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Method and system for accessing subterranean deposits from the surface

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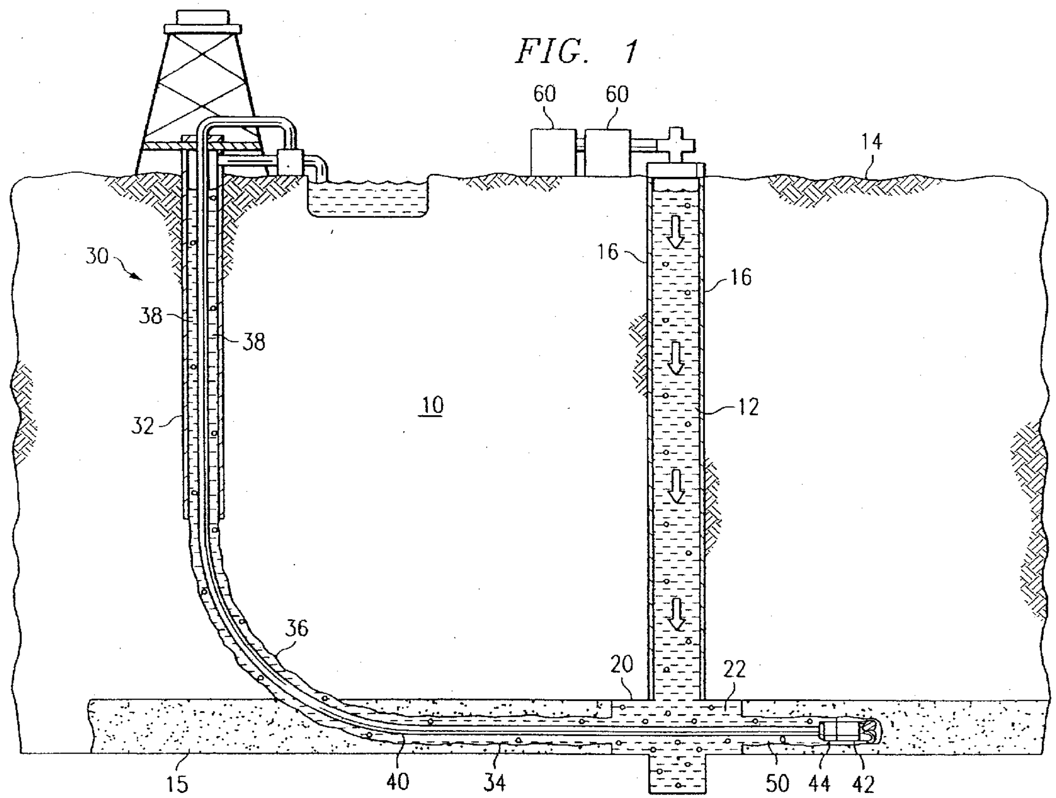
ABSTRACT

Improved method and system for accessing subterranean deposits from the surface that substantially eliminates or reduces the disadvantages and problems associated with previous systems and methods. In particular, the present invention provides an articulated well with a drainage pattern that intersects a horizontal cavity well. The drainage patterns provide access to a large subterranean area from the surface while the vertical cavity well allows entrained water, hydrocarbons, and other deposits to be efficiently removed and/or produced.

FIG. 1



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APPLICANT: **CDX GAS, L.L.C.**

Invention Title: **METHOD AND SYSTEM FOR ACCESSING SUBTERRANEAN DEPOSITS FROM THE SURFACE**

The following statement is a full description of this invention, including the best method of performing it known to me:

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METHOD AND SYSTEM FOR ACCESSING SUBTERRANEAN DEPOSITS FROM THE SURFACE

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to the recovery of subterranean deposits, and more particularly to a method and system for accessing subterranean deposits from the surface.

BACKGROUND OF THE INVENTION

Subterranean deposits of coal contain substantial quantities of entrained methane gas limited in production in 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 seams may extend over large areas of up to several thousand acres, the coal seams are fairly shallow in depth, varying from a few inches to several meters. Thus, while the coal seams are often relatively near the surface, vertical wells drilled into the coal deposits for obtaining methane gas can only drain a fairly small radius around the coal deposits. Further, coal deposits are not amendable 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 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 radiused bores.

A further problem for surface production of gas from coal seams is the difficulty presented by under balanced drilling conditions caused by the porousness of the coal seam. During both vertical and horizontal surface drilling operations, drilling fluid is used to remove cuttings from the well bore to the surface. The drilling fluid exerts a hydrostatic pressure on the formation which, if it exceeds the hydrostatic pressure of the formation, can result in a loss of drilling fluid into the formation. This results in entrainment of drilling finds in the formation, which tends to plug the pores, cracks, and fractures that are needed to produce the gas.

As a result of these difficulties in surface production of methane gas from coal deposits, the methane gas which must be removed from a coal seam prior to mining, has been removed from coal seams through the use of subterranean methods. While the use of subterranean methods allows water to be easily removed from a coal seam and eliminates under balanced drilling conditions, they can only access a limited amount of the coal seams exposed by current mining operations. Where longwall mining is practiced, for example, underground drilling rigs are used to drill horizontal holes from a panel currently being mined into an adjacent panel that will later be mined. The limitations of underground rigs limits the reach of such horizontal holes and thus the area that can be effectively drained. In addition, the degasification of a next panel during mining of a current panel limits the time for degasification. As a result, many horizontal bores must be drilled to remove the gas in a limited period of time. Furthermore, in conditions of high gas content or migration of gas through a coal seam, mining may need to be halted or delayed until a next panel can be adequately degasified. These production delays add to the expense associated with degasifying a coal seam.

SUMMARY OF THE INVENTION

The present invention provides an improved method and system for accessing subterranean deposits from the surface that substantially eliminates or reduces the disadvantages and problems associated with previous systems and methods. In particular, the present invention provides an articulated well with a drainage pattern that intersects a horizontal cavity well. The drainage patterns provide access to a large subterranean area from the surface while the vertical cavity well allows entrained water, hydrocarbons, and other deposits to be efficiently removed and/or produced.

In accordance with one embodiment of the present invention, a method for accessing a subterranean zone from the surface includes drilling a substantially vertical well bore from the surface to the subterranean zone. An articulated well bore is drilled from the surface to the subterranean zone. The articulated well bore is horizontally offset from the substantially vertical well bore at the surface and intersects the substantially vertical well bore at a junction proximate to the subterranean zone. A substantially horizontal drainage pattern is drilled through the articulated well bore from the junction into the subterranean zone.

In accordance with another aspect of the present invention, the substantially horizontal drainage pattern may comprise a pinnate pattern including a substantially horizontal diagonal well bore extending from the substantially vertical well bore that defines a first end of an area covered by the drainage pattern to a distant end of the area. A first of substantially horizontal lateral well bores extend in space relation to each other from the diagonal well bore to the periphery of the area on a first side of the diagonal well bore. A second set of substantially horizontal lateral well bores extend in space relation to each other from the diagonal well bore to the periphery of the area on a second, opposite side of the diagonal.

In accordance with still another aspect of the present invention, a method for preparing a subterranean zone for mining uses the substantially vertical and articulated well bores and the drainage pattern. Water is drained from the subterranean zone through the drainage pattern to the junction of the substantially vertical well bore. Water is pumped from the junction to the surface through the substantially vertical well bore. Gas is produced from the subterranean zone through at least one of the substantially vertical and articulated well bores. After degasification has been completed, the subterranean zone may be further prepared by pumping water and other additives into the zone through the drainage pattern.

In accordance with yet another aspect of the present invention, a pump positioning device is provided to accurately position a downhole pump in a cavity of a well bore.

Technical advantages of the present invention include providing an improved method and system for accessing subterranean deposits from the surface. In particular, a horizontal drainage pattern is drilled in a target zone from an articulated surface well to provide access to the zone from the surface. The drainage pattern intersected by a vertical cavity well from which entrained water, hydrocarbons, and other fluids drained from the zone can be efficiently removed and/or produced by a rod pumping unit. As a result, gas, oil, and other fluids can be efficiently produced at the surface from a low pressure or low porosity formation.

Another technical advantage of the present invention includes providing an improved method and system for drilling into low-pressure reservoirs. In particular, a downhole pump or gas lift is used to lighten hydrostatic pressure exerted by drilling fluids used to remove cuttings during drilling operations. As a result, reservoirs may be drilled at ultra-low pressures without loss of drilling fluids into the formation and plugging of the formation.

Yet another technical advantage of the present invention includes providing an improved horizontal drainage pattern for accessing a subterranean zone. In particular, a pinnate structure with a main diagonal and opposed laterals is used to maximize access to a subterranean zone from a single vertical well bore. Length of the laterals is maximized proximate to the vertical well bore and decreased toward the end of the main diagonal to provide uniform access to a quadrilateral or other grid area. This allows the drainage pattern to be aligned with longwall panels and other subsurface structures for degasification of a mine coal seam or other deposit.

Still another technical advantage of the present invention includes providing an improved method and system for preparing a coal seam or other subterranean deposit for mining. In particular, surface wells are used to degasify a coal seam ahead of mining operations. This reduces underground equipment and activities and increases the time provided to degasify the seam which minimizes shutdowns due to high gas content. In addition, water and additives may be pumped into the degasified coal seam prior to mining operations to minimize dust and other hazardous conditions, to improve efficiency of the mining process, and to improve the quality of the coal product.

Still another technical advantage of the present invention includes providing an improved method and system for producing methane gas from a mined coal seam. In particular, well bores used to initially degasify a coal seam prior to mining operations may be reused to collect gob gas from the seam after mining operation. As a result, costs associated with the collection of gob gas are minimized to facilitate or make feasible the collection of gob gas from previously mined seams.

Still another technical advantage of the present invention includes providing a positioning device for automatically positioning down-hole pumps and other equipment in a cavity. In particular, a rotatable cavity positioning device is configured to retract for transport in a well bore and to extend within a down-hole cavity to optimally position the equipment within the cavity. This allows down-hole equipment to be easily positioned and secured within the cavity.

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

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 like parts, in which:

FIGURE 1 is a cross-sectional diagram illustrating formation of a horizontal drainage pattern in a subterranean zone through an articulated surface well intersecting a vertical cavity well in accordance with one embodiment of the present invention;

FIGURE 2 is a cross-sectional diagram illustrating formation of the horizontal drainage pattern in the subterranean zone through the articulated surface well intersecting the vertical cavity well in accordance with another embodiment of the present invention;

FIGURE 3 is a cross-sectional diagram illustrating production of fluids from a horizontal draining pattern in a subterranean zone through a vertical well bore in accordance with one embodiment of the present invention;

FIGURE 4 is a top plan diagram illustrating a pinnate drainage pattern for accessing deposits in a subterranean zone in accordance with one embodiment of the present invention;

FIGURE 5 is a top plan diagram illustrating a pinnate drainage pattern for accessing deposits in a subterranean zone in accordance with another embodiment of the present invention;

FIGURE 6 is a top plan diagram illustrating a quadrilateral pinnate drainage pattern for accessing deposits in a subterranean zone in accordance with still another embodiment of the present invention;

FIGURE 7 is a top plan diagram illustrating the alignment of pinnate drainage patterns within panels of a coal seam for degasifying and preparing the coal seam for mining operations in accordance with one embodiment of the present invention;

FIGURE 8 is a flow diagram illustrating a method for preparing a coal seam for mining operations in accordance with one embodiment of the present invention;

FIGURES 9A-C are cross-sectional diagrams illustrating a cavity well positioning tool in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 illustrates a cavity and articulated well combination for accessing a subterranean zone from the surface in accordance with one embodiment of the present invention. In this embodiment, the subterranean zone is a coal seam. It will be understood that other low pressure, ultra-low pressure, and low porosity subterranean zones can be similarly accessed using the dual well system of the present invention to remove and/or produce water, hydrocarbons and other fluids in the zone and to treat minerals in the zone prior to mining operations.

Referring to FIGURE 1, a substantially vertical well bore 12 extends from the surface 14 to a target coal seam 15. The substantially vertical well bore 12 intersects, penetrates and continues below the coal seam 15. The substantially vertical well bore is lined with a suitable well casing 16 that terminates at or above the level of the coal seam 15.

The substantially vertical well bore 12 is logged either during or after drilling in order to locate the exact vertical depth of the coal seam 15. As a result, the coal seam is not missed in subsequent drilling operations and techniques used to locate the seam 15 while drilling need not be employed. An enlarged diameter cavity 20 is formed in the substantially vertical well bore 12 at the level of the coal seam 15. As described in more detail below, the enlarged diameter cavity 20 provides a junction for intersection of the substantially vertical well bore by articulated well bore used to form a substantially horizontal drainage pattern in the coal seam 15. The enlarged diameter cavity 20 also provides a collection point for fluids drained from the coal seam 15 during production operations.

In one embodiment, the enlarged diameter cavity 20 has a radius of approximately eight feet and a vertical dimension which equals or exceeds the vertical dimension of the coal seam 15. The enlarged diameter cavity 20 is formed using suitable under-reaming techniques and equipment. A vertical portion of the substantially vertical well bore 12 continues below the enlarged diameter cavity 20 to form a sump 22 for the cavity 20.

An articulated well bore 30 extends from the surface 14 to the enlarged diameter cavity 20 of the substantially vertical well bore 12. The articulated well bore 30 includes a substantially vertical portion 32, a substantially horizontal portion 34, and a curved or radiused portion 36 interconnecting the vertical and horizontal portions 32 and 34. The horizontal portion 34 lies substantially in the horizontal plane of the coal seam

15 and intersects the large diameter cavity 20 of the substantially vertical well bore 12.

The articulated well bore 30 is offset a sufficient distance from the substantially vertical well bore 12 at the surface 14 to permit the large radius curved section 36 and any desired horizontal section 34 to be drilled before intersecting the enlarged diameter cavity 20. To provide the curved portion 36 with a radius of 100-150 feet, the articulated well bore 30 is offset a distance of about 300 feet from the substantially vertical well bore 12. This spacing minimizes the angle of the curved portion 36 to reduce friction in the bore 30 during drilling operations. As a result, reach of the articulated drill string drilled through the articulated well bore 30 is maximized.

The articulated well bore 30 is drilled using articulated drill string 40 that includes a suitable down-hole motor and bit 42. A measurement while drilling (MWD) device 44 is included in the articulated drill string 40 for controlling the orientation and direction of the well bore drilled by the motor and bit 42. The substantially vertical portion 32 of the articulated well bore 30 is lined with a suitable casing 38.

After the enlarged diameter cavity 20 has been successfully intersected by the articulated well bore 30, drilling is continued through the cavity 20 using the articulated drill string 40 and appropriate horizontal drilling apparatus to provide a substantially horizontal drainage pattern 50 in the coal seam 15. The substantially horizontal drainage pattern 50 and other such well bores include sloped, undulating, or other inclinations of the coal seam 15 or other subterranean zone. During this operation, gamma ray logging tools and conventional measurement while drilling devices may be employed to control and direct the orientation of the drill bit to retain the drainage pattern 50 within the confines of the coal seam 15 and to provide substantially uniform coverage of a desired area within the coal seam 15. Further information regarding the drainage pattern is described in more detail below in connection with FIGURES 4-7.

During the process of drilling the drainage pattern 50, drilling fluid or "mud" is pumped down the articulated drill string 40 and circulated out of the drill string 40 in the vicinity of the bit 42, where it is used to scour the formation and to remove formation cuttings. The cuttings are then entrained in the drilling fluid which circulates up through the annulus between the drill string 40 and the well bore walls until it reaches the surface 14, where the cuttings are removed from the drilling fluid and the fluid is then recirculated. This conventional drilling operation produces a standard column of drilling fluid having a vertical height equal to the depth of the well bore 30 and produces a hydrostatic pressure on the well bore corresponding to the well bore depth. Because coal seams tend to be porous and fractured, they may be unable to sustain such hydrostatic pressure, even if formation water is also present in the coal seam 15. Accordingly, if the full hydrostatic pressure is allowed to act on the coal seam 15, the result may be loss of drilling fluid and entrained cuttings into the formation. Such a circumstance is referred to as an "over balanced" drilling operation in which the hydrostatic fluid pressure in the well bore exceeds the ability of the formation to withstand the pressure. Loss of drilling fluids in cuttings into the formation not only is expensive in terms of the lost drilling fluids, which must be made up, but it tends to plug the pores in the coal seam 15, which are needed to drain the coal seam of gas and water.

To prevent over balance drilling conditions during formation of the drainage pattern 50, air compressors 60 are provided to circulate compressed air down the substantially vertical well bore 12 and back up through the articulated well bore 30. The circulated air will admix with the drilling fluids in the annulus around the articulated drill string 40 and create bubbles throughout the column of drilling fluid. This has the effective of lightening the hydrostatic pressure of the drilling fluid and reducing the down-hole pressure sufficiently that drilling conditions do not become over balanced. Aeration of the drilling fluid reduces down-hole pressure to approximately 150-200 pounds per square inch (psi). Accordingly, low pressure coal seams and other subterranean zones can be drilling without substantial loss of drilling fluid and contamination of the zone by the drilling fluid.

Foam, which may be compressed air mixed with water, may also be circulated down through the articulated drill string 40 along with the drilling mud in order to aerate the drilling fluid in the annulus as the articulated well bore 30 is being drilled and, if desired, as the drainage pattern 50 is being drilled. Drilling of the drainage pattern 50 with the use of an air hammer bit or an air-powered down-hole motor will also supply compressed air or foam to the drilling fluid. In this case, the compressed air or foam which is used to power the bit or down-hole motor exits the vicinity of the drill bit 42. However, the larger volume of air which can be circulated down the substantially vertical well bore 12, permits greater aeration of the drilling fluid than generally is possible by air supplied through the articulated drill string 40.

FIGURE 2 illustrates method and system for drilling the drainage pattern 50 in the coal seam 15 in accordance with another embodiment of the present invention. In this embodiment, the substantially vertical well bore 12, enlarged diameter cavity 20 and articulated well bore 32 are positioned and formed as previously described in connection with the FIGURE 1.

Referring to FIGURE 2, after intersection of the enlarged diameter cavity 20 by the articulated well bore 30 a pump 52 is installed in the enlarged diameter cavity 20 to pump drilling fluid and cuttings to the surface 14 through the substantially vertical well bore 12. This eliminates the friction of air and fluid returning up the articulated well bore 30 and reduces down-hole pressure to nearly zero. Accordingly, coal seams and other subterranean zones having ultra low pressures below 150 psi can be accessed from the surface. Additionally, the risk of combining air and methane in the well is eliminated.

FIGURE 3 illustrates production of fluids from the horizontal drainage pattern 50 in the coal seam 15 in accordance with one embodiment of the present invention. In this embodiment, after the substantially vertical and articulated well bores 12 and 30 as well as desired drainage pattern 50 have been drilled, the articulated drill string 40 is removed from the articulated well bore 30 and the articulated well bore is capped. For multiple pinnate structure described below, the articulated well 30 may be plugged in the substantially horizontal portion 34. Otherwise, the articulated well 30 may be left unplugged.

Referring to FIGURE 3, a down hole pump 80 is disposed in the substantially vertical well bore 12 in the enlarged diameter cavity 22. The enlarged cavity 20 provides a reservoir for accumulated fluids allowing intermittent pumping without adverse effects of a hydrostatic head caused by accumulated fluids in the well bore.

The down hole pump 140 is connected to the surface 14 via a tubing string 82 and may be powered by sucker rods 84 extending down through the well bore 12 of the tubing. The sucker rods 84 are reciprocated by a suitable surface mounted apparatus, such as a powered walking beam 86 to operate the down hole pump 80. The down hole pump 80 is used to remove water and entrained coal fines from the coal seam 15 via the drainage pattern 50. Once the water is removed to the surface, it may be treated for separation of methane which may be dissolved in the water and for removal of entrained fines. After sufficient water has been removed from the coal seam 15, pure coal seam gas may be allowed to flow to the surface 14 through the annulus of the substantially vertical well bore 12 around the tubing string 82 and removed via piping attached to a wellhead apparatus. At the surface, the methane is treated, compressed and pumped through a pipeline for use as a fuel in a conventional manner. The down hole pump 80 may be operated continuously or as needed to remove water drained from the coal seam 15 into the enlarged diameter cavity 22.

FIGURES 4-7 illustrate substantially horizontal drainage patterns 50 for accessing the coal seam 15 or other subterranean zone in accordance with one embodiment of the present invention. In this embodiment, the drainage patterns comprise pinnate patterns that have a central diagonal with generally symmetrically arranged and appropriately spaced laterals extending from each side of the diagonal. The pinnate pattern approximates the pattern of veins in a leaf or the design of a feather in that it has similar, substantially parallel, auxiliary drainage bores arranged in substantially equal and parallel spacing or opposite sides of an axis. The pinnate drainage pattern with its central bore and generally symmetrically arranged and appropriately spaced auxiliary drainage bores on each side provides a uniform pattern for draining fluids from a coal seam or other subterranean formation. As described in more detail below, the pinnate pattern provides substantially uniform coverage of a square, other quadrilateral, or grid area and may be aligned with longwall mining panels for preparing the coal seam 15 for mining operations. It will be understood that other suitable drainage patterns may be used in accordance with the present invention.

The pinnate and other suitable drainage patterns drilled from the surface provide surface access to subterranean formations. The drainage pattern may be used to uniformly remove and/or insert fluids or otherwise manipulate a subterranean deposit. In non coal applications, the drainage pattern may be used initiating in-situ burns, "huff-puff" steam operations for heavy crude oil, and the removal of hydrocarbons from low porosity reservoirs.

FIGURE 4 illustrates a pinnate drainage pattern 100 in accordance with one embodiment of the present invention. In this embodiment, the pinnate drainage pattern 100 provides access to a substantially square area 102 of a subterranean zone. A number of the pinnate patterns 60 may be used together to provide uniform access to a large subterranean region.

Referring to FIGURE 4, the enlarged diameter cavity 20 defines a first corner of the area 102. The pinnate pattern 100 includes a substantially horizontal main well bore 104 extending diagonally across the area 102 to a distant corner 106 of the area 102. Preferably, the substantially vertical and articulated well bores 12 and 30 are positioned over the area 102 such that the diagonal bore 104 is drilled up the slope of the coal seam 15. This will facilitate collection of water, gas from the area 102. The diagonal bore 104 is drilled using the articulated drill string 40 and extends from the enlarged cavity 20 in alignment with the articulated well bore 30.

A plurality of lateral well bores 110 extend from the opposites sides of diagonal bore 104 to a periphery 112 of the area 102. The lateral bores 122 may mirror each other on opposite sides of the diagonal bore 104 or may be offset from each other along the diagonal bore 104. Each of the lateral bores 110 includes a radius curving portion 114 coming off of the diagonal bore 104 and an elongated portion 116 formed after the curved portion 114 has reached a desired orientation. For uniform coverage of the square area 102, pairs of lateral bores 110 are substantially evenly spaced on each side of the diagonal bore 104 and extend from the diagonal 64 at an angle of approximately 45 degrees. The lateral bores 110 shorten in length based on progression away from the enlarged diameter cavity 20 in order to facilitate drilling of the lateral bores 110.

The pinnate drainage pattern 100 using a single diagonal bore 104 and five pairs of lateral bores 110 may drain a coal seam area of approximately 150 acres in size. Where a smaller area is to be drained, or where the coal seam has a different shape, such as a long, narrow shape or due to surface or subterranean topography, alternate pinnate drainage patterns may be employed by varying the angle of the lateral bores 110 to the diagonal bore 104 and the orientation of the lateral bores 110. Alternatively, lateral bores 120 can be drilled from only one side of the diagonal bore 104 to form a one-half pinnate pattern.

The diagonal bore 104 and the lateral bores 110 are formed by drilling through the enlarged diameter cavity 20 using the articulated drill string 40 and appropriate horizontal drilling apparatus. During this operation, gamma ray logging tools and conventional measurement while drilling technologies may be employed to control the direction and orientation of the drill bit so as to retain the drainage pattern within the confines of the coal seam 15 and to maintain proper spacing and orientation of the diagonal and lateral bores 104 and 110.

In a particular embodiment, the diagonal bore 104 is drilled with an incline at each of a plurality of lateral kick-off points 108. After the diagonal 104 is complete, the articulated drill string 40 is backed up to each successive lateral point 108 from which a lateral bore 110 is drilled on each side of the diagonal 104. It will be understood that the pinnate drainage pattern 100 may be otherwise suitably formed in accordance with the present invention.

FIGURE 5 illustrates a pinnate drainage pattern 120 in accordance with another embodiment of the present invention. In this embodiment, the pinnate drainage pattern 120 drains a substantially rectangular area 122 of the coal seam 15. The pinnate drainage pattern 120 includes a main diagonal bore 124 and a plurality of lateral bores 126 that are formed as described in connection with diagonal and lateral bores 104 and 110 of FIGURE 4. For the substantially rectangular area 122, however, the lateral bores 126 on a first side of the diagonal 124 include a shallow angle while the lateral bores 126 on the opposite side of the diagonal 124 include a steeper angle to together provide uniform coverage of the area 12.

FIGURE 6 illustrates a quadrilateral pinnate drainage pattern 140 in accordance with another embodiment of the present invention. The quadrilateral drainage pattern 140 includes four discrete pinnate drainage patterns 100 each draining a quadrant of a region 142 covered by the pinnate drainage pattern 140.

Each of the pinnate drainage patterns 100 includes a diagonal well bore 104 and a plurality of lateral well bores 110 extending from the diagonal well bore 104. In the quadrilateral embodiment, each of the diagonal and lateral bores 104 and 110 are drilled from a common articulated well bore 141. This allows tighter spacing of the surface production equipment, wider coverage of a drainage pattern and reduces drilling equipment and operations.

FIGURE 7 illustrates the alignment of pinnate drainage patterns 100 with subterranean structures of a coal seam for degasifying and preparing the coal seam for mining operations in accordance with one embodiment of the present invention. In this embodiment, the coal seam 15 is mined using a longwall process. It will be understood that the present invention can be used to degassify coal seams for other types of mining operations.

Referring to FIGURE 7, coal panels 150 extend longitudinally from a longwall 152. In accordance with longwall mining practices, each panel 150 is subsequently mined from a distant end toward the longwall 152 and the mine roof allowed to cave and fracture into the opening behind the mining process. Prior to mining of the panels 150, the pinnate drainage patterns 100 are drilled into the panels 150 from the surface to degasify the panels 150 well ahead of mining operations. Each of the pinnate drainage patterns 100 is aligned with the longwall 152 and panel 150 grid and covers portions of one or more panels 150. In this way, a region of a mine can be degasified from the surface based on subterranean structures and constraints.

FIGURE 8 is a flow diagram illustrating a method for preparing the coal seam 15 for mining operations in accordance with one embodiment of the present invention. In this embodiment, the method begins at step 160 in which areas to be drained and drainage patterns 50 for the areas are identified. Preferably, the areas are aligned with the grid of a mining plan for the region. Pinnate structures 100, 120 and 140 may be used to provide optimized coverage for the region. It will be understood that other suitable patterns may be used to degasify the coal seam 15.

Proceeding to step 162, the substantially vertical well 12 is drilled from the surface 14 through the coal seam 15. Next, at step 164, down hole logging equipment is utilized to exactly identify the location of the coal seam in the substantially well bore 12. At step 164, the enlarged diameter cavity 22 is formed in the substantially vertical well bore 12 at the location of the coal seam 15. As previously discussed, the enlarged diameter cavity 20 may be formed by under reaming and other conventional techniques.

Next, at step 166, the articulated well bore 30 is drilled to intersect the enlarged diameter cavity 22. At step 168, the main diagonal bore 104 for the pinnate drainage pattern 100 is drilled through the articulated well bore 30 into the coal seam 15. After formation of the main diagonal 104, lateral bores 110 for the pinnate drainage pattern 100 are drilled at step 170. As previously described, lateral kick-off points may be formed in the diagonal bore 104 during its formation to facilitate drilling of the lateral bores 110.

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At step 172, the articulated well bore 30 is capped. Next, at step 174, the enlarged diagonal cavity 22 is cleaned in preparation for installation of downhole production equipment. The enlarged diameter cavity 22 may be cleaned by pumping compressed air down the substantially vertical well bore 12 or other suitable techniques. At step 176, production equipment is installed in the substantially vertical well bore 12. The production equipment includes a sucker rod pump extending down into the cavity 22 for removing water from the coal seam 15. The removal of water will drop the pressure of the coal seam and allow methane gas to diffuse and be produced up the annulus of the substantially vertical well bore 12.

Proceeding to step 178, water that drains from the drainage pattern 100 into the cavity 22 is pumped to the surface with the rod pumping unit. Water may be continuously or intermittently be pumped as needed to remove it from the cavity 22. At step 180, methane gas diffused from the coal seam 15 is continuously collected at the surface 14. Next, at decisional step 182 it is determined whether the production of gas from the coal seam 15 is complete. In one embodiment, the production of gas may be complete after the cost of the collecting the gas exceeds the revenue generated by the well. In another embodiment, gas may continue to be produced from the well until a remaining level of gas in the coal seam 15 is below required levels for mining operations. If production of the gas is not complete, the No branch of decisional step 182 returns to steps 178 and 180 in which water and gas continue to be removed from the coal seam 15. Upon completion of production, the Yes branch of decisional step 182 leads to step 184 in which the production equipment is removed.

Next, at decisional step 186, it is determined whether the coal seam 15 is to be further prepared for mining operations. If the coal seam 15 is to be further prepared for mining operations, the Yes branch of decisional step 186 leads to step 188 in which water and other additives may be injected back into the coal seam 15 to rehydrate the coal seam in order to minimize dust, to improve the efficiency of mining, and to improve the mined product.

Step 188 and the No branch of decisional step 186 lead to step 190 in which the coal seam 15 is mined. The removal of the coal from the seam causes the mined roof to cave and fracture into the opening behind the mining process. The collapsed roof creates gob gas which may be collected at step 192 through the substantially vertical well bore 12. Accordingly, additional drilling operations are not required to recover gob gas from a mined coal seam. Step 192 leads to the end of the process by which a coal seam is efficiently degasified from the surface. The method provides a symbiotic relationship with the mine to remove unwanted gas prior to mining and to rehydrate the coal prior to the mining process.

FIGURES 9A through 9C are diagrams illustrating deployment of a well cavity pump 200 in accordance with an embodiment of the present invention. Referring to FIGURE 9A, well cavity pump 200 comprises a well bore portion 202 and a cavity positioning device 204. Well bore portion 202 comprises an inlet 206 for drawing and transferring well fluid contained within cavity 20 to a surface of vertical well bore 12.

In this embodiment, cavity positioning device 204 is rotatably coupled to well bore portion 202 to provide rotational movement of cavity positioning device 204 relative to well bore portion 202. For example, a pin, shaft, or other suitable method or device (not explicitly shown) may be used to rotatably couple cavity position device 204 to well bore portion 202 to provide pivotal movement of cavity positioning device 204 about an axis 208 relative to well bore portion 202. Thus, cavity positioning device 204 may be coupled to well bore portion 202 between an end 210 and an end 212 of cavity positioning device 204 such that both ends 210 and 212 may be rotatably manipulated relative to well bore portion 202.

Cavity positioning device 204 also comprises a counter balance portion 214 to control a position of ends 210 and 212 relative to well bore portion 202 in a generally unsupported condition. For example, cavity positioning device 204 is generally cantilevered about axis 208 relative to well bore portion 202. Counter balance portion 214 is disposed along cavity positioning device 204 between axis 208 and end 210 such that a weight or mass of counter balance portion 214 counter balances cavity positioning device 204 during deployment and withdrawal of well cavity pump 200 relative to vertical well bore 12 and cavity 20.

In operation, cavity positioning device 204 is deployed into vertical well bore 12 having end 210 and counter balance portion 214 positioned in a generally retracted condition, thereby disposing end 210 and counter balance portion 214 adjacent well bore portion 202. As well cavity pump 200 travels downwardly within vertical well bore 12 in the direction indicated generally by arrow 216, a length of cavity positioning device 204 generally prevents rotational movement of cavity positioning device 204 relative to well bore portion 202. For example, the mass of counter balance portion 214 may cause counter balance portion 214 and end 212 to be generally supported by contact with a vertical wall 218 of vertical well bore

12 as well cavity pump 200 travels downwardly within vertical well bore 12.

Referring to FIGURE 9B, as well cavity pump 200 travels downwardly within vertical well bore 12, counter balance portion 214 causes rotational or pivotal movement of cavity positioning device 204 relative to well bore portion 202 as cavity positioning device 204 transitions from vertical well bore 12 to cavity 20. For example, as cavity positioning device 204 transitions from vertical well bore 12 to cavity 20, counter balance portion 214 and end 212 become generally unsupported by vertical wall 218 of vertical well bore 12. As counter balance portion 214 and end 212 become generally unsupported, counter balance portion 214 automatically causes rotational movement of cavity positioning device 204 relative to well bore portion 202. For example, counter balance portion 214 generally causes end 210 to rotate or extend outwardly relative to vertical well bore 12 in the direction indicated generally by arrow 220. Additionally, end 212 of cavity positioning device 204 extends or rotates outwardly relative to vertical well bore 12 in the direction indicated generally by arrow 222.

The length of cavity positioning device 204 is configured such that ends 210 and 212 of cavity positioning device 204 become generally unsupported by vertical well bore 12 as cavity positioning device 204 transitions from vertical well bore 12 into cavity 20, thereby allowing counter balance portion 214 to cause rotational movement of end 212 outwardly relative to well bore portion 202 and beyond an annulus portion 224 of sump 22. Thus, in operation, as cavity positioning device 204 transitions from vertical well bore 12 to cavity 20, counter balance portion 214 causes end 212 to rotate or extend outwardly in the direction indicated generally by arrow 222 such that continued downward travel of well cavity pump 200 results in contact of end 12 with a horizontal wall 226 of cavity 20.

Referring to FIGURE 9C, as downwardly travel of well cavity pump 200 continues, the contact of end 212 with horizontal wall 226 of cavity 20 causes further rotational movement of cavity positioning device 204 relative to well bore portion 202. For example, contact between end 212 and horizontal 226 combined with downward travel of well cavity pump 200 causes end 210 to extend or rotate outwardly relative to vertical well bore 12 in the direction indicated generally by arrow 228 until counter balance portion 214 contacts a horizontal wall 230 of cavity20. Once counter balance portion 214 and end 212 of cavity positioning device 204 become generally supported by horizontal walls 226 and 230 of cavity 20, continued downward travel of well cavity pump 200 is substantially prevented, thereby positioning inlet 206 at a predefined location within cavity 20.

Thus, inlet 206 may be located at various positions along well bore portion 202 such that inlet 206 is disposed at the predefined location within cavity 20 as cavity positioning device 204 bottoms out within cavity 20. Therefore, inlet 206 may be accurately positioned within cavity 20 to substantially prevent drawing in debris or other material disposed within sump or rat hole 22 and to prevent gas interference caused by placement of the inlet 20 in the narrow well bore. Additionally, inlet 206 may be positioned within cavity 20 to maximize fluid withdrawal from cavity 20.

In reverse operation, upward travel of well cavity pump 200 generally results in releasing contact between counter balance portion 214 and end 212 with horizontal walls 230 and 226, respectively. As cavity positioning device 204 becomes generally unsupported within cavity 20, the mass of cavity positioning device 204 disposed between end 212 and axis 208 generally causes cavity positioning device 204 to rotate in directions opposite the directions indicated generally by arrows 220 and 222 as illustrated FIGURE 9B. Additionally, counter balance portion 214 cooperates with the mass of cavity positioning device 204 disposed between end 212 and axis 208 to generally align cavity positioning device 204 with vertical well bore 12. Thus, cavity positioning device 204 automatically becomes aligned with vertical well bore 12 as well cavity pump 200 is withdrawn from cavity 20. Additional upward travel of well cavity pump 200 then may be used to remove cavity positioning device 204 from cavity 20 and vertical well bore 12.

Therefore, the present invention provides greater reliability than prior systems and methods by positively locating inlet 206 of well cavity pump 200 at a predefined location within cavity 20. Additionally, well cavity pump 200 may be efficiently removed from cavity 20 without requiring additional unlocking or alignment tools to facilitate the withdrawal of well cavity pump 200 from cavity 20 and vertical well bore 12.

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.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgement or any form of suggestion that the prior art forms part of the common general knowledge in Australia.

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CLAIMS

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

forming a first well bore extending from the surface to the subterranean zone;

forming a second well bore extending downward to the subterranean zone, the second well bore intersecting the first well bore at a junction proximate the subterranean zone;

forming a drainage bore within the subterranean zone extending from the junction using a drill string extending downwardly through the second well bore;

supplying drilling fluid downwardly through the drill string to remove cuttings generated by the drill string; and

minimizing down-hole pressure within the subterranean zone by pumping the drilling fluid and the cuttings to the surface through the first well bore.

2. The method of Claim 1, wherein forming the second well bore comprises forming the second well bore offset from the first well bore at the surface.

3. The method of Claim 1, wherein forming the second well bore comprises forming the second well bore extending from the first well bore at a location between the surface and the subterranean zone.

4. The method of Claim 1, wherein forming the drainage bore comprises:

forming a main well bore extending from the junction; and

forming a plurality of lateral well bores extending outwardly from the main well bore.

5. The method of Claim 1, wherein forming the drainage bore comprises:

forming a main well bore extending from the junction;

forming a first plurality of lateral well bores extending outwardly from the main well bore; and

forming a second plurality of lateral well bores extending from the first plurality of lateral well bores.

6. The method of Claim 1, wherein forming the drainage bore comprises:

forming a main well bore extending from the junction; and

forming a plurality of lateral well bores extending outwardly from the main well bore, a length of each of the lateral well bores decreasing as a distance from the respective lateral well bore and the junction increases.

7. The method of Claim 1, further comprising forming an enlarged cavity at the junction of the first and second well bores.

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

forming a first well bore extending from the surface to the subterranean zone;

forming a second well bore extending downward to the subterranean zone, the second well bore intersecting the first well bore at a junction proximate to the subterranean zone; and

forming, through the second well bore, a drainage bore from the junction into the subterranean zone, wherein forming the drainage bore comprises:

forming the drainage bore using an articulated drill string extending through the second well bore and the junction;

supplying drilling fluid through the articulated drill string to remove cuttings generated by the drill string; and

pumping the drilling fluid with the cuttings to the surface through the first well bore to minimize hydrostatic pressure on the subterranean zone during drilling of the drainage bore.

9. A method for accessing a subterranean zone from the surface substantially as herein described.

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FIG. 1

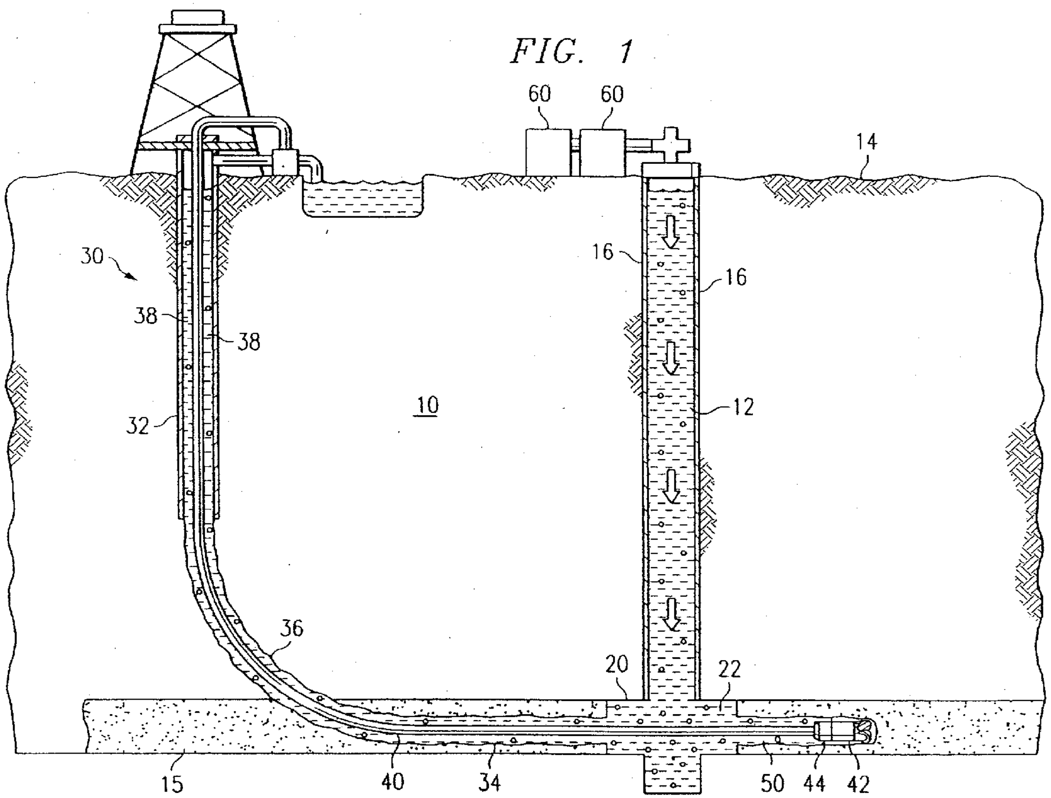

FIG. 2

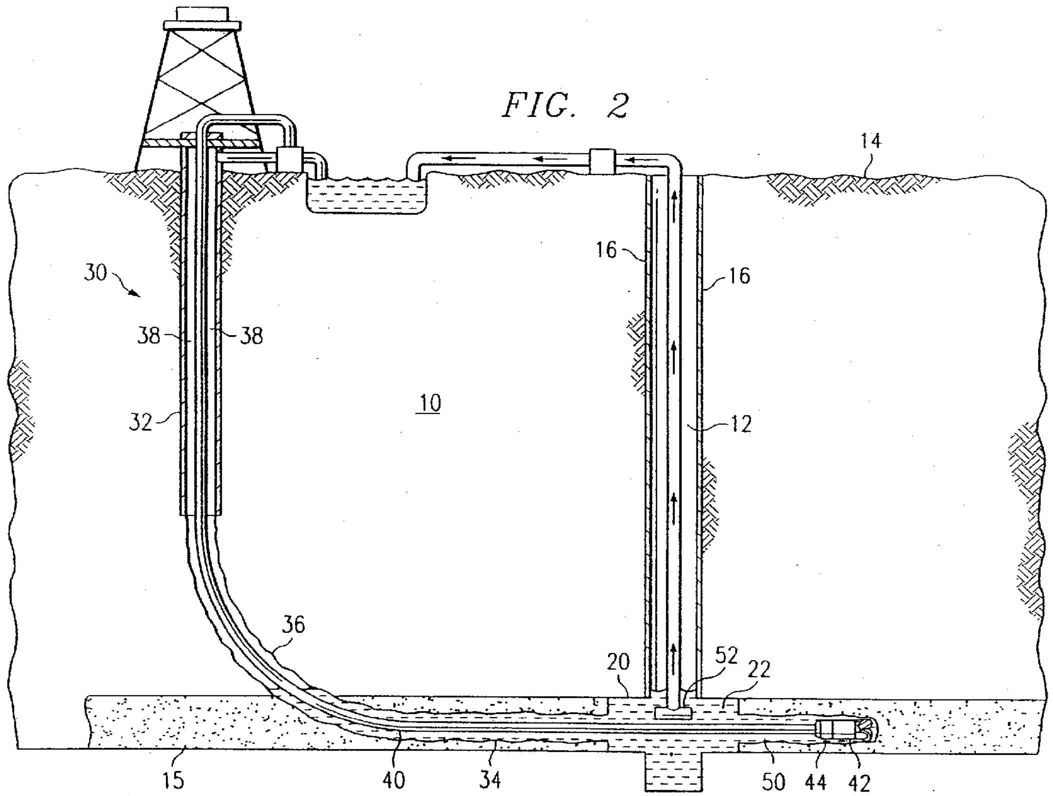

FIG. 3

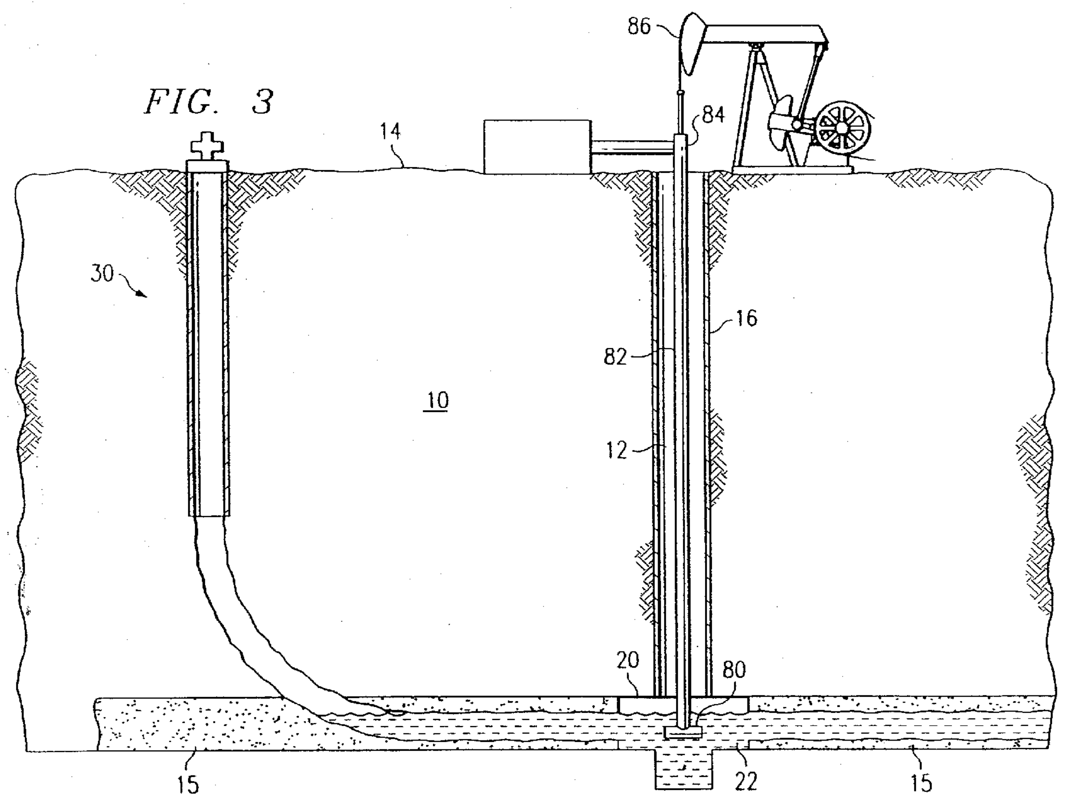

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FIG. 4

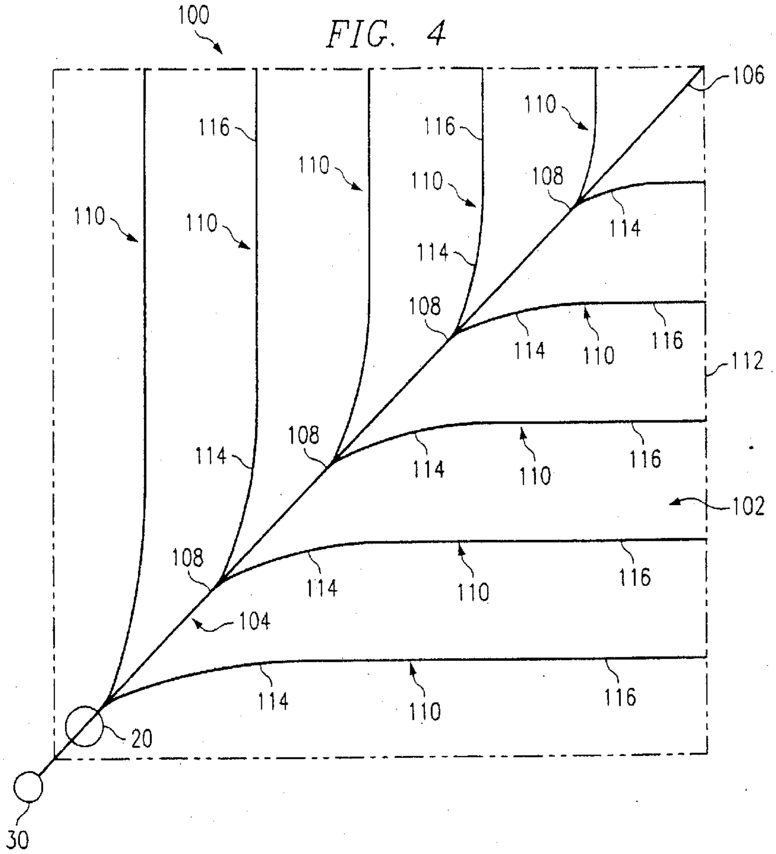
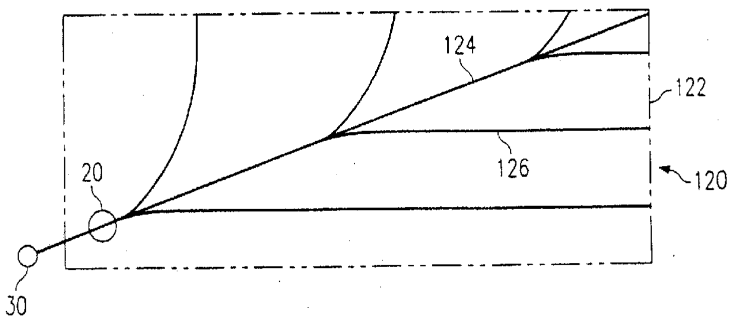


FIG. 5



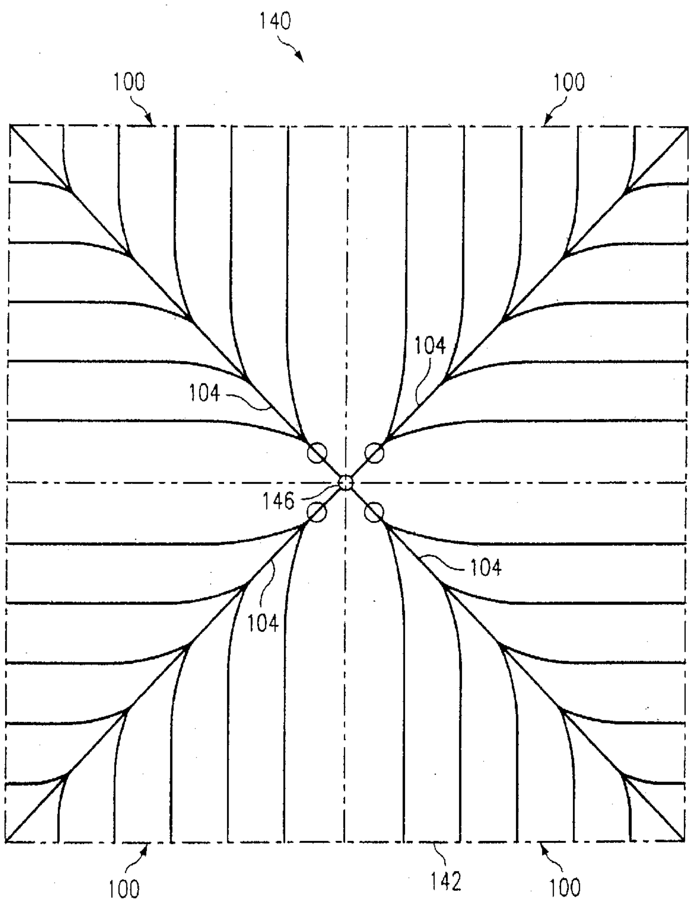


FIG. 6

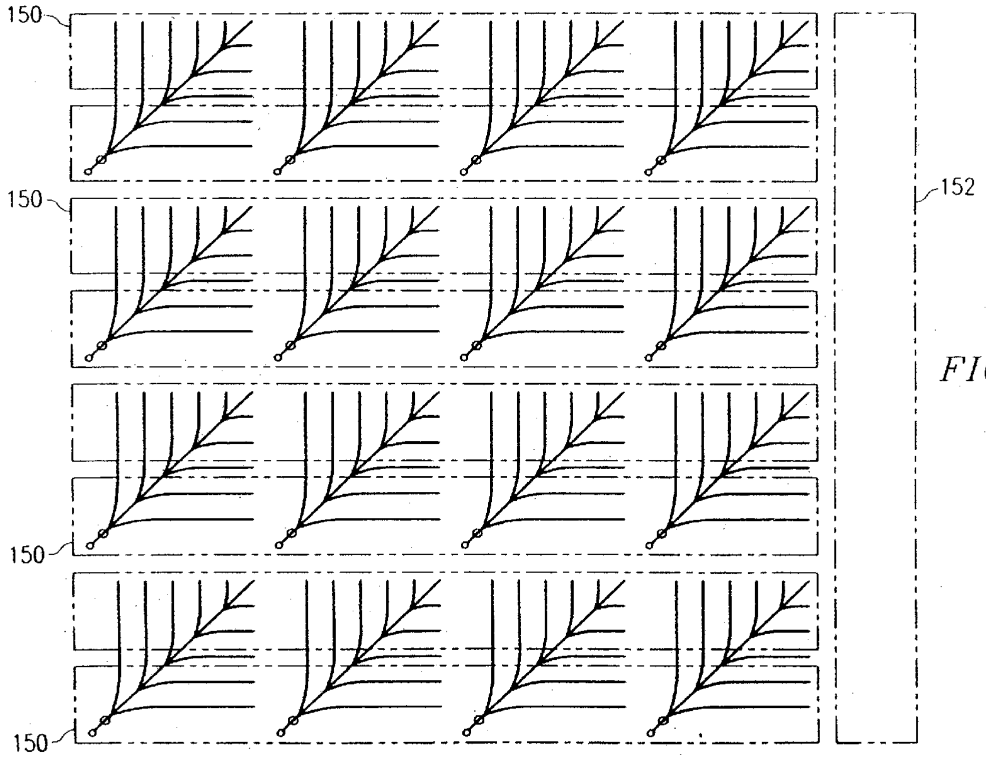


FIG. 7

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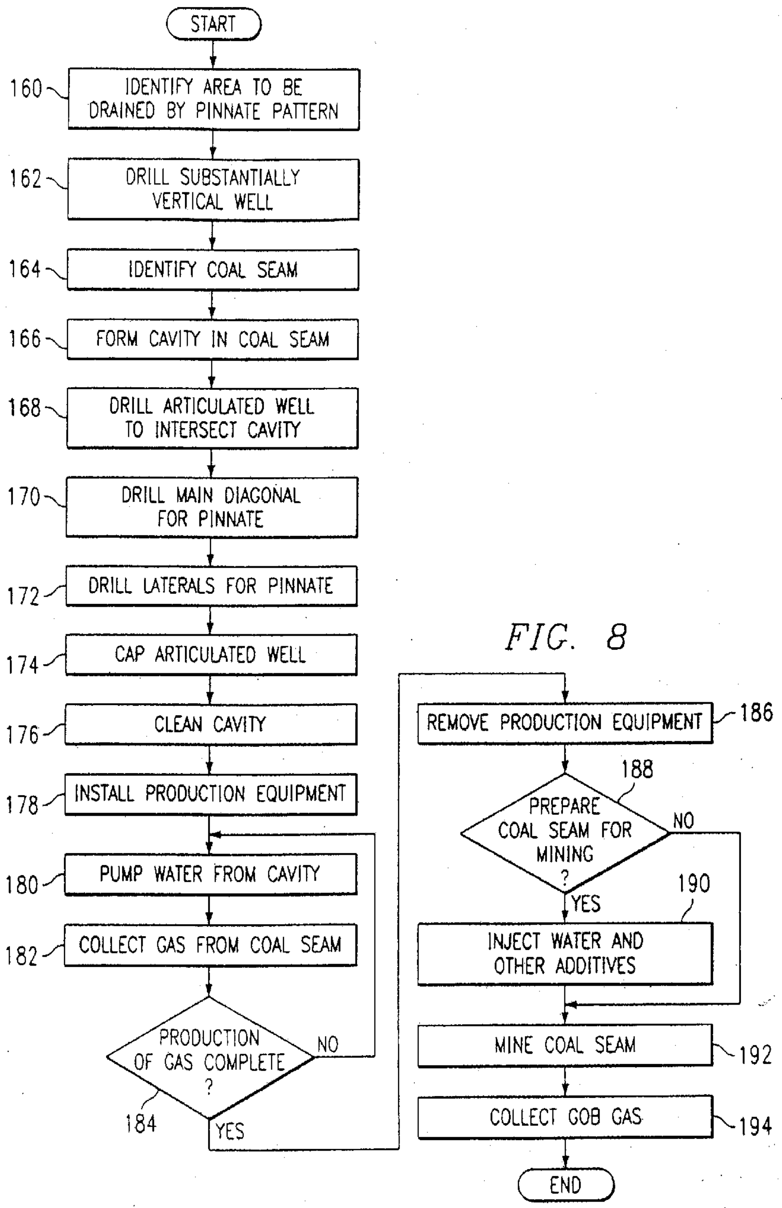

FIG. 8

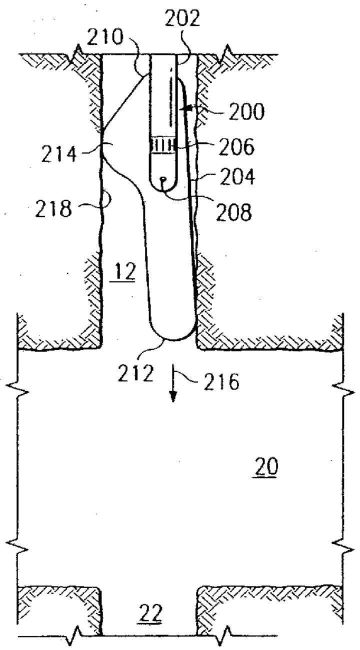

FIG. 9A

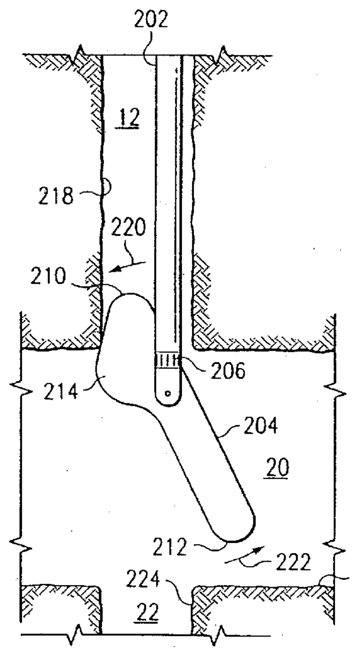

FIG. 9B

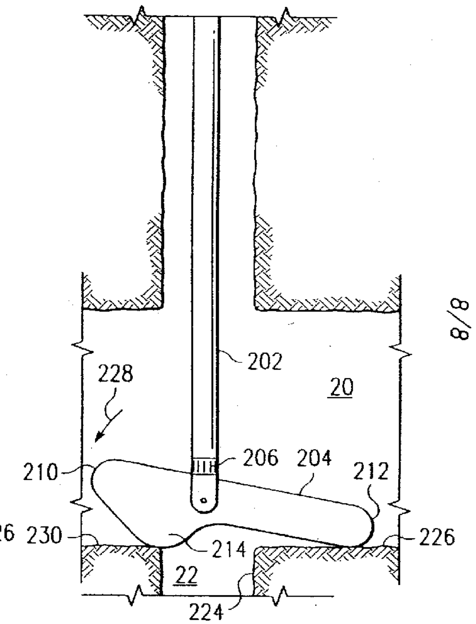

FIG. 9C