



(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

(22) Date de dépôt/Filing Date: 2019/04/04

(41) Mise à la disp. pub./Open to Public Insp.: 2019/10/17

(62) Demande originale/Original Application: 3 095 181

(30) Priorité/Priority: 2018/04/11 (US62/655,875)

(51) Cl.Int./Int.Cl. *E21B 43/119* (2006.01),
E21B 21/08 (2006.01), *E21B 23/08* (2006.01),
E21B 47/09 (2012.01), *E21B 33/13* (2006.01),
E21B 43/26 (2006.01)

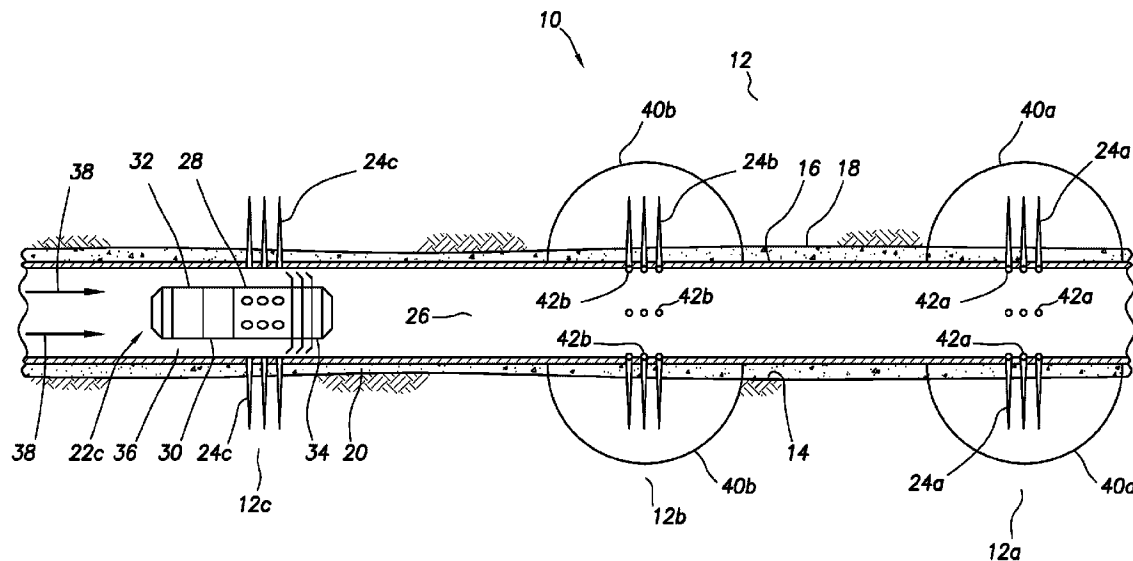
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(54) Titre : SYSTEMES DE PERFORATION ET REGULATION D'ECOULEMENT DESTINES A ETRE UTILISES AVEC
DES COMPLETIONS DE PUITS

(54) Title: PERFORATING SYSTEMS AND FLOW CONTROL FOR USE WITH WELL COMPLETIONS



(57) Abrégé/Abstract:

A perforating assembly for use in a subterranean well. The perforating assembly includes a perforator, a flow restrictor connected by a first tether to a first end of the perforator, and a drag device connected by a second tether to a second end of the perforator opposite the first end, in which one or more diverters are configured to displace with the perforating assembly.

ABSTRACT

5 A perforating assembly for use in a subterranean well. The perforating
assembly includes a perforator, a flow restrictor connected by a first tether to a first
end of the perforator, and a drag device connected by a second tether to a second
end of the perforator opposite the first end, in which one or more diverters are
configured to displace with the perforating assembly.

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PERFORATING SYSTEMS AND FLOW CONTROL FOR USE WITH WELL COMPLETIONS

This application is divided from Canadian Patent Application Serial No.
5 3095181 filed on April 4, 2019.

TECHNICAL FIELD

10 This disclosure relates generally to equipment and techniques used in
conjunction with a subterranean well and, in an example described below, more
particularly provides perforating systems and flow control for use with well
completions.

BACKGROUND

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Perforating systems are designed to form perforations through a well casing or
other wellbore lining. The perforations permit fluid communication between an earth
formation penetrated by the wellbore and an interior of the casing. In this manner,
fluids can be produced from the formation into the casing and then to surface. In
20 other examples, fluids can be injected from the interior of the casing into the
formation via the perforations.

It will, therefore, be readily appreciated that improvements are continually
needed in the arts of constructing and operating perforating systems, and controlling
flow through perforations. Such improvements can be useful in a wide variety of
25 different types of well completions.

SUMMARY

Accordingly, there is described a perforating assembly for use in a subterranean well, the perforating assembly comprising: a perforator; a flow restrictor connected by a first tether to a first end of the perforator; and a drag device
5 connected by a second tether to a second end of the perforator opposite the first end, in which one or more diverters are configured to displace with the perforating assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-D are representative partially cross-sectional views of successive steps in an example of a well completion system and associated
5 method which can embody principles of this disclosure.

FIG. 2 is a representative partially cross-sectional view of an example of a perforating assembly that may be used in the FIGS. 1A-D system and method, and which can embody the principles of this disclosure.

FIGS. 3A & B are representative partially cross-sectional views of
10 successive steps in another example of the well completion system and associated method.

FIG. 4 is a representative partially cross-sectional view of another example of the well completion system and associated method.

FIG. 5 is a representative partially cross-sectional view of another example
15 of the well completion system and associated method.

FIGS. 6A & B are representative partially cross-sectional views of successive steps in another example of the well completion system and associated method.

FIGS. 7A & B are representative partially cross-sectional views of
20 successive steps in another example of the well completion system and associated method.

FIGS. 8-13 are representative partially cross-sectional views of additional examples of the perforating assembly.

FIG. 14 is a representative partially cross-sectional view of another
25 example of the well completion system and associated method.

FIG. 15 is a representative partially cross-sectional view of another example of the well completion system and associated method.

DETAILED DESCRIPTION

Representatively illustrated in FIG. 1 is a well completion system 10 and associated method for use with a subterranean well, which system and method
5 can 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 limited at all to the details of the system 10 and method described herein and/or
10 depicted in the drawings.

Using the system 10, multiple zones 12a-c of an earth formation 12 penetrated by a wellbore 14 are to be individually perforated and fractured. Although three zones 12a-c are depicted in the drawings and described herein, any number of zones may be completed using the system 10 and method. In
15 addition, although the zones 12a-c in the FIG. 1 system 10 and method are completed individually, in other examples multiple zones could be simultaneously completed.

In the FIG. 1 example, the wellbore 14 is lined with casing 16 and cement 18. The casing 16 could be any type of segmented, continuous or formed *in situ*
20 tubular or wellbore liner, including (but not limited to) the types known to those skilled in the art as casing, liner, tubing, pipe, etc. The scope of this disclosure is not limited to use of any particular type of casing, or to use of any casing in the formation 12.

The cement 18 could be a Portland cement composition or any other type
25 of seal or sealant for isolating the zones 12a-c from each other in an annulus 20 formed between the wellbore 14 and the casing 16. In other examples, external casing packers, swellable seals or other sealing devices could be used in place of the cement 18. The scope of this disclosure is not limited to use of any particular type of cement, or to use of any cement in the formation 12.

The wellbore 14 is illustrated in the figures as being generally horizontal or highly deviated from vertical. Although the system 10 and method provide certain advantages in situations where a well completion is to be performed in a horizontal or highly deviated wellbore, the wellbore 14 could be generally vertical or otherwise deviated in keeping with the scope of this disclosure.

As depicted in FIG. 1A, a perforating assembly 22a is displaced to a location in the wellbore 14 at which it is desired to form perforations 24a through the casing 16 and cement 18, in order to establish fluid communication between the zone 12a and an interior flow passage 26 of the casing. Although the perforating assembly 22a and the perforations 24a are both depicted in FIG. 1A, in some examples the perforating assembly 22a may break up, disintegrate, dissolve, disperse, degrade or otherwise cease to exist as a distinct structural entity as/once the perforations 24a are/have been formed.

For example, the perforating assembly 22a could be made up of materials that are friable, frangible, dissolvable, subject to galvanic corrosion, or otherwise dispersible or degradable in a well environment. The disintegration, dispersal, degrading, dissolution, etc., of the perforating assembly 22a may begin at any point in the method, such as, at introduction of the perforating assembly into the well, in response to contact with a particular activating fluid (for example, a fluid having a particular pH level or chemical composition) already present or later introduced into the well or released from a container, in response to shock produced when a perforator 28 of the perforating assembly is fired to form the perforations 24a, in response to exposure to an elevated temperature or pressure, or in response to another event or stimulus. However, note that it is not necessary for the perforating assembly 22a to break up, disintegrate, dissolve, disperse, degrade or otherwise cease to exist as a distinct structural entity in keeping with the scope of this disclosure.

In the FIG. 1A example, the perforating assembly 22a includes the perforator 28, a firing head 30, a control module 32 and a flow restrictor 34. In other examples, the perforating assembly 22a could include other, different, more

or less components. The scope of this disclosure is not limited to use of any particular components or combination of components in a perforating assembly.

The perforator 28 in this example comprises an explosive shaped charge-type perforator or perforating gun, in which one or more explosive shaped
5 charges are contained in an outer tubular gun body (see FIG. 2). The shaped charges are detonated, in order to form the perforations 24a. Other types of perforators (such as, drills, bullet-type perforating guns, etc.) may be used in other examples.

The firing head 30 in this example functions to detonate the shaped
10 charges in the perforator 28 when desired, for example, by initiating detonation of a detonating cord extending to each of the shaped charges. The firing head 30 may initiate the detonation mechanically, electrically, chemically or in any other manner, or in response to any event, stimulus or condition. The scope of this disclosure is not limited to use of any particular type of firing head.

15 The control module 32 in this example is used to control when or if the perforator 28 is fired, such as, by controlling when or if the firing head 30 detonates the shaped charges. The control module 32 may cause the firing head 30 to fire the perforator 28 in response to any predetermined number or combination of events, stimuli or conditions, such as, elapse of time, pressure or
20 pattern of pressure variations, flow or pattern of flow variations, temperature, vibration or pattern of vibration changes, acceleration or pattern of acceleration variations, etc. The scope of this disclosure is not limited to any particular number or combination of events, stimuli or conditions that will cause the control module to activate the firing head 30.

25 The flow restrictor 34 in this example is used to restrict flow through an annulus 36 formed radially between the perforating assembly 22a and the casing 16. As depicted in FIG. 1A, the flow restrictor 34 comprises multiple swab cups or cup-type packers that do not necessarily fully seal against the casing 16, but that do at least substantially restrict flow through the annulus 36 past the perforating
30 assembly 22a (although the flow restrictor could seal against the casing, if desired).

In other examples, the flow restrictor 34 could be in the form of a tortuous path, outwardly extending stiff fibers or bristles, or a gauge ring or other enlarged diameter on the perforating assembly 22a. In further examples, the perforating assembly 22a could be dimensioned so that flow through the annulus 36 is
5 significantly restricted, without use of a separate flow restrictor. Thus, the scope of this disclosure is not limited to use of any particular type of flow restrictor, or to use of a flow restrictor at all in the perforating assembly 22a.

Although the perforator 28, firing head 30, control module 32 and flow restrictor 34 are depicted in the drawings as being separate connected-together
10 components of the perforating assembly 22a, in other examples any or all of the perforating assembly components could be integral or combined. For example, the firing head 30 and control module 32 could be a single integrated component, the perforator 28, firing head, control module and flow restrictor 34 could be combined in a single outer housing, etc. Thus, the scope of this disclosure is not
15 limited to any particular structural form of the perforating assembly 22a.

In the FIG. 1A example, the perforating assembly 22a is displaced, transported or conveyed to the desired location for forming the perforations 24a by a flow of fluid 38 in the flow passage 26. The fluid 38 may be pumped through the flow passage 26 by use of one or more pumps at surface (see FIG. 14).
20 However, the scope of this disclosure is not limited to use of fluid flow to convey the perforating assembly 22a, to use of pumps to cause the fluid flow, or to use of pumps at any particular location.

The perforating assembly 22a may be conveyed to a desired location by flowing a corresponding volume of the fluid 38 through the flow passage 26. In a
25 simplified example, the volume of fluid required to displace the perforating assembly 28 a certain distance is given by the formula: $V = A \times D$, in which V is the required volume, A is the cross-sectional area of the flow passage 26, and D is the distance to the desired location.

As those skilled in the art will appreciate, this simplified example does not
30 account for variations in the flow passage 26 cross-sectional area, leakage of the fluid 38 past the flow restrictor 34, etc. Described more fully below is a

“calibration” method whereby the volume required to displace the perforating assembly 22a to a desired location along the wellbore 14 can be determined (see FIG. 15).

5 Once it is known what volume of the fluid 38 is required to be flowed through the flow passage 26 to displace the perforating assembly 22a to the desired location, this volume may be measured by use of various techniques or equipment, such as, by counting pump strokes, by use of a flow meter, etc. The scope of this disclosure is not limited to use of any particular technique or equipment for measuring the volume of the fluid 38.

10 Once the perforating assembly 22a is at the desired location for forming the perforations 24a, the perforator 28 is fired to thereby form the perforations. In one example, the control module 32 may be configured to require the perforating assembly 22a to remain motionless for a predetermined period of time, prior to the perforator 28 being fired. In other examples, the control module 32 could
15 cause the firing head 30 to fire the perforator 28 immediately upon detecting that the perforating assembly 22a is positioned at the desired location, whether or not the perforating assembly is motionless. The scope of this disclosure is not limited to any particular combination or sequence of events, stimuli or conditions that will cause the perforator 28 to be fired at the desired location.

20 Referring additionally now to FIG. 1B, the zone 12a is fractured after the perforations 24a are formed. To fracture the zone 12a, a fracturing fluid is pumped under elevated pressure from the flow passage 26, through the perforations 24a and into the zone 12a, until the earth fractures (see fractures 40a depicted in FIG. 1B).

25 The fracturing fluid may be the same as, or may be pumped concurrently with, the fluid 38 used to displace the perforating assembly 22a through the flow passage 26. Thus, the zone 12a can be fractured immediately after the perforations 24a are formed. In other examples, the fracturing fluid could be different from the fluid 38, or the fractures 40a may not be formed immediately
30 after the perforations 24a are formed (for example, a period of time may elapse after the perforations are formed, e.g., to allow sufficient time for the perforating

assembly 22a to dissolve, degrade, be dispersed, etc., prior to the fracturing operation). The scope of this disclosure is not limited to any particular timing, combination or sequence of events associated with forming the perforations 24a and the fractures 40a.

5 In addition to the actual fracturing of the zone 12a, the fracturing operation may include a variety of different techniques or procedures of the type well known to those skilled in the art. For example, various stages may be pumped as part of the fracturing operation, such as, including pads, gels, breakers, proppant, stimulation fluids, conformance agents, permeability enhancers, etc. The scope
10 of this disclosure is not limited to use of any particular number or combination of fluids, substances or other agents in procedures associated with the fracturing operation.

 After or during the fracturing operation (including any associated propping, breaking, stimulating, conformance or other procedures), one or more plugs or
15 diverters 42a is/are used to isolate the zone 12a from pressure in the flow passage 26, so that further fracturing of the zone is prevented. The diverter(s) 42a may plug the perforations 24a during the fracturing operation (e.g., so that flow is diverted from perforations taking more flow to perforations taking less flow), or the diverter(s) may plug the perforations at the conclusion of the
20 fracturing operation. The scope of this disclosure is not limited to any particular timing of the diverter(s) 42a preventing outward flow through any or all of the perforations 24a.

 The diverter(s) 42a may be any type of plugging device or substance capable of entirely preventing or substantially restricting flow outward into the
25 zone 12a via the perforations 24a. The diverter(s) 42a could in some examples be discrete plugging devices, such as, frac balls or those plugging devices described more fully in US patent nos. 9523267, 9567824, 9567825, 9567826, 9708883, 9816341, or in US application nos. 15/567779, 15/138685, 15/138968, 15/615136 or 15/609671. The discrete plugging devices may be dispensed into
30 the flow passage 26 using any of the techniques described more fully in the above-mentioned US patents and applications, or in US application nos.

15/745608, 15/162334, 15/837502, 62/588150 or 62/638059. However, it should be clearly understood that discrete plugging devices and dispensing techniques other than those described in the above-listed patents and application may be used, in keeping with the scope of this disclosure.

5 The diverter(s) 42a could in some examples be in particulate, gel or other non-discrete form. For example, substances such as sand, calcium carbonate, poly-lactic acid (PLA), poly-glycolic acid (PGA), polyvinyl alcohol (PVA), anhydrous boron compounds, particulate nylon, etc., may be used. Many such plugging substances are described in the US patents and applications listed above, although other
10 substances may be used in other examples.

 The diverter(s) 42a may be dissolvable, dispersible, melt-able, corrodible, or otherwise degradable in the well. The diverter(s) 42a may self-degrade, or a particular activating fluid or other condition or stimulus may be required to cause the diverter(s) to degrade. In some examples, the diverter(s) 42a may comprise a mixture
15 or combination of degradable and non-degradable materials. In other examples, the diverter(s) 42a may not be degradable in the well at all. The scope of this disclosure is not limited to any particular form, composition or degradability of the diverter(s) 42a.

 The diverter(s) 42a may enter the perforations 24a and seal against a surface
20 or face of the zone 12a or the fractures 40a. In other examples, the diverter(s) 42a may seal off the perforations 24a at an interior of the casing 16, as depicted in FIG. 1B. The scope of this disclosure is not limited to any particular location at which the diverter(s) 42a prevent flow into the zone 12a.

 As depicted in FIG. 1B, another perforating assembly 22b has been conveyed
25 or displaced to a desired location for forming perforations 24b into the zone 12b. The perforating assembly 22b may be the same as, or different in some respects from, the perforating assembly 22a.

The perforating assembly 22b may be conveyed or displaced to the desired location in the same manner as described above for the perforating assembly 22a (such as, by flowing a particular volume of the fluid 38 through the flow passage 26), or the perforating assembly 22b could be conveyed or
5 displaced using another technique (such as, using wireline, slickline, coiled tubing, jointed tubing, a downhole tractor, etc.).

The perforating assembly 22b may be conveyed or displaced to the location for forming the perforations 24b after or while the fractures 40a are being formed, or after or while the diverter(s) 42a are being used to prevent flow into
10 the zone 12a. For example, the perforating assembly 22b could be introduced into the well and displaced through the wellbore 14 by flow of the fluid 38 while the fluid is also being used to form the fractures 40a or place the diverter(s) 42a. Thus, the scope of this disclosure is not limited to any particular relative timing between conveyance of the perforating assembly 22b, forming the fractures 40a
15 and placing the diverter(s) 42a.

The zone 12b is fractured after the perforations 24b are formed. To form fractures 40b in the zone 12b, a fracturing fluid is pumped under elevated pressure from the flow passage 26, through the perforations 24b and into the zone 12b. The fracturing fluid and associated fracturing operation may be the
20 same as, or different from, that described above for forming the fractures 40a in the zone 12a.

After or during the fracturing operation (including any associated propping, breaking, stimulating, conformance or other procedures), one or more plugs or diverters 42b (see FIG. 1C) is/are used to isolate the zone 12b from pressure in
25 the flow passage 26, so that further fracturing of the zone is prevented. The diverter(s) 42b may be the same as, or different from, the diverter(s) 42a described above.

Referring additionally now to FIG. 1C, another perforating assembly 22c has been conveyed or displaced to a desired location for forming perforations 24c
30 into the zone 12c. The perforating assembly 22c may be the same as, or different in some respects from, the perforating assemblies 22a,b described above.

The perforating assembly 22c may be conveyed or displaced to the desired location in the same manner as described above for the perforating assemblies 22a,b, or the perforating assembly 22c could be conveyed or displaced using another technique. The perforating assembly 22c may be
5 conveyed or displaced to the location for forming the perforations 24c after or while the fractures 40b are being formed, or after or while the diverter(s) 42b are being used to prevent flow into the zone 12b.

Referring additionally now to FIG. 1D, the zone 12c is fractured after the perforations 24c are formed. To form fractures 40c in the zone 12c, a fracturing
10 fluid is pumped under elevated pressure from the flow passage 26, through the perforations 24c and into the zone 12c. The fracturing fluid and associated fracturing operation may be the same as, or different from, that described above for forming the fractures 40a,b in the respective zones 12a,b.

The diverter(s) 42a,b may dissolve, melt, corrode, disperse or otherwise
15 degrade after the zones 12a-c have been fractured. In some examples, the diverter(s) 42a,b may flow to surface with fluids 44a-c produced from the respective zones 12a-c. The scope of this disclosure is not limited to any particular technique or process for permitting flow between the zones 12a-c and the flow passage 26 after all of the zones have been fractured. Note that, in some
20 examples, the well may be an injection well instead of, or in addition to, a production well, in which case production of the fluids 44a-c may not be an ultimate goal of the well completion.

Referring additionally now to FIG. 2, an example of a perforating assembly 22 that may be used for any of the perforating assemblies 22a-c in the system 10
25 and method described above is representatively illustrated. In this example, the perforator 28, firing head 30 and control module 32 are contained in a same generally tubular outer housing 46, but in other examples separate housings may be used. The scope of this disclosure is not limited to any particular details of the perforating assembly 22 as described herein or depicted in the drawings.

30 The perforator 28 in the FIG. 2 example comprises multiple explosive shaped charges 48, a detonating cord 50 and an electrical detonator 52. When

an electric current is applied to the detonator 52, the detonator detonates and thereby initiates an explosive chain reaction, in which the detonating cord 50 detonates and thereby causes the shaped charges 48 to detonate.

5 The shaped charges 48, detonating cord 50 and detonator 52 can be conventional components of the type well known to those skilled in the art, and so they are not described further herein. However, it should be understood that other mechanisms or techniques (such as, bullet-type perforators, percussive detonators, drills, etc.) may be used to form perforations, without departing from the scope of this disclosure.

10 The firing head 30 in the FIG. 2 example includes electrical switches 54, 56 connected in series between a battery 58 and the detonator 52. The switch 54 is a fail-safe switch for absolutely preventing electrical current from flowing through the detonator 52, unless the switch is activated.

15 A mechanical or other type of safety mechanism 60 may be used to prevent activation of the switch 54, for example, during transport of the perforating assembly 22 to a wellsite, or immediately prior to deployment of the perforating assembly 22 into a well. In some examples, the fail-safe switch 54 could be a three-way switch that electrically connects electrical leads of the detonator 52 to each other, to thereby preclude an electrical potential from being
20 created across the leads, until the switch is activated by the safety mechanism 60.

 After the fail-safe switch 54 is activated, the switch 56 can be activated by the control module 32 downhole. In this example, the control module 32 comprises a controller 62, a memory 64, a timer 66, a pressure sensor 68, a
25 temperature sensor 70 and an accelerometer or other type of motion sensor 72. An optional collar locator 74 may be included in some examples.

 The controller 62 may be a programmable logic controller (PLC), or another type of controller capable of activating the switch 56 in response to a pre-programmed combination of events, stimuli or conditions as sensed, determined
30 or measured using the timer 66, pressure sensor 68, temperature sensor 70,

motion sensor 72 and/or collar locator 74. The memory 64 may be used to store the combination of events, stimuli or conditions.

The memory 64 may in some examples be used to store well parameters, such as, casing collar locations, expected downhole temperatures, expected hydrostatic pressures, desired perforating location, etc. In this manner, the perforating assembly 22 can be programmed so that it fires in response to events, stimuli or conditions unique to a particular well completion, including unique to a particular zone to be perforated.

In one example, the memory 64 may store instructions that cause the controller 62 to activate the switch 56 only after a certain minimum amount of time has elapsed since the perforating assembly 22 was deployed into the well (as measured by the timer 66), only if a certain level of pressure is detected by the pressure sensor 68, only if a certain level of temperature is detected by the temperature sensor 70, and only if the perforating assembly 22 has remained motionless for a certain period of time (e.g., as detected using the motion sensor 72 and the timer 66). If the collar locator 74 is included in the control module 32, the controller 62 may in addition only activate the switch 56 if a certain number of casing collars have been detected.

In other examples, different numbers and/or combinations of sensors, memory, controllers, switches, etc., may be used in the control module 32. Thus, the scope of this disclosure is not limited to any particular configuration of the control module 32.

The flow restrictor 34 in the FIG. 2 example is in the form of a gauge ring or other enlarged diameter secured on the outer housing 46. In other examples, the enlarged diameter could be formed as part of the outer housing 46.

Although not depicted in FIG. 2, the perforating assembly 22 could include a self-destruct capability, so that the perforating assembly disintegrates, dissolves, breaks apart or otherwise degrades, if it is not properly fired at the desired location in the well (such as, if the sensors 66, 68, 70, 72, 74 do not detect a pre-programmed set of events, conditions or stimuli). For example, the

perforating assembly 22 could include an explosive charge or a container of activating fluid (such as an acid or corrosive fluid), whereby the explosive charge is detonated or the activating fluid is released in the perforating assembly after a certain period of time has elapsed (the period of time being greater than that at which it was expected that the pre-programmed set of events, conditions or stimuli would occur).

The self-destruct capability can prevent a "live" perforating assembly from being left downhole or retrieved to surface in an unknown or unsafe state. Alternatively, if, for example, the perforating assembly 22 can reliably be dissolved or otherwise degraded downhole, the self-destruct capability may not be used.

Referring additionally now to FIGS. 3A & B, another example of the system 10 and method are representatively illustrated. In this example, the diverter(s) 42a are conveyed or displaced through the flow passage 26 with the perforating assembly 22b after or during the forming of the fractures 40a in the zone 12a.

Note that the flow restrictor 34 in the FIGS. 3A & B example is spaced apart from the remainder of the perforating assembly 22b as the perforating assembly displaces through the flow passage 26. However, the flow restrictor 34 is connected to the perforator 28, firing head 30 and control module 32 by a tether 76, so that the perforator is positioned a known distance from the flow restrictor 34.

As depicted in FIG. 3A, a portion of the flow passage 26 is, thus, defined between the flow restrictor 34 and the remainder of the perforating assembly 22b. The diverter(s) 42a are positioned in this portion of the flow passage 26 as the perforating assembly 22b displaces through the flow passage.

As depicted in FIG. 3B, when the flow restrictor 34 passes the open perforations 24a, the diverter(s) 42a can then engage the perforations or enter the perforations to thereby prevent flow through the perforations into the zone 12a. At this point (the flow restrictor 34 having passed the open perforations 24a),

the perforator 28 is appropriately positioned in the desired location for forming the perforations 24b. Flow of the fluid 38 can be ceased, so that the perforating assembly 22b becomes motionless, and the perforator 28 will eventually fire (e.g., after a certain period of time, and at or above a certain minimum pressure level and temperature level, as described above). In some examples, the perforator 28 may form the perforations 24b as soon as the control module 32 determines that the perforator is at the desired location for forming the perforations.

A decreased pressure and/or increased flow rate may be detected by an operator at surface as an indication that the flow restrictor 34 has passed the open perforations 24a. Then, the operator may detect an increased pressure and/or decreased flow rate when the diverter(s) 42a prevent flow into the zone 12a. These or other indications may be used by the operator to confirm the operation's progress and to determine when flow of the fluid 38 should be ceased, so that the perforator 28 is positioned at the desired location for forming the perforations 24b.

The configuration of the perforating assembly 22b and diverter(s) 42a in FIGS. 3A & B may be used in any portion of the system 10 and method. For example, the FIGS. 3A & B configuration could be used for the perforating assembly 22c and diverter(s) 42b (see FIG. 1C).

Referring additionally now to FIG. 4, another example of the system 10 and method is representatively illustrated. In this example, the diverter(s) 42 are releasably attached to the tether 76, at least initially when the perforating assembly 22 is deployed into the well.

For example, the diverter(s) 42 could be adhered, bonded or otherwise secured to the tether 76 using a dissolvable material (such as PLA, PGA or PVA) so that, after deployment into the well, the diverters are released into the portion of the flow passage 26 between the flow restrictor 34 and the remainder of the perforating assembly 22. In another example, the diverters 42 could be released from the tether 76 in response to firing of the perforator 28 (e.g., due to a mechanical or pressure shock wave caused by the firing), in which case the

diverters can engage or otherwise prevent flow through the perforations 24 after the perforator has been fired.

Referring additionally now to FIG. 5, another example of the system 10 and method is representatively illustrated. In this example, the diverter(s) 42 are
5 contained in a container 78, which may be attached or secured to the flow restrictor 34 and/or the tether 76. The container 78 may be in the form of a flexible bag or sack, or the container may be made of a rigid material.

The container 78 may be dissolvable, melt-able or otherwise degradable downhole to thereby release the diverters 42 into the portion of the flow passage
10 26 between the flow restrictor 34 and the remainder of the perforating assembly 22 after deployment into the well. In some examples, the container 78 may be designed to release the diverters 42 in response to firing of the perforator 28 (e.g., due to a mechanical or pressure shock wave caused by the firing), in which case the diverters can engage or otherwise prevent flow through the perforations
15 24 after the perforator has been fired.

Referring additionally now to FIGS. 6A & B, another example of the system 10 and method is representatively illustrated. In this example, the diverter(s) 42a are deployed into the flow passage 26 before or "ahead of" the perforating assembly 22. The perforating assembly 22 and the diverter(s) 42a are
20 displaced together through the flow passage 26 by the flow of the fluid 38.

Eventually, the diverter(s) 42a engage the perforations 24a or otherwise prevent flow through the perforations 24a. At or after this point, the flow of the fluid 38 is ceased, so that the perforator 28 is positioned at the desired location for forming the perforations 24b.

Additional diverter(s) 42b may be deployed into the flow passage 26 for
25 displacement with the perforating assembly 22 by the flow of the fluid 38. The diverter(s) 42b can engage the perforations 24b or otherwise prevent flow out of the perforations after the perforator 28 has been fired.

Referring additionally now to FIGS. 7A & B, another example of the
30 system 10 and method is representatively illustrated. In this example, the

diverter(s) 42 are contained in the container 78, which is part of the perforating assembly 22, or which is attached or secured to the perforating assembly.

As depicted in FIG. 7A, the diverter(s) 42 are displaced or conveyed with the perforating assembly 22 by the flow of the fluid 38 through the flow passage 26. The container 78 may be dissolvable, melt-able or otherwise degradable
5 downhole to thereby release the diverters 42 into the flow passage 26 "ahead of" the perforating assembly 22 after deployment into the well.

In some examples, the container 78 may be designed to release the diverters 42 in response to firing of the perforator 28 (e.g., due to a mechanical or
10 pressure shock wave caused by the firing), in which case the diverters can engage or otherwise prevent flow through the perforations 24 after the perforator has been fired. As depicted in FIG. 7B, the perforator assembly 22 and the container 78 have dissolved, disintegrated or otherwise degraded after firing of the perforator 28, so that the diverter(s) 42 now prevent flow into the perforations
15 24a, and fracturing fluid 38 can flow through the perforations 24b and into the zone 12b to form the fractures 40b.

Referring additionally now to FIG. 8, another example of the perforating assembly 22 is representatively illustrated. In this example, the container 78, with the diverter(s) 42 therein is secured to the perforating assembly 22 (similar to the
20 FIG. 7A example). However, the perforator 28 includes an additional shaped charge 80 or other explosive device (or a propellant and bullet, etc.) that is directed toward the container 78.

When the perforator 28 is fired, the shaped charge or other device 80 pierces, opens, breaks, fractures, disperses or otherwise causes the diverter(s)
25 42 to be released from the container 78. In this example, the container 78 may be made of a friable or frangible material and/or may be configured to conveniently break open in response to firing of the device 80.

Referring additionally now to FIG. 9, another example of the perforating assembly 22 is representatively illustrated. In this example, the container 78, with

the diverter(s) 42 therein is secured to the perforating assembly 22 via the tether 76.

When the perforator 28 is fired, the shaped charge or other device 80 pierces, opens, breaks, fractures, disperses or otherwise causes the diverter(s) 42 to be released from the container 78, which may be made of a friable or frangible material and/or may be configured to conveniently break open in response to firing of the device 80. Alternatively, the firing of the device 80 could release or break the tether 76, thereby allowing the container 78 with the diverter(s) 42 therein to separate from the remainder of the perforating assembly 22. The diverter(s) 42 could be released from the container 78 in response to dissolution, corrosion, dispersal, melting, breaking or other degrading of the container.

In the FIG. 9 example, the perforating assembly 22 also includes a drag device 82 connected to the remainder of the perforating assembly by another tether 76. As depicted in FIG. 9, the drag device 82 includes pads or arms 84 that extend outward to resiliently engage an interior surface of the casing 16. In some examples, the drag device 82 could be similar to drag blocks of the type used with mechanically-set packers.

Friction between the drag device arms 84 and the interior surface of the casing 16 imparts a drag force via the tether 76 to the remainder of the perforating assembly 22, thereby ensuring that the perforator 28 will remain "behind" the diverter(s) 42 and container 78, as the perforating assembly 22 is displaced through the flow passage by the flow of the fluid 38. In this manner, the diverter(s) 42 will continue downhole to previously formed perforations, rather than engage perforations formed by the perforator 28 to which the container 78 is attached.

Note that the drag device 82 may be used with any of the perforating assemblies 22 and methods described herein, in which the diverter(s) 42, 42a-c are conveyed through the flow passage 26 concurrently with a perforating assembly (for example, see FIG. 5).

Referring additionally now to FIGS. 10-13, additional examples of the perforating assembly 22 are representatively illustrated. In these examples, the diverter(s) 42 are secured on an exterior of the perforating assembly 22.

The diverter(s) 42 may be released from the exterior of the perforating
5 assembly 22 examples of FIGS. 10-13 using any suitable technique. For
example, the diverter(s) 42 could be adhered or bonded to the exterior of the
perforating assembly 22 using a substance that dissolves, melts, corrodes or
otherwise degrades in the well environment, so that the diverter(s) are released
10 from the perforating assembly downhole after deployment of the perforating
assembly into the well. In other examples, the diverter(s) 42 could be attached to
the exterior of the perforating assembly 22 using frangible or friable fasteners,
clamps or other attachment devices that break in response to shock produced
when the perforator 28 is fired. The scope of this disclosure is not limited to any
particular technique for releasing the diverter(s) 42 from the exterior of the
15 perforating assembly 22 downhole.

As depicted in FIG. 10, the diverter(s) 42 are attached, fastened, clamped,
adhered, bonded or otherwise secured to an exterior of the outer housing 46. The
diverter(s) 42 may be released from the perforating assembly 22 after the
perforating assembly is introduced into the well (e.g., due to contact with an
20 activating fluid or elevated temperature in the well), or in response to firing of the
perforator 28.

As depicted in FIG. 11, the diverter(s) 42 are attached, fastened, clamped,
adhered, bonded or otherwise secured in a groove, channel or recess 86 on the
perforating assembly 22. In this example, the recess 86 is formed between rails
25 88 secured on the outer housing 46, but in other examples the recess (or multiple
recesses) could be formed directly in the outer housing, or otherwise arranged on
the perforating assembly 22. The diverter(s) 42 may be released from the
perforating assembly 22 after the perforating assembly is introduced into the well
(e.g., due to contact with an activating fluid or elevated temperature in the well),
30 or in response to firing of the perforator 28.

As depicted in FIG. 12, the diverter(s) 42 are attached, fastened, clamped, adhered, bonded or otherwise secured between multiple flow restrictors 34 on the perforating assembly 22. The diverter(s) 42 may be released from the perforating assembly 22 after the perforating assembly is introduced into the well (e.g., due to contact with an activating fluid or elevated temperature in the well), or in response to firing of the perforator 28.

In other examples, the diverter(s) 42 may be contained between the flow restrictors 34, without being attached, bonded, etc., to the outer housing 46. For example, the “lower” (further downhole) flow restrictor 34 could dissolve or otherwise degrade downhole (for example, in response to contact with an activating fluid in the well) to release the diverter(s) 42 from the perforating assembly 22.

As depicted in FIG. 13, the diverter(s) 42 are retained on the exterior of the perforating assembly 22 by a degradable sleeve 90. For example, the sleeve 90 could be made of a material that is capable of “shrinking” onto the perforating assembly 22, so that the diverter(s) 42 are captured between the sleeve and the outer housing 46. The sleeve 90 could dissolve, melt or otherwise degrade downhole (e.g., in response to contact with an activating fluid or elevated temperature in the well), or the sleeve could disperse or break in response to firing of the perforator 28.

Note that a separate flow restrictor 34 is not depicted for the FIG. 13 example. The perforating assembly 22 in this example could be used without a separate flow restrictor, or the sleeve 90 could serve as the flow restrictor, at least until it degrades to release the diverter(s) 42 (at which point the perforating assembly may be disposed in a smaller diameter casing, so that the flow restrictor 34 is not needed).

Referring additionally now to FIG. 14, an example surface installation 92 for practice of the system 10 and method is representatively illustrated. The surface installation 92 is depicted as being attached to a wellhead 94 from which the casing 16 is hung.

However, as will be appreciated by those skilled in the art, multiple casing strings are typically hung from a wellhead facility, so it should be understood that the single casing 16 is depicted in FIG. 14 merely for clarity of illustration and description. In addition, it is not necessary for the casing 16 in which perforations
5 24 are formed in the method to be hung from a surface wellhead facility. Thus, the scope of this disclosure is not limited at all to the details of the surface installation 92 as depicted in FIG. 14.

In the FIG. 14 example, a variety of valves 96 are connected between the wellhead 94 and pumps 100, 102 for pumping fluid 38 into the flow passage 26.
10 The valves 96, pumps 100, 102 and a flow head 104 may be of the types typically used in well fracturing operations.

The perforating assembly 22 may be contained in a tubular housing 106 connected above the flow head 104. The housing 106 and associated connections, valves, etc., may be of the type commonly referred to by those
15 skilled in the art as a "lubricator," although other types of housings may be used if desired.

The perforating assembly 22 may be deployed into the flow passage 26 by opening the valves 96 between the pump 102 and the wellhead 94, and operating the pump 102 to flow the fluid 38 into the well. Any of the perforating
20 assemblies 22, 22a-c described herein may be deployed using this technique.

If it is desired to deploy diverter(s) 42 with the perforating assembly 22, the diverter(s) may also be contained in the housing 106 with the perforating assembly. Diverter(s) 42 may be positioned above and/or below the perforating assembly 22 in the housing 106.

25 Diverter(s) 42 may be separately deployed into the well by use of a dispenser 108, for example, connected to the flow head 104. The dispenser 108 may comprise a container 110 for containing the diverter(s) 42 and a valve 98 for selectively permitting the diverter(s) to enter a flow line 112 connected between the pump 100 and the flow head 104. Alternatively, any of the dispensers

described in the US patents and applications listed above may be used for the dispenser 108.

5 The diverter(s) 42 may be deployed into the well by opening the valve 98 and the valves 96 between the pump 100 and the flow head 104, and between the flow head and the wellhead 94, and operating the pump 100 to flow the fluid 38 into the well. The diverter(s) 42 may be deployed from the dispenser 108 before and/or after a perforating assembly 22 is deployed.

10 It is contemplated that the perforating assembly 22 and the diverters 42 will not necessarily displace through the flow passage 26 with the fluid 38 at a same speed for a given flow rate. This difference in speeds may be used to achieve a desired spacing between the perforating assembly 22 and the diverters 42 in the well (for example, so that the diverters 42 engage previously formed perforations 24 when, or just after, the perforating assembly 22 arrives at a desired location for forming new perforations).

15 In a simplified example, the following equation may be used to determine a spacing between the diverters 42 and the perforating assembly 22: $S = (S_D - S_{PA}) \times T$, in which S is the spacing, S_D is the speed of the diverters 42 at a given fluid 38 flow rate, S_{PA} is the speed of the perforating assembly 22 at the given flow rate, and T is the elapsed time. The diverters 42 and perforating assembly 20 22 may also, or alternatively, be released into the flow passage 26 at different times, in order to achieve a desired spacing between them.

Referring additionally now to FIG. 15, an example of a calibration method that may be used with the system 10 is representatively illustrated. The FIG. 15 method may be used to determine the volume of fluid 38 that should be flowed 25 through the flow passage 26, in order to position a perforating assembly 22 at a desired location for forming perforations 24 (see, e.g., FIG. 4).

In the FIG. 15 method, a plug or "pig" 114 is introduced into the flow passage 26, and then the fluid 38 is pumped into the flow passage behind the pig, in order to displace the pig through the flow passage, similar to the manner 30 described above for the perforating assembly 22. The volume of the fluid 38

flowed into the passage 26 is monitored during this process. Note that the fluid 38 used in this calibration method is not necessarily the same as the fluid used to convey the perforating assembly 22 or diverters 42 through the passage 26, or the same fluid used to form the fractures 40.

5 Eventually, the pig 114 will engage a restriction 116 positioned at a known distance along the flow passage 26. An operator at surface will note a pressure increase and/or a flow rate decrease as an indication that the pig 114 has engaged the restriction 116.

10 In the FIG. 15 example, the restriction 116 comprises a cementing shoe connected proximate a distal end of the casing 16. However, other types of restrictions (such as liner hangers, bridge plugs, etc.) may be used in other examples.

15 Since the restriction 116 is at a known distance along the flow passage 26, and the volume of the fluid 38 required to displace the pig 114 to the restriction is measured in the FIG. 15 method, a determination can be conveniently made as to what volume of fluid is required to displace the perforating assembly 22 through the flow passage to a desired location.

20 In a simplified example, the following equation may be used: $V_{PA} = V_{PR} \times (D_{PA}/D_{PR})$, in which V_{PA} is the volume to displace the perforating assembly 22 to the desired location, V_{PR} is the volume to displace the pig 114 to the restriction 116, D_{PA} is the distance to the desired location of the perforating assembly, and D_{PR} is the distance to the restriction.

25 The above equation results from assumptions, including that the flow passage 26 has a consistent cross-sectional area to the restriction 116, and that the perforating assembly 22 and the pig 114 displace the same in response to the flow of the fluid 38. In some circumstances (for example, long horizontal wellbores with long productive intervals), inaccuracies due to these assumptions may be acceptable. To reduce the inaccuracies, differences in the flow passage 26 cross-sectional area can be accounted for, and the pig 114 can be configured
30 to displace the same as the perforating assembly 22 in response to the fluid flow

(or the differences between the displacements of the pig and the perforating assembly could be empirically determined and accounted for).

5 The above disclosure provides to the art a well completion system 10. In one example, the well completion system 10 may comprise fluid 38 flow through a flow passage 26 of a casing 16 having first perforations 24a formed therein. One or more first diverters 42a are deployed into the flow passage 26 downhole of a perforating assembly 22. The one or more first diverters 42a and the perforating assembly 22 are concurrently displaced through the flow passage 26 by the fluid 38 flow.

10 In any of the well completion systems 10 described herein, the perforating assembly 22 may be free of any umbilical (such as, a coiled tubing, wireline, slickline, segmented tubing, etc.) as it is displaced through the flow passage 26 by the fluid 38 flow. The perforating assembly 22 in these examples may not be connected to the surface via any umbilical.

15 In any of the well completion systems 10 described herein, one or more second diverters 42b may be deployed into the flow passage 26 uphole of the perforating assembly 22, so that the second diverters 42b and the perforating assembly 22 are concurrently displaced by the fluid 38 flow through the flow passage 26.

20 In any of the well completion systems 10 described herein, the first diverters 42a may block the fluid 38 flow through the first perforations 24a.

25 In any of the well completion systems 10 described herein, the perforating assembly 22 may be configured to degrade after the perforating assembly 22 forms second perforations 24b through the casing 16. In any of the well completion systems 10 described herein, one or more second diverters 42b may be deployed into the flow passage 26 uphole of the perforating assembly 22, and the second diverters 42b may block flow through the second perforations 24b.

 In any of the well completion systems 10 described herein, fractures 40a may be formed into an earth formation 12 by the fluid 38 flow through the first

perforations 24a concurrently with the perforating assembly 22 and first diverters 42a being displaced through the flow passage 26 by the fluid 38 flow.

5 In any of the well completion systems 10 described herein, the perforating assembly 22 may be displaced by the fluid 38 flow to a desired location along the wellbore 14, and a perforator 28 of the perforating assembly 22 may fire only if the perforating assembly 22 remains motionless at the desired location for a predetermined period of time.

10 In any of the well completion systems 10 described herein, the perforating assembly 22 may include a collar locator 74, and a perforator 28 of the perforating assembly 22 may fire only if the collar locator 74 detects a predetermined number of casing collars.

15 In any of the well completion systems 10 described herein, the perforating assembly 22 may include a flow restrictor 34 that restricts flow through an annulus 36 formed between the perforating assembly 22b and the casing 16. In any of the well completion systems 10 described herein, the first diverters 42a may be retained between a flow restrictor 34 and a perforator 28 of the perforating assembly 22.

20 In any of the well completion systems 10 described herein, the first diverters 42a may be contained in a container 78 between the flow restrictor 34 and the perforating assembly 22. In any of the well completion systems 10 described herein, the first diverters 42a may be contained in a container 78 that is configured to degrade downhole and release the first diverters 42a from the container 78.

25 In any of the well completion systems 10 described herein, a flow restrictor 34 may be connected to the perforating assembly 22 by a tether 76. In any of the well completion systems 10 described herein, the first diverters 42a may be releasably attached to the tether 76. In any of the well completion systems 10 described herein, the first diverters 42a may be released from the tether 76 downhole.

The above disclosure also provides to the art a well completion method. In one example, the method can comprise: flowing fluid 38 through a flow passage 26 of a casing 16 lining a wellbore 14; deploying one or more diverters 42 and a perforating assembly 22 into the flow passage 26; displacing the diverters 42 and
5 the perforating assembly 22 together through the flow passage 26 by the fluid 38 flow; and ceasing the fluid 38 flow, thereby placing the perforating assembly 22 at a desired location for forming perforations 24 through the casing 16.

In any of the well completion methods described herein, the deploying step may comprise deploying the diverters 42 into the flow passage 26 prior to
10 deploying the perforating assembly 22 into the flow passage 26, so that the diverters 42 precede the perforating assembly 22 through the flow passage 26. In any of the well completion methods described herein, the deploying step may comprise deploying the diverters 42 into the flow passage 26 after deploying the perforating assembly 22 into the flow passage 26, so that the diverters 42 follow
15 the perforating assembly 22 through the flow passage 26.

In any of the well completion methods described herein, the method can comprise the diverters 42 blocking the fluid 38 flow through the perforations 24. In any of the well completion methods described herein, the ceasing may comprise the diverters 42 blocking the fluid 38 flow through the perforations 24. As used
20 herein, the phrase "blocking the fluid 38 flow through the perforations 24" does not require that a diverter 42 seals against the perforation itself since, as described above, a suitable diverter may pass through the perforation and engage a face of the earth formation 12, instead of or in addition to engaging the perforation itself.

25 In any of the well completion methods described herein, the method can comprise the perforating assembly 22 degrading downhole after the perforating assembly 22 forms the perforations 24 through the casing 16.

In any of the well completion methods described herein, the method can comprise forming fractures 40 into an earth formation 12 by the fluid flow 38
30 concurrently with the displacing of the perforating assembly 22 and/or the diverters 42 through the flow passage 26 by the fluid 38 flow.

In any of the well completion methods described herein, the flowing step can comprise restricting the fluid 38 flow through an annulus 36 formed between the perforating assembly 22 and the casing 16.

5 In any of the well completion methods described herein, the method can comprise firing a perforator 28 of the perforating assembly 22 in response to the perforating assembly 22 remaining motionless at the desired location for a predetermined period of time.

10 In any of the well completion methods described herein, the perforating assembly 22 may include a collar locator 74, and the method may comprise firing a perforator 28 of the perforating assembly 22 in response to the collar locator 74 detecting a predetermined number of casing collars.

In any of the well completion methods described herein, the method can comprise retaining the diverters 42 between a flow restrictor 34 and a perforator 28 of the perforating assembly 22.

15 In any of the well completion methods described herein, the method may further comprise containing the diverters 42 in a container 78, and degrading the container 78 downhole, thereby releasing the diverters 42 from the container 78.

20 In any of the well completion methods described herein, the method can comprise containing the diverters 42 in a container 78 between the flow restrictor 34 and the perforating assembly 22.

25 In any of the well completion methods described herein, the method can comprise connecting a flow restrictor 34 to the perforating assembly 22 by a tether 76. In any of the well completion methods described herein, the method can comprise releasably attaching the diverters 42 to the tether 76. In any of the well completion methods described herein, the method can comprise releasing the diverters 42 from the tether 76 downhole.

30 A perforating assembly 22 for use in a subterranean well is also provided to the art by the above disclosure. In one example, the perforating assembly 22 can comprise: a perforator 28, and a control module 32 including a memory 64, a motion sensor 72, a timer 66, and a controller 62 that causes the perforator 28 to

fire in response to a lack of motion sensed by the motion sensor 72 for a predetermined period of time.

5 In any of the perforating assemblies 22 described herein, the perforating assembly 22 may comprise a collar locator 74, and the controller 62 may cause the perforator 28 to fire in response to the lack of motion sensed by the motion sensor 72 for the predetermined period of time after detection of a predetermined number of casing collars by the collar locator 74.

10 In any of the perforating assemblies 22 described herein, the perforating assembly 22 can comprise a collar locator 74, and the perforator 28 of the perforating assembly 22 may fire only if the collar locator 74 detects a predetermined number of casing collars.

In any of the perforating assemblies 22 described herein, one or more diverters 42 may be retained between a flow restrictor 34 and the perforator 28 of the perforating assembly 22.

15 In any of the perforating assemblies 22 described herein, the diverters 42 may be contained in a container 78 between the flow restrictor 34 and the perforating assembly 22. In any of the perforating assemblies 22 described herein, the container 78 may be configured to degrade downhole and release the diverters 42 from the container 78.

20 In any of the perforating assemblies 22 described herein, a flow restrictor 34 may be connected to the perforating assembly 22 by a tether 76. In any of the perforating assemblies 22 described herein, one or more diverters 42 may be releasably attached to the tether 76.

25 Another perforating assembly 22 example described above can comprise: a perforator 28, and one or more diverters 42 attached to the perforator 28.

In any of the perforating assemblies 22 described herein, the diverters 42 may be attached exterior to the perforator 28. In any of the perforating assemblies 22 described herein, the diverters 42 may be secured to an outer housing 46 of the perforating assembly 22.

Another well completion method described above can comprise: flowing fluid 38 through a flow passage 26 of a casing 16 lining a wellbore 14; deploying a perforating assembly 22 into the flow passage 26; and displacing the perforating assembly 22 through the flow passage 26 by the fluid 38 flow at a predetermined flow rate for a predetermined flow time; and ceasing the fluid 38 flow at an end of the predetermined flow time, thereby placing the perforating assembly 22 at a desired location for forming perforations 24 through the casing 16.

In any of the well completion methods described herein, the method may comprise displacing a plug (such as the pig 114) to a predetermined location along the flow passage 26, thereby determining a volume of the fluid 38 corresponding to displacement of the perforating assembly 22 to the desired location along the flow passage 26. In any of the well completion methods described herein, the predetermined location may comprise a restriction 116 in the flow passage 26.

In any of the well completion methods described herein, the ceasing step may comprise one or more diverters 42 blocking the fluid 38 flow through the perforations 24 in the casing 16. In any of the well completion methods described herein, the perforating assembly 22 may be displaced to the desired location, without use of a collar locator 74.

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 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.

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 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 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 examples, directional terms (such as "above," "below," "upper," "lower," "upward," "downward," 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.

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, device, etc., can include that feature or element, and can also include other features or elements. Similarly, the term "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 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, 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 limited solely by the appended claims and their equivalents.

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSVIE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

1. A perforating assembly for use in a subterranean well, the perforating
5 assembly comprising:

a perforator;

a flow restrictor connected by a first tether to a first end of the perforator; and

a drag device connected by a second tether to a second end of the perforator
opposite the first end, in which one or more diverters are configured to displace with
10 the perforating assembly.

2. The perforating assembly of claim 1, in which the diverters are
attached exterior to the perforator.

15 3. The perforating assembly of claim 1, in which the diverters are secured
to an outer housing of the perforating assembly.

4. The perforating assembly of claim 1, in which the diverters are retained
between the flow restrictor and the perforator.

20

5. The perforating assembly of claim 1, in which the diverters are
contained in a container between the flow restrictor and the perforating assembly.

6. The perforating assembly of claim 5, in which the container is
25 configured to degrade downhole and release the diverters from the container.

7. The perforating assembly of claim 1, in which the diverters are releasably attached to the first tether.

5 8. The perforating assembly of claim 1, further comprising a control module including a memory, a motion sensor, a timer, and a controller that causes the perforator to fire in response to a lack of motion sensed by the motion sensor for a predetermined period of time.

10 9. The perforating assembly of claim 8, further comprising a collar locator, and in which the controller causes the perforator to fire in response to the lack of motion sensed by the motion sensor for the predetermined period of time after detection of a predetermined number of casing collars by the collar locator.

15 10. The perforating assembly of claim 8, further comprising a collar locator, and in which the perforator of the perforating assembly fires only if the collar locator detects a predetermined number of casing collars.

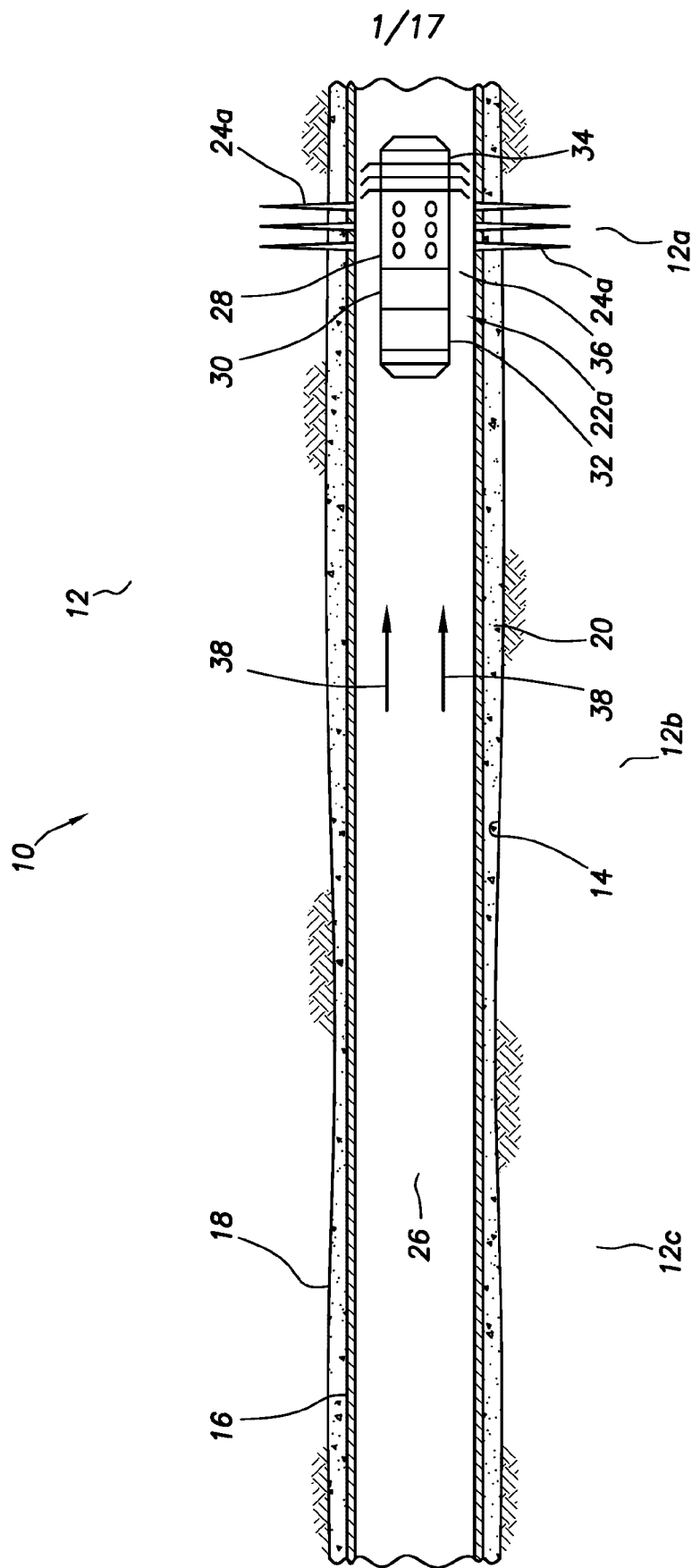


FIG. 1A

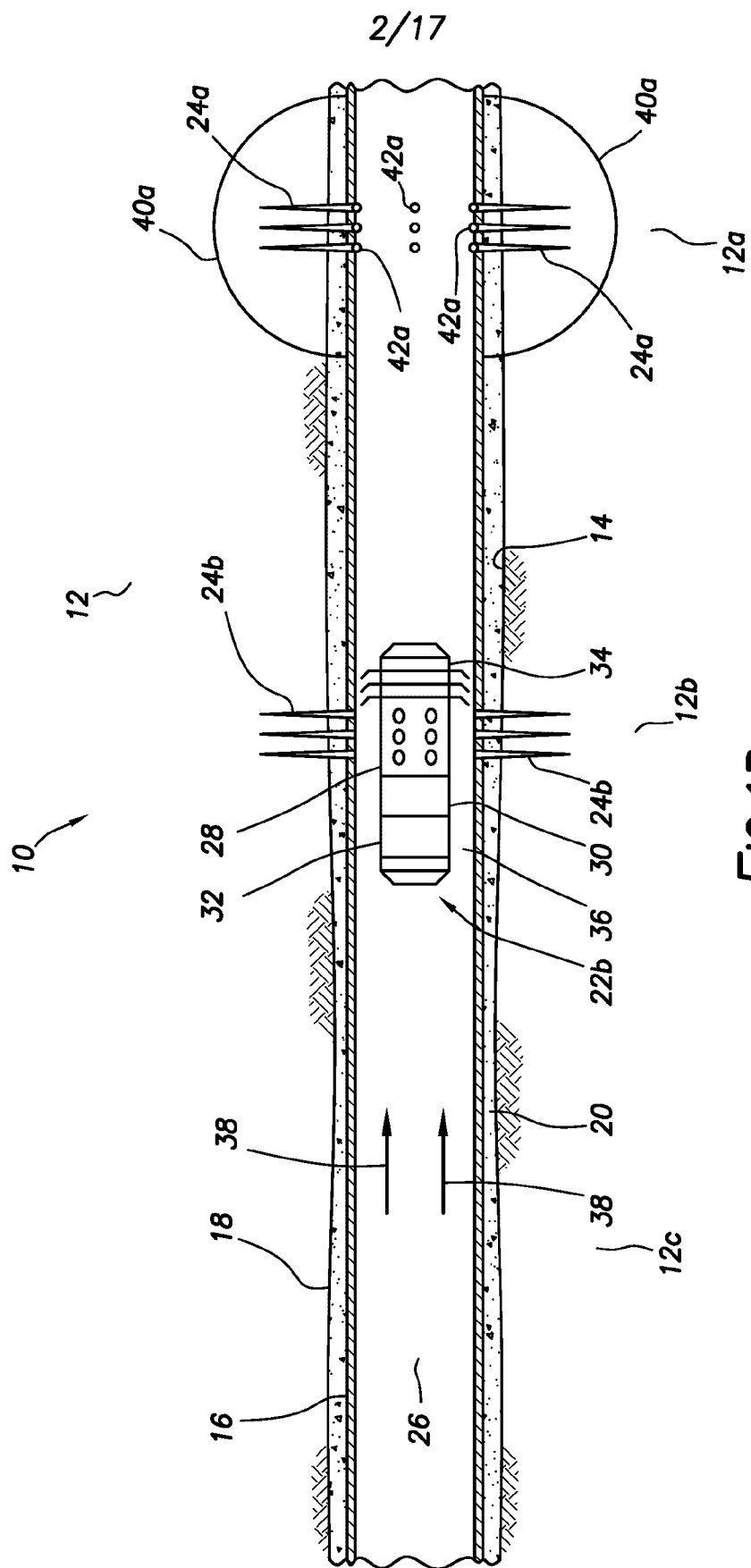


FIG.1B

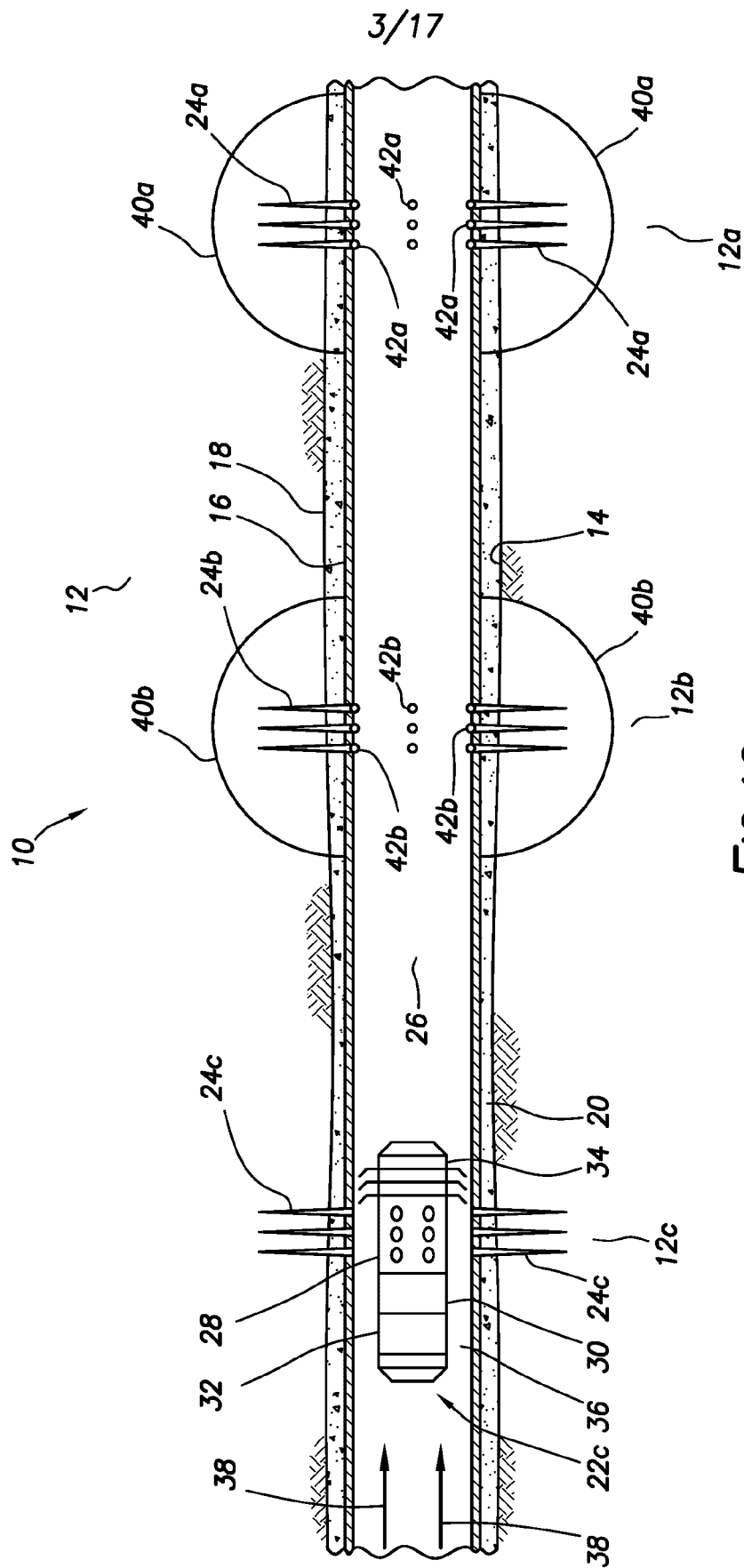
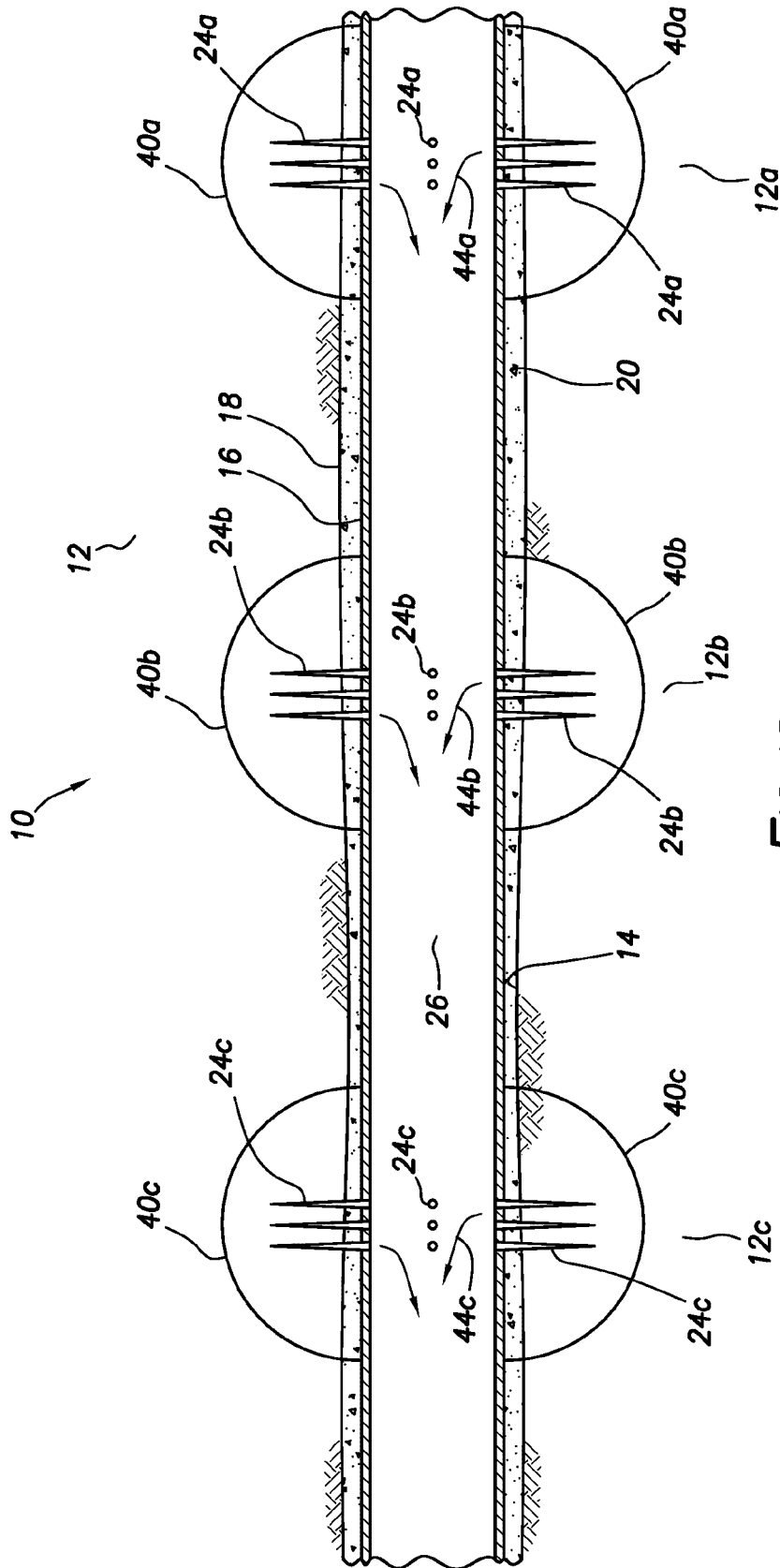


FIG. 1C



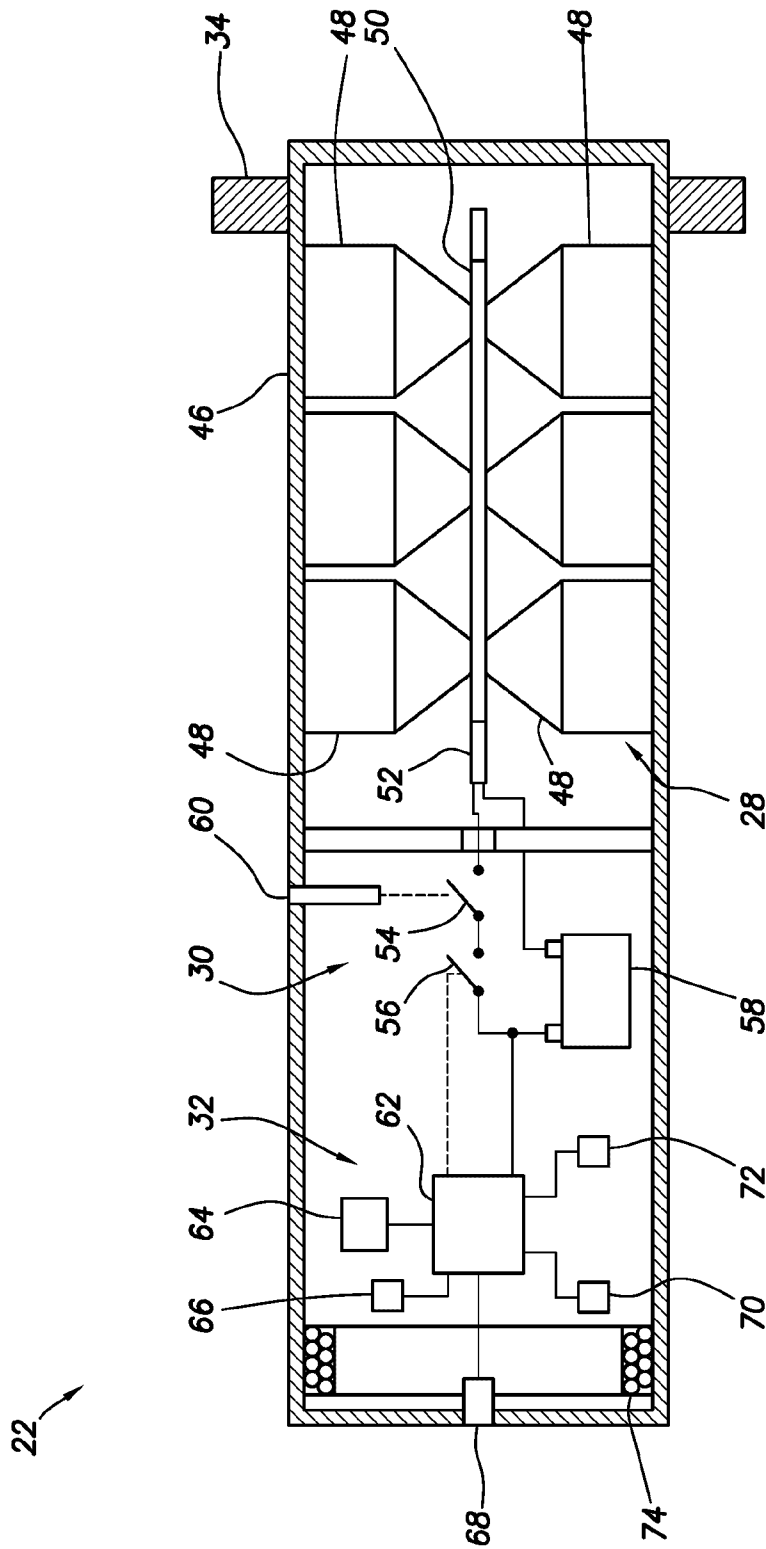


FIG. 2



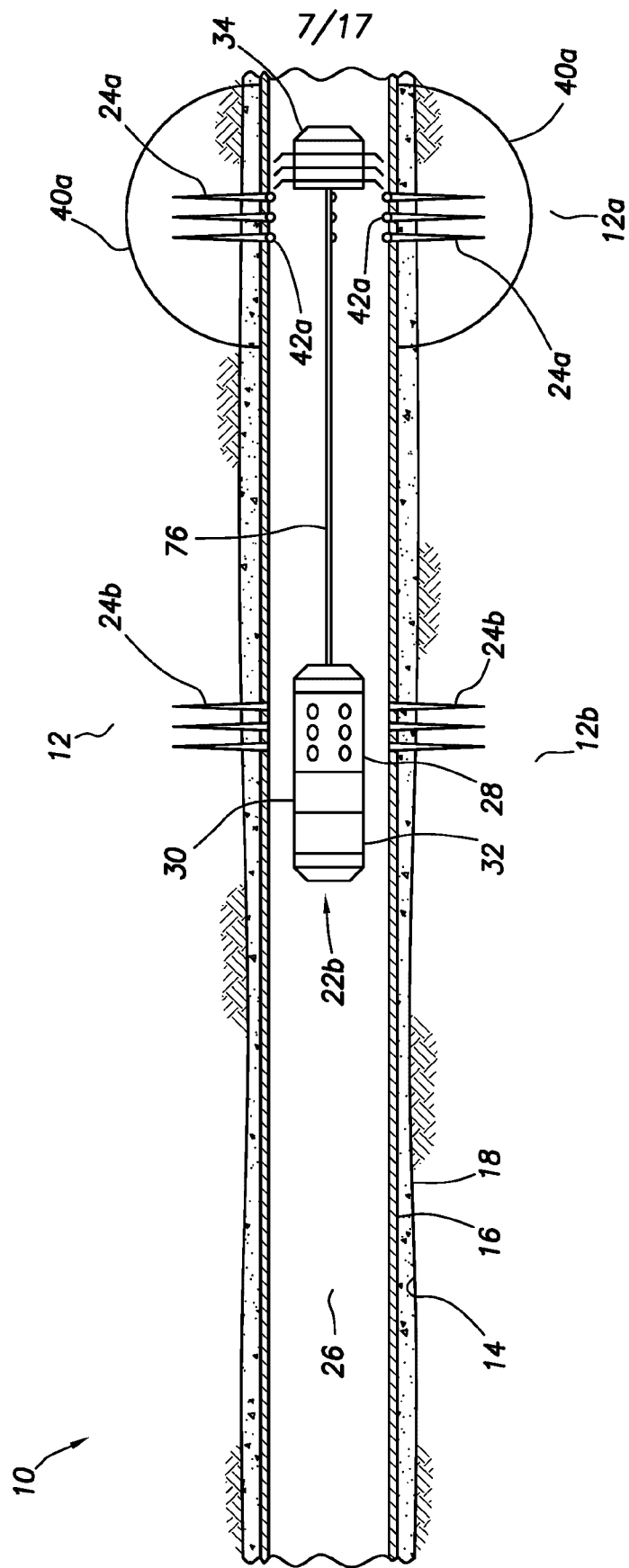


FIG. 3B

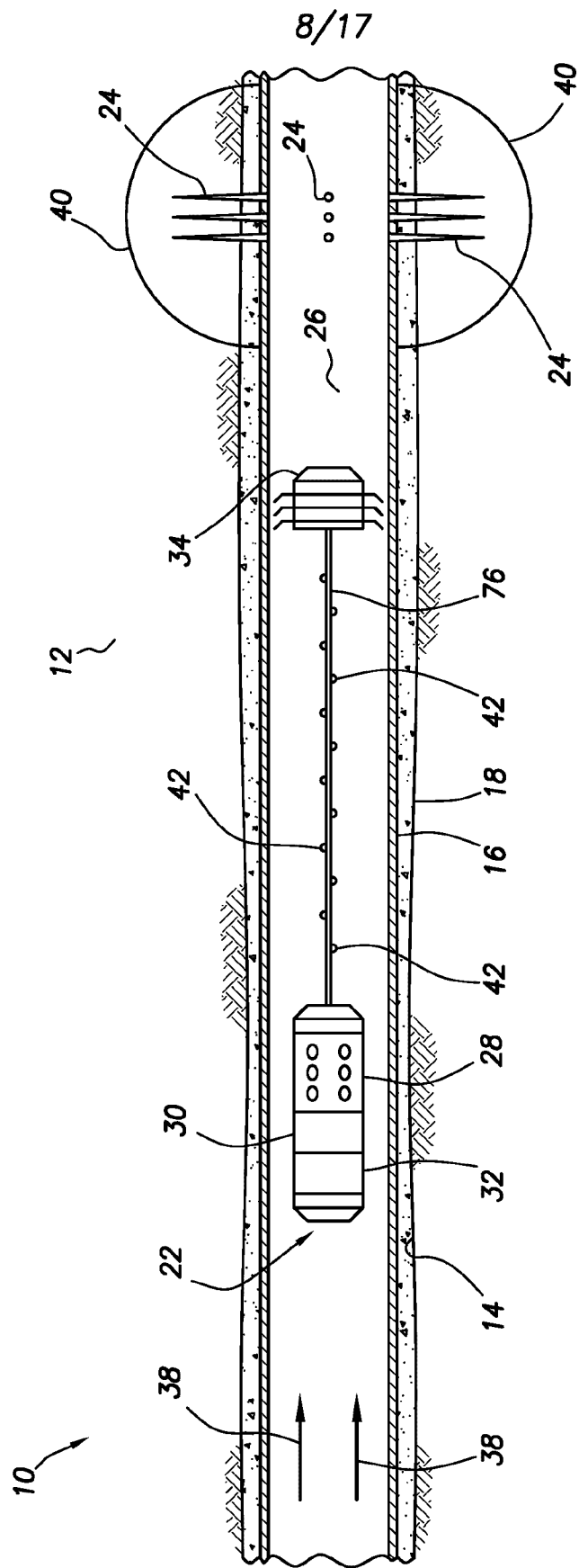


FIG.4

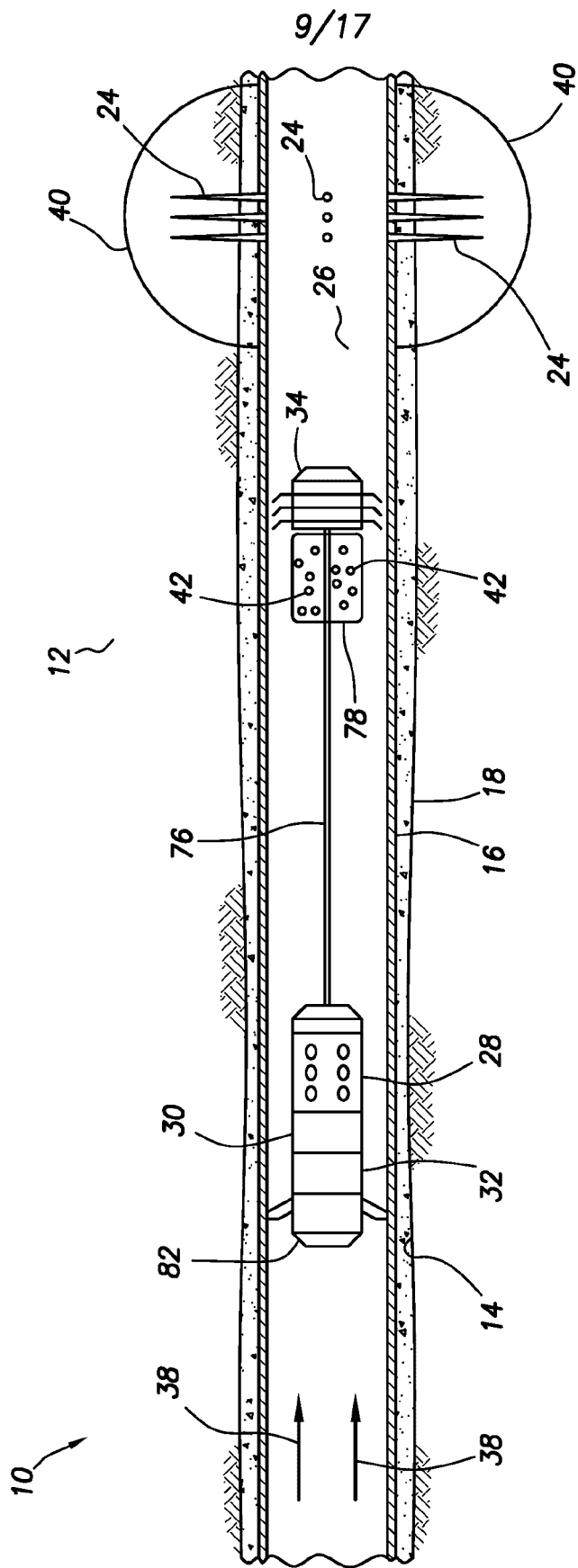


FIG.5

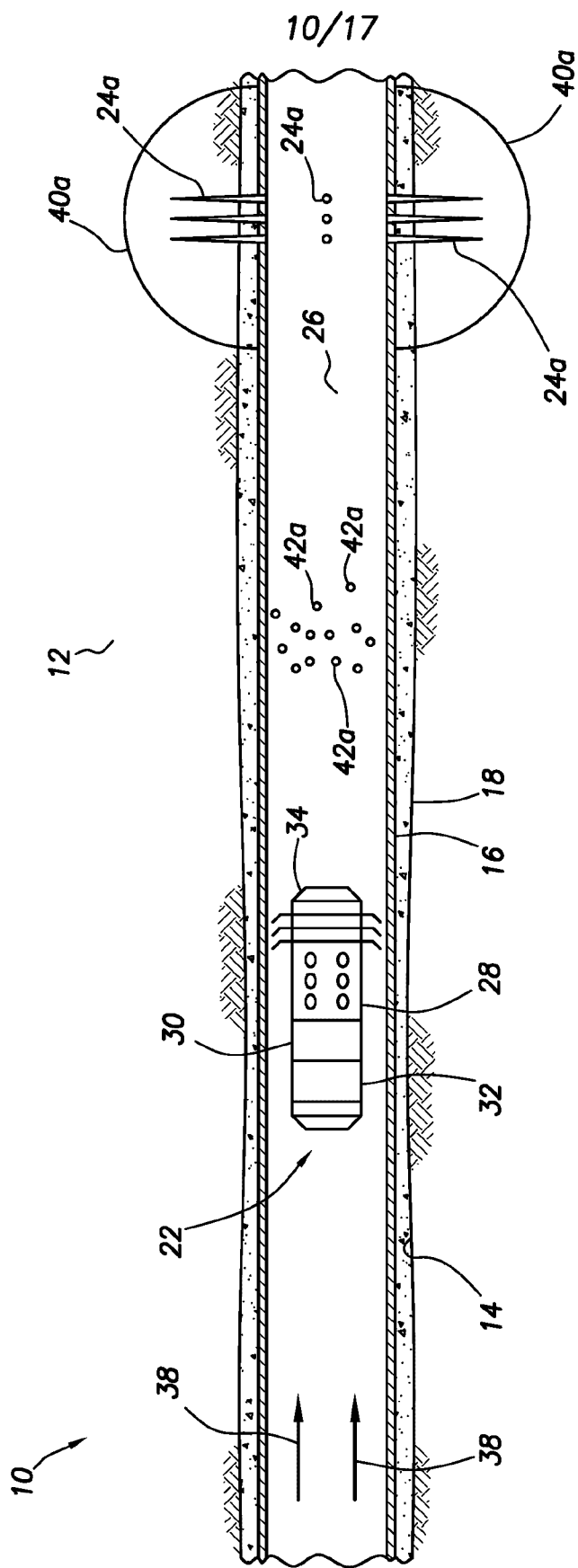


FIG. 6A

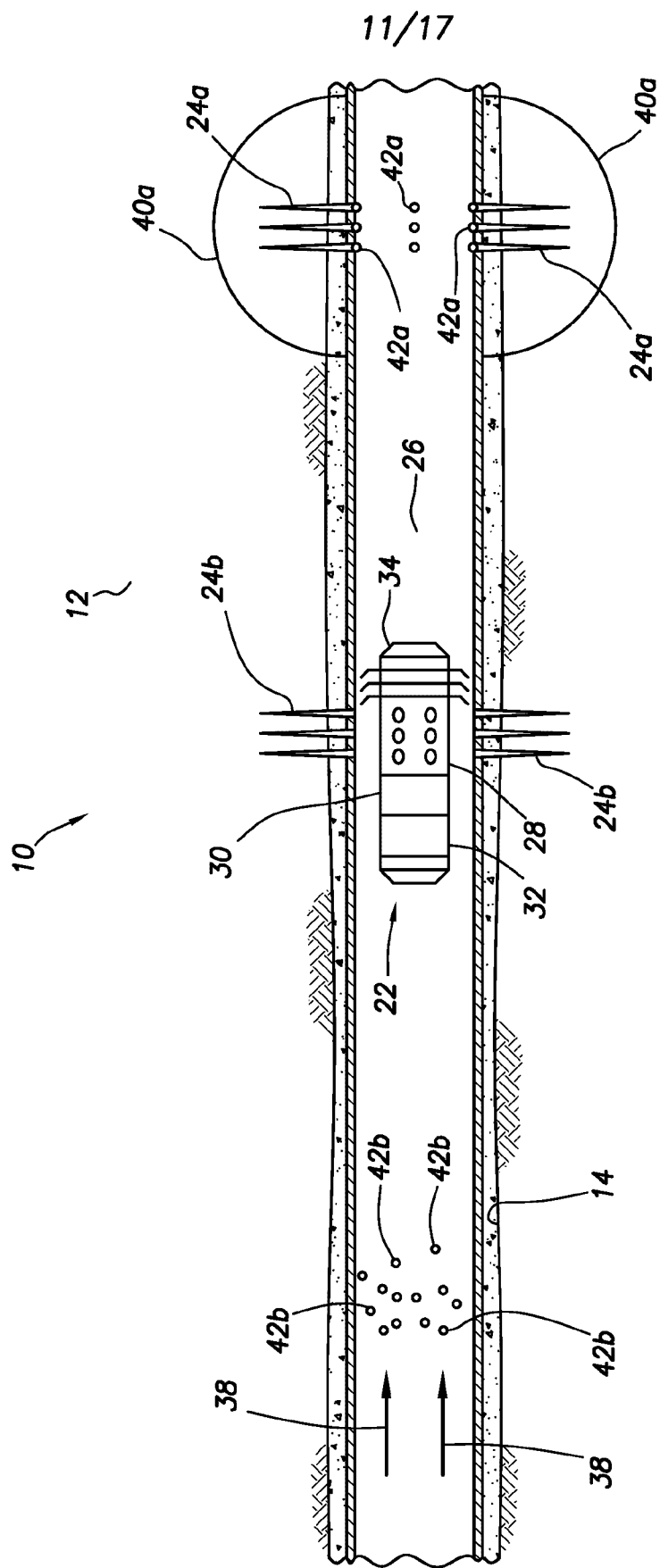
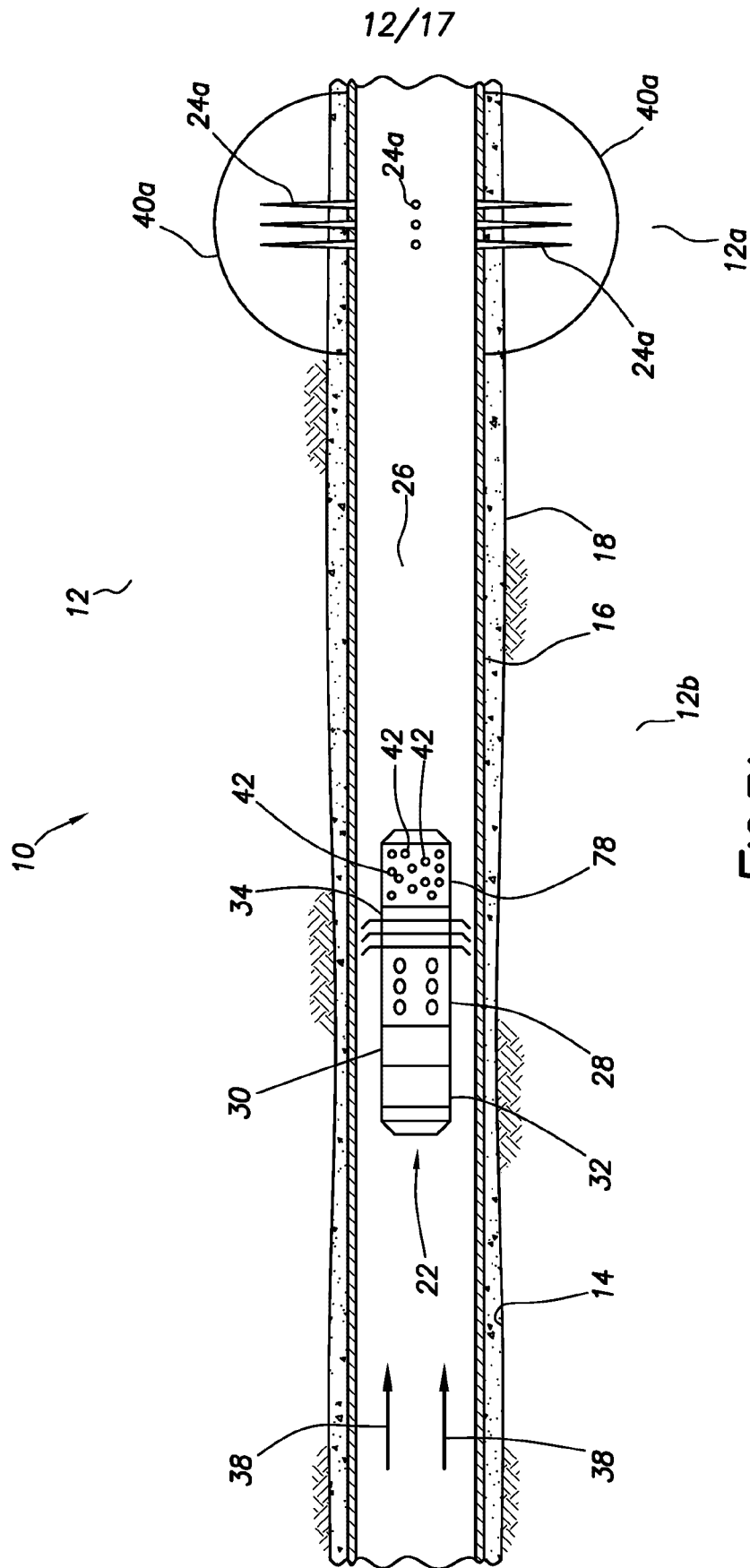


FIG. 6B



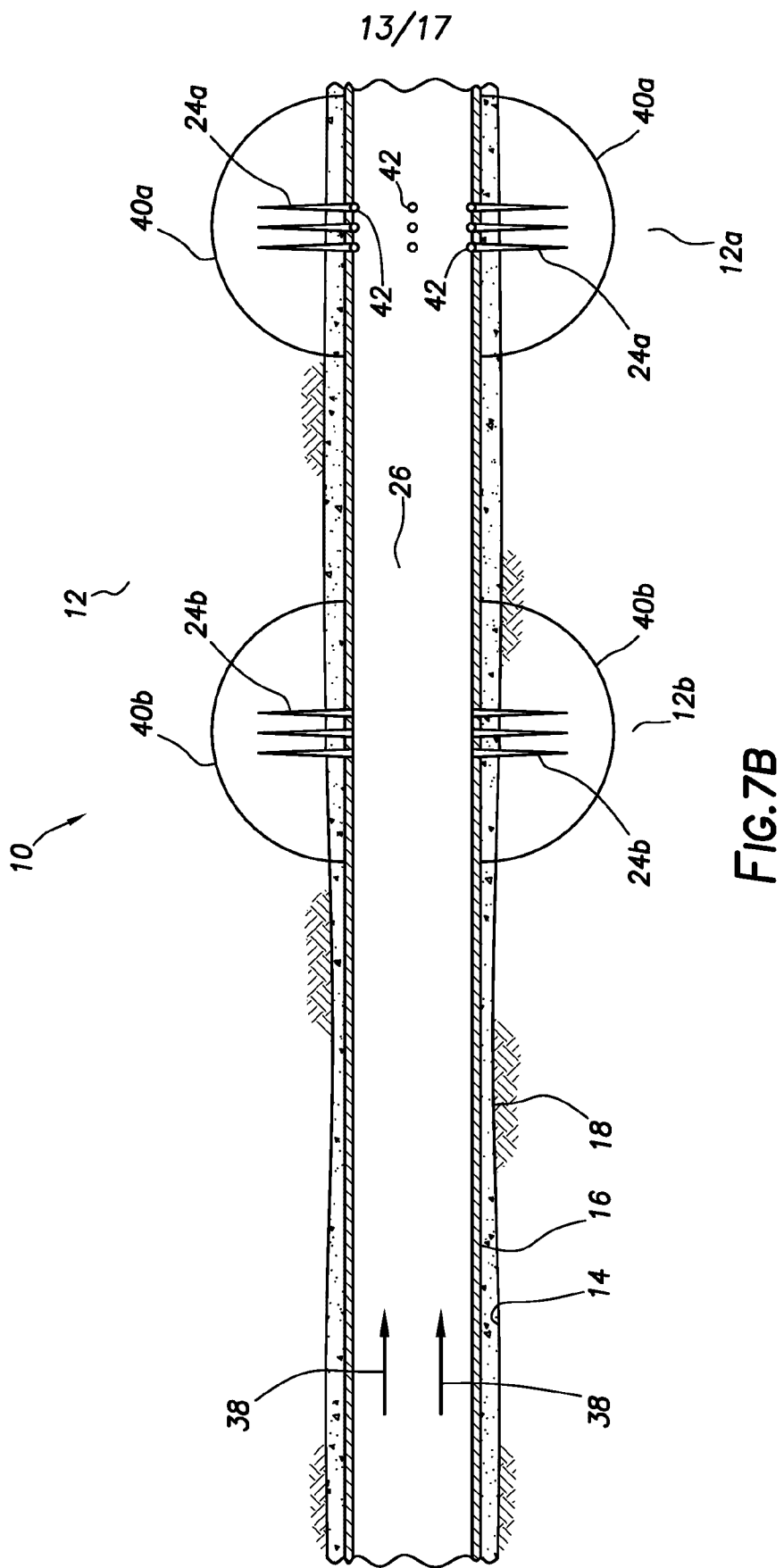


FIG. 7B

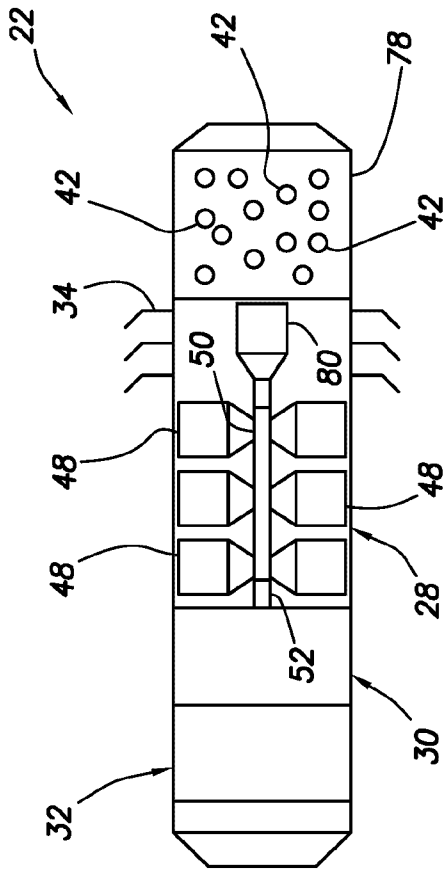


FIG. 8

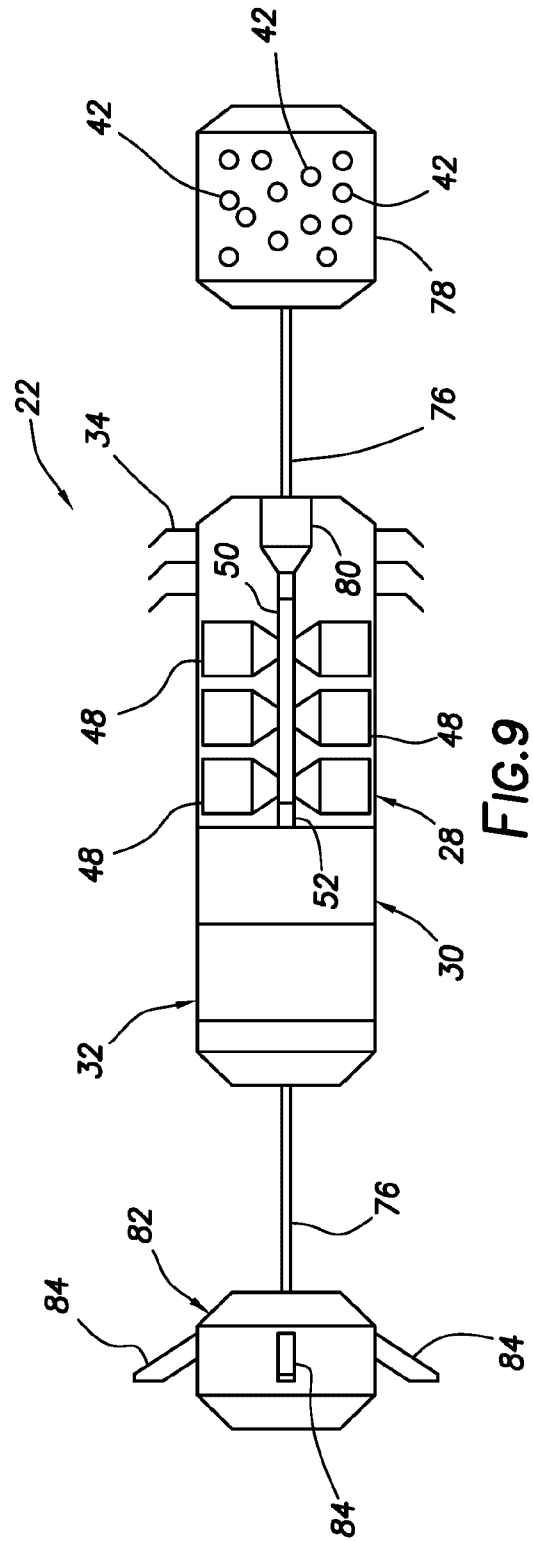


FIG. 9

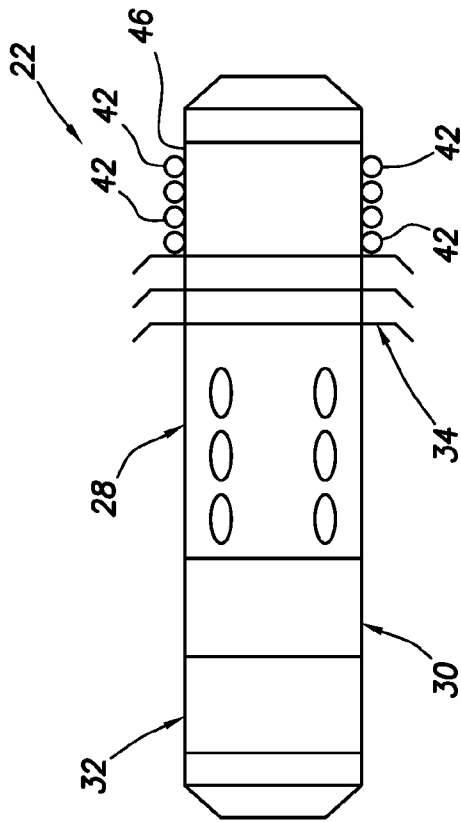


FIG. 10

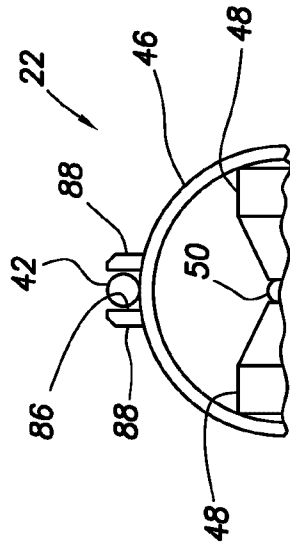


FIG. 11

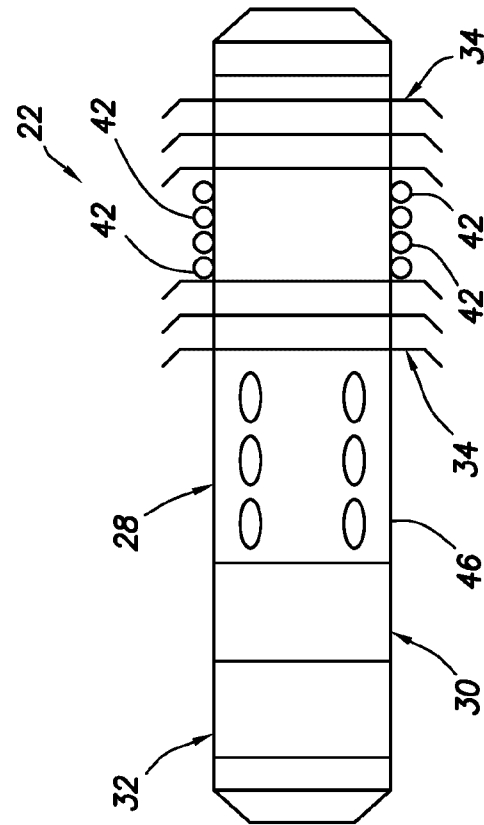


FIG. 12

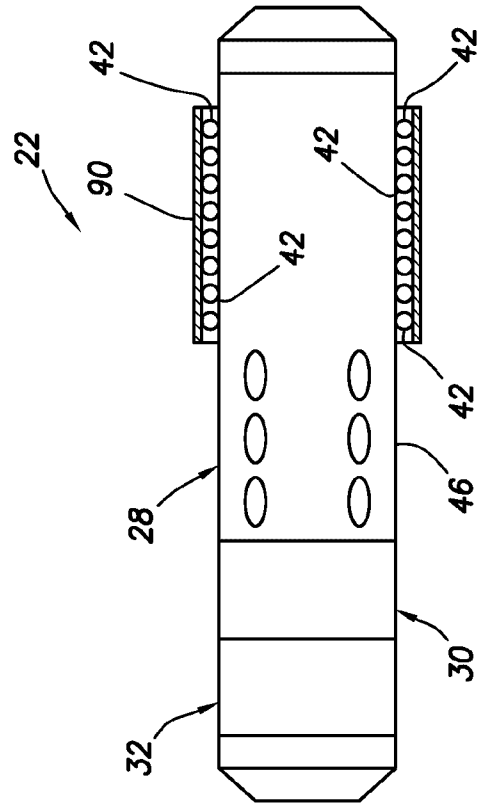


FIG. 13

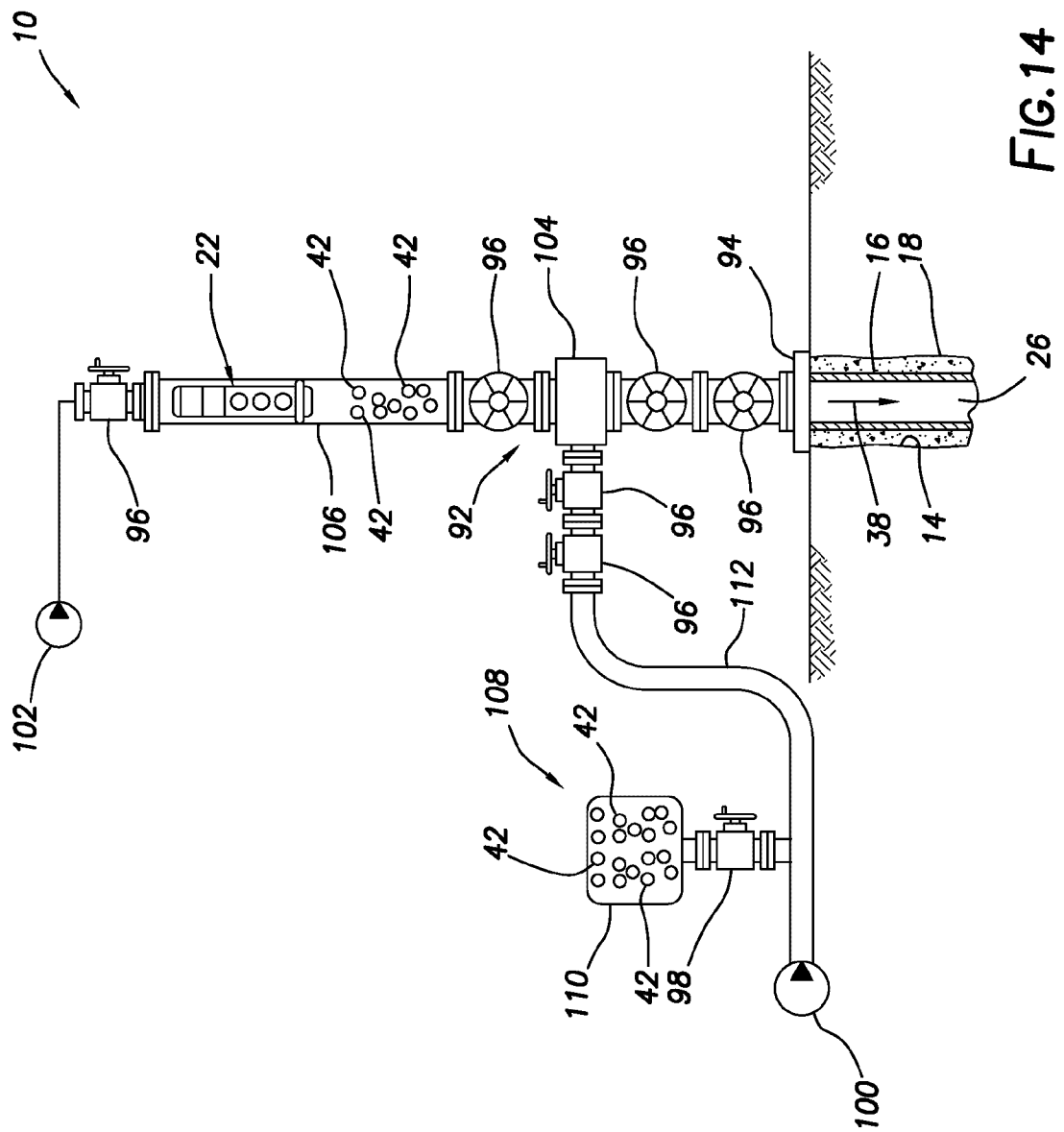


FIG.14

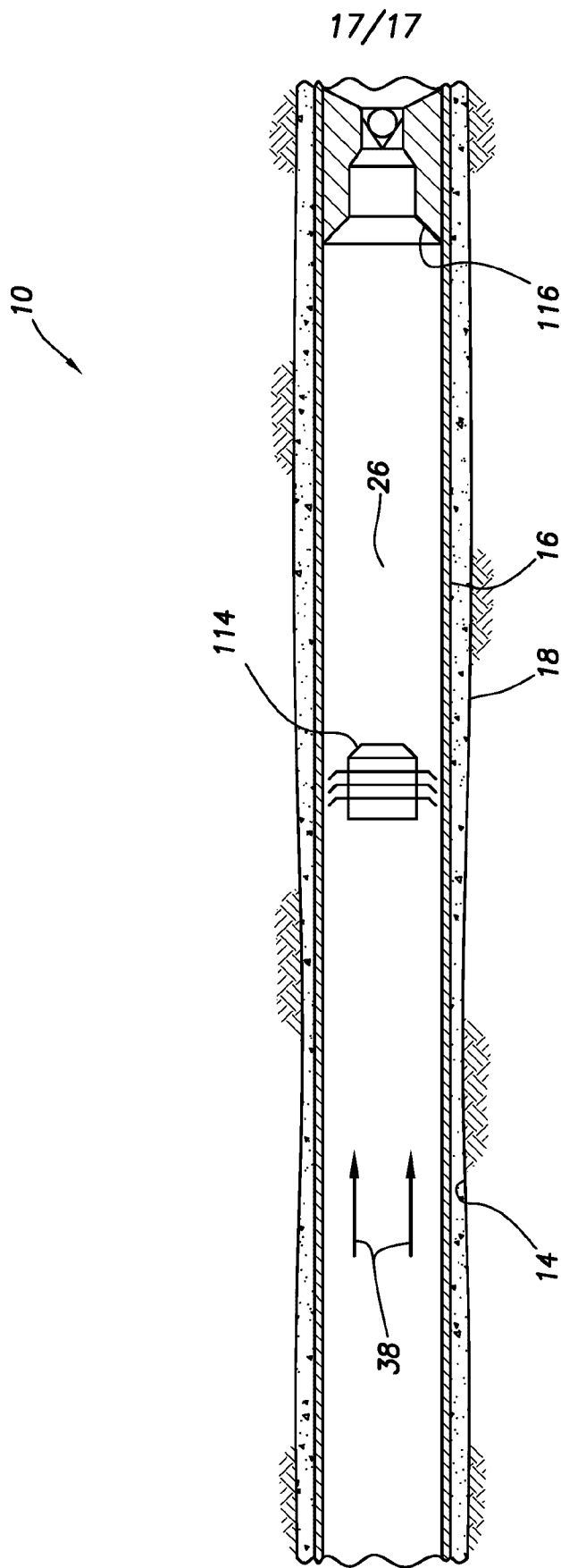


FIG. 15