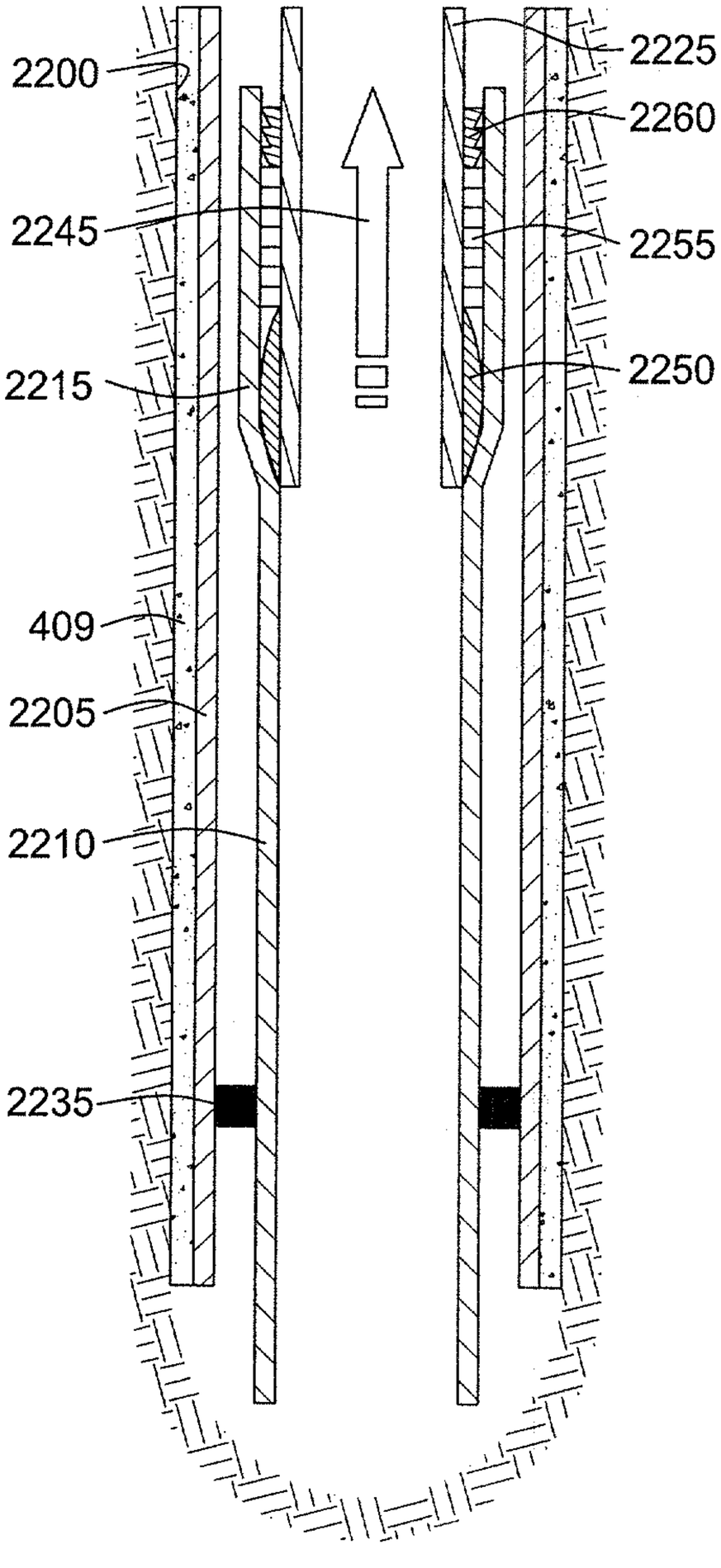


FIG. 22A

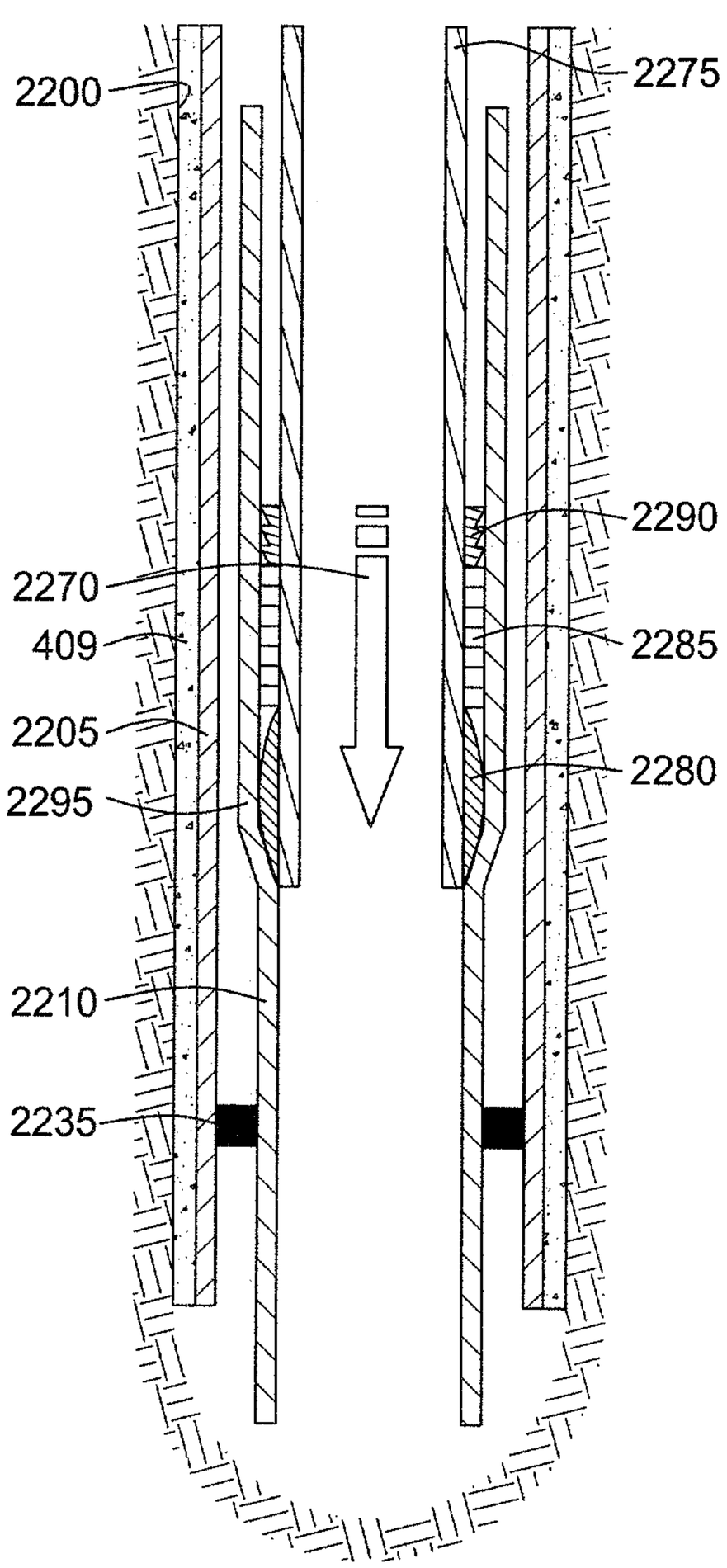
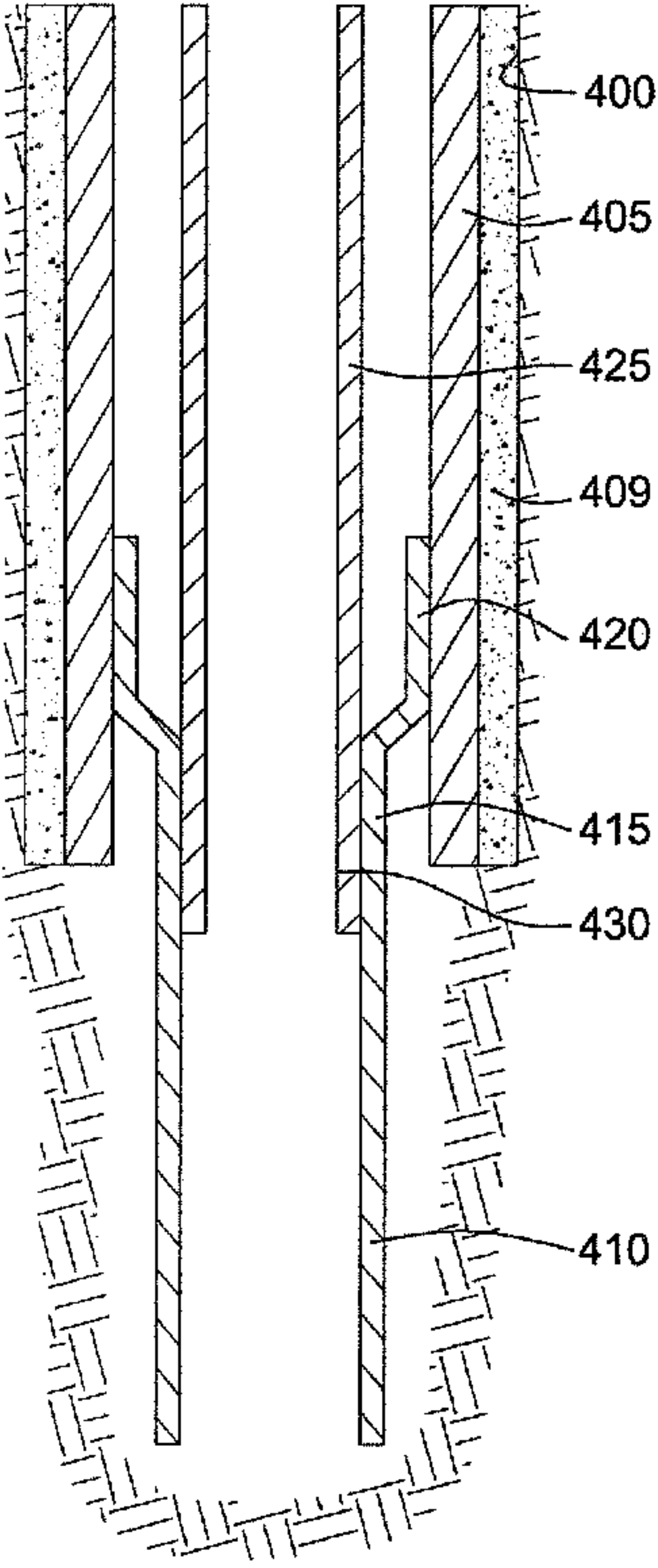


FIG. 22B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