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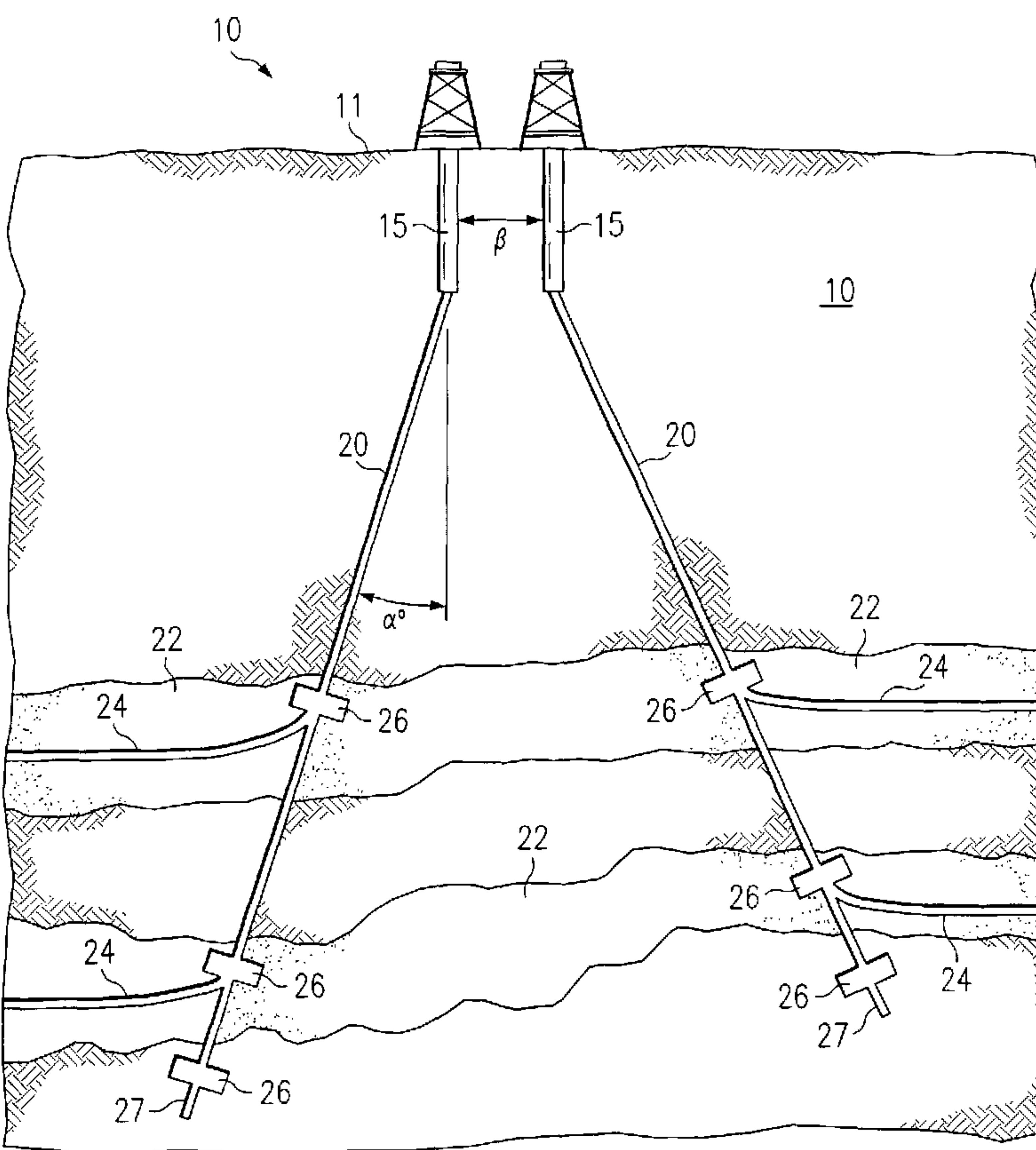
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(57) Abrégé/Abstract:

A system for accessing a subterranean zone from the surface includes a first, second and third entry well bore extending from the surface, the first, second and third entry well bores (15) located on the same drilling pad (92) at the surface. A slanted well bore (20) extends from each of the entry well bores to the subterranean zone (22). A substantially horizontal drainage pattern extends from the slanted well bores into the subterranean zone.

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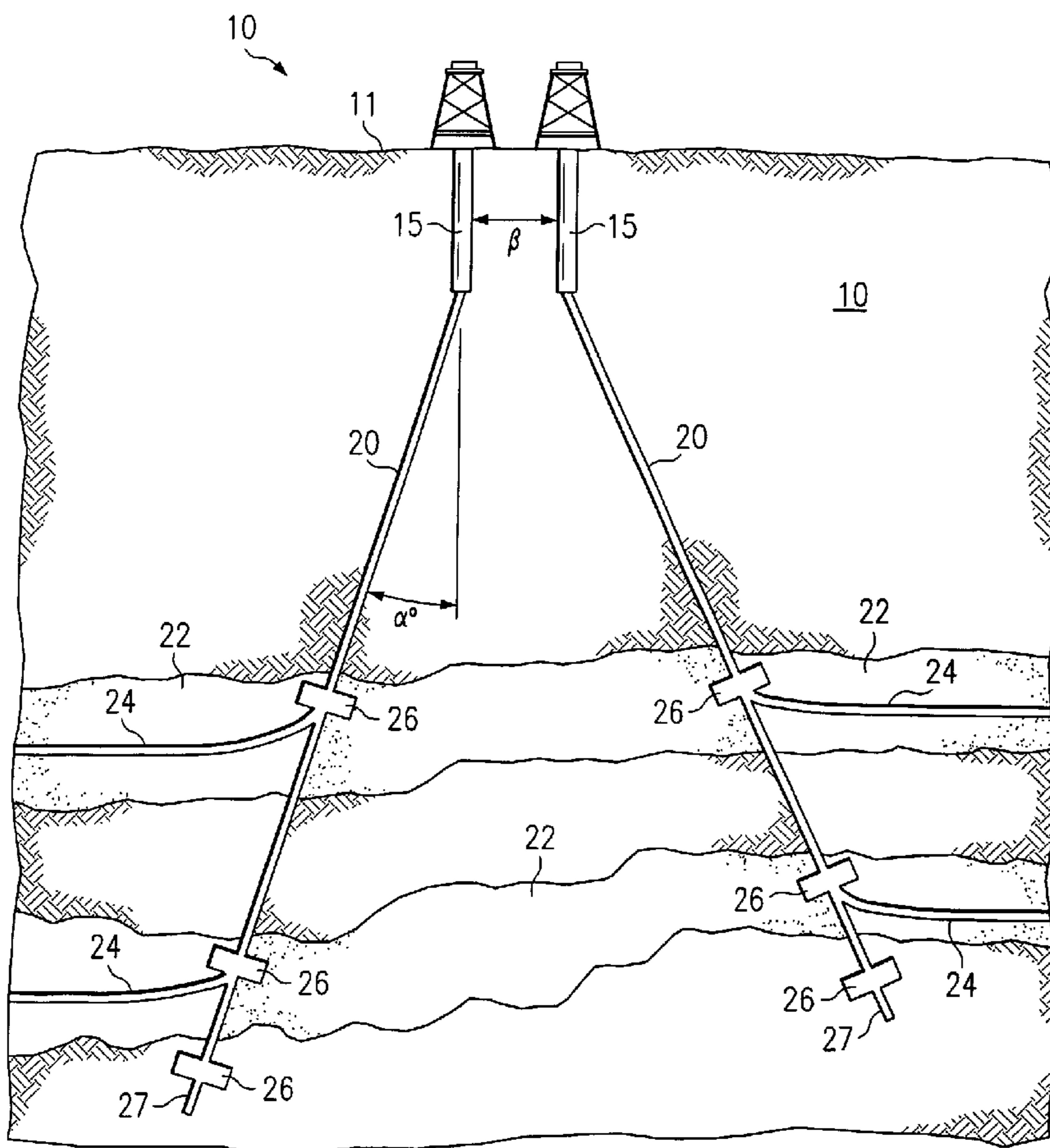
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(54) Title: SYSTEM AND METHOD FOR SUBTERRANEAN ACCESS



(57) Abstract: A system for accessing a subterranean zone from the surface includes a first, second and third entry well bore extending from the surface, the first, second and third entry well bores (15) located on the same drilling pad (92) at the surface. A slanted well bore (20) extends from each of the entry well bores to the subterranean zone (22). A substantially horizontal drainage pattern extends from the slanted well bores into the subterranean zone.

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SYSTEM AND METHOD FOR SUBTERRANEAN ACCESS

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to systems and methods for the recovery of subterranean resources and, more particularly, to a system and method for 5 subterranean access.

BACKGROUND OF THE INVENTION

Subterranean deposits of coal contain substantial quantities of entrained methane gas. Limited production 10 and use of methane gas from coal deposits has occurred for many years. Substantial obstacles, however, have frustrated more extensive development and use of methane gas deposits in coal seams. The foremost problem in producing methane gas from coal seams is that while coal 15 seams may extend over large areas of up to several thousand acres, the coal seams are fairly thin, varying from a few inches to several meters. Vertical wells drilled into the coal deposits for obtaining methane gas can only drain a fairly small radius around the coal 20 deposits. Further, coal deposits are not amenable to pressure fracturing and other methods often used for increasing methane gas production from rock formations. As a result, once the gas easily drained from a vertical well bore in a coal seam is produced, further production 25 is limited in volume. Additionally, coal seams are often associated with subterranean water, which must be drained from the coal seam in order to produce the methane.

Horizontal drilling patterns have been tried in order to extend the amount of coal seams exposed to a drill bore for gas extraction. Such horizontal drilling techniques, however, require the use of a radiused well bore which presents difficulties in removing the entrained water from the coal seam. The most efficient method for pumping water from a subterranean well, a sucker rod pump, does not work well in horizontal or short radiused bores.

A single slanted well bore allows for effective water removal via a sucker rod pump, capturing a benefit of a horizontal well system, without limiting the use of horizontal drainage patterns in the target zone.

15 SUMMARY OF THE INVENTION

The present invention provides a slant entry well system and method for accessing a subterranean zone from the surface that substantially eliminate or reduce the disadvantages and problems associated with previous systems and methods. In particular, certain embodiments of the present invention provide a slant entry well system and method for efficiently producing and removing entrained methane gas and water from a coal seam without requiring excessive use of radiused or articulated well bores or large surface area in which to conduct drilling operations.

In accordance with one embodiment of the present invention, a system for accessing a subterranean zone from the surface includes a first, second, and third entry well bore extending from the surface, the first, second, and third entry well bores located no more than one thousand feet away from each other at the surface. A

slanted well bore extends from each of the first and second entry well bores to the subterranean zone. A substantially horizontal drainage pattern extends from the slanted well bores into the subterranean zone.

5 According to another embodiment of the present invention, a method for accessing a subterranean zone from the surface includes forming three or more closely spaced entry well bores and forming a plurality of slanted well bores from the entry well bores to the
10 subterranean zone. The method also includes forming drainage patterns from the slanted well bores into the subterranean zone and enlarged cavities in the slanted well bores.

Embodiments of the present invention may provide one
15 or more technical advantages. These technical advantages may include the formation of three or more closely spaced entry well bores, a plurality of slanted well bores, and drainage patterns to optimize the area of a subsurface formation which may be drained of gas and liquid
20 resources. This allows for more efficient drilling and production and greatly reduces costs and problems associated with other systems and methods. Another technical advantage includes providing a method for accessing a subterranean zone from the surface using a
25 plurality of slanted well bores with one or more enlarged cavities. The enlarged cavities allow for reduction of velocity of gases escaping through the slanted well bores, aiding in the removal of entrained liquids and optimizing the removal of resources from the subterranean
30 zone.

Other technical advantages of the present invention will be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

5 BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, wherein like numerals represent 10 like parts, in which:

FIGURE 1 illustrates an example slant well system for production of resources from a subterranean zone;

FIGURE 2A illustrates a vertical well system for production of resources from a subterranean zone;

15 FIGURE 2B illustrates a portion of an example slant entry well system in further detail;

FIGURE 3 illustrates an example method for producing water and gas from a subsurface formation;

FIGURE 4 illustrates an example entry well bore ;

20 FIGURE 5 illustrates the use of an example system of an entry well bore and a slanted well bore;

FIGURE 6 illustrates an example system of an entry well bore and a slanted well bore;

25 FIGURE 7 illustrates an example system of a slanted well bore and an articulated well bore;

FIGURE 8 illustrates production of water and gas in an example slant well system; and

FIGURE 9 illustrates an example drainage pattern for use with a slant well system.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 illustrates an example slant well system for accessing a subterranean zone from the surface. In the embodiment described below, the subterranean zone is 5 a coal seam. It will be understood that other subterranean formations and/or zones can be similarly accessed using the slant well system of the present invention to remove and/or produce water, hydrocarbons, and other fluids in the zone, to treat minerals in the 10 zone prior to mining operations, to inject or introduce fluids, gases, or other substances into the zone or for any other appropriate purpose.

Referring to FIGURE 1, a slant well system 10 includes entry well bores 15, slant wells 20, articulated 15 well bores 24, cavities 26, and rat holes 27. Entry well bores 15 extend from the surface 11 towards the subterranean zone 22. Slant wells 20 extend from the terminus of each entry well bore 15 to the subterranean zone 22, although slant wells 20 may alternatively extend 20 from any other suitable portion of an entry well bore 15. As used herein, "each" means all of a particular subset. Where there are multiple subterranean zones 22 at varying depths, as in the illustrated example, slant wells 20 extend through the subterranean zones 22 closest to the 25 surface into and through the deepest subterranean zone 22. Articulated well bores 24 may extend from each slant well 20 into each subterranean zone 22. One or more cavities 26 may be located along a slant well 20 and a cavity 26 or a rat hole 27 may be located at the terminus 30 of each slant well 20.

In FIGURES 1, and, 4-8, entry well bores 15 are illustrated as being substantially vertical; however, it

should be understood that entry well bores 15 may be formed at any suitable angle relative to the surface 11 to accommodate, for example, surface geometries and attitudes and/or the geometric configuration or attitude 5 of a subterranean resource. In the illustrated embodiment, each slant well 20 is formed to angle away from entry well bore 15 at an angle designated α , which in the illustrated embodiment is approximately 20 degrees. It will be understood that each slant well 20 10 may be formed at other angles to accommodate surface topologies and other factors similar to those affecting entry well bores 15. In the illustrated embodiment, slant wells 20 are formed in relation to each other at an angular separation of approximately sixty degrees. It 15 will be understood that slant wells 20 may be separated by other angles depending likewise on the topology and geography of the area and location of the target coal seam 22.

Entry well bores 15 are formed at the surface at a 20 distance of β feet apart. In the illustrated embodiment, entry well bores 15 are approximately twenty feet apart. It will be understood that entry well bores 15 may be formed at other separations to accommodate surface topologies and/or the geometric configuration or attitude 25 of a subterranean resource.

In some embodiments, entry well bores 15 may be between two feet and one hundred feet apart. In some embodiments, the entry well bores 15 may be located on the same drilling pad. As used herein, "on the same 30 drilling pad" means located at the same drilling location where drilling operations are being conducted. In some embodiments, entry well bores 15 are closely spaced

together. As used herein, "closely spaced" means on the same drilling pad.

Cavities 26 may be formed at intervals along slant wells 20 above one or more of articulated well bores 24. 5 For example, cavities 26 may be formed immediately above an articulated well bore 24. Cavities 26 may also be formed proximate to the junction of slant well 20 and articulated well bore 24. As used herein, proximate means immediately above, below, or at the junction of 10 slant well 20 and articulated well bore 24. It will be understood that other appropriate spacing may also be employed to accommodate, for example, sub-surface geometries and attitudes and/or the geometric configuration or attitude of a subterranean resource. 15 Slant well 20 may also include a cavity 26 and/or a rat hole 27 located at the terminus of each slant well 20. Slant wells 20 may include one, both, or neither of cavity 26 and rat hole 27.

FIGURES 2A and 2B illustrate by comparison the 20 advantage of forming slant wells 20 at an angle off the vertical. Referring to FIGURE 2A, a vertical well bore 30 is shown with an articulated well bore 32 extending into a coal seam 22. As shown by the illustration, fluids drained from coal seam 22 into articulated well 25 bore 32 must travel along articulated well bore 32 upwards towards vertical well bore 30, a distance of approximately W feet before they may be collected in vertical well bore 30. This distance of W feet is known as the hydrostatic head and must be overcome before the 30 fluids may be collected from vertical well bore 30. Referring now to FIGURE 2B, a slant entry well 34 is shown with an articulated well bore 36 extending into

coal seam 22. Slant entry well 34 is shown at an angle α away from the vertical. As illustrated, fluids collected from coal seam 22 must travel along articulated well bore 36 up to slant entry well 34, a distance of W' feet.

5 Thus, the hydrostatic head of a slant entry well system is reduced as compared to a substantially vertical system. Furthermore, by forming slant entry well 34 at angle α , the articulated well bore 36 drilled from tangent or kick off point 38 has a greater radius of

10 curvature than articulated well bore 32 associated with vertical well bore 30. This allows for articulated well bore 36 to be longer than articulated well bore 32 (since the friction of a drill string against the radiused portion is reduced), thereby penetrating further into

15 coal seam 22 and draining more of the subterranean zone.

FIGURE 3 illustrates an example method of forming a slant entry well 20. The steps of FIGURE 3 will be further illustrated in subsequent FIGURES 4-8. The method begins at step 100 wherein an entry well bore is formed. At step 105, a fresh water casing or other suitable casing is installed into the entry well bore formed at step 100. At step 110, the fresh water casing is cemented in place inside the entry well bore of step 100.

25 At step 115, a drill string is inserted through the entry well bore, and is used to drill approximately fifty feet past the casing. In some embodiments, a short, radiused bore is formed. In some embodiments, the radiused bore may be two hundred feet long and articulate thirty-five degrees over its length. It will be understood that other lengths and degrees may be employed based on the local geology and topography. At step 120,

the drill is oriented to the desired angle of the slant well and, at step 125, a slant well bore is drilled down into and through the target subterranean zone. At step 130, one or more cavities are formed in the slant well.

5 At step 135 the slant well casing is installed. Next, at step 140, a short radius curve is drilled into the target coal seam. Next, at step 145, a substantially horizontal well bore is drilled into and along the coal seam. It will be understood that the substantially 10 horizontal well bore may depart from a horizontal orientation to account for changes in the orientation of the coal seam. Next, at step 150, a drainage pattern is drilled into the coal seam through the substantially horizontal well. The drainage pattern may comprise a 15 pinnate pattern, a crow's foot pattern, or other suitable pattern. At decisional step 155, a determination is made whether additional subterranean zones are to be drained as, for example, when multiple subterranean zones are present at varying depths below the surface. If 20 additional subterranean zones are to be drained, the process repeats steps 140 through 155 for each additional subterranean zone. If no further subterranean zones are to be drained, the process continues to step 160.

At decisional step 160, a determination is made 25 whether additional slant wells are required. If additional slant wells are required, the process returns along the Yes branch to step 100 and repeats through step 155. A separate entry well bore may be formed for each individual slant well bore. Thus, for each slant well, 30 the process begins at step 100, wherein a substantially vertical well bore is found. In some embodiments,

however, multiple slant wells may be formed from one entry well bore.

If no additional slant wells are required, the process continues along the No branch to step 165.

5 At step 165, production equipment is installed into each slant well and at step 170 the process ends with the production of water and gas from the subterranean zone.

10 Although the steps have been described in a certain order, it will be understood that they may be performed in any other appropriate order. Furthermore, one or more steps may be omitted, or additional steps performed, as appropriate.

15 For example, where multiple target zones are present (as determined at step 155), an enlarged diameter cavity may be found (step 130) above each target zone before any of the short radius curves are drilled (step 140). Alternatively, all of the short radius curves may be found in each target zone (step 140) before any enlarged diameter cavities are found (step 130). Other suitable 20 modifications will be apparent to one skilled in the art.

FIGURE 4 illustrates entry well bore 15 and casing 44 in its operative mode as a slant well 20 is about to be drilled. Corresponding with step 110 of FIGURE 3, a cement retainer 46 is poured or otherwise installed 25 around the casing inside entry well bore 15. The cement casing may be any mixture or substance suitable to maintain casing 44 in the desired position with respect to entry well bore 15. A drill string 50 is positioned to begin forming a slant well. In order to keep drill 30 string 50 relatively centered in casing 44, a stabilizer 52 may be employed. Stabilizer 52 may be a ring and fin type stabilizer or any other stabilizer suitable to keep

drill string 50 relatively centered. To keep stabilizer 52 at a desired depth in well bore 15, stop ring 53 may be employed. Stop ring 53 may be constructed of rubber or metal or any other suitable down-hole environment 5 material.

FIGURE 5 illustrates an example system of a slant well 20. Corresponding with step 115 of FIGURE 3, well bore 60 is drilled approximately fifty feet past the end of entry well bore 15 (although any other appropriate 10 distance may be drilled). Well bore 60 is drilled away from casing 44 in order to minimize magnetic interference and improve the ability of the drilling crew to guide the drill bit in the desired direction. As described above in conjunction with FIGURE 3, well bore 60 may also 15 comprise an articulated well bore with a radius of thirty-five degrees in two hundred feet.

Corresponding with step 120 of FIGURE 3, the drill bit is oriented in preparation for drilling slant entry well bore 64. Corresponding with step 125 of FIGURE 3, a 20 slant entry well bore 64 is drilled from the end of the radius well bore 62 into and through the subterranean zone 22. Alternatively, slant well 20 may be drilled directly from entry well bore 15, without including tangent well bore 60 or radiused well bore. A rat hole 25 66, which is an extension of slant well 64, is also formed. Rat hole 66 may also be an enlarged diameter cavity or other suitable structure. Corresponding with step 130 of FIGURE 3, a cavity 26 is formed in slant well 64.

30 Cavity 26 acts as a velocity reduction chamber, separating entrained liquids from gasses destined for the surface. Without at least one cavity 26 located closer

to the surface than the shallowest lateral well bore, entrained liquids form a mist that raises down-hole pressure. Friction is increased by the liquids entrained in escaping gasses, creating increased back pressure 5 (down-hole pressure). Reducing the gas velocity separates out the liquid as the velocity drops below the speed at which the gas can entrain liquids. Cavity 26 lowers the velocity of the gas enough to separate out the entrained liquids, allowing the gas to proceed to the 10 surface more efficiently.

In the illustrated embodiment, cavity 26 is shown immediately above the expected kick-off point for a subsequent short radiused well bore. It will be understood that cavity 26 may be otherwise suitably 15 located. Moreover, it will be understood that cavity 26 may also be formed after the horizontal drainage pattern is formed.

FIGURE 6 is an illustration of the positioning of the casing in a slant well 64. For ease of illustration, 20 only one slant well 64 is shown. Corresponding with step 135 of FIGURE 3, a whipstock casing 70 is installed into the slant entry well bore 64. In the illustrated embodiment, whipstock casing 70 includes a whipstock 72 which is used to mechanically direct a drill string into 25 a desired orientation. It will be understood that other suitable techniques may be employed and the use of a whipstock 72 is not necessary when other suitable methods of orienting a drill bit through slant well 64 into the subterranean zone 22 are used. Whipstock casing 70 is 30 oriented such that whipstock 72 is positioned so that a subsequent drill bit is aligned to drill into the subterranean zone 22 at a desired depth.

FIGURE 7 illustrates whipstock casing 70 and slant entry well bore 64 in further detail. As discussed in conjunction with FIGURE 6, whipstock casing 70 is positioned within slant entry well bore 64 such that a 5 drill string 50 will be oriented to pass through slant entry well bore 64 at a desired tangent or kick off point 38. This corresponds with step 140 of FIGURE 3. Drill string 50 is used to drill through slant entry well bore 64 at tangent or kick off point 38 to form articulated 10 well bore 36. In a particular embodiment, articulated well bore 36 has a radius of approximately seventy-one feet and a curvature of approximately eighty degrees per one hundred feet. In the same embodiment, slant entry well 15 bore 64 is angled away from the vertical at approximately ten degrees. In this embodiment, the hydrostatic head generated in conjunction with production is roughly thirty feet. However, it should be understood that any other appropriate radius, curvature, and slant angle may be used.

20 FIGURE 8 illustrates a slant entry well 64 and articulated well bore 36 after drill string 50 has been used to form articulated well bore 36. In a particular embodiment, a horizontal well and drainage pattern may then be formed in subterranean zone 22, as represented by 25 step 145 and step 150 of FIGURE 3.

Referring to FIGURE 8, whipstock casing 70 is set on the bottom of rat hole 66 to prepare for production of oil and gas. A sealer ring 74 may be used around the whipstock casing 70 to prevent gas produced from 30 articulated well bore 36 from escaping outside whipstock casing 70. Gas ports 76 allow escaping gas to enter into and up through whipstock casing 70 for collection at the

surface. As described above, liquids entrained in the escaping gas may be separated from the gas in enlarged diameter cavities 26 situated above the articulated well bore 36. As the liquids separate from the gas, the 5 liquids travel down slant well 64 and are collected in rat hole 66. Rat hole 66 may also comprise an enlarged diameter cavity (not shown) to collect liquids arriving from above.

A pump string 78 and submersible pump 80 is used to 10 remove water and other liquids that are collected from the subterranean zone through articulated well bore 36. As shown in FIGURE 9, the liquids, under the power of gravity and the pressure in subterranean zone 22, pass through articulated well bore 36 and down slant entry 15 well bore 64 into rat hole 66. From there the liquids travel into the opening in the whipstock 72 of whipstock casing 70 where they come in contact with the installed pump string 78 and submersible pump 80. Submersible pump 80 may be a variety of submersible pumps suitable for use 20 in a down-hole environment to remove liquids and pump them to the surface through pump string 78. Installation of pump string 78 and submersible pump 80 corresponds with step 165 of FIGURE 3. Production of liquid and gas corresponds with step 170 of FIGURE 3.

25 FIGURE 9 illustrates an example drainage pattern 90 that may be drilled from articulated well bores 36. At the center of drainage pattern 90 is a plurality of entry well bores 15 on a drilling pad 92 at the surface. In one embodiment, entry well bores 15 are spaced 30 approximately twenty feet apart. It will be understood that other suitable spacings may also be employed.

Connecting to each entry well bore 15 is a slant well 20. At the terminus of slant well 20, as described above, are substantially horizontal well bores 94 roughly forming a "crow's foot" pattern off of each of the slant wells 20. It will be understood that any other suitable drainage patterns, for example, a pinnate pattern, may be used. In an example embodiment, the horizontal reach of each substantially horizontal well bore 94 is approximately three hundred feet. Additionally, the lateral spacing between the parallel substantially horizontal well bores 94 is approximately eight hundred feet. In this particular embodiment, a drainage area of approximately six hundred and forty acres would result.

Although the present invention has been described with several embodiments, various changes and modifications may be suggested to one skilled in the art. It is intended that the present invention encompass such changes and modifications as fall within the scope of the appended claims.

CLAIMS

1. A method for accessing a subterranean zone from the surface, comprising:

forming a first entry well bore from the surface;

forming one or more slanted well bores from the first entry well bore to the subterranean zone;

forming a second entry well bore from the surface, the second entry well bore located on the same drilling location as the first entry well bore at the surface;

forming one or more slanted well bores from the second entry well bore to the subterranean zone;

forming a third entry well bore from the surface, the third entry well bore located on the same drilling location as the first and second entry well bores at the surface;

forming one or more slanted well bores from the third entry well bore to the subterranean zone; and

forming a substantially horizontal drainage pattern through at least one of the slanted well bores into the subterranean zone.

2. The method of Claim 1, wherein the horizontal drainage patterns comprise a horizontal well bore extending from the slanted well bore and a plurality of lateral well bores extending from the horizontal well bore.

3. The method of Claim 2, wherein the horizontal drainage patterns comprise a crow's foot configuration.

4. The method of Claim 2, wherein the lateral well bores are configured to drain an area of the subterranean zone of at least 640 acres.

5 5. The method of Claim 2, wherein the horizontal drainage patterns comprise a pinnate configuration.

10 6. The method of Claim 1, further comprising removing resources from the subterranean zone through the horizontal drainage patterns to the surface.

7. The method of Claim 1, further comprising forming an enlarged cavity in each of the slanted well bores proximate to and above the subterranean zone.

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8. The method of Claim 1, further comprising forming an enlarged cavity in each of the slanted well bores above the horizontal drainage pattern.

20 9. The method of Claim 7, wherein the enlarged cavity is located proximate to the junction of the slanted well bore and the substantially horizontal drainage pattern.

25 10. The method of Claim 1, wherein the first, second, and third entry well bores are spaced approximately twenty feet apart.

30 11. The method of Claim 1, further comprising forming a second horizontal drainage pattern from each of the slanted well bores into a second subterranean zone.

12. A system for accessing a subterranean zone from the surface, comprising:

a first entry well bore from the surface;

a second entry well bore from the surface, the second entry well bore located on the same drilling location as the first entry well bore at the surface;

a third entry well bore from the surface, the third entry well bore located on the same drilling location as the first and second entry well bores at the surface;

one or more slanted well bores extending from each of the first, second and third entry well bores to the subterranean zone; and

a substantially horizontal drainage pattern drilled through at least one of the slanted well bores into the subterranean zone.

13. The system of Claim 12, wherein the horizontal drainage patterns comprise a horizontal well bore extending from the slanted well bore and a plurality of lateral well bores extending from the horizontal well bore.

14. The system of Claim 13, wherein the horizontal drainage patterns comprise a crow's foot configuration.

15. The system of Claim 13, wherein the lateral well bores are configured to drain an area of the subterranean zone of at least 640 acres.

16. The system of Claim 13, wherein the horizontal drainage patterns comprise a pinnate configuration.

17. The system of Claim 12, further comprising an enlarged cavity in each of the slanted well bores proximate to the subterranean zone.

5 18. The system of Claim 12, further comprising an enlarged cavity in each of the slanted well bores between the surface and the horizontal drainage pattern.

10 19. The system of Claim 17, wherein the enlarged cavity is located proximate to the junction of the slanted well bore and the substantially horizontal drainage pattern.

15 20. The system of Claim 12, wherein the first, second, and third entry well bores are spaced approximately twenty feet apart at the surface.

20 21. The system of Claim 12, further comprising a second substantially horizontal drainage pattern extending from each slanted well bore into a second subterranean zone.

22. A system for accessing a subterranean zone from the surface, comprising:

three or more entry well bores extending from the surface;

one or more slanted well bores extending from each entry well bore to the subterranean zone;

a substantially horizontal drainage pattern drilled through at least one of the slanted well bores into the subterranean zone; and

an enlarged cavity in each of the one or more slanted well bores, located proximate to the junction of the slanted well bore and the substantially horizontal drainage pattern.

23. A system for accessing multiple subterranean zones from the surface, comprising:

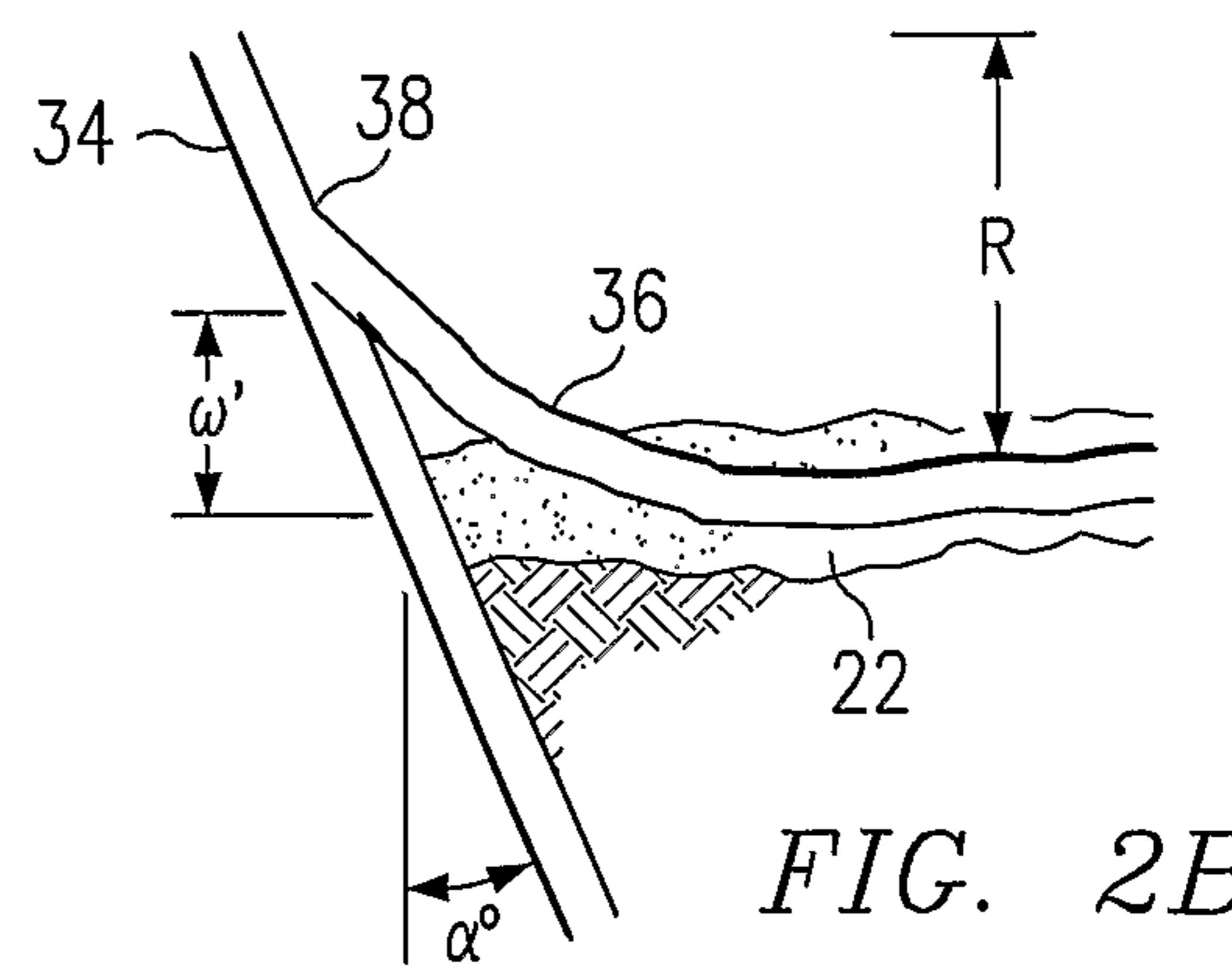
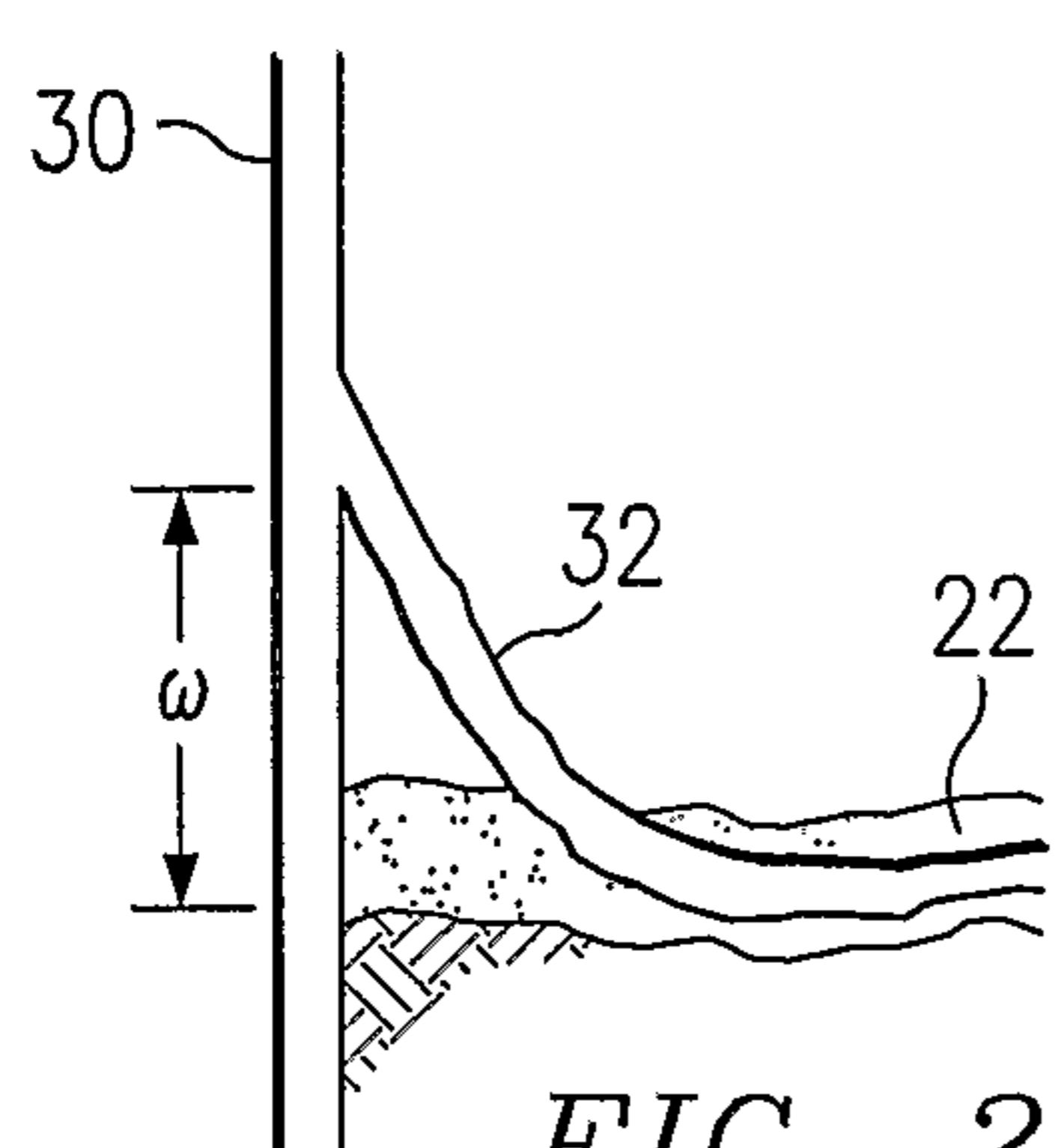
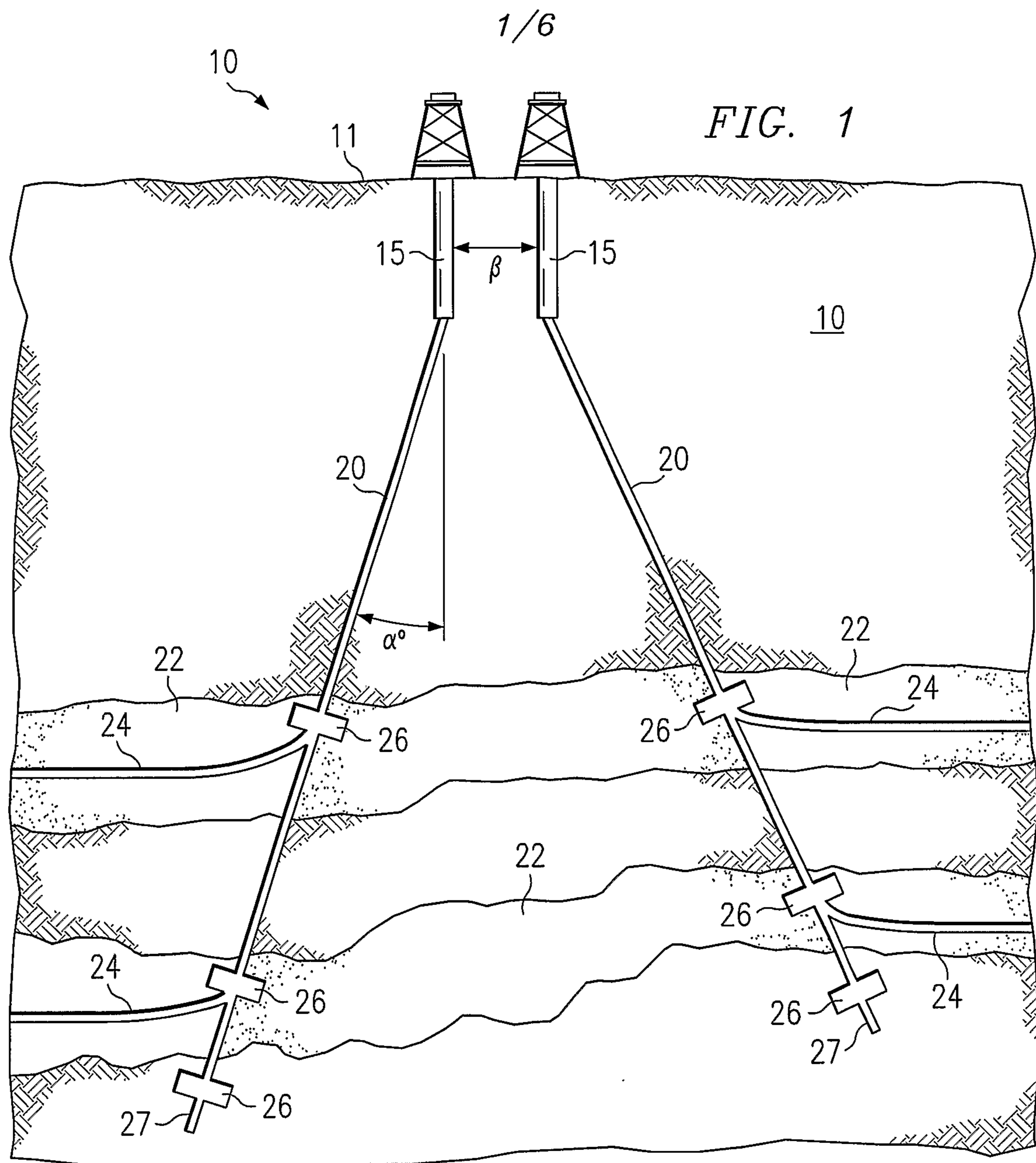
three or more entry well bores extending from the surface;

one or more slanted well bores extending from each entry well bore to one or more subterranean zones;

one or more substantially horizontal drainage patterns drilled through at least one of the slanted well bores into each of the one or more subterranean zones; and

one or more enlarged cavities in each of the slanted well bores positioned proximate to the junction of the slanted well bores and the one or more of the substantially horizontal drainage patterns.

24. The system of Claim 23, wherein the three or more entry well bores are located on the same drilling pad.



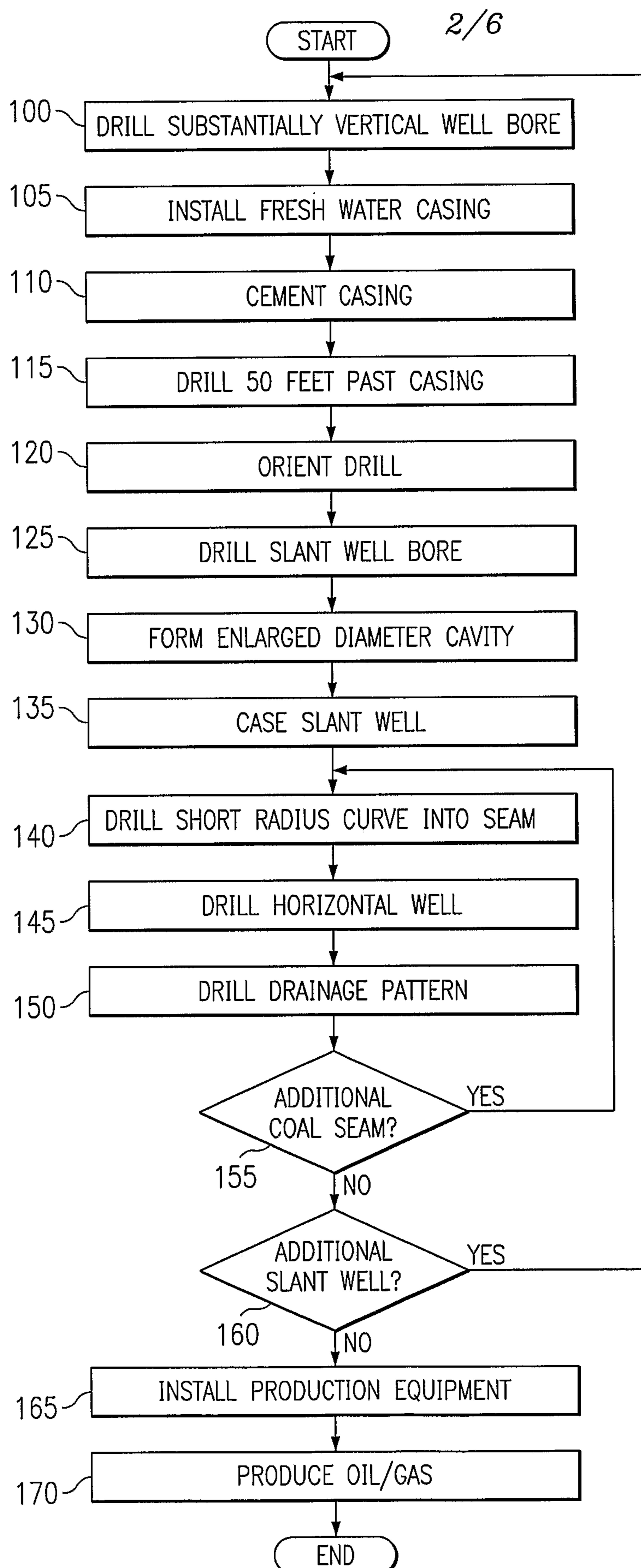
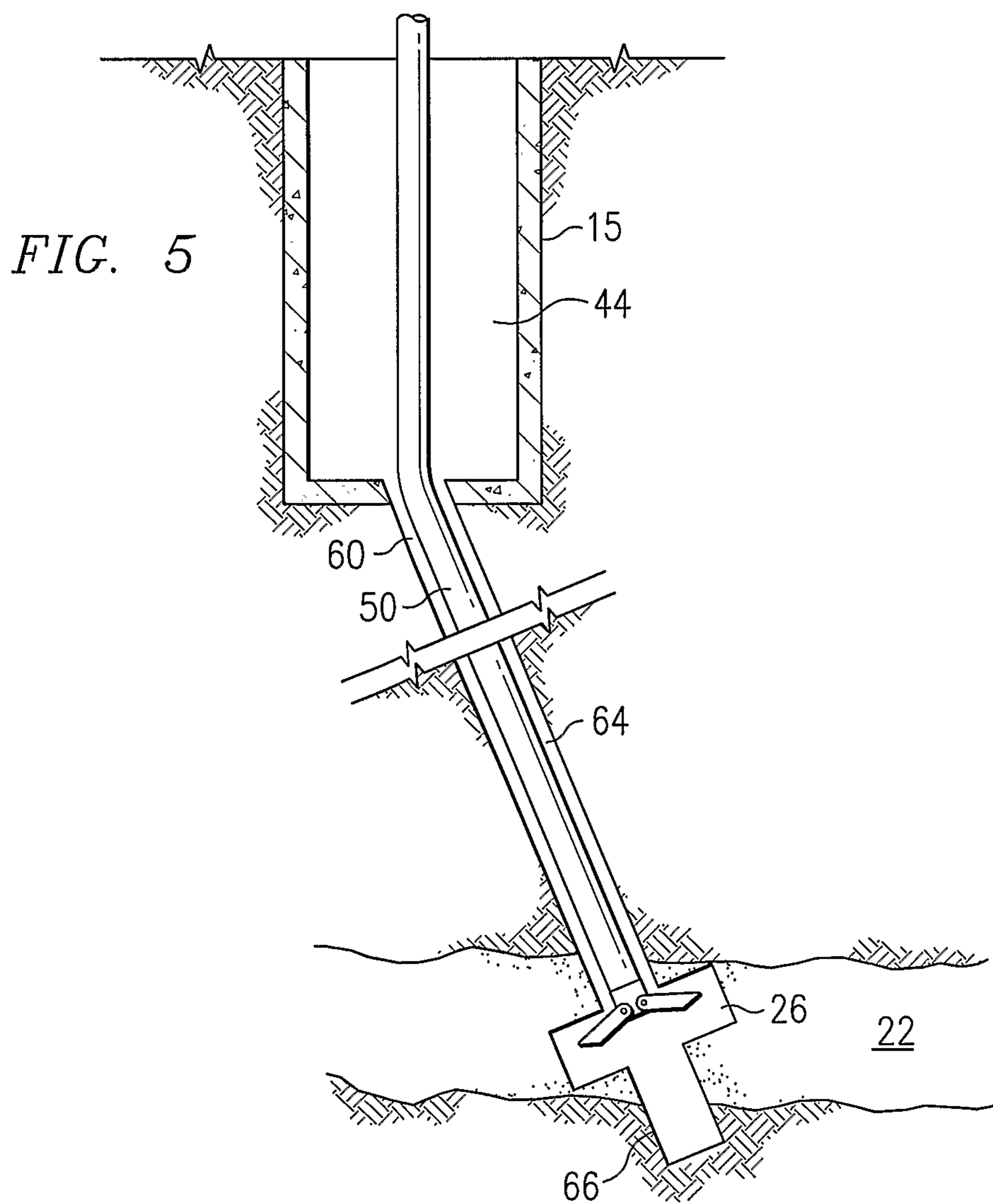
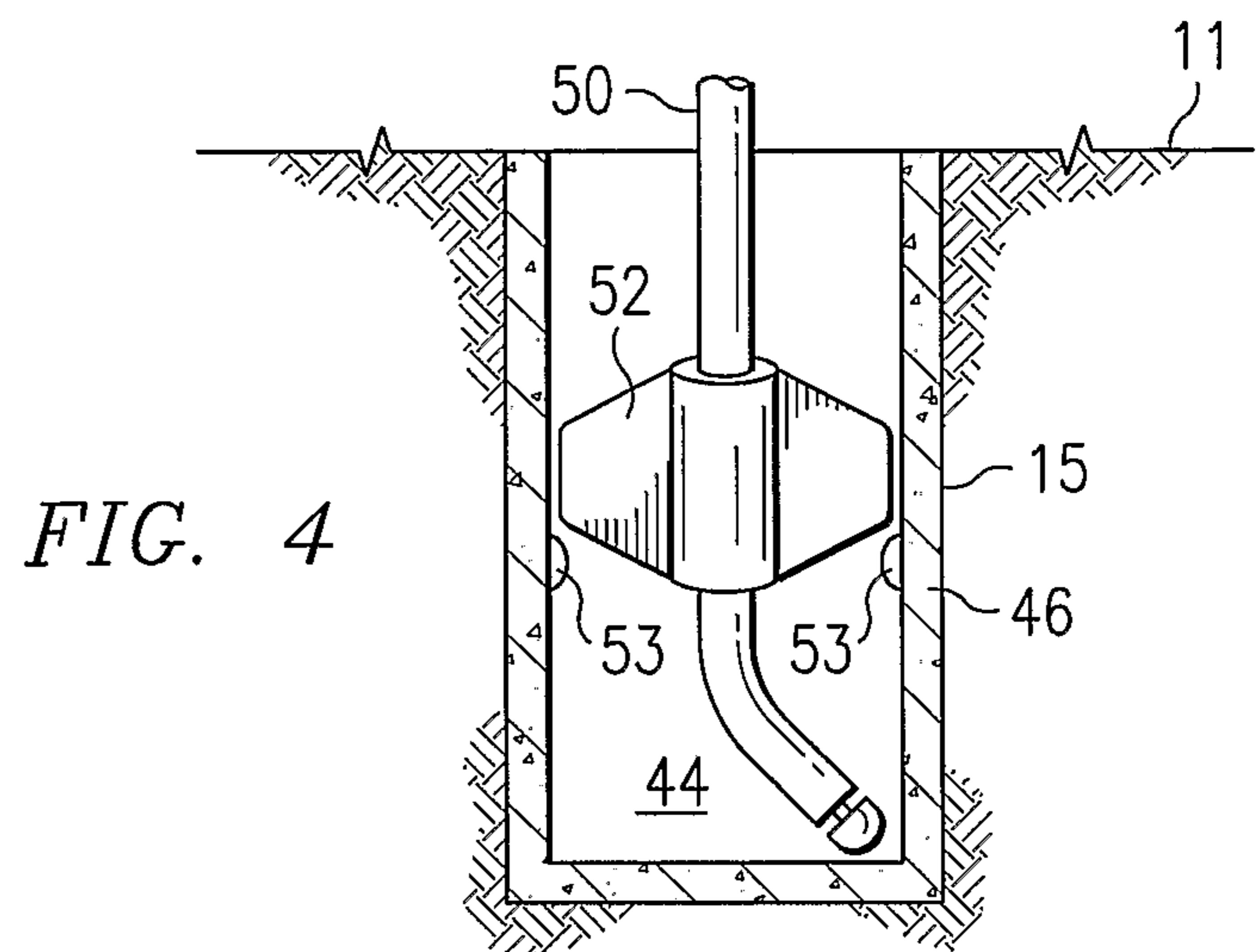


FIG. 3

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FIG. 6

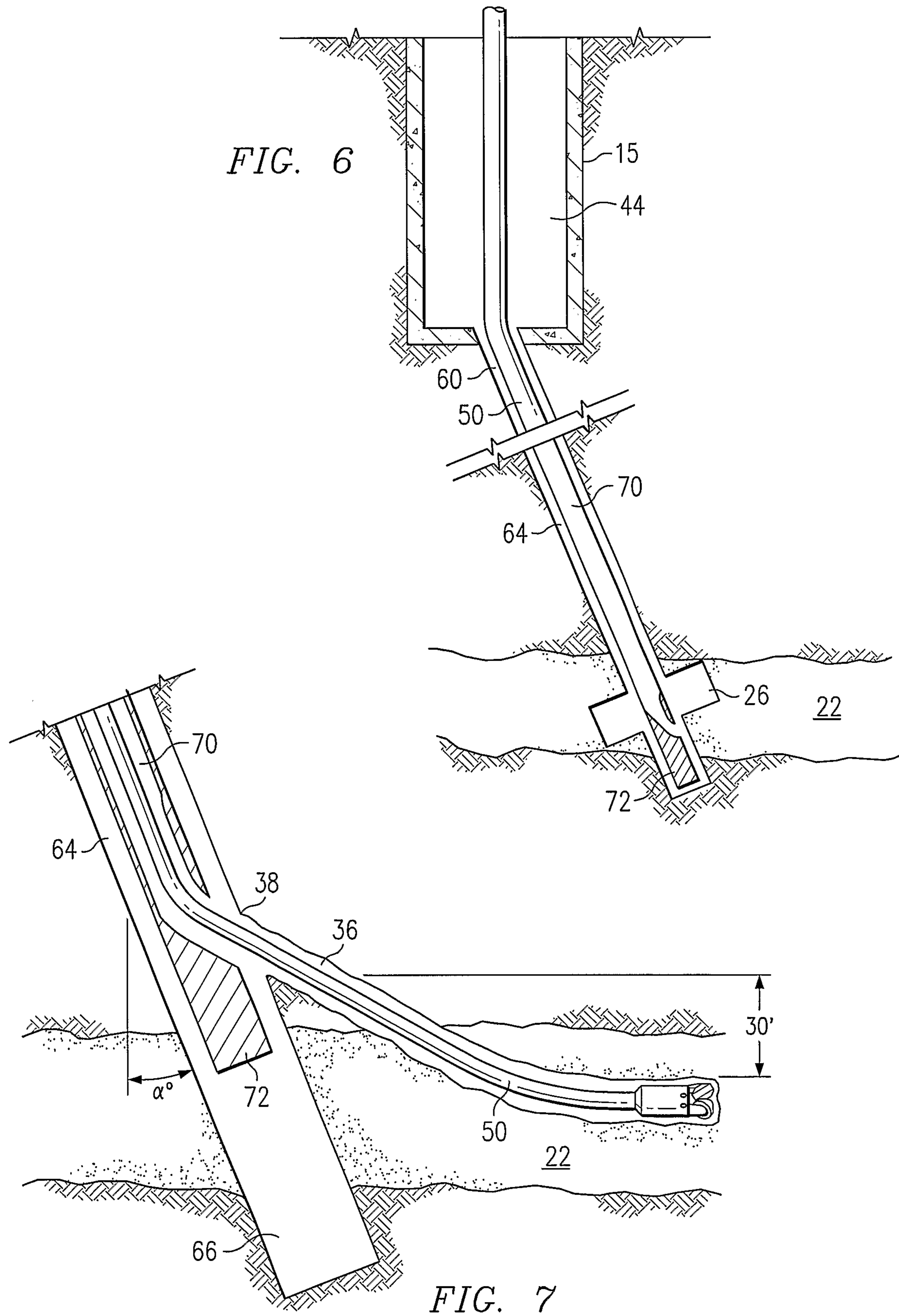


FIG. 7

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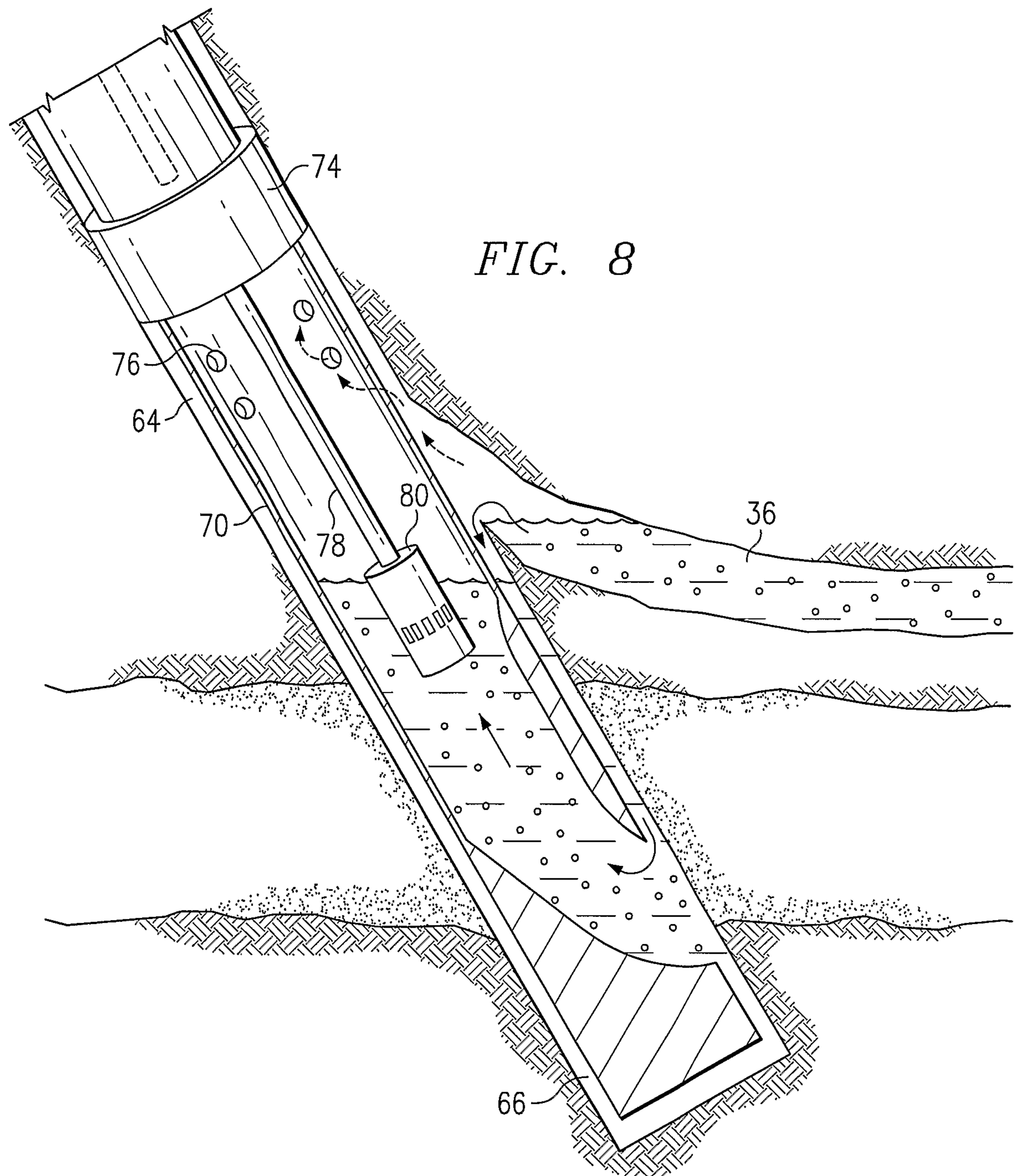


FIG. 8

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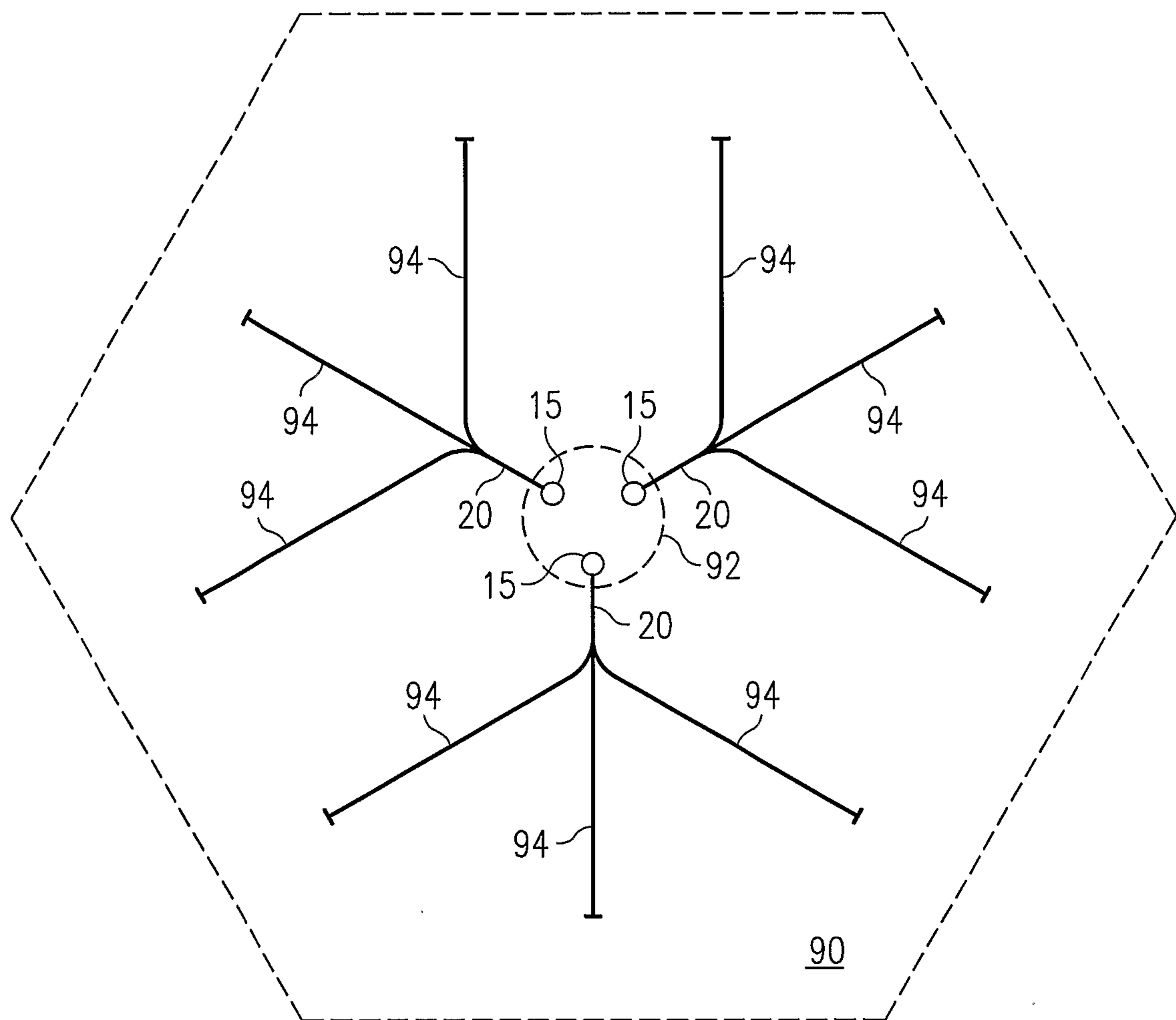


FIG. 9

