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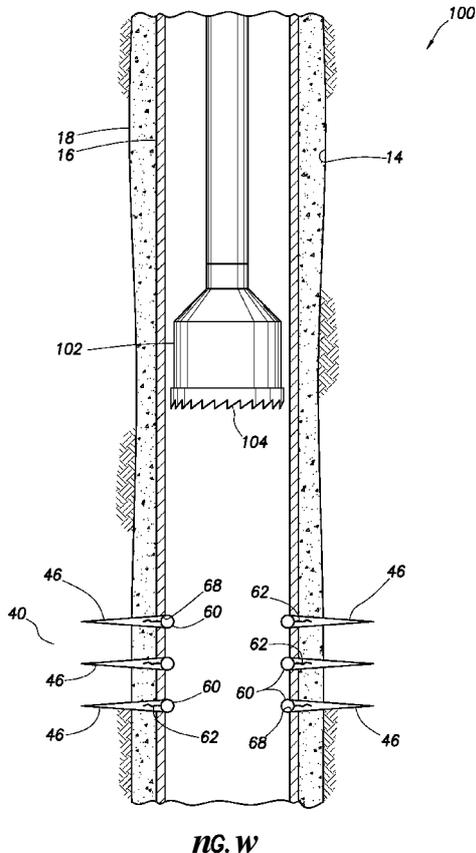
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(54) Title: FLOW CONTROL IN SUBTERRANEAN WELLS

(57) Abstract: A method of restoring flow through an opening in a well, the opening being blocked by a plugging device, can include conveying a well tool into the well, contacting the plugging device with the well tool, and permitting flow through the opening as a result of the contacting step. Another method of restoring flow through an opening blocked by a plugging device in a well can include conveying a well tool into the well, reducing pressure in the well with the well tool, and permitting flow through the opening as a result of the pressure reducing step.



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FLOW CONTROL IN SUBTERRANEAN WELLS

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TECHNICAL FIELD

This disclosure relates generally to equipment utilized and operations performed in conjunction with a subterranean well and, in one example described below, more particularly provides for flow control in wells.

15

BACKGROUND

It can be beneficial to be able to control how and where fluid flows in a well. For example, it may be desirable in some circumstances to be able to prevent fluid from flowing into a particular formation zone. As another example, it may be desirable in some circumstances to cause fluid to flow into a particular formation zone, instead of into another formation zone. Therefore, it will be readily appreciated that improvements are continually needed in the art of controlling fluid flow in wells.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a representative partially cross-sectional view of an example of a well system and associated method which can embody principles of this disclosure.

5 FIGS. 2A-D are enlarged scale representative partially cross-sectional views of steps in an example of a re-completion method that may be practiced with the system of FIG. 1.

10 FIGS. 3A-D are representative partially cross-sectional views of steps in another example of a method that may be practiced with the system of FIG. 1.

15 FIGS. 4A & B are enlarged scale representative elevational views of examples of a flow conveyed device that may be used in the system and methods of FIGS. 1-3D, and which can embody the principles of this disclosure.

FIG. 5 is a representative elevational view of another example of the flow conveyed device.

20 FIGS. 6A & B are representative partially cross-sectional views of the flow conveyed device in a well, the device being conveyed by flow in FIG. 6A, and engaging a casing opening in FIG. 6B.

FIGS. 7-9 are representative elevational views of examples of the flow conveyed device with a retainer.

25 FIG. 10 is a representative partially cross-sectional view of an example of a technique for removing the flow conveyed plugging device from an opening.

FIG. 11 is a representative partially cross-sectional view of another example of a technique for removing the flow conveyed plugging device from an opening.

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FIGS. 12 & 13 are representative cross-sectional views of additional examples of the flow conveyed device.

FIG. 14 is a representative cross-sectional view of a well tool that may be operated using the flow conveyed
5 device .

DETAILED DESCRIPTION

Representatively illustrated in FIG. 1 is a system 10 for use with a well, and an associated method, which can
10 embody principles of this disclosure. However, it should be clearly understood that the system 10 and method are merely one example of an application of the principles of this disclosure in practice, and a wide variety of other examples are possible. Therefore, the scope of this disclosure is not
15 limited at all to the details of the system 10 and method described herein and/or depicted in the drawings.

In the FIG. 1 example, a tubular string 12 is conveyed into a wellbore 14 lined with casing 16 and cement 18. Although multiple casing strings would typically be used in
20 actual practice, for clarity of illustration only one casing string 16 is depicted in the drawings.

Although the wellbore 14 is illustrated as being vertical, sections of the wellbore could instead be horizontal or otherwise inclined relative to vertical.
25 Although the wellbore 14 is completely cased and cemented as depicted in FIG. 1, any sections of the wellbore in which operations described in more detail below are performed could be uncased or open hole. Thus, the scope of this disclosure is not limited to any particular details of the
30 system 10 and method.

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The tubular string 12 of FIG. 1 comprises coiled tubing 20 and a bottom hole assembly 22. As used herein, the term "coiled tubing" refers to a substantially continuous tubing that is stored on a spool or reel 24. The reel 24 could be mounted, for example, on a skid, a trailer, a floating vessel, a vehicle, etc., for transport to a wellsite. Although not shown in FIG. 1, a control room or cab would typically be provided with instrumentation, computers, controllers, recorders, etc., for controlling equipment such as an injector 26 and a blowout preventer stack 28.

As used herein, the term "bottom hole assembly" refers to an assembly connected at a distal end of a tubular string in a well. It is not necessary for a bottom hole assembly to be positioned or used at a "bottom" of a hole or well.

When the tubular string 12 is positioned in the wellbore 14, an annulus 30 is formed radially between them. Fluid, slurries, etc., can be flowed from surface into the annulus 30 via, for example, a casing valve 32. One or more pumps 34 may be used for this purpose. Fluid can also be flowed to surface from the wellbore 14 via the annulus 30 and valve 32.

Fluid, slurries, etc., can also be flowed from surface into the wellbore 14 via the tubing 20, for example, using one or more pumps 36. Fluid can also be flowed to surface from the wellbore 14 via the tubing 20.

In the further description below of the examples of FIGS. 2A-9, one or more flow conveyed devices are used to block or plug openings in the system 10 of FIG. 1. However, it should be clearly understood that these methods and the flow conveyed device may be used with other systems, and the flow conveyed device may be used in other methods in keeping with the principles of this disclosure.

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The example methods described below allow existing fluid passageways to be blocked permanently or temporarily in a variety of different applications. Certain flow conveyed device examples described below are made of a fibrous material and comprise a central body, a "knot" or other enlarged geometry. Other flow control device examples may not be made of a fibrous material, may not have a centrally positioned body, and/or may not comprise a knot.

The devices are conveyed into leak paths using pumped fluid. Fibrous material extending outwardly from a body of a device can "find" and follow the fluid flow, pulling the enlarged geometry into a restricted portion of a flow path, causing the enlarged geometry and additional strands to become tightly wedged into the flow path thereby sealing off fluid communication.

The devices can be made of degradable or non-degradable materials. The degradable materials can be either self-degrading, or can require degrading treatments, such as, by exposing the materials to certain acids, certain base compositions, certain chemicals, certain types of radiation (e.g., electromagnetic or "nuclear"), or elevated temperature. The exposure can be performed at a desired time using a form of well intervention, such as, by spotting or circulating a fluid in the well so that the material is exposed to the fluid.

In some examples, the material can be an acid degradable material (e.g., nylon, etc.), a mix of acid degradable material (for example, nylon fibers mixed with particulate such as calcium carbonate), self-degrading material (e.g., poly-lactic acid (PLA), poly-glycolic acid (PGA), etc.), material that degrades by galvanic action (such as, magnesium alloys, aluminum alloys, etc.), a

combination of different self-degrading materials, or a combination of self-degrading and non-self-degrading materials .

Multiple materials can be pumped together or
5 separately. For example, nylon and calcium carbonate could be pumped as a mixture, or the nylon could be pumped first to initiate a seal, followed by calcium carbonate to enhance the seal.

In certain examples described below, the device can be
10 made of knotted fibrous materials. Multiple knots can be used with any number of loose ends . The ends can be frayed or un-frayed. The fibrous material can be rope, fabric, cloth or another woven or braided structure.

The device can be used to block open sleeve valves,
15 perforations or any leak paths in a well (such as, leaking connections in casing, corrosion holes, etc.). An opening in a well tool, whether formed intentionally or inadvertently, can be blocked using the device. Any opening through which fluid flows can be blocked with a suitably configured
20 device.

In one example method described below, a well with an existing perforated zone can be re-completed. Devices (either degradable or non-degradable) are conveyed by flow to plug all existing perforations.

25 The well can then be re-completed using any desired completion technique. If the devices are degradable, a degrading treatment can then be placed in the well to open up the plugged perforations (if desired).

In another example method described below, multiple
30 formation zones can be perforated and fractured (or otherwise stimulated, such as, by acidizing) in a single

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trip of the bottom hole assembly 22 into the well. In the method, one zone is perforated, the zone is fractured or otherwise stimulated, and then the perforated zone is plugged using one or more devices.

5 These steps are repeated for each additional zone, except that a last zone may not be plugged. All of the plugged zones are eventually unplugged by waiting a certain period of time (if the devices are self-degrading) , by applying an appropriate degrading treatment, or by
10 mechanically removing the devices.

Referring specifically now to FIGS. 2A-D, steps in an example of a method in which the bottom hole assembly 22 of FIG. 1 can be used in re-completing a well are representatively illustrated. In this method (see FIG. 2A) ,
15 the well has existing perforations 38 that provide for fluid communication between an earth formation zone 40 and an interior of the casing 16. However, it is desired to re-complete the zone 40, in order to enhance the fluid communication .

20 Referring additionally now to FIG. 2B, the perforations 38 are plugged, thereby preventing flow through the perforations into the zone 40. Plugs 42 in the perforations can be flow conveyed devices, as described more fully below. In that case, the plugs 42 can be conveyed through the
25 casing 16 and into engagement with the perforations 38 by fluid flow 44.

Referring additionally now to FIG. 2C, new perforations 46 are formed through the casing 16 and cement 18 by use of an abrasive jet perforator 48. In this example, the bottom
30 hole assembly 22 includes the perforator 48 and a circulating valve assembly 50. Although the new perforations 46 are depicted as being formed above the existing

perforations 38, the new perforations could be formed in any location in keeping with the principles of this disclosure.

Note that other means of providing perforations 46 may be used in other examples. Explosive perforators, drills, etc., may be used if desired. The scope of this disclosure is not limited to any particular perforating means, or to use with perforating at all.

The circulating valve assembly 50 controls flow between the coiled tubing 20 and the perforator 48, and controls flow between the annulus 30 and an interior of the tubular string 12. Instead of conveying the plugs 42 into the well via flow 44 through the interior of the casing 16 (see FIG. 2B), in other examples the plugs could be deployed into the tubular string 12 and conveyed by fluid flow 52 through the tubular string prior to the perforating operation. In that case, a valve 54 of the circulating valve assembly 50 could be opened to allow the plugs 42 to exit the tubular string 12 and flow into the interior of the casing 16 external to the tubular string.

Referring additionally now to FIG. 2D, the zone 40 has been fractured or otherwise stimulated by applying increased pressure to the zone after the perforating operation. Enhanced fluid communication is now permitted between the zone 40 and the interior of the casing 16.

Note that fracturing is not necessary in keeping with the principles of this disclosure. Although certain examples described herein utilize fracturing, it should be understood that other types of stimulation operations (such as acidizing) may be performed instead of, or in addition to, fracturing.

In the FIG. 2D example, the plugs 42 prevent the pressure applied to fracture the zone 40 via the

perforations 46 from leaking into the zone via the perforations 38. The plugs 42 may remain in the perforations 38 and continue to prevent flow through the perforations, or the plugs may degrade, if desired, so that flow is eventually permitted through the perforations.

In other examples, fractures may be formed via the existing perforations 38, and no new perforations may be formed. In one technique, pressure may be applied in the casing 16 (e.g., using the pump 34), thereby initially fracturing the zone 40 via some of the perforations 38 that receive most of the fluid flow 44. After the initial fracturing of the zone 40, and while the fluid is flowed through the casing 16, plugs 42 can be released into the casing, so that the plugs seal off those perforations 38 that are receiving most of the fluid flow.

In this way, the fluid 44 will be diverted to other perforations 38, so that the zone 40 will also be fractured via those other perforations 38. The plugs 42 can be released into the casing 16 continuously or periodically as the fracturing operation progresses, so that the plugs gradually seal off all, or most, of the perforations 38 as the zone 40 is fractured via the perforations. That is, at each point in the fracturing operation, the plugs 42 will seal off those perforations 38 through which most of the fluid flow 44 passes, which are the perforations via which the zone 40 has been fractured.

Referring additionally now to FIGS. 3A-D, steps in another example of a method in which the bottom hole assembly 22 of FIG. 1 can be used in completing multiple zones 40a-c of a well are representatively illustrated. The multiple zones 40a-c are each perforated and fractured during a single trip of the tubular string 12 into the well.

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In FIG. 3A, the tubular string 12 has been deployed into the casing 16, and has been positioned so that the perforator 48 is at the first zone 40a to be completed. The perforator 48 is then used to form perforations 46a through the casing 16 and cement 18, and into the zone 40a.

In FIG. 3B, the zone 40a has been fractured by applying increased pressure to the zone via the perforations 46a. The fracturing pressure may be applied, for example, via the annulus 30 from the surface (e.g., using the pump 34 of FIG. 1), or via the tubular string 12 (e.g., using the pump 36 of FIG. 1). The scope of this disclosure is not limited to any particular fracturing means or technique, or to the use of fracturing at all.

After fracturing of the zone 40a, the perforations 46a are plugged by deploying plugs 42a into the well and conveying them by fluid flow into sealing engagement with the perforations. The plugs 42a may be conveyed by flow 44 through the casing 16 (e.g., as in FIG. 2B), or by flow 52 through the tubular string 12 (e.g., as in FIG. 2C).

The tubular string 12 is repositioned in the casing 16, so that the perforator 48 is now located at the next zone 40b to be completed. The perforator 48 is then used to form perforations 46b through the casing 16 and cement 18, and into the zone 40b. The tubular string 12 may be repositioned before or after the plugs 42a are deployed into the well.

In FIG. 3C, the zone 40b has been fractured by applying increased pressure to the zone via the perforations 46b. The fracturing pressure may be applied, for example, via the annulus 30 from the surface (e.g., using the pump 34 of FIG. 1), or via the tubular string 12 (e.g., using the pump 36 of FIG. 1).

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After fracturing of the zone 40b, the perforations 46b are plugged by deploying plugs 42b into the well and conveying them by fluid flow into sealing engagement with the perforations. The plugs 42b may be conveyed by flow 44
5 through the casing 16, or by flow 52 through the tubular string 12.

The tubular string 12 is repositioned in the casing 16, so that the perforator 48 is now located at the next zone 40c to be completed. The perforator 48 is then used to form
10 perforations 46c through the casing 16 and cement 18, and into the zone 40c. The tubular string 12 may be repositioned before or after the plugs 42b are deployed into the well.

In FIG. 3D, the zone 40c has been fractured by applying increased pressure to the zone via the perforations 46c. The
15 fracturing pressure may be applied, for example, via the annulus 30 from the surface (e.g., using the pump 34 of FIG. 1), or via the tubular string 12 (e.g., using the pump 36 of FIG. 1).

In some examples, the perforations 46c could be plugged
20 after the zone 40c is fractured or otherwise stimulated. For example, such plugging of the perforations 46c could be performed in order to verify that the plugs are effectively blocking flow from the casing 16 to the zones 40a-c.

The plugs 42a,b are then degraded and no longer prevent
25 flow through the perforations 46a,b. Thus, as depicted in FIG. 3D, flow is permitted between the interior of the casing 16 and each of the zones 40a-c.

The plugs 42a,b may be degraded in any manner. The plugs 42a,b may degrade in response to application of a
30 degrading treatment, in response to passage of a certain period of time, or in response to exposure to elevated downhole temperature. The degrading treatment could include

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exposing the plugs 42a,b to a particular type of radiation, such as electromagnetic radiation (e.g., light having a certain wavelength or range of wavelengths, gamma rays, etc.) or "nuclear" particles (e.g., gamma, beta, alpha or
5 neutron) .

The plugs 42a,b may degrade by galvanic action or by dissolving. The plugs 42a,b may degrade in response to exposure to a particular fluid, either naturally occurring in the well (such as water or hydrocarbon fluid), or
10 introduced therein (such as a fluid having a particular pH).

Note that any number of zones may be completed in any order in keeping with the principles of this disclosure. The zones 40a-c may be sections of a single earth formation, or they may be sections of separate formations .

15 In other examples, the plugs 42 may not be degraded. The plugs 42 could instead be mechanically removed, for example, by milling or otherwise cutting the plugs 42 away from the perforations, or by grabbing and pulling the plugs from the perforations. In any of the method examples
20 described above, after the fracturing or other stimulating operation(s) are completed, the plugs 42 can be milled off or otherwise removed from the perforations 38, 46, 46a,b without dissolving, melting, dispersing or otherwise degrading a material of the plugs.

25 Referring additionally now to FIG. 4A, an example of a flow conveyed device 60 that can incorporate the principles of this disclosure is representatively illustrated. The device 60 may be used for any of the plugs 42, 42a,b in the method examples described above, or the device may be used
30 in other methods.

The device 60 example of FIG. 4A includes multiple fibers 62 extending outwardly from an enlarged body 64. As

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depicted in FIG. 4A, each of the fibers 62 has a lateral dimension (e.g., a thickness or diameter) that is substantially smaller than a size (e.g., a thickness or diameter) of the body 64.

5 The body 64 can be dimensioned so that it will effectively engage and seal off a particular opening in a well. For example, if it is desired for the device 60 to seal off a perforation in a well, the body 64 can be formed so that it is somewhat larger than a diameter of the
10 perforation. If it is desired for multiple devices 60 to seal off multiple openings having a variety of dimensions (such as holes caused by corrosion of the casing 16), then the bodies 64 of the devices can be formed with a corresponding variety of sizes.

15 In the FIG. 4A example, the fibers 62 are joined together (e.g., by braiding, weaving, cabling, etc.) to form lines 66 that extend outwardly from the body 64. In this example, there are two such lines 66, but any number of lines (including one) may be used in other examples.

20 The lines 66 may be in the form of one or more ropes, in which case the fibers 62 could comprise frayed ends of the rope(s). In addition, the body 64 could be formed by one or more knots in the rope(s). In some examples, the body 64 can comprise a fabric or cloth, the body could be formed by
25 one or more knots in the fabric or cloth, and the fibers 62 could extend from the fabric or cloth.

 In the FIG. 4A example, the body 64 is formed by a double overhand knot in a rope, and ends of the rope are frayed, so that the fibers 62 are splayed outward. In this
30 manner, the fibers 62 will cause significant fluid drag when the device 60 is deployed into a flow stream, so that the

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device will be effectively "carried" by, and "follow," the flow.

However, it should be clearly understood that other types of bodies and other types of fibers may be used in other examples. The body 64 could have other shapes, the
5 body could be hollow or solid, and the body could be made up of one or multiple materials. The fibers 62 are not necessarily joined by lines 66, and the fibers are not necessarily formed by fraying ends of ropes or other lines.
10 Thus, the scope of this disclosure is not limited to the construction, configuration or other details of the device 60 as described herein or depicted in the drawings.

Referring additionally now to FIG. 4B, another example of the device 60 is representatively illustrated. In this
15 example, the device 60 is formed using multiple braided lines 66 of the type known as "mason twine." The multiple lines 66 are knotted (such as, with a double or triple overhand knot or other type of knot) to form the body 64. Ends of the lines 66 are not necessarily be frayed in these
20 examples, although the lines do comprise fibers (such as the fibers 62 described above).

Referring additionally now to FIG. 5, another example of the device 60 is representatively illustrated. In this example, four sets of the fibers 62 are joined by a
25 corresponding number of lines 66 to the body 64. The body 64 is formed by one or more knots in the lines 66.

FIG. 5 demonstrates that a variety of different configurations are possible for the device 60. Accordingly, the principles of this disclosure can be incorporated into
30 other configurations not specifically described herein or depicted in the drawings. Such other configurations may

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include fibers joined to bodies without use of lines, bodies formed by techniques other than knotting, etc.

Referring additionally now to FIGS. 6A & B, an example of a use of the device 60 of FIG. 4 to seal off an opening
5 68 in a well is representatively illustrated. In this example, the opening 68 is a perforation formed through a sidewall 70 of a tubular string 72 (such as, a casing, liner, tubing, etc.). However, in other examples the opening 68 could be another type of opening, and may be formed in
10 another type of structure.

The device 60 is deployed into the tubular string 72 and is conveyed through the tubular string by fluid flow 74. The fibers 62 of the device 60 enhance fluid drag on the device, so that the device is influenced to displace with
15 the flow 74.

Since the flow 74 (or a portion thereof) exits the tubular string 72 via the opening 68, the device 60 will be influenced by the fluid drag to also exit the tubular string via the opening 68. As depicted in FIG. 6B, one set of the
20 fibers 62 first enters the opening 68, and the body 64 follows. However, the body 64 is appropriately dimensioned, so that it does not pass through the opening 68, but instead is lodged or wedged into the opening. In some examples, the body 64 may be received only partially in the opening 68,
25 and in other examples the body may be entirely received in the opening.

The body 64 may completely or only partially block the flow 74 through the opening 68. If the body 64 only partially blocks the flow 74, any remaining fibers 62
30 exposed to the flow in the tubular string 72 can be carried by that flow into any gaps between the body and the opening

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68, so that a combination of the body and the fibers completely blocks flow through the opening.

In another example, the device 60 may partially block flow through the opening 68, and another material (such as, calcium carbonate, PLA or PGA particles) may be deployed and conveyed by the flow 74 into any gaps between the device and the opening, so that a combination of the device and the material completely blocks flow through the opening.

The device 60 may permanently prevent flow through the opening 68, or the device may degrade to eventually permit flow through the opening. If the device 60 degrades, it may be self-degrading, or it may be degraded in response to any of a variety of different stimuli. Any technique or means for degrading the device 60 (and any other material used in conjunction with the device to block flow through the opening 68) may be used in keeping with the scope of this disclosure .

In other examples, the device 60 may be mechanically removed from the opening 68. For example, if the body 64 only partially enters the opening 68, a mill or other cutting device may be used to cut the body from the opening.

Referring additionally now to FIGS. 7-9, additional examples of the device 60 are representatively illustrated. In these examples, the device 60 is surrounded by, encapsulated in, molded in, or otherwise retained by, a retainer 80.

The retainer 80 aids in deployment of the device 60, particularly in situations where multiple devices are to be deployed simultaneously. In such situations, the retainer 80 for each device 60 prevents the fibers 62 and/or lines 66 from becoming entangled with the fibers and/or lines of other devices .

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The retainer 80 could in some examples completely enclose the device 60. In other examples, the retainer 80 could be in the form of a binder that holds the fibers 62 and/or lines 66 together, so that they do not become
5 entangled with those of other devices.

In some examples, the retainer 80 could have a cavity therein, with the device 60 (or only the fibers 62 and/or lines 66) being contained in the cavity. In other examples, the retainer 80 could be molded about the device 60 (or only
10 the fibers 62 and/or lines 66).

At least after deployment of the device 60 into the well, the retainer 80 dissolves, melts, disperses or otherwise degrades, so that the device is capable of sealing off an opening 68 in the well, as described above. For
15 example, the retainer 80 can be made of a material 82 that degrades in a wellbore environment.

The retainer material 82 may degrade after deployment into the well, but before arrival of the device 60 at the opening 68 to be plugged. In other examples, the retainer
20 material 82 may degrade at or after arrival of the device 60 at the opening 68 to be plugged. If the device 60 also comprises a degradable material, then preferably the retainer material 82 degrades prior to the device material.

The material 82 could, in some examples, melt at
25 elevated wellbore temperatures. The material 82 could be chosen to have a melting point that is between a temperature at the earth's surface and a temperature at the opening 68, so that the material melts during transport from the surface to the downhole location of the opening.

30 The material 82 could, in some examples, dissolve when exposed to wellbore fluid. The material 82 could be chosen so that the material begins dissolving as soon as it is

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deployed into the wellbore 14 and contacts a certain fluid (such as, water, brine, hydrocarbon fluid, etc.) therein. In other examples, the fluid that initiates dissolving of the material 82 could have a certain pH range that causes the material to dissolve.

Note that it is not necessary for the material 82 to melt or dissolve in the well. Various other stimuli (such as, passage of time, elevated pressure, flow, turbulence, etc.) could cause the material 82 to disperse, degrade or otherwise cease to retain the device 60. The material 82 could degrade in response to any one, or a combination, of: passage of a predetermined period of time in the well, exposure to a predetermined temperature in the well, exposure to a predetermined fluid in the well, exposure to radiation in the well and exposure to a predetermined chemical composition in the well. Thus, the scope of this disclosure is not limited to any particular stimulus or technique for dispersing or degrading the material 82, or to any particular type of material.

In some examples, the material 82 can remain on the device 60, at least partially, when the device engages the opening 68. For example, the material 82 could continue to cover the body 64 (at least partially) when the body engages and seals off the opening 68. In such examples, the material 82 could advantageously comprise a relatively soft, viscous and/or resilient material, so that sealing between the device 60 and the opening 68 is enhanced.

Suitable relatively low melting point substances that may be used for the material 82 can include wax (e.g., paraffin wax, vegetable wax), ethylene-vinyl acetate copolymer (e.g., ELVAX(TM) available from DuPont), atactic polypropylene and eutectic alloys. Suitable relatively soft

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substances that may be used for the material 82 can include a soft silicone composition or a viscous liquid or gel. Suitable dissolvable materials can include PLA, PGA, anhydrous boron compounds (such as anhydrous boric oxide and anhydrous sodium borate), polyvinyl alcohol (PVA), polyvinyl acetate (PVAc), polyethylene oxide, salts and carbonates.

In FIG. 7, the retainer 80 is in a cylindrical form. The device 60 is encapsulated in, or molded in, the retainer material 82. The fibers 62 and lines 66 are, thus, prevented from becoming entwined with the fibers and lines of any other devices 60.

In FIG. 8, the retainer 80 is in a spherical form. In addition, the device 60 is compacted, and its compacted shape is retained by the retainer material 82. A shape of the retainer 80 can be chosen as appropriate for a particular device 60 shape, in compacted or un-compacted form. A frangible coating 88 may be provided on the retainer 80.

In FIG. 9, the retainer 80 is in a cubic form. Thus, any type of shape (polyhedron, spherical, cylindrical, etc.) may be used for the retainer 80, in keeping with the principles of this disclosure.

In some examples, the devices 60 can be prepared from non-fibrous or nonwoven material, and the devices may or may not be knotted. The devices 60 can also be prepared from film, tube, or nonwoven fabric. The devices 60 may be prepared from a single sheet of material or multiple strips of sheet material.

Polyvinyl alcohol (PVA) and polyvinyl acetate (PVAc) are described above as suitable soluble retainer materials 82, but these materials may be used for the device 60 itself (with or without the retainer 80). PVA is available with

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dissolution temperatures in water over a wide range (e.g., ambient temperature to 175 °F). PVA and PVAc can be used in the form of film, tube, and fiber or filament.

Some advantages of PVA include: 1) PVA can be
5 formulated to be insoluble at a typically lowered
circulating temperature during a fracturing operation, and
later dissolve when heated to bottom hole static
temperature. No additional treatment is required to remove
the knot or other plugging device made with PVA. 2) PVA can
10 be cross-linked with borate ion or aluminum ion to decrease
its dissolution rate. 3) PVA properties can be modified by
varying a degree of hydrolysis, copolymerization, or
addition of plasticizer.

An example of a PVA knot device 60 can be formed as
15 follows: A length of PVA tube (for example, a 4 inch (-10
cm) width flat tube made from 3 mil (-0.08 mm) M1030 PVA
film available from MonoSol, LLC of Portage, Indiana USA) is
turned halfway inside-out to form a double-walled tube. The
tube is folded in half lengthwise and one end is pinched in
20 a vise. The other end is connected to a vacuum pump to
remove air from the tube. The resulting flattened tube is
twisted into a tight strand. The resulting strand is tied in
a triple overhand knot. The knot can be seated against a
0.42 inch (-10.7 mm) diameter orifice and pressurized to
25 4500 psi (-31 MPa) with water. The knot seals the orifice,
completely shutting off the flow of water.

Another material suitable for use in the device 60 is
an acid-resistant material that is water-soluble. Poly-
methacrylic acid is insoluble at low pH, but dissolves at
30 neutral pH. Devices 60 made from poly-methacrylic acid could
be used as a diverter in an acid treatment to block treated
perforations and divert the acid to other perforations.

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After the treatment is complete, the devices 60 would dissolve as the pH rises. No remedial treatment would be required to remove the plugs .

Referring additionally now to FIG. 10, a method 100 of restoring flow through the openings 68 in the well is representatively illustrated. The openings 68 in this example are formed by perforations 46 through casing 16 and cement 18 lining the wellbore 14, and flow through the openings has previously been blocked by flow conveyed plugging devices 60 (for example, as part of a stimulation operation) .

In other examples, the openings 68 may not be formed by perforations through casing or liner. The openings 68 could be formed in a side or end of a well tool, could be formed in a casing or liner without perforating, etc. The scope of this disclosure is not limited to any particular type of opening blocked by the plugging device 60.

In the FIG. 10 example, when it is desired to restore fluid communication between the interior of the casing 16 and the formation 40 penetrated by the perforations 46, a well tool 102 is conveyed into the wellbore 14. The well tool 102 in this example has cutters 104 at a distal end thereof .

The well tool 102 may be of the type known to those skilled in the art as a mill, an overshot or a fishing tool. However, it should be clearly understood that the scope of this disclosure is not limited to use of any particular type of well tool for restoring flow through the openings 68.

It is not necessary for the well tool 102 to include the cutters 104 as depicted in FIG. 10. In some examples, the well tool 102 could be configured to dislodge the plugging devices 60, without cutting into the plugging

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devices, or without use of the cutters 104. For example, a gauge of the type used to verify an inner diameter of casing could be used to contact and dislodge the plugging devices 60 from the openings 68.

5 In the FIG. 10 example, the well tool 102 is conveyed through the casing 16, so that the cutters 104 contact and cut into the plugging devices 60. If the plugging devices 60 comprise a material degradable in response to contact with a fluid in the well, the degradable material can be exposed to
10 the fluid as a result of the well tool 102 cutting into the plugging devices (for example, the degradable material could be coated or covered by a non-degradable material that is penetrated by the cutters 104). When the material degrades, flow through the openings 68 will be restored.

15 In some examples, the cutters 104 could comprise one or more fluid jet nozzles. Fluid can be pumped out of the nozzles, so that fluid jets will contact and/or cut into the plugging devices 60, in order to dislodge the plugging
20 devices from the openings 68 or to expose a degradable material of the plugging devices to fluid in the well (e.g., the fluid discharged from the nozzles, or fluid already present in the wellbore 14).

 In some examples, the cutters 104 could serve to engage or "grab" the plugging devices 60, and pull the plugging
25 devices from the openings 68. When the plugging devices 60 are dislodged from the openings 68, flow through the openings is restored.

 Referring additionally now to FIG. 11, another example of the method 100 is representatively illustrated. In this
30 example, the well tool 102 includes seals 106 that can sealingly engage the interior of the casing 16. The seals

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106 may be of the type known to those skilled in the art as "swab cups."

In the FIG. 11 example, the well tool 102 is lowered through the wellbore 14, until it is relatively close to the plugging devices 60 and openings 68. The well tool 102 is then relatively quickly displaced upward, to thereby produce a reduced pressure in the wellbore 14 proximate the plugging devices 60 and openings 68.

Preferably, the pressure in the wellbore 14 becomes less than pressure in the formation 40, so that a pressure differential is created across the plugging devices 60. This pressure differential biases the plugging devices 60 inward, so that they are dislodged from the openings 68. When the plugging devices are dislodged, flow through the openings 68 is restored.

Pressure in the well can be reduced by use of techniques other than displacement of the well tool 102. For example, a relatively low pressure chamber could be opened in the well proximate the plugging devices 60 and openings 68 to thereby allow well fluid to enter the chamber and reduce pressure in the well. Thus, the scope of this disclosure is not limited to any particular technique for reducing pressure in the well.

Note that the method 100 examples as depicted in FIGS. 10 & 11 are merely a few of a wide variety of different techniques that can be used to restore flow through openings in a well. In some examples, flow through openings may be restored by the plugging devices degrading or becoming dislodged from the openings without use of the well tool 102 or any other intervention into the well. Therefore, the scope of this disclosure is not limited to use of the well tool 102 or any other intervention into the well.

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Referring additionally now to FIG. 12, a cross-sectional view of another example of the device 60 is representatively illustrated. The device 60 may be used in any of the systems and methods described herein, or may be
5 used in other systems and methods .

In this example, the body of the device 60 is made up of filaments or fibers 62 formed in the shape of a ball or sphere. Of course, other shapes may be used, if desired.

The filaments or fibers 62 may make up all, or
10 substantially all, of the device 60. The fibers 62 may be randomly oriented, or they may be arranged in various orientations as desired.

In the FIG. 12 example, the fibers 62 are retained by the dissolvable, degradable or dispersible material 82. In
15 addition, a frangible coating may be provided on the device 60, for example, in order to delay dissolving of the material 82 until the device has been deployed into a well (as in the examples of FIGS. 8 & 10).

The device 60 of FIG. 12 can be used in a diversion
20 fracturing operation (in which perforations receiving the most fluid are plugged to divert fluid flow to other perforations), in a re-completion operation (e.g., as in the FIGS. 2A-D example), or in a multiple zone perforate and fracture operation (e.g., as in the FIGS. 3A-D example).

25 One advantage of the FIG. 12 device 60 is that it is capable of sealing on irregularly shaped openings, perforations, leak paths or other passageways. The device 60 can also tend to "stick" or adhere to an opening, for example, due to engagement between the fibers 62 and
30 structure surrounding (and in) the opening. In addition, there is an ability to selectively seal openings.

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The fibers 62 could, in some examples, comprise wool fibers. The device 60 may be reinforced (e.g., using the material 82 or another material) or may be made entirely of fibrous material with a substantial portion of the fibers 62 randomly oriented.

The fibers 62 could, in some examples, comprise metal wool, or crumpled and/or compressed wire. Wool may be retained with wax or other material (such as the material 82) to form a ball, sphere, cylinder or other shape.

In the FIG. 12 example, the material 82 can comprise a wax (or eutectic metal or other material) that melts at a selected predetermined temperature. A wax device 60 may be reinforced with fibers 62, so that the fibers and the wax (material 82) act together to block a perforation or other passageway.

The selected melting point can be slightly below a static wellbore temperature. The wellbore temperature during fracturing is typically depressed due to relatively low temperature fluids entering wellbore. After fracturing, wellbore temperature will typically increase, thereby melting the wax and releasing the reinforcement fibers 62.

This type of device 60 in the shape of a ball or other shapes may be used to operate downhole tools in a similar fashion. In FIG. 14, a well tool 110 is depicted with a passageway 112 extending longitudinally through the well tool. The well tool 110 could, for example, be connected in the casing 16 of FIG. 1, or it could be connected in another tubular string (such as a production tubing string, the tubular string 12, etc.).

The device 60 is depicted in FIG. 14 as being sealingly engaged with a seat 114 formed in a sliding sleeve 116 of the well tool 110. When the device 60 is so engaged in the

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well tool 110 (for example, after the well tool is deployed into a well and appropriately positioned), a pressure differential may be produced across the device and the sliding sleeve 116, in order to shear frangible members 118 and displace the sleeve downward (as viewed in FIG. 14), thereby allowing flow between the passageway 112 and an exterior of the well tool 110 via openings 120 formed through an outer housing 122.

The material 82 of the device 60 can then dissolve, disperse or otherwise degrade to thereby permit flow through the passageway 112. Of course, other types of well tools (such as, packer setting tools, frac plugs, testing tools, etc.) may be operated or actuated using the device 60 in keeping with the scope of this disclosure.

A drag coefficient of the device 60 in any of the examples described herein may be modified appropriately to produce a desired result. For example, in a diversion fracturing operation, it is typically desirable to block perforations in a certain location in a wellbore. The location is usually at the perforations taking the most fluid.

Natural fractures in an earth formation penetrated by the wellbore make it so that certain perforations receive a larger portion of fracturing fluids. For these situations and others, the device 60 shape, size, density and other characteristics can be selected, so that the device tends to be conveyed by flow to a certain corresponding section of the wellbore.

For example, devices 60 with a larger coefficient of drag (C_d) may tend to seat more toward a toe of a generally horizontal or lateral wellbore. Devices 60 with a smaller C_d may tend to seat more toward a heel of the wellbore. For

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example, if the wellbore 14 depicted in FIG. 2B is horizontal or highly deviated, the heel would be at an upper end of the illustrated wellbore, and the toe would be at the lower end of the illustrated wellbore (e.g., the direction
5 of the fluid flow 44 is from the heel to the toe).

Smaller devices 60 with long fibers 62 floating freely (see the example of FIG. 13) may have a strong tendency to seat at or near the heel. A diameter of the device 60 and the free fiber 62 length can be appropriately selected, so
10 that the device is more suited to stopping and sealingly engaging perforations anywhere along the length of the wellbore .

Acid treating operations can benefit from use of the device 60 examples described herein. Pumping friction causes
15 hydraulic pressure at the heel to be considerably higher than at the toe. This means that the fluid volume pumped into a formation at the heel will be considerably higher than at the toe. Turbulent fluid flow increases this effect. Gelling additives might reduce an onset of turbulence and
20 decrease the magnitude of the pressure drop along the length of the wellbore.

Higher initial pressure at the heel allows zones to be acidized and then plugged starting at the heel, and then progressively down along the wellbore. This mitigates waste
25 of acid from attempting to acidize all of the zones at the same time.

The free fibers 62 of the FIGS. 4-6B & 13 examples greatly increase the ability of the device 60 to engage the first open perforation (or other leak path) it encounters.
30 Thus, the devices 60 with low Cd and long fibers 62 can be used to plug from upper perforations to lower perforations, while turbulent acid with high frictional pressure drop is

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used so that the acid treats the unplugged perforations nearest the top of the wellbore with acid first.

In examples of the device 60 where a wax material (such as the material 82) is used, the fibers 62 (including the body 64, lines 66, knots, etc.) may be treated with a treatment fluid that repels wax (e.g., during a molding process). This may be useful for releasing the wax from the fibrous material after fracturing or otherwise compromising the retainer 80 and/or a frangible coating thereon.

Suitable release agents are water-wetting surfactants (e.g., alkyl ether sulfates, high hydrophilic-lipophilic balance (HLB) nonionic surfactants, betaines, alkyarylsulfonates, alkyldiphenyl ether sulfonates, alkyl sulfates). The release fluid may also comprise a binder to maintain the knot or body 64 in a shape suitable for molding. One example of a binder is a polyvinyl acetate emulsion.

Broken-up or fractured devices 60 can have lower Cd. Broken-up or fractured devices 60 can have smaller cross-sections and can pass through the annulus 30 between tubing 20 and casing 16 more readily.

The restriction 98 (see FIG. 10) may be connected in any line or pipe that the devices 60 are pumped through, in order to cause the devices to fracture as they pass through the restriction. This may be used to break up and separate devices 60 into wax and non-wax parts. The restriction 98 may also be used for rupturing a frangible coating covering a soluble wax material 82 to allow water or other well fluids to dissolve the wax.

Fibers 62 may extend outwardly from the device 60, whether or not the body 64 or other main structure of the device also comprises fibers. For example, a ball (or other

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shape) made of any material could have fibers 62 attached to and extending outwardly therefrom. Such a device 60 will be better able to find and cling to openings, holes, perforations or other leak paths near the heel of the wellbore, as compared to the ball (or other shape) without the fibers 62.

For any of the device 60 examples described herein, the fibers 62 may not dissolve, disperse or otherwise degrade in the well. In such situations, the devices 60 (or at least the fibers 62) may be removed from the well by swabbing, scraping, circulating, milling or other mechanical methods.

In situations where it is desired for the fibers 62 to dissolve, disperse or otherwise degrade in the well, nylon is a suitable acid soluble material for the fibers. Nylon 6 and nylon 66 are acid soluble and suitable for use in the device 60. At relatively low well temperatures, nylon 6 may be preferred over nylon 66, because nylon 6 dissolves faster or more readily.

Self-degrading fiber devices 60 can be prepared from poly-lactic acid (PLA), poly-glycolic acid (PGA), or a combination of PLA and PGA fibers 62. Such fibers 62 may be used in any of the device 60 examples described herein.

Fibers 62 can be continuous monofilament or multifilament, or chopped fiber. Chopped fibers 62 can be carded and twisted into yarn that can be used to prepare fibrous flow conveyed devices 60.

The PLA and/or PGA fibers 62 may be coated with a protective material, such as calcium stearate, to slow its reaction with water and thereby delay degradation of the device 60. Different combinations of PLA and PGA materials may be used to achieve corresponding different degradation times or other characteristics.

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PLA resin can be spun into fiber of 1-15 denier, for example. Smaller diameter fibers 62 will degrade faster. Fiber denier of less than 5 may be most desirable. PLA resin is commercially available with a range of melting points
5 (e.g., 140 to 365 °F). Fibers 62 spun from lower melting point PLA resin can degrade faster.

PLA bi-component fiber has a core of high-melting point PLA resin and a sheath of low-melting point PLA resin (e.g., 140 °F melting point sheath on a 265 °F melting point core).
10 The low-melting point resin can hydrolyze more rapidly and generate acid that will accelerate degradation of the high-melting point core. This may enable the preparation of a fibrous device 60 that will have higher strength in a wellbore environment, yet still degrade in a reasonable
15 time. In various examples, a melting point of the resin can decrease in a radially outward direction in the fiber.

It may now be fully appreciated that the above disclosure provides significant advancements to the art of controlling flow in subterranean wells. In some examples
20 described above, the device 60 may be used to block flow through openings in a well, with the device being uniquely configured so that its conveyance with the flow is enhanced.

The above disclosure provides to the art a method 100 of restoring flow through an opening 68 in a well, the
25 opening being blocked by a plugging device 60. In one example, the method 100 comprises conveying a well tool 102 into the well, contacting the plugging device 60 with the well tool 102, and permitting flow through the opening 68 as a result of the contacting step.

30 The plugging device 60 may include a body 64 that prevents flow through the opening 68 prior to the contacting

step. The body 64 may comprise a knot. The body 64 may comprise a degradable material.

The plugging device 60 may also include, extending outwardly from the body 64, at least one of fibers 62 and lines 66. The at least one of fibers 62 and lines 66 may extend through the opening 68 prior to the contacting step. The at least one of fibers 62 and lines 66 may extend into a perforation 46 prior to the contacting step.

The plugging device 60 may include, extending outwardly from the body 64, at least one of film, tube, filament, fabric and sheet material. The at least one of film, tube, filament, fabric and sheet material may extend through the opening 68 prior to the contacting step. The at least one of film, tube, filament, fabric and sheet material may extend into a perforation 68 prior to the contacting step.

The contacting step may include cutting into the plugging device 60. The cutting step may include exposing a degradable material of the plugging device 60 to fluid in the well. The degradable material may be selected from the group consisting of poly-vinyl alcohol, poly-vinyl acetate and poly-methacrylic acid.

The contacting step may include engaging the plugging device 60 and dislodging the plugging device from the opening 68. The contacting step may include contacting the plugging device 60 with a fluid jet.

Another method 100 of restoring flow through an opening 68 blocked by a plugging device 60 in a well is provided to the art by the above disclosure. In one example, the method 100 can comprise conveying a well tool 102 into the well, reducing pressure in the well with the well tool 102, and permitting flow through the opening 68 as a result of the pressure reducing step.

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The plugging device 60 may include a body 64 that prevents flow through the opening 68 prior to the pressure reducing step. The body 64 may comprise a knot.

5 The body 64 may comprise a degradable material. The degradable material may be selected from the group consisting of poly-vinyl alcohol, poly-vinyl acetate and poly-methacrylic acid.

10 The plugging device 60 can include, extending outwardly from the body 64, at least one of the group consisting of fibers 62 and lines 66. The at least one of fibers 62 and lines 66 may extend through the opening 68 prior to the pressure reducing step.

15 The plugging device 60 can include, extending outwardly from the body 64, at least one of film, tube, filament, fabric and sheet material. The at least one of film, tube, filament, fabric and sheet material may extend through the opening 68 prior to the pressure reducing step.

20 The pressure reducing step may comprise creating a pressure differential across the plugging device 60. The pressure differential creating step may comprise biasing the plugging device 60 inward.

The pressure reducing step can include dislodging the plugging device 60 from the opening 68. The pressure reducing step can include displacing seals 106 in the well.

25 Although various examples have been described above, with each example having certain features, it should be understood that it is not necessary for a particular feature of one example to be used exclusively with that example. Instead, any of the features described above and/or depicted
30 in the drawings can be combined with any of the examples, in addition to or in substitution for any of the other features

of those examples. One example's features are not mutually exclusive to another example's features. Instead, the scope of this disclosure encompasses any combination of any of the features .

5 Although each example described above includes a certain combination of features, it should be understood that it is not necessary for all features of an example to be used. Instead, any of the features described above can be used, without any other particular feature or features also
10 being used.

 It should be understood that the various embodiments described herein may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the
15 principles of this disclosure. The embodiments are described merely as examples of useful applications of the principles of the disclosure, which is not limited to any specific details of these embodiments.

 In the above description of the representative
20 examples, directional terms (such as "above," "below," "upper," "lower," etc.) are used for convenience in referring to the accompanying drawings. However, it should be clearly understood that the scope of this disclosure is not limited to any particular directions described herein.

25 The terms "including," "includes," "comprising," "comprises," and similar terms are used in a non-limiting sense in this specification. For example, if a system, method, apparatus, device, etc., is described as "including" a certain feature or element, the system, method, apparatus,
30 device, etc., can include that feature or element, and can also include other features or elements. Similarly, the term

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"comprises" is considered to mean "comprises, but is not limited to."

Of course, a person skilled in the art would, upon a careful consideration of the above description of
5 representative embodiments of the disclosure, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to the specific embodiments, and such changes are contemplated by the principles of this disclosure. For example,
10 structures disclosed as being separately formed can, in other examples, be integrally formed and *vice versa*. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the invention being
15 limited solely by the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A method of restoring flow through an opening
blocked by a plugging device in a well, the method
5 comprising:

conveying a well tool into the well;

contacting the plugging device with the well tool; and

10 permitting flow through the opening as a result of the
contacting.

2. The method of claim 1, wherein the plugging device
comprises a body that prevents flow through the opening
prior to the contacting.

15 3. The method of claim 2, wherein the body comprises
a knot.

4. The method of claim 2, wherein the body comprises
a degradable material.

20 5. The method of claim 2, wherein the plugging device
further comprises, extending outwardly from the body, at
least one of the group consisting of fibers and lines.

25 6. The method of claim 5, wherein the at least one of
the group consisting of fibers and lines extends through the
opening prior to the contacting.

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7. The method of claim 5, wherein the at least one of the group consisting of fibers and lines extends into a perforation prior to the contacting.

5 8. The method of claim 2, wherein the plugging device further comprises, extending outwardly from the body, at least one of the group consisting of film, tube, filament, fabric and sheet material.

10 9. The method of claim 8, wherein the at least one of the group consisting of film, tube, filament, fabric and sheet material extends through the opening prior to the contacting.

15 10. The method of claim 8, wherein the at least one of the group consisting of film, tube, filament, fabric and sheet material extends into a perforation prior to the contacting.

20 11. The method of claim 1, wherein the contacting comprises cutting into the plugging device.

25 12. The method of claim 11, wherein the cutting comprises exposing a degradable material of the plugging device to fluid in the well.

30 13. The method of claim 12, wherein the degradable material is selected from the group consisting of poly-vinyl alcohol, poly-vinyl acetate, poly-methacrylic acid, poly-lactic acid and poly-glycolic acid.

14. The method of claim 1, wherein the contacting comprises engaging the plugging device and dislodging the plugging device from the opening.

5

15. The method of claim 1, wherein the contacting comprises contacting the plugging device with a fluid jet.

16. A method of restoring flow through an opening
10 blocked by a plugging device in a well, the method comprising:

conveying a well tool into the well;

reducing pressure in the well with the well tool; and

15 permitting flow through the opening as a result of the pressure reducing.

17. The method of claim 16, wherein the plugging device comprises a body that prevents flow through the opening prior to the pressure reducing.

20

18. The method of claim 17, wherein the body comprises a knot.

19. The method of claim 17, wherein the body comprises
25 a degradable material.

20. The method of claim 19, wherein the degradable material is selected from the group consisting of poly-vinyl

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alcohol, poly-vinyl acetate, poly-methacrylic acid, poly-lactic acid and poly-glycolic acid.

21. The method of claim 17, wherein the plugging
5 device further comprises, extending outwardly from the body,
at least one of the group consisting of fibers and lines.

22. The method of claim 21, wherein the at least one
of the group consisting of fibers and lines extends through
10 the opening prior to the pressure reducing.

23. The method of claim 17, wherein the plugging
device further comprises, extending outwardly from the body,
at least one of the group consisting of film, tube,
15 filament, fabric and sheet material.

24. The method of claim 23, wherein the at least one
of the group consisting of film, tube, filament, fabric and
sheet material extends through the opening prior to the
20 pressure reducing.

25. The method of claim 16, wherein the pressure
reducing comprises creating a pressure differential across
the plugging device.

25

26. The method of claim 25, wherein the pressure
differential creating comprises biasing the plugging device
inward .

27. The method of claim 16, wherein the pressure reducing comprises dislodging the plugging device from the opening.

5 28. The method of claim 16, wherein the pressure reducing comprises displacing seals in the well.

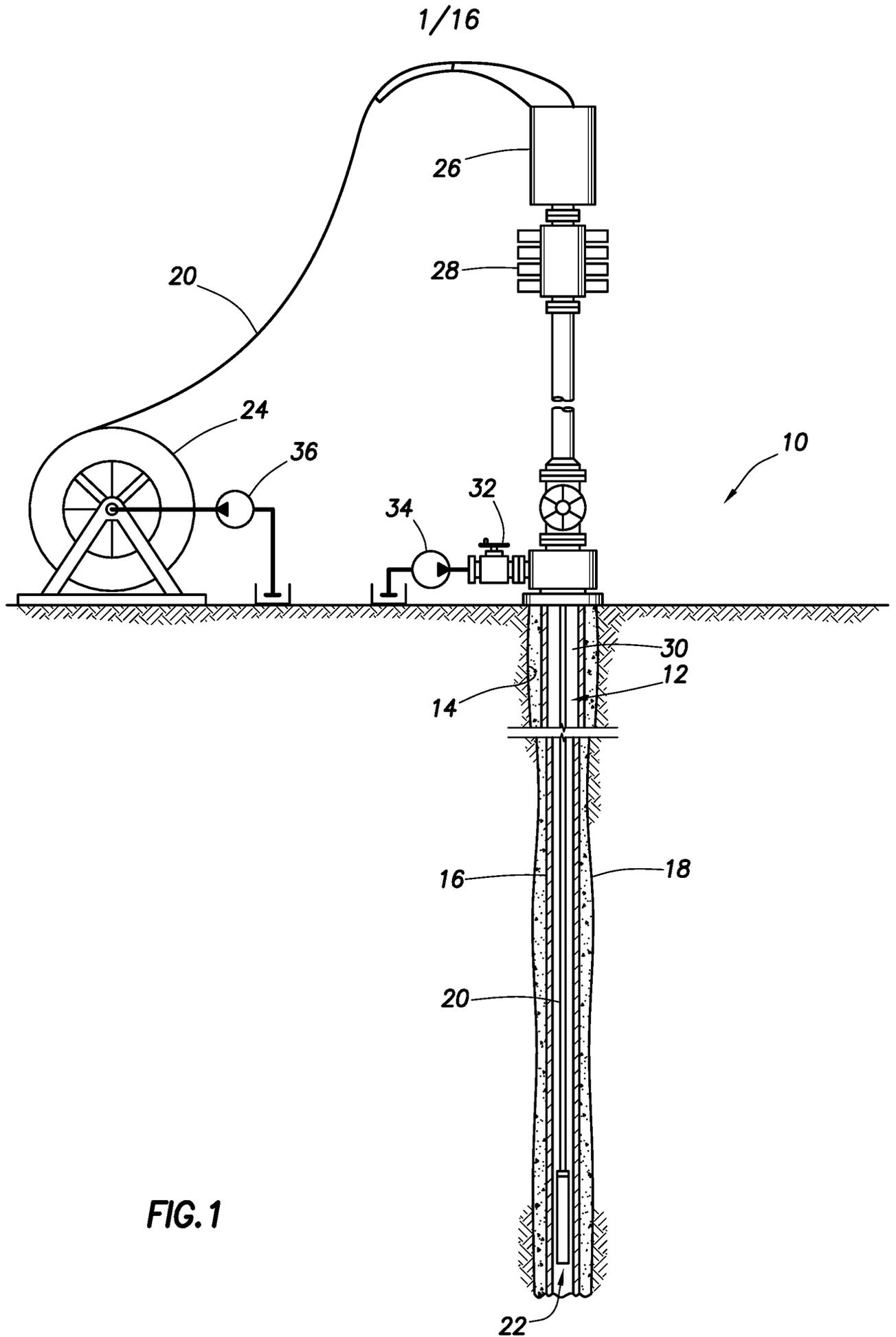


FIG. 1

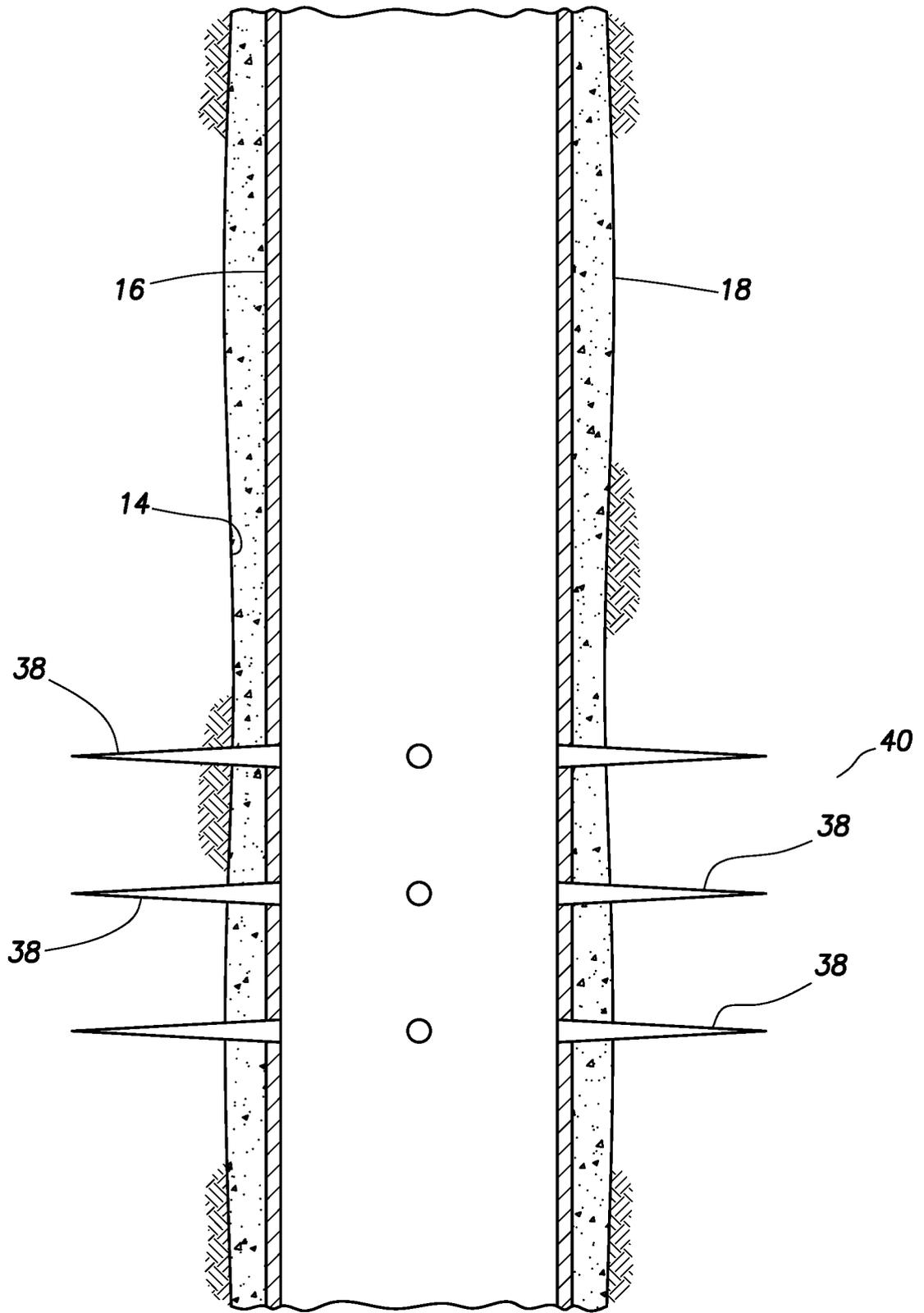


FIG.2A

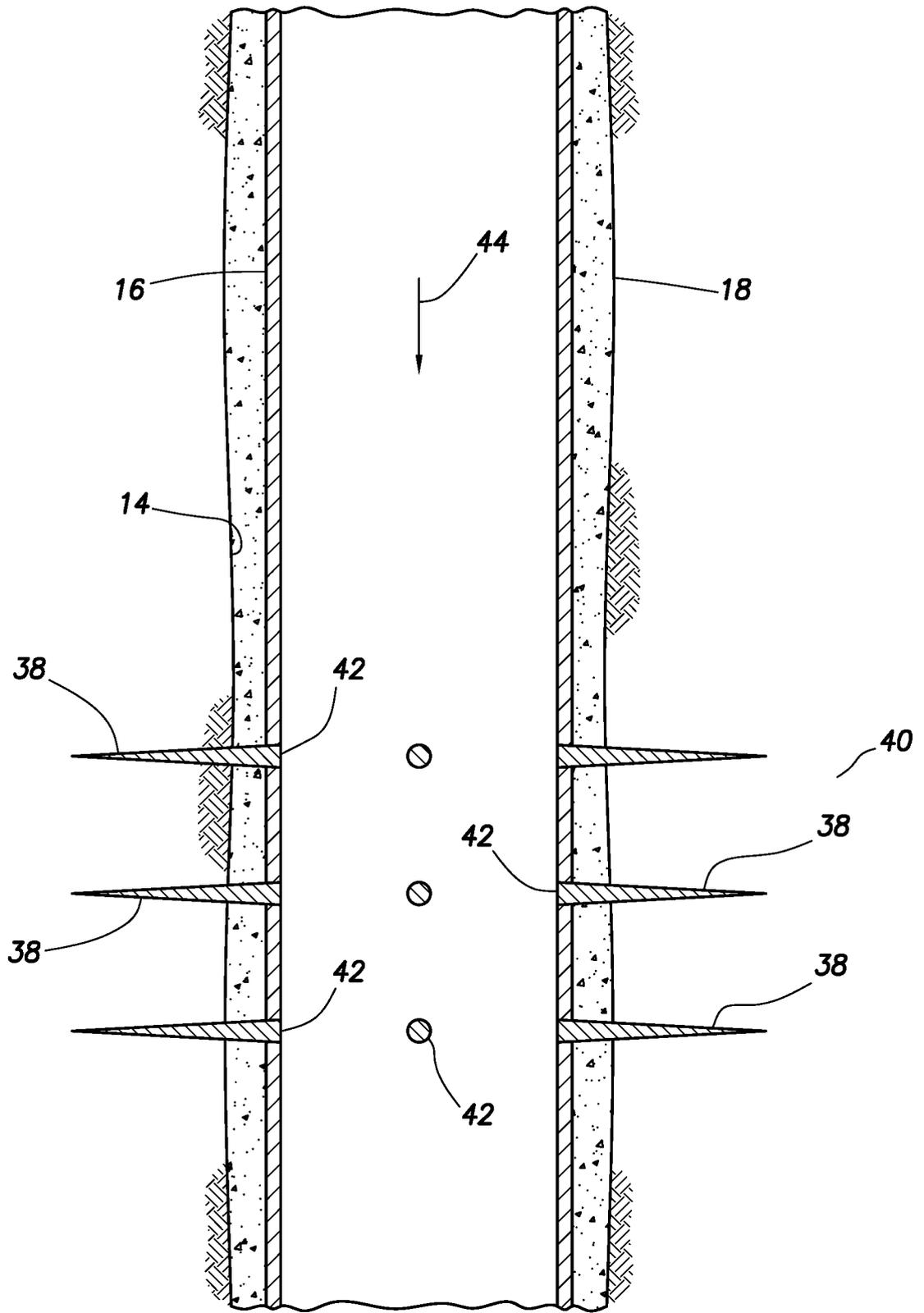


FIG.2B

4/16

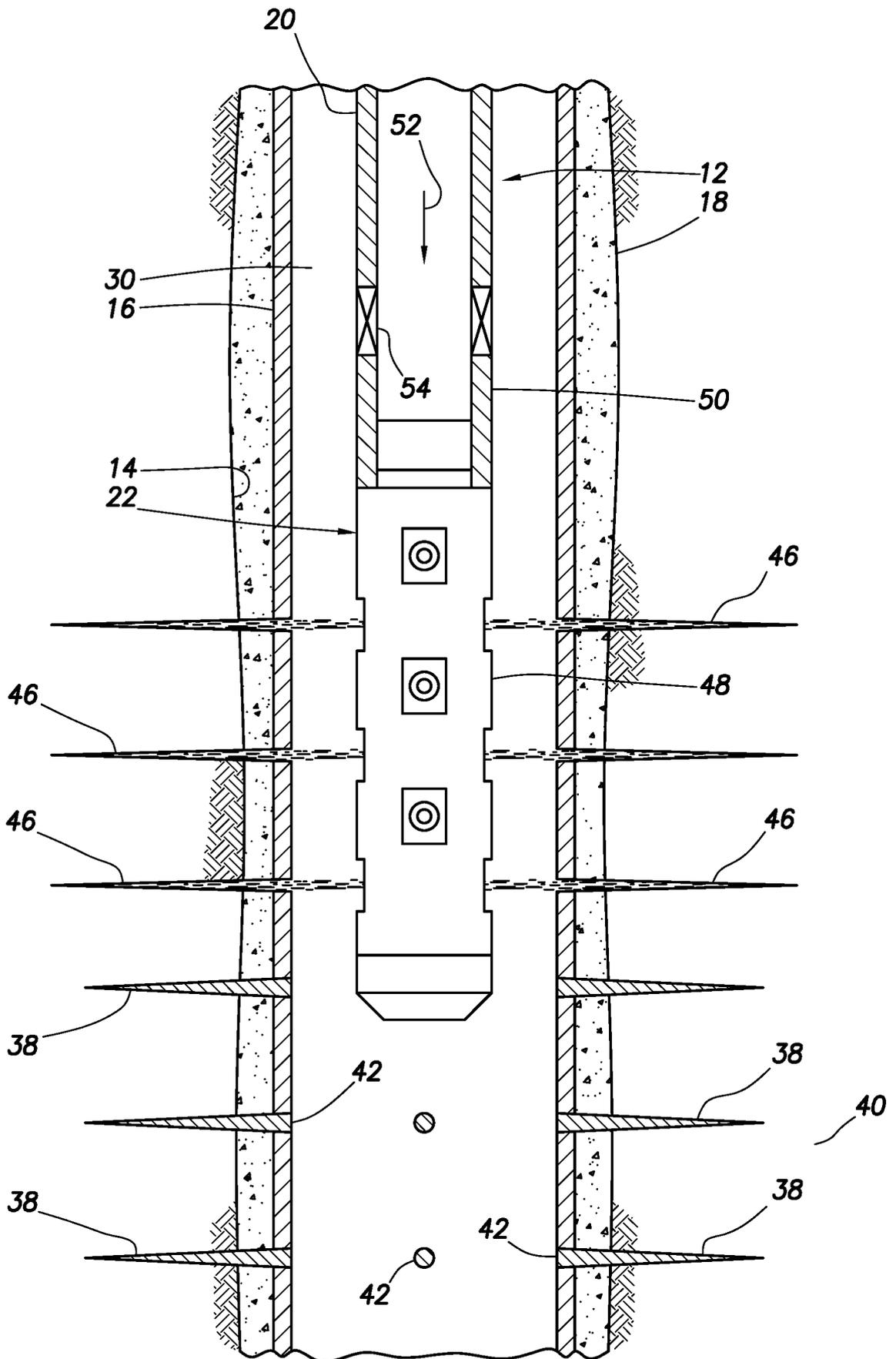


FIG.2C

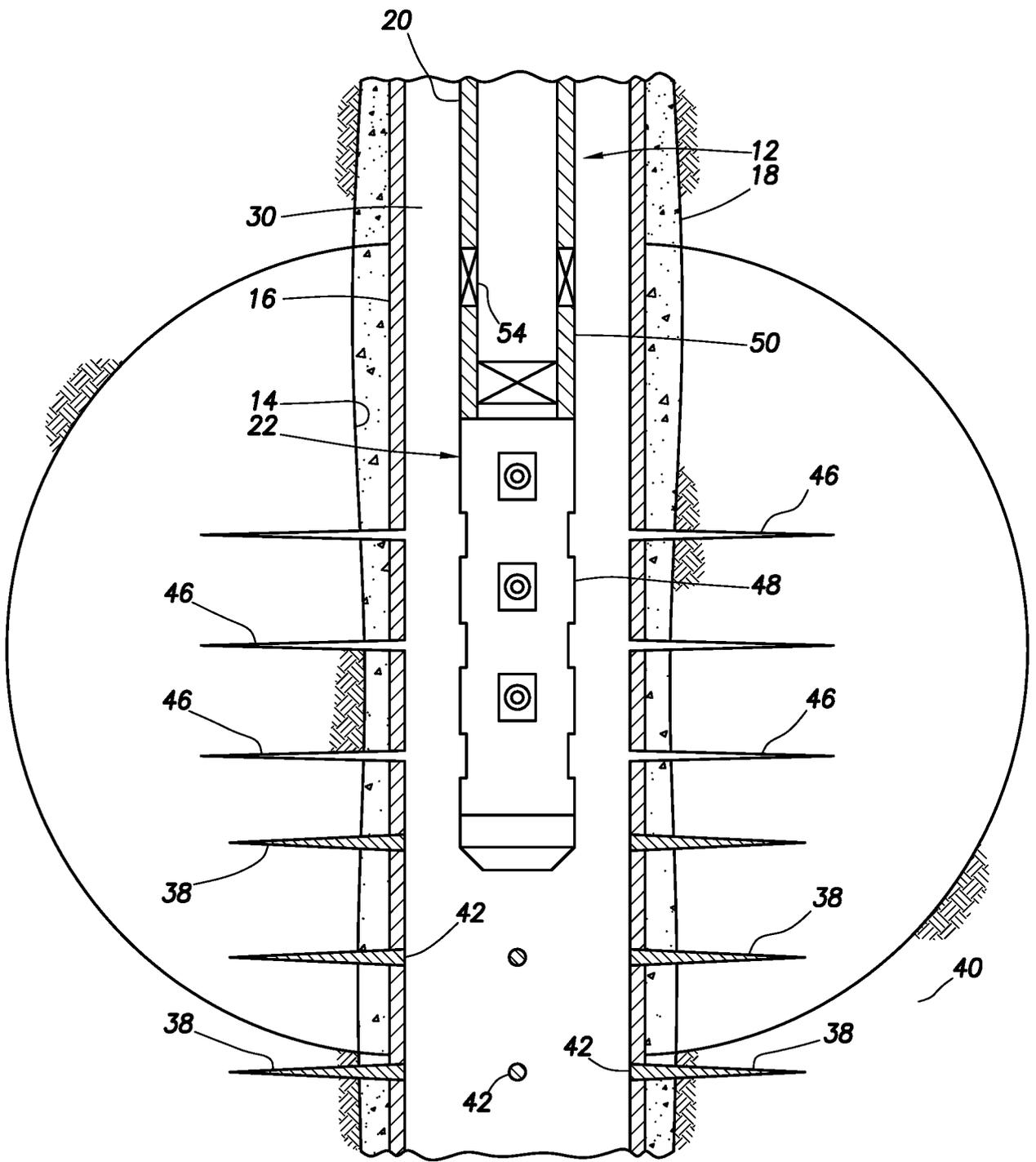


FIG.2D

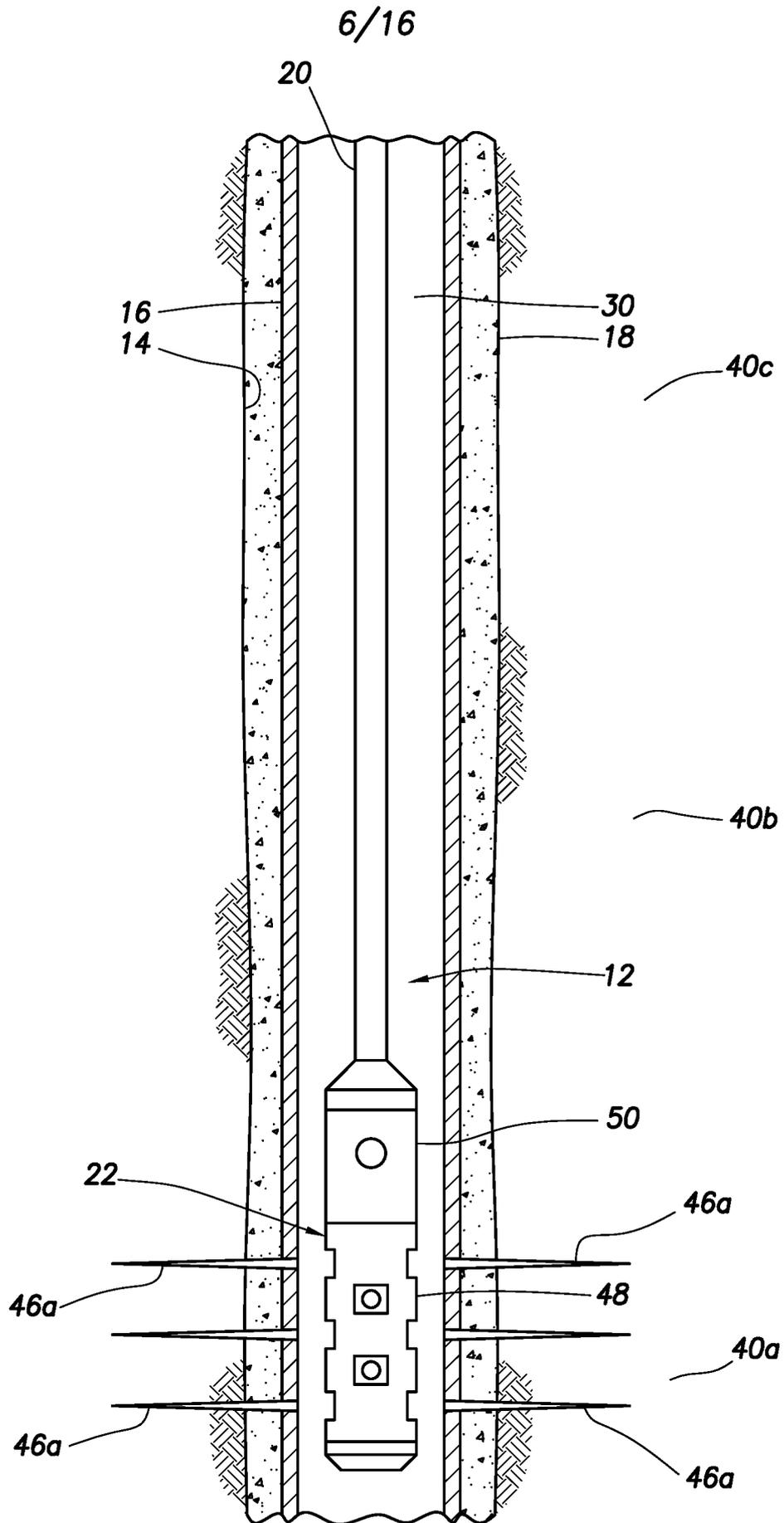


FIG.3A

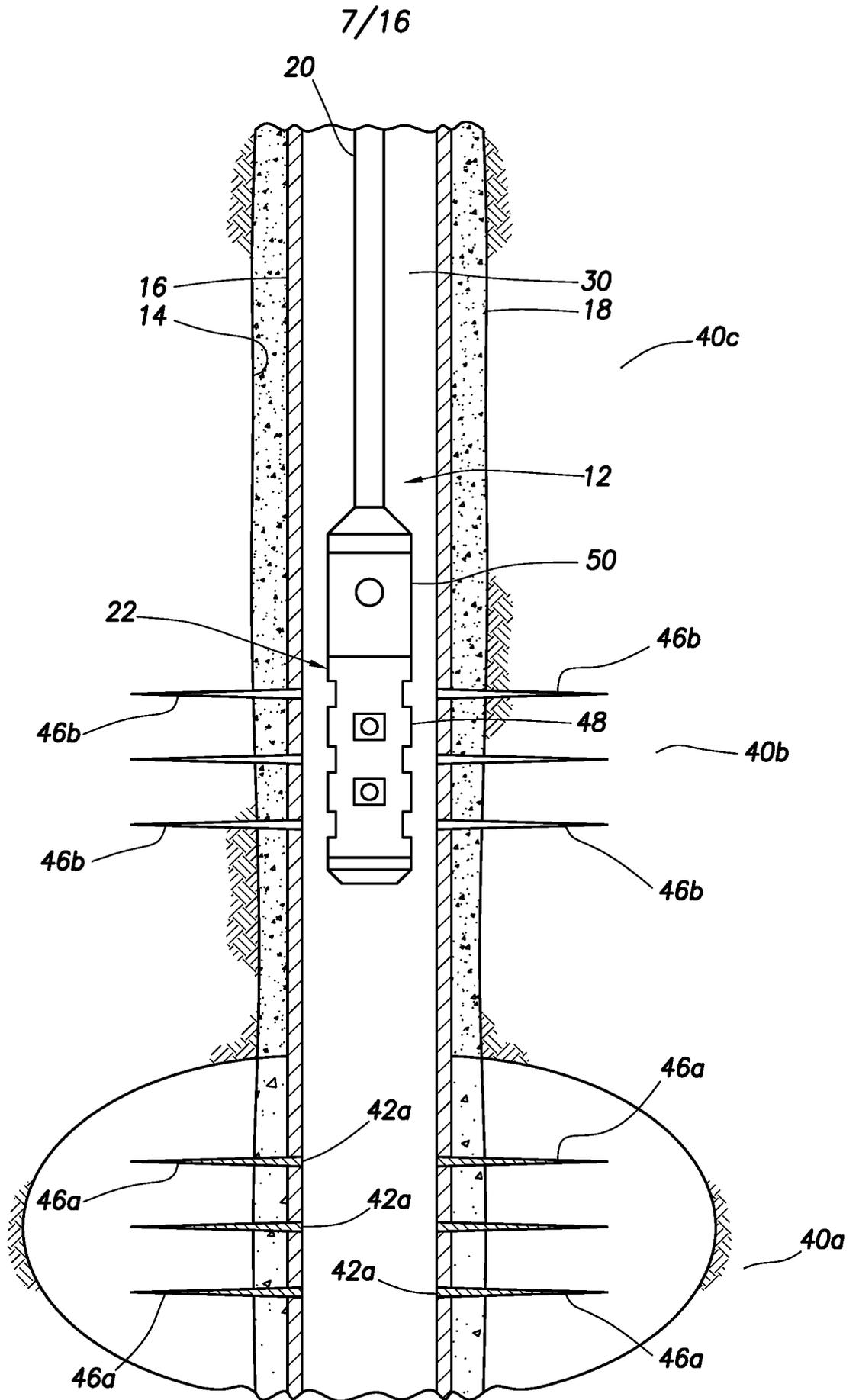


FIG.3B

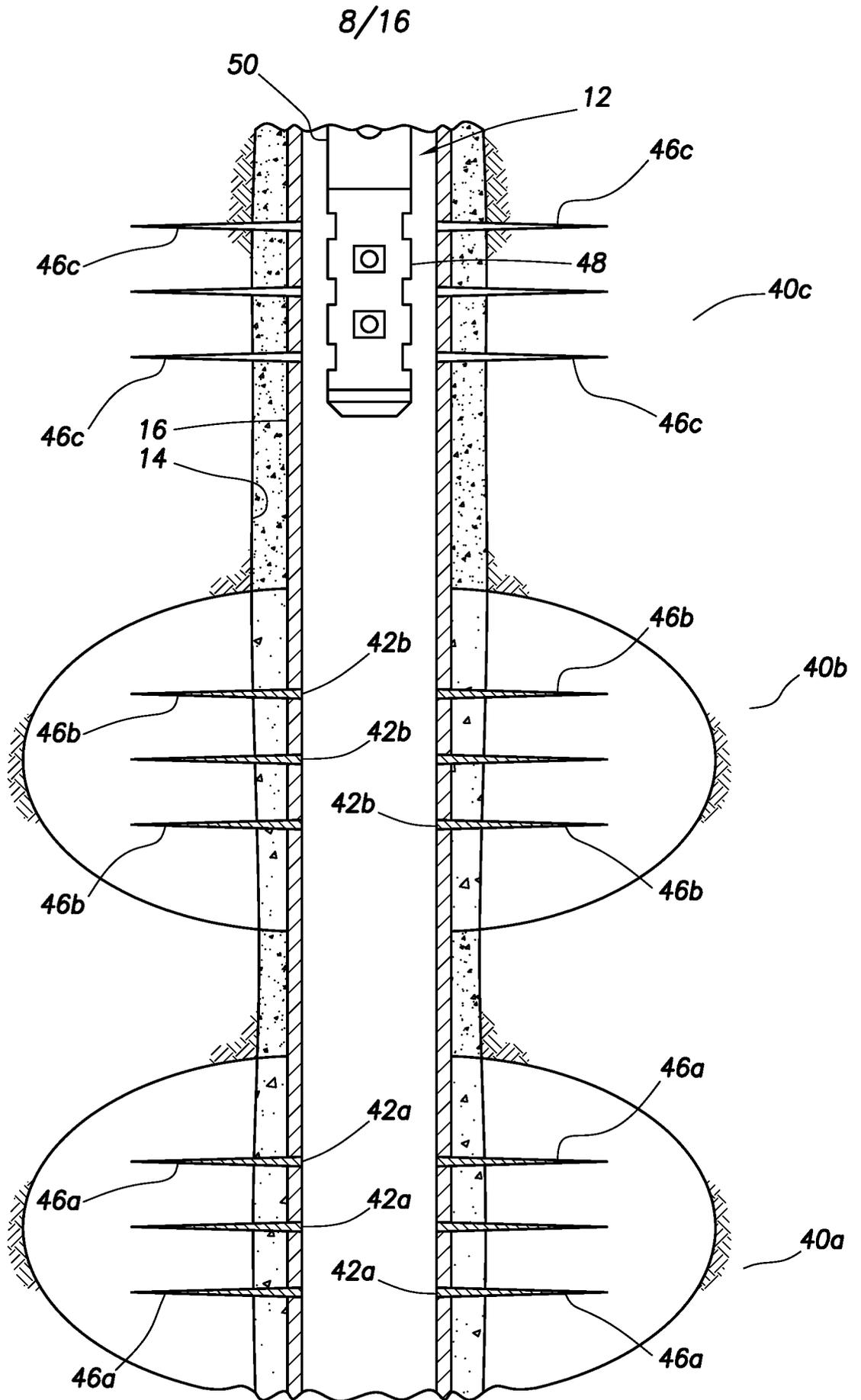


FIG.3C

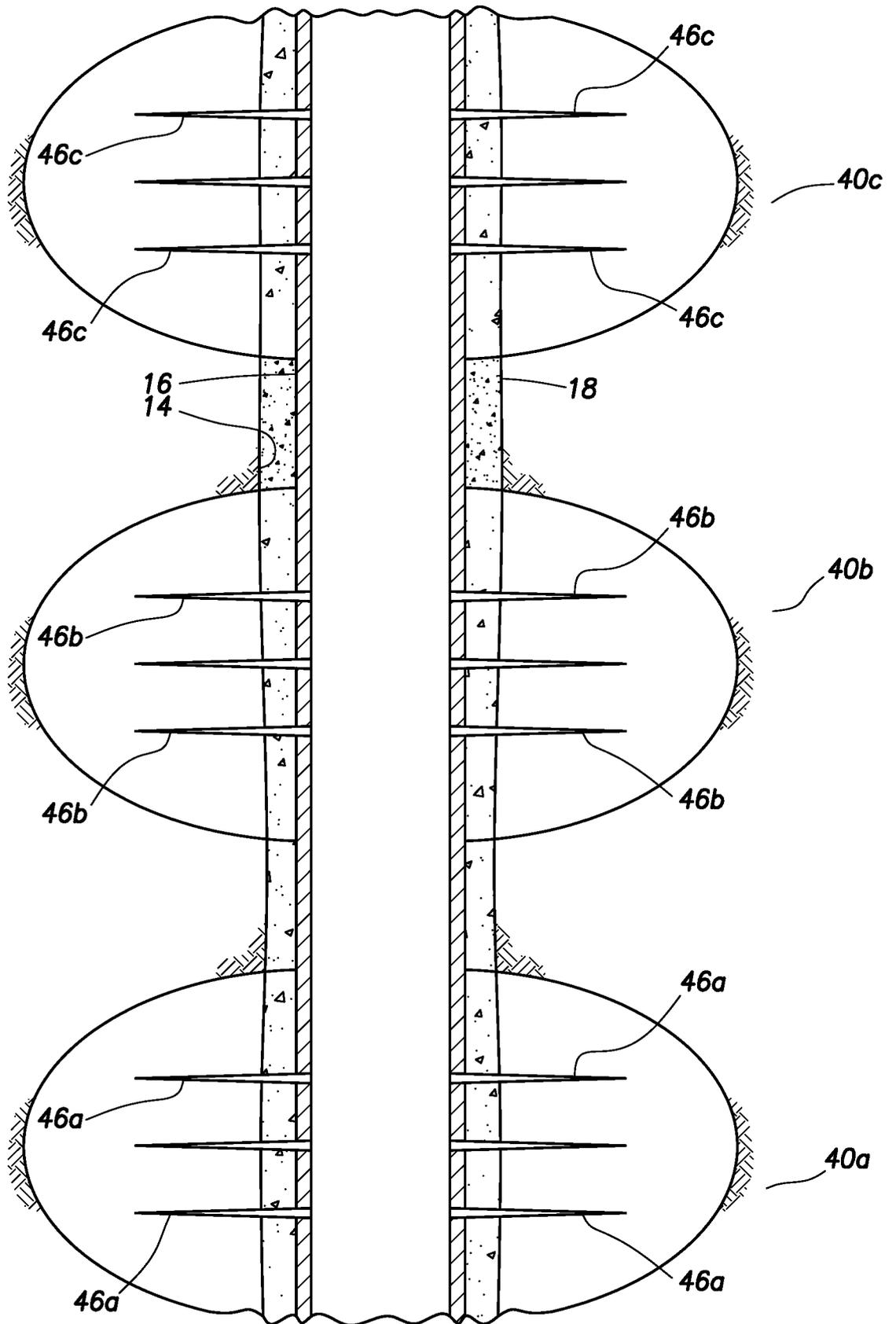


FIG.3D

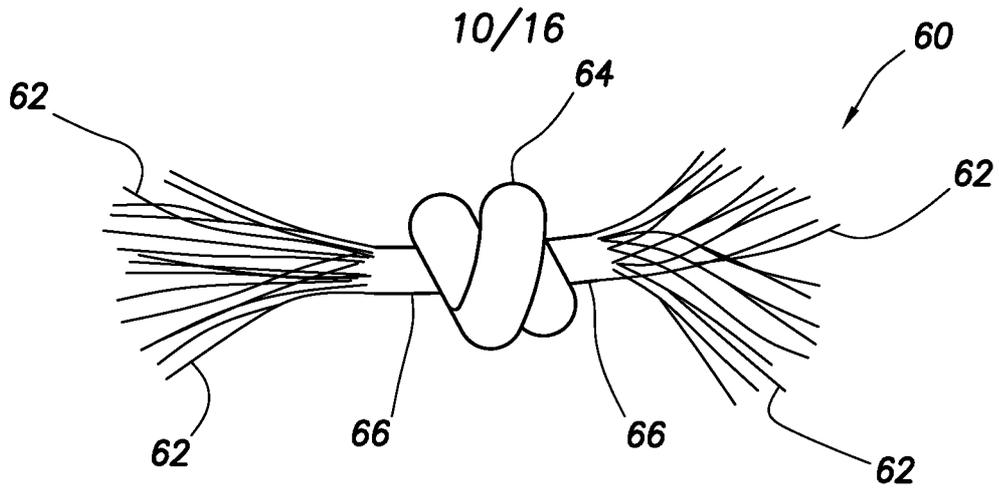


FIG. 4A

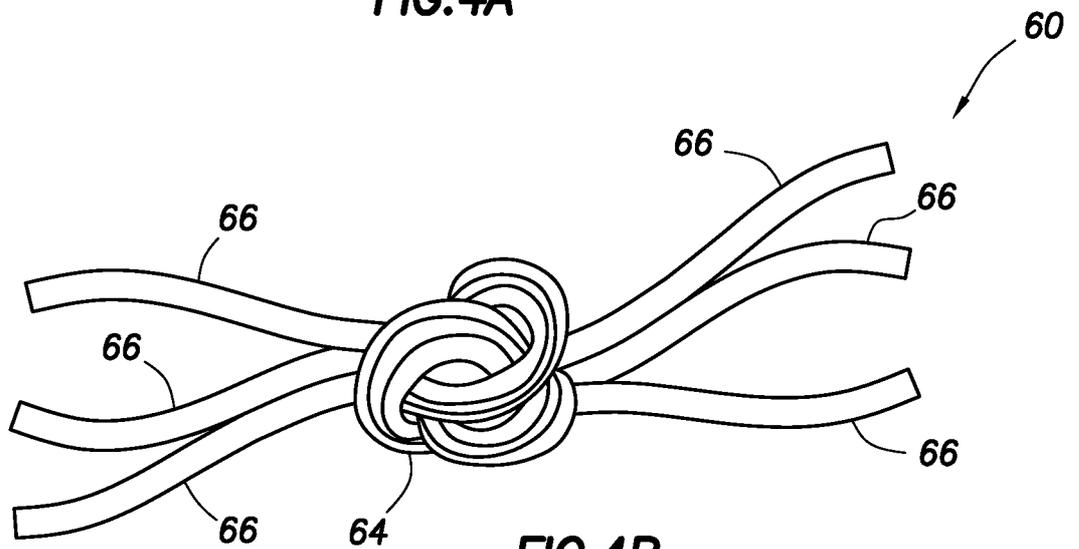


FIG. 4B

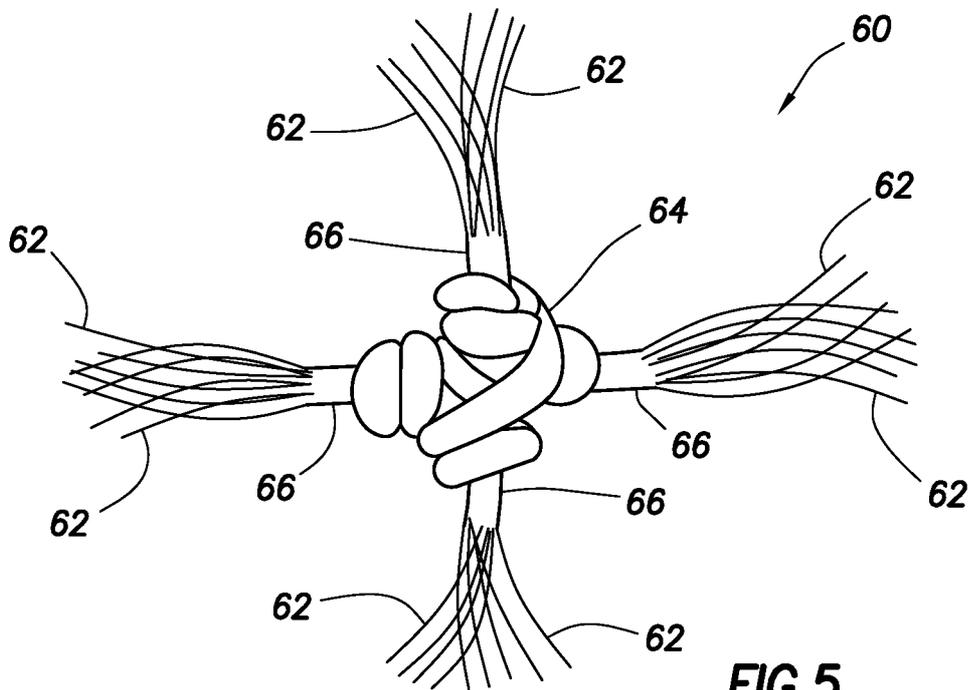


FIG. 5

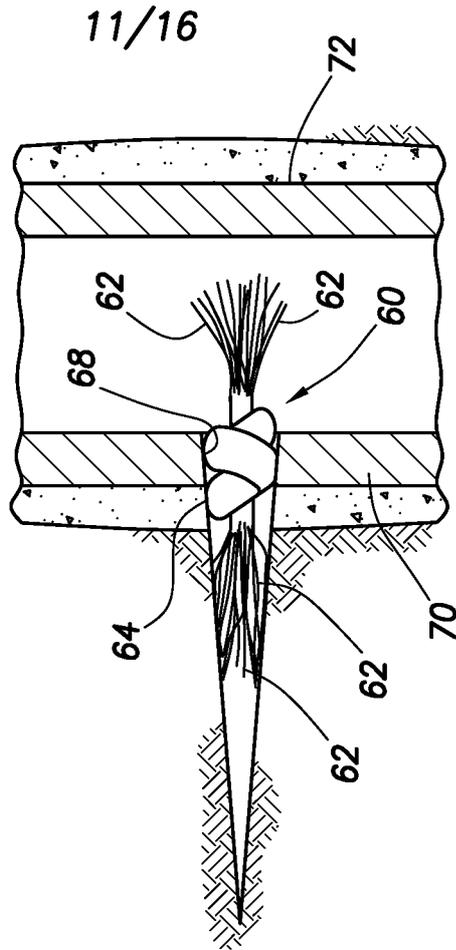


FIG. 6B

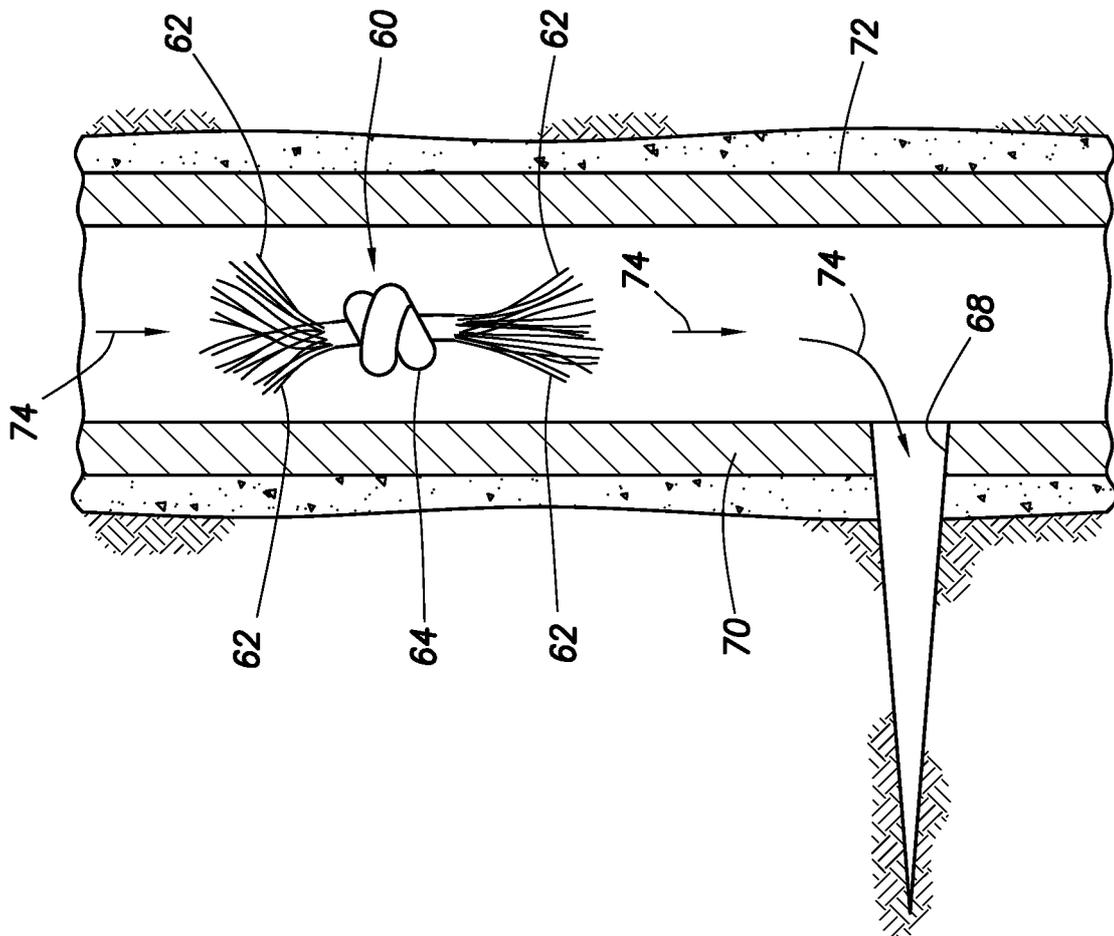


FIG. 6A

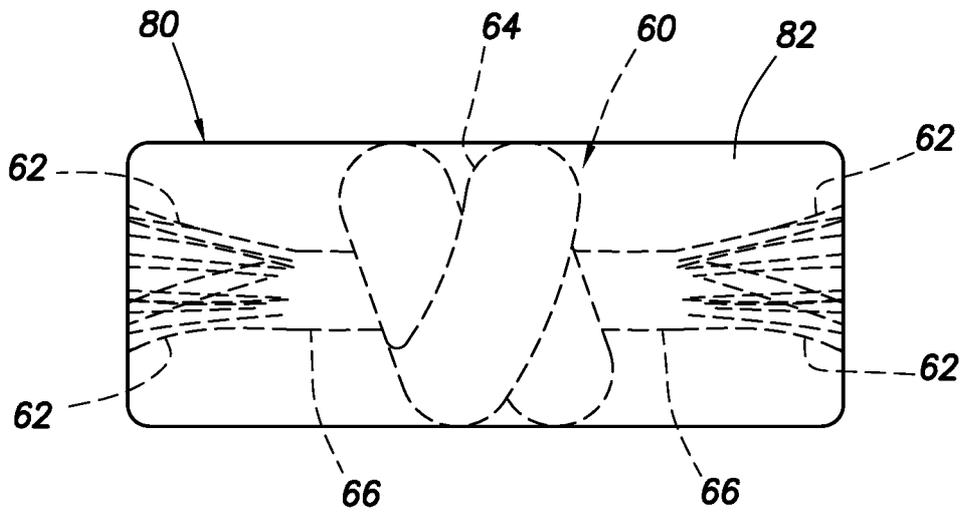


FIG. 7

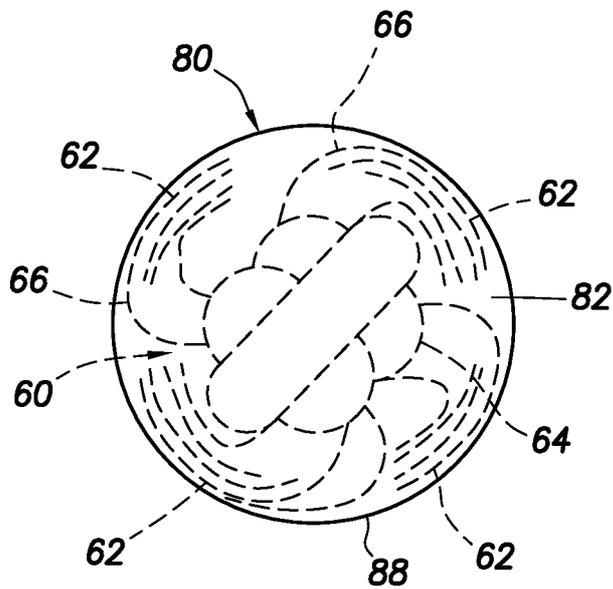


FIG. 8

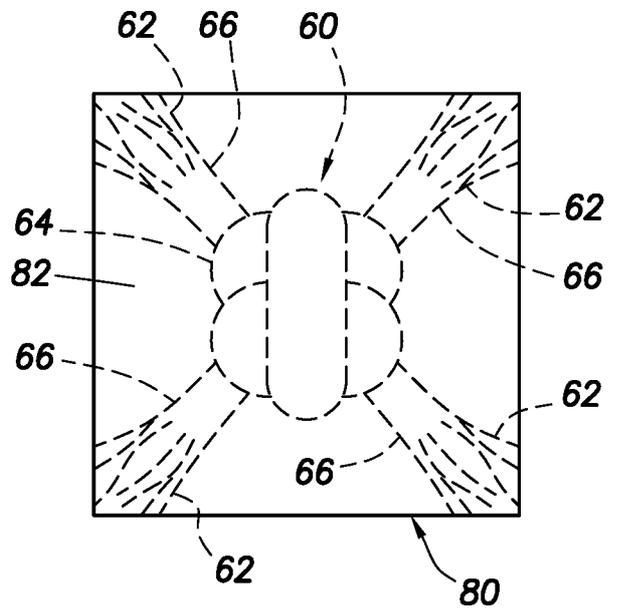


FIG. 9

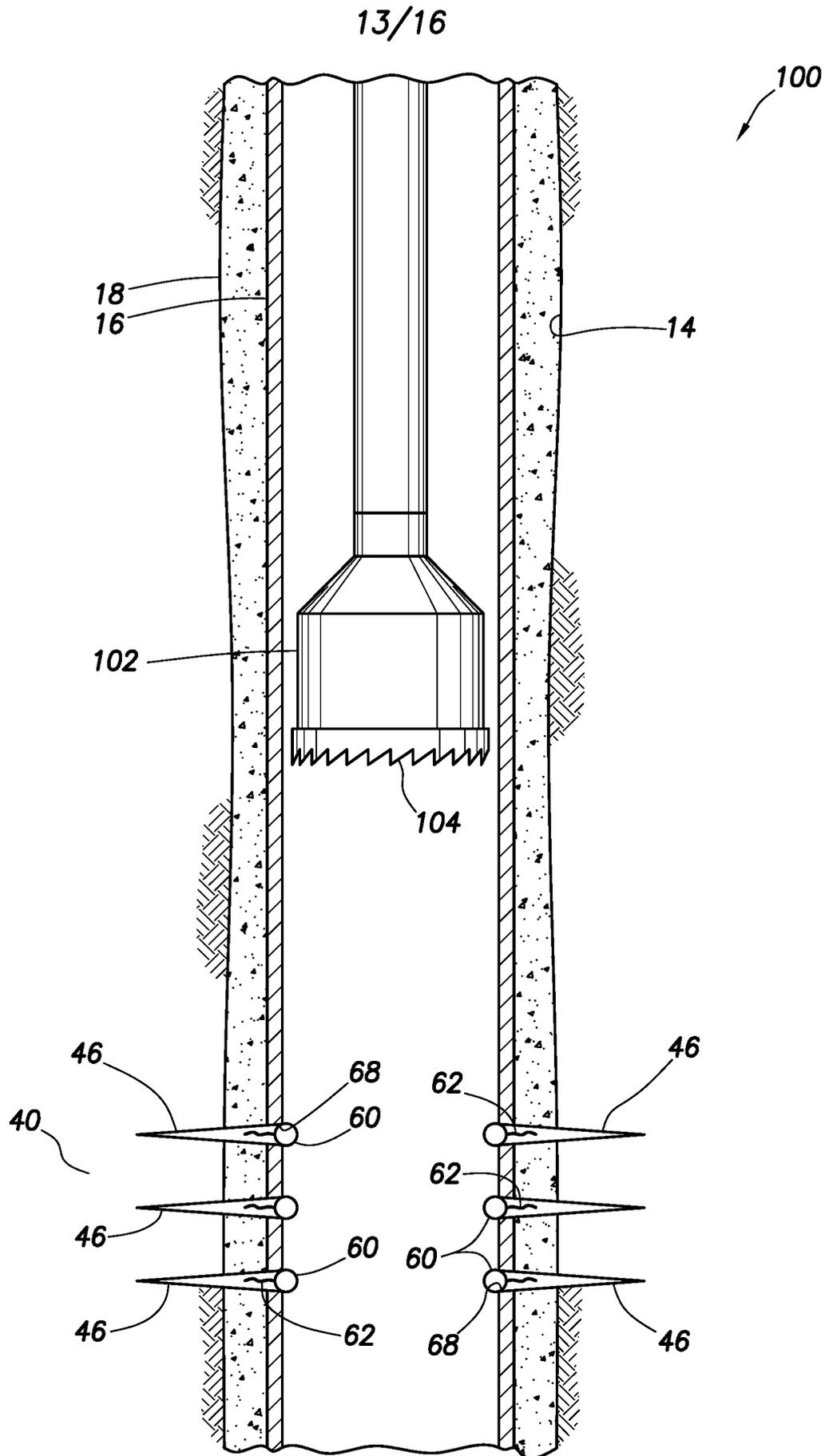


FIG.10

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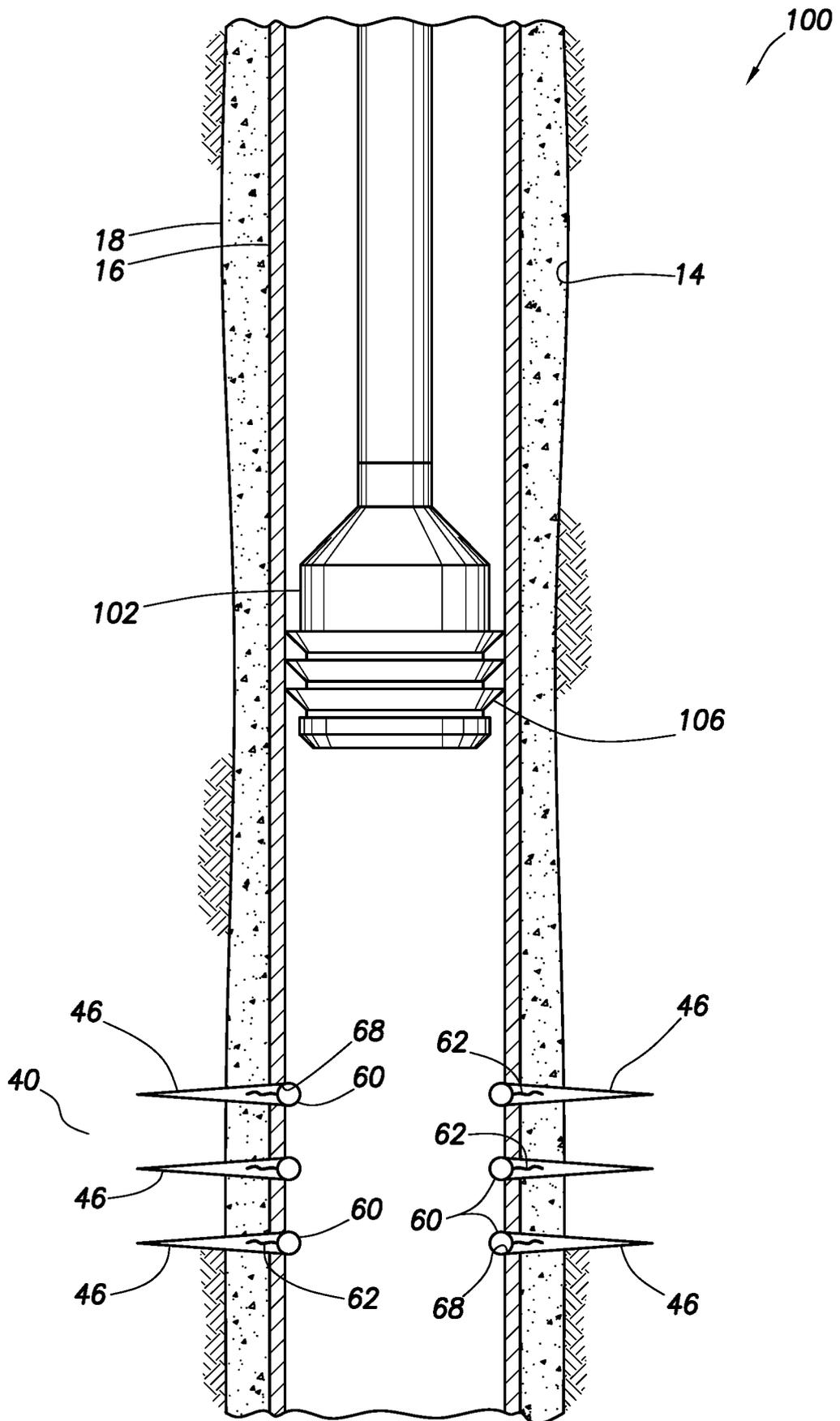


FIG.11

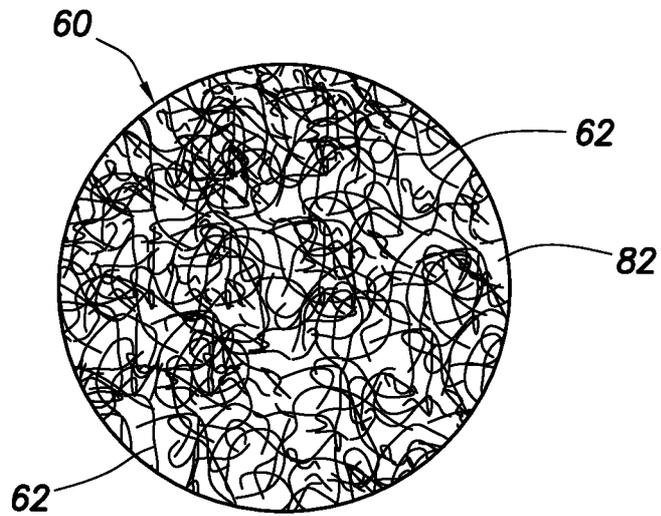


FIG. 12

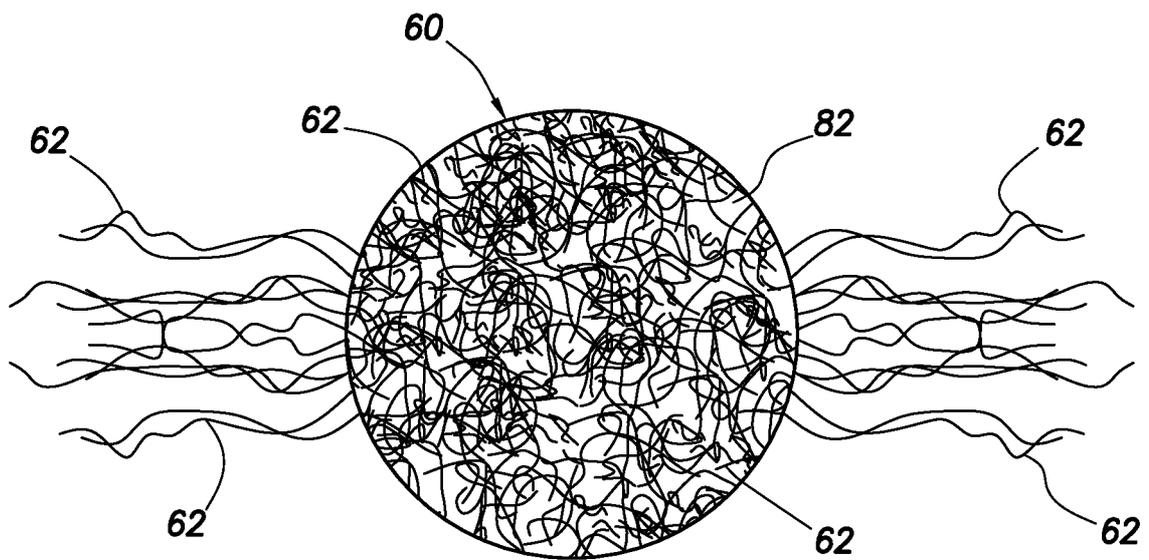


FIG. 13

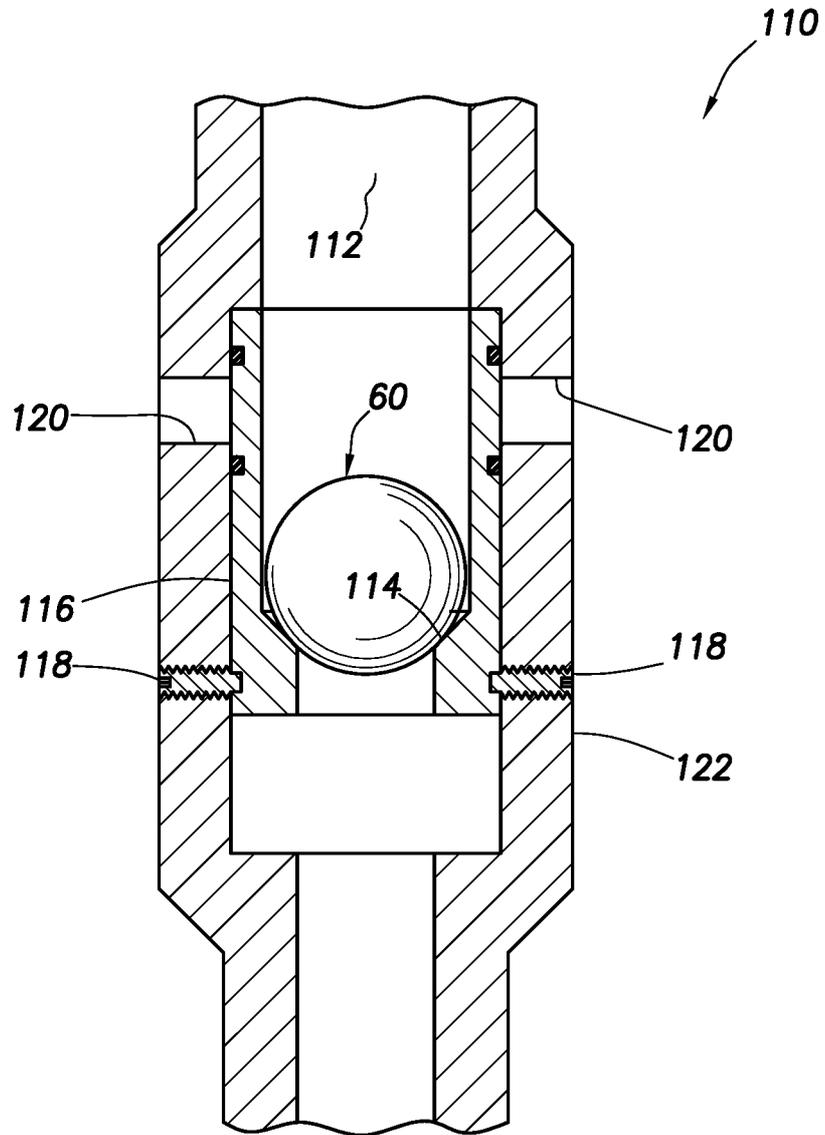


FIG.14

A. CLASSIFICATION OF SUBJECT MATTER**E21B 33/13(2006.01)i, E21B 33/138(2006.01)i, E21B 23/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 33/13; E21B 34/06; E21B 33/124; E21B 17/18; E21B 43/00; E21B 34/14; C09K 8/60; C09K 8/00; E21B 33/138; E21B 23/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: well, flow control, restore, plugging device, fiber, and reducing pressure

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category ^b	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	W0 2014-099206 A1 (EXXONMOBIL UPSTREAM RESEARCH COMPANY et al.) 26 June 2014 See paragraph [0053] and figure 8.	1-28
Y	US 2014-0151052 A1 (THEMIG et al.) 05 June 2014 See paragraphs [0027], [0044] and figure 4.	1-15
Y	US 2008-0093073 A1 (BUSTOS et al.) 24 April 2008 See paragraphs [0016], [0021], [0107] and figure 7B.	4-10,12-13,19-24
Y	US 4628994 A (TOWNER et al.) 16 December 1986 See column 2, lines 26-52 and figure 1.	16-28
A	US 8397820 B2 (FEHR et al.) 19 March 2013 See column 5, line 66 - column 8, line 24 and figures 1a-1b.	1-28

I Further documents are listed in the continuation of Box C. See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 August 2016 (18.08.2016)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

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International application No.

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