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(71) Applicant *(for all designated States except US)*: **BAKER HUGHES INCORPORATED** [US/US]; P.O. Box 4740, Houston, TX 77210-4740 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **CROW, Steve, L.** [US/US]; 5019 Fox Grass Trail, Kingwood, TX 77345 (US). **HAYTER, Steven, R.** [US/US]; 9404 West Road, Houston, TX 77064 (US). **HOLMES, Kevin, C.** [US/US]; 4110 Whitman Street, Houston, TX 77027 (US). **RANJAN, Priyesh** [IN/US]; 777 Dunlavy, Apt. 6107, Houston, TX 77019 (US).

(74) Agent: DUPHORNE, Darin, H.; Baker Oil Tools Division-baker Hughes Incorporated, Division Intellectual Property Counsel, P.O. Box 4740, Houston, TX 77210-4740 (US).

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(54) Title: WATER SENSING DEVICES AND METHODS UTILIZING SAME TO CONTROL FLOW OF SUBSURFACE FLUIDS

(57) Abstract: An apparatus for controlling fluid flow in a wellbore includes a reactive element that reacts when exposed to a fluid and a flow control device configured to control a flow of the fluid. The flow control device may be actuated by a reaction of the reactive element to the fluid. In embodiments, the reactive element reacts by exhibiting a change in a material property. The reaction of the reactive element may be reversible. In embodiments, the reactive element may be a shape memory polymer. The flow control device may include an actuating element operably coupled to the reactive element. The reaction of the reactive element to a given fluid releases the actuating element to actuate the flow control device.

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TITLE: WATER SENSING DEVICES AND METHODS UTILIZING SAME TO CONTROL FLOW OF SUBSURFACE FLUIDS

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates generally to systems and methods for selective control of fluid flow into a wellbore.

2. Description of the Related Art

[0002] Hydrocarbons such as oil and gas are recovered from a subterranean formation using a wellbore drilled into the formation. Such wells are typically completed by placing a casing along the wellbore length and perforating the casing adjacent each such production zone to extract the formation fluids (such as hydrocarbons) into the wellbore. These production zones are sometimes separated from each other by installing a packer between the production zones. Fluid from each production zone entering the wellbore is drawn into a tubing that runs to the surface. It is desirable to have substantially even drainage along the production zone. Uneven drainage may result in undesirable conditions such as an invasive gas cone or water cone. In the instance of an oil-producing well, for example, a gas cone may cause an inflow of gas into the wellbore that could significantly reduce oil production. In like fashion, a water cone may cause an inflow of water into the oil production flow that reduces the amount and quality of the produced oil. Accordingly, it is desired to provide even drainage across a production zone and / or the ability to selectively close off or reduce inflow within production zones experiencing an undesirable influx of water and/or gas.

[0003] The present disclosure addresses these and other needs of the prior art.

SUMMARY OF THE DISCLOSURE

[0004] In aspects, the present disclosure provides an apparatus for controlling fluid flow into a wellbore tubular. In one embodiment, the apparatus includes a reactive element configured to react when exposed to a fluid and a flow control device configured to control a flow of the fluid. The flow control device may be actuated by a reaction of the reactive element to the fluid, which may be water, a hydrocarbon, an engineered fluid, and / or a naturally occurring fluid.

[0005] In embodiments, the reactive element reacts by exhibiting a change in a mechanical material property, a modulus, a storage modulus, a shear strength, a glass transition temperature, ductility, hardness and / or density. In embodiments, the reaction of the reactive element may a deformation, a bending, an expansion, contraction, and / or a twisting. In aspects, the reactive element may be configured to have a chemical reaction to the fluid, and / or a molecular reaction to the fluid. In aspects, the reaction of the reactive element is reversible. In some embodiments, the reactive element may be a shape memory polymer.

[0006] In embodiments, the flow control device may be a valve, an orifice, and / or a tortuous path. Depending on the configuration of the flow control device, the flow control device may be actuated by a compression applied by the reactive element, and / or a tension applied by the reactive element. In some arrangements, the flow control device includes an actuating element operably coupled to the reactive element. The reaction of the reactive element to a given fluid, such as water, releases the actuating element to actuate the flow control device.

[0007] In aspects, the present disclosure provides a method for producing fluid from a subterranean formation. The method may include positioning a reactive element downhole in a wellbore, and actuating a flow control device in response to a reaction of the reactive element to a given fluid. The fluid may be water, a hydrocarbon, an engineered fluid, and / or a naturally occurring fluid. In some embodiments, the reactive element may be a shape memory polymer.

[0008] In aspects, the present disclosure provides a system for controlling flow of one or more fluids into a wellbore intersecting a subterranean formation. The system may include a wellbore tubular conveying the one or more fluids to a surface location, and a plurality of flow control devices distributed along a section of the wellbore tubular. Each flow control device may include a reactive element configured to react when exposed to a fluid. Each of the flow control device may be actuated by a reaction of the reactive element to the fluid to control a flow of the fluid into the wellbore tubular. In some embodiments, the reactive element may be a shape memory polymer.

[0009] It should be understood that examples of the more important features of the disclosure have been summarized rather broadly in order that detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The advantages and further aspects of the disclosure will be readily appreciated by those of ordinary skill in the art as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings in which like reference characters designate like or similar elements throughout the several figures of the drawing and wherein:

Fig. 1 is a schematic elevation view of an exemplary multi-zonal wellbore and production assembly which incorporates an inflow control system in accordance with one embodiment of the present disclosure;

Fig. 2 is a schematic elevation view of an exemplary open hole production assembly which incorporates an inflow control system in accordance with one embodiment of the present disclosure;

Fig. 3 is a schematic cross-sectional view of an exemplary production control device made in accordance with one embodiment of the present disclosure;

Fig. 4 is a schematic view of a flow control device made in accordance with one embodiment of the present disclosure;

Fig. 5 is a schematic view of another flow control device made in accordance with one embodiment of the present disclosure; and

Fig. 6 is a schematic view of still another flow control device made in accordance with one embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] The present disclosure relates to devices and methods for controlling production of a hydrocarbon producing well. The present disclosure is susceptible to embodiments of different forms. There are shown in the drawings, and herein will be described in detail, specific embodiments of the present disclosure with the understanding that the present disclosure is to be considered an exemplification of the principles of the disclosure, and is not intended to limit the disclosure to that illustrated and described herein. Further, while embodiments may be described as having one or more features or a combination of two or more features, such a feature or a combination of features should not be construed as essential unless expressly stated as essential.

[0012] Referring initially to **Fig. 1**, there is shown an exemplary wellbore **10** that has been drilled through the earth **12** and into a pair of formations **14**, **16** from which it is desired to produce hydrocarbons. The wellbore **10** is cased by metal casing, as is known in the art, and a number of perforations **18** penetrate and extend into the formations **14**, **16** so that production fluids may flow from the formations **14**, **16** into the wellbore **10**. The wellbore **10** has a deviated, or substantially horizontal leg **19**. The wellbore **10** has a late-stage production assembly, generally indicated at **20**, disposed therein by a wellbore tubular or tubing string **22** that extends downwardly from a wellhead **24** at the surface **26** of the wellbore **10**. The production assembly **20** defines an internal axial flowbore **28** along its length. An annulus **30** is defined between the production assembly **20** and the wellbore casing. The production assembly **20** has a deviated, generally horizontal portion **32** that extends along the deviated leg **19** of the wellbore **10**. Production devices **34** are positioned at selected points along the production assembly **20**. Optionally, each production device **34** is isolated within the wellbore **10** by a pair of packer devices **36**. Although only two production devices **34** are shown in **Fig. 1**, there may, in fact, be a large number of such production devices arranged in serial fashion along the horizontal portion **32**.

[0013] Each production device **34** features a production control device **38** that is used to govern one or more aspects of a flow of one or more fluids into the production assembly **20**. As used herein, the term "fluid" or "fluids" includes liquids, gases, hydrocarbons, multi-phase fluids, mixtures of two of more fluids, water, brine, engineered fluids such as drilling mud, fluids injected from the surface such as water, and naturally occurring fluids such as oil and gas. Additionally, references to water should be construed to also include water-based fluids; *e.g.*, brine or salt water. In accordance with embodiments of the present disclosure, the production control device **38** may have a number of alternative constructions that ensure selective operation and controlled fluid flow therethrough.

[0014] **Fig. 2** illustrates an exemplary open hole wellbore arrangement **11** wherein the production devices of the present disclosure may be used. Construction and operation of the open hole wellbore **11** is similar in most respects to the wellbore **10** described previously. However, the wellbore arrangement **11** has an uncased borehole that is directly open to the formations **14**, **16**. Production fluids, therefore, flow directly from the formations **14**, **16**, and into the annulus **30** that is defined between the production assembly **21** and the wall of the wellbore **11**. There are no perforations, and open hole packers **36** may be used to isolate the production control devices **38**. The nature of the production control device is such that the fluid flow is directed from the formation **16** directly to the nearest production device **34**, hence resulting in a balanced flow. In some instances, packers maybe omitted from the open hole completion.

[0015] Referring now to **Fig. 3**, there is shown one embodiment of a production control device **100** for controlling the flow of fluids from a reservoir into a production string. This flow control can be a function of one or more characteristics or parameters of the formation fluid, including water content, fluid velocity, gas content, etc. Furthermore, the control devices **100** can be distributed along a section of a production well to provide fluid control at multiple locations. This can be advantageous, for example, to equalize production flow of oil in situations wherein a greater flow rate is expected at a "heel" of a horizontal well than at the "toe" of the horizontal well. By appropriately configuring the production control devices **100**, such as by pressure equalization or by restricting inflow of gas or water, a well owner can increase the likelihood that an oil bearing reservoir will drain efficiently. Exemplary production control devices are discussed herein below.

[0016] In one embodiment, the production control device **100** includes a particulate control device **110** for reducing the amount and size of particulates entrained in the fluids, an in-flow control device **120** that controls overall drainage rate from the formation, and a flow control device **130** that controls in-flow area based upon the composition of a flowing fluid. The particulate control device **110** can include known devices such as sand screens and associated gravel packs and the in-flow control device **120** can utilize devices employing tortuous fluid paths designed to control inflow rate by created pressure drops.

[0017] An exemplary flow control device **130** may be configured to control fluid flow into a flow bore **102** based upon one or more characteristics (*e.g.*, water content) of the in-flowing fluid. In embodiments, the flow control device **130** is actuated by a reactive element **132** that reacts with a specified fluid in the vicinity of the flow control device **130**. By react or reaction, it is meant that the reactive element **132** undergoes a change in one or more characteristics or properties upon exposure to the specified fluid. The characteristic or property may include, but is not limited to, a mechanical property, an electrical property, and a material composition. Moreover, the change may be reversible in some arrangements. That is, the reactive element **132** may revert to an original condition once the specified fluid has dissipated or is no longer present. Also, the reactive element **132** may revert to an original condition upon exposure to another specified fluid. Illustrative reactive elements are described below.

[0018] Referring now to **Figs. 4** and **5**, there are shown embodiments of flow control devices **200** and **240** that are actuated using reactive elements **202** and **242**, respectively. In one illustrative arrangement, the reactive elements **202** and **242** incorporate a shaped memory polymer (SMP) material. An SMP material may be configured such that when a threshold value for an activation parameter is exceeded, the SMP material undergoes a transformation that manifests as a change in a material property. Illustrative activation parameters include chemistry and heat. In one arrangement, a water-activated SMP may use a glass transition temperature, or *Tg*, as a threshold value for an activation parameter based on heat. The material property affected may be storage modulus. In an exemplary configuration, exposing a water-activated SMP material to water causes a transformation in the SMP that manifests as a change in storage modulus. Thus, for instance, prior to exposure to water, the SMP material may have a first *Tg* and after exposure to water may have a lower second *Tg*. If a surrounding temperature is between the first *Tg* and the second *Tg*, then exposing a water-activated SMP material to water causes a shift between a relatively stiff condition to a relatively flexible condition.

[0019] Referring now to **Fig. 4**, the flow control device **200** utilizes a reactive element **202** that may be operably coupled to a flow restriction element **204** that is configured to partially or completely restrict flow through an orifice **206**. The orifice **206**, when open, may provide fluid communication between the formation and the flow bore **102** (**Fig. 3**). The reactive element **202** is formed of a water-activated SMP material that has a *Tg* greater than the ambient downhole temperature encountered by the flow control device **200** when the reactive element **202** is not exposed to water. For clarity, the condition wherein the reactive element **202** is not exposed to a fluid that induces a transformation will be referred to as a "null" activation. When exposed to water, the water-activated SMP material has a *Tg* lower than the ambient downhole temperature encountered by the flow control device **200**. In one arrangement, a lever **208** having a fulcrum at a connection point **210** connects the reactive element **202** to the flow restriction element **204**. The reactive element **202** may be formed as a band that engages one end of the lever **208** that generates a force that counteracts the force urging the flow restriction element **204** into a sealing engagement with the orifice **206**. In this case, the force is gravity, but in other cases, a biasing member, hydraulic pressure, etc., may urge the flow restriction element **204** toward the orifice

206.

[0020] During the "null" activation, the reactive element **202** is sized to orient the lever **208** such that the flow restriction element **204** is not engaged with or seated on the orifice **206**. Because the reactive element **202** is relatively stiff in the "null" activation, the lever **208** and flow restriction element **204** are generally static and remain in this position. A counter weight lobe **212** may also be positioned on the lever **208** to assist the reactive element **202** in applying the necessary force on the lever **208** to keep the flow restriction element **204** unseated. When a sufficient amount of water surrounds the reactive element **202**, the reactive element **202** undergoes a transformation that causes a drop in the value of *Tg*. Because the new *Tg* is below the ambient downhole temperature, the reactive element **202** becomes flexible and loses its capacity to apply a counter force on the lever **208**. As the weight of the flow restriction element **204** overcomes the force applied by the reactive element **202**, the flow restriction element **204** rotates into a seating engagement with the orifice **206**. Thus, the flow control device **200** is actuated by the reaction of the reactive element **202** when exposed to water. This reaction may be characterized as a change in material property in one aspect, a change in shape in another aspect or a change in *Tg* in still another aspect.

[0021] If water no longer surrounds the reactive element **202**, the value of *Tg* returns to that for "null" activation. Thus, the reactive element **202** reverts to its shape and / or size during "null" activation, which causes the flow restriction element **202** to rotate out of engagement with the orifice **206**. Thus, the reaction of the reactive element **204** may be considered reversible.

[0022] In some embodiments, the **Fig. 4** flow control device **200** may be oriented in the wellbore such that gravity can pull the flow restriction element **204** downward into engagement with the orifice **206**. In other embodiments, the flow control device **200** may be rotatably mounted on a wellbore tubular **22** (**Fig. 1**) and include a counter weight (not shown). Thus, upon being positioned in the wellbore, the counter weight causes the flow restriction element **204** to rotate into a wellbore highside position, which thus allows gravity to act on the flow restriction element **204** in a manner previously described.

[0023] Referring now to **Fig. 5**, the flow control device **240** utilizes the reactive element **242** in an electrical circuit **244** that can move or displace a flow restriction element **246** that partially or completely restricts flow through an orifice **248**. The orifice **248**, when open, may provide fluid communication between the formation and the flow bore **102** (**Fig. 3**). The reactive element **242** is formed of a water-activated SMP material and is configured in the same manner as described with respect to **Fig. 4**. In one arrangement, the flow restriction element **246** is coupled at a pivoting element **250** in a manner that allows rotation between an open and closed position. The flow restriction element **246** may be formed of a non-metallic material that includes a magnetic element **252** that co-acts with the electrical circuit **244**. In an illustrative configuration, the electrical circuit **248** generates a magnetic field that attracts the magnetic element **252**. The force applied by the generated magnetic field pulls or rotates the flow restriction element **246** out of engagement with the orifice **248**. The electrical circuit **244** may be energized using a surface power source that supplies power using a suitable conductor and / or a downhole power source. Exemplary downhole power sources include power generators and batteries.

[0024] The electrical circuit **244** includes a switch **254** that selectively energizes an electromagnetic circuit **256**. In some embodiments, the switch **254** may be a switch that is activated using an applied magnetic field, such as a Reed switch. For example, the switch **254** may be moved between an energized and non-energized position by a magnetic trigger **258**. The magnetic trigger **258** includes a magnetic element **260** that may slide or shift between two positions. In a first position, the magnetic field generated by the magnetic element **260** is distant from and does not affect the switch **254**. In a second position, the magnetic field generated by the magnetic element **260** is proximate to and does affect the switch **254**. The switch **254** may be configured to energize the electromagnetic circuit **256**when the magnetic trigger **258** is in the first position and de-energize the electromagnetic circuit **256**when the magnetic trigger **258** is in the second position. It should be understood that, in addition to magnetic fields, the switch **254** may also be activated by mechanical co-action, an electrical signal, a hydraulic or pneumatic arrangement, a chemical or additive, or other suitable activation systems.

[0025] Movement of the magnetic trigger **258** between the first position and the second position is controlled by the reactive element **242** and a biasing element **262**. In the "null" activation, the reactive element **242** has a size and stiffness than maintains the biasing element **262** in a compressed state and the magnetic trigger **258** in the first position. When a sufficient amount of water surrounds the reactive element **242**, the reactive element **242** loses its capacity to resist the biasing force applied by the biasing element **262**. As the biasing element **262** overcomes the resistive force of the reactive element **242**, the biasing element **262** slides the magnetic trigger **260** into the second position. When magnetic elements **262** of the magnetic trigger **260** are sufficiently close to the switch **254**, the switch **254** opens or breaks the electromagnetic circuit **256** and thereby de-activates the magnetic field generated by the electromagnetic circuit **256**. Thereafter, gravity or some other force urges the flow restriction element **246** to rotate into engagement with the orifice **248**.

[0026] If water no longer surrounds the reactive element **242**, the value of *Tg* returns to that for "null" activation. Thus, the reactive element **242** reverts to shape and / or size during "null" activation, which compresses the spring **262** and causes the magnetic trigger **260** to return to the first position. Because the magnetic elements **260** no longer affect the switch **254**, the switch **254** re-energizes the electromagnetic circuit **244** and the generated magnetic field causes the flow restriction element **244** to rotate out of engagement with the orifice **248**. Thus, again, the reaction of the reactive element **242** may be considered reversible.

[0027] In some embodiments, the **Fig. 5** flow control device **240** may be positioned in the wellbore such that gravity can pull the flow restriction element **246** downward into engagement with the orifice **248**. In other embodiments, the flow control device **200** may be rotatably mounted on a wellbore tubular **22** (**Fig. 1**) and include a counter weight (not shown) in a manner previously described in connection with **Fig. 4**.

[0028] Referring now to **Fig. 6**, there is shown a flow control device **280** that utilizes a reactive element **282** that selectively blocks flow across an orifice **284**. The reactive element **282** may be formed of a water-activated SMP material and utilized as an object commonly referred to as a "dart" that may be pumped down from the surface. The reactive element **282** may have a "null" activation during the pump down in which the reactive element **282** has a shape and / or dimensions that allow the element **282** to enter the orifice **284**. Thereafter, exposure to water causes the element **282** to expand and become secured within the orifice **284** and thereby partially or fully occlude the orifice **284**. In other embodiments, the reactive element **282** may be positioned in the orifice **284** during initial installation and be formed of an SMP material that is oil-activated. Exposure to oil, or some other hydrocarbon, may cause the reactive element **282** to transform from one size to a smaller size. Thus, when oil surrounds the orifices **284**, the reactive element **282** reduces in size and falls out of the orifice **284**. In still other embodiments, the reactive element **282** may be positioned on or in the orifice **284** to selectively control flow through the orifice **284** based on the nature of the surrounding fluid.

[0029] It should be understood that the above arrangements are merely illustrative of flow devices according to the present disclosure. For example, in some variants, a reactive element may be formed to have a non-reversible reaction with a fluid. For instance, the reactive element may use a material that reacts to a specified fluid by disintegrating. Exemplary types of disintegration include, but are not limited to, oxidizing, dissolving, melting, and fracturing. Referring to **Fig. 5**, the reactive element **242** may be formed of a material, such as aluminum, that oxidizes, or corrodes, when exposed to water. Thus, once water has sufficiently corroded an aluminum-based reactive element **242**, the biasing element **262** will shift the magnetic trigger **258** to the second position.

[0030] In other variants, a reactive element may be configured to react with fluids other than water. For example, a reactive element may be configured to utilize an oil-activated SMP material. Referring now to **Fig. 4**, an oil-activated reactive element **202** may be configured to have a shape or dimension that applies the counter force to maintain the flow restriction element **204** in an open position as long as oil is present. If water displaces the oil, then the oil-activated reactive element **202** reverts to a shape or dimension associated with the "null" activation and the flow restriction element **204** moves to a closed position. In still other embodiments, the reactive element **202** may be configured to react with an engineered fluid, such as drilling mud, or fluids introduced from the surface such as brine. It should also be understood that SMP materials are merely illustrative of the type of materials that may be used for the reactive element. Any material that undergoes a transformation in a property, dimension, shape, size, a response to stimulus, etc. may be used for the reactive element.

[0031] In still other variants, an SMP material may be configured to use activation thresholds based on parameters other than temperature, such as pressure or downhole compositions. Moreover, the activation parameter may also be varied to provide an additional layer of control over the flow control devices. For instance, the threshold value may be selected such that human intervention may be used to complete an actuation of the flow control device. In one scenario, the "null" activation *Tg* and the transformed value for *Tg* may both be selected to be higher than the ambient wellbore temperature. Thus, a second step of raising the ambient wellbore temperature may be used to complete the actuation process for the flow control device.

[0032] In still other variants, forces other than gravity may be used to move flow restriction elements between an open position and a closed position. For example, biasing members, such as springs, may be used to apply a force that either keeps a flow restriction element in an open or closed position. The reactive element may be configured to counteract or restrain the force applied by such a biasing element. Additionally, while **Figs. 1** and **2** show production wells wherein fluid flows from a formation into a wellbore tubular, embodiments of the present disclosure may be utilized in connection with activities wherein fluid flows out of the wellbore tubular. For instance, injection wells may be used to assist in drainage of a production well. In a common use, water is injected into an offset well to increase production from a main well. Embodiments of the present disclosure may be used in those and other situations to control fluid flow out of a wellbore tubular.

[0033] It should be understood that **Figs. 1** and **2** are intended to be merely illustrative of the production systems in which the teachings of the present disclosure may be applied. For example, in certain production systems, the wellbores **10, 11** may utilize only a casing or liner to convey production fluids to the surface. The teachings of the present disclosure may be applied to control flow to those and other wellbore tubulars.

[0034] For the sake of clarity and brevity, descriptions of most threaded connections between tubular elements, elastomeric seals, such as o-rings, and other well-understood techniques are omitted in the above description. The foregoing description is directed to particular embodiments of the present disclosure for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above are possible without departing from the scope of the disclosure.

CLAIMS

What is claimed is:

1. An apparatus for controlling fluid flow between a wellbore tubular and a formation, comprising:

(a) a reactive element configured to react when exposed to a fluid; and

(b) a flow control device configured to control a flow of the fluid and being actuated by a reaction of the reactive element to the fluid.

2. The apparatus according to claim 1 wherein the fluid includes one of: (i) water, (ii) a hydrocarbon, (iii) an engineered fluid, and (iv) a naturally occurring fluid.

3. The apparatus according to claim 1 wherein the reaction of the reactive element is one of a change in: (i) a mechanical material property, (ii) a modulus, (iii) a storage modulus, (iv) shear strength, (v) glass transition temperature, (vi) ductility, (vii) hardness (vi) density; (vii) a chemical resistance; and (viii) resistance to corrosion.

4. The apparatus according to claim 1 wherein the reaction of the reactive element is one of: (i) a deformation, (ii) a bending, (iii) an expansion, (iv) a contraction, and (v) a twisting.

5. The apparatus according to claim 1 wherein the reactive element is configured to have one of: (i) a chemical reaction to the fluid, and (ii) a molecular reaction to the fluid.

6. The apparatus according to claim 1 wherein the reaction is reversible.

7. The apparatus according to claim 1 wherein the flow control device is one of: (i) a valve, (ii) an orifice , and (iii) a tortuous path.

8. The apparatus according to claim 1 wherein the flow control device is actuated by of: (i) a compression applied by the reactive element, (ii) a tension applied by the reactive element; and (iii) a torsion applied by the reactive element.

9. The apparatus according to claim 1 wherein the flow control device includes an actuating element operably coupled to the reactive element, wherein the reaction releases the actuating element to actuate the flow control device.

10. A method for producing fluid from a subterranean formation, comprising:

(a) positioning a reactive element downhole in a wellbore;

(b) actuating a flow control device in response to a reaction of the reactive element to a fluid.

11. The method according to claim 10 wherein the fluid is one of: (i) water, (ii) a hydrocarbon, (iii) an engineered fluid, and (iv) a naturally occurring fluid.

12. The method according to claim 10 wherein the reaction of the reactive element is one of a change in: (i) a mechanical material property, (ii) a modulus, (iii) a storage modulus, (iv) shear strength, (v) glass transition temperature, (vi) ductility, (vii) hardness and (viii) density.

13. The method according to claim 10 wherein the reaction of the reactive element is one of: (i) a deformation, (ii) a bending, (iii) an expansion, (iv) a contraction, and (v) a twisting.

14. The method according to claim 10 wherein the reactive element is configured to have one of (i) a chemical reaction to the fluid, and (ii) a molecular reaction to the fluid.

15. The method according to claim 10 the reaction is reversible.

16. The method according to claim 10 wherein the flow control device is one of: (i) a valve, and (ii) an orifice; and (iii) a tortuous path.

17. A system for controlling flow of one or more fluids into a wellbore intersecting a subterranean formation, comprising:

(a) a wellbore tubular conveying the one or more fluids to a surface location;

(b) a plurality of flow control devices distributed along a section of the wellbore tubular, each flow control device including a reactive element configured to react when exposed to a fluid, each flow control device being actuated by a reaction of the reactive element to the fluid to control a flow of the fluid into the wellbore tubular.

18. The system according to claim 17 wherein the reactive element is a shape memory polymer.

19. The system according to claim 18 wherein the reaction is one of: (i) an applied compression, and (ii) an applied tension.

20. The system according to claim 18 wherein the flow control device includes an actuating element operably coupled to the reactive element, wherein the reaction releases the actuating element.

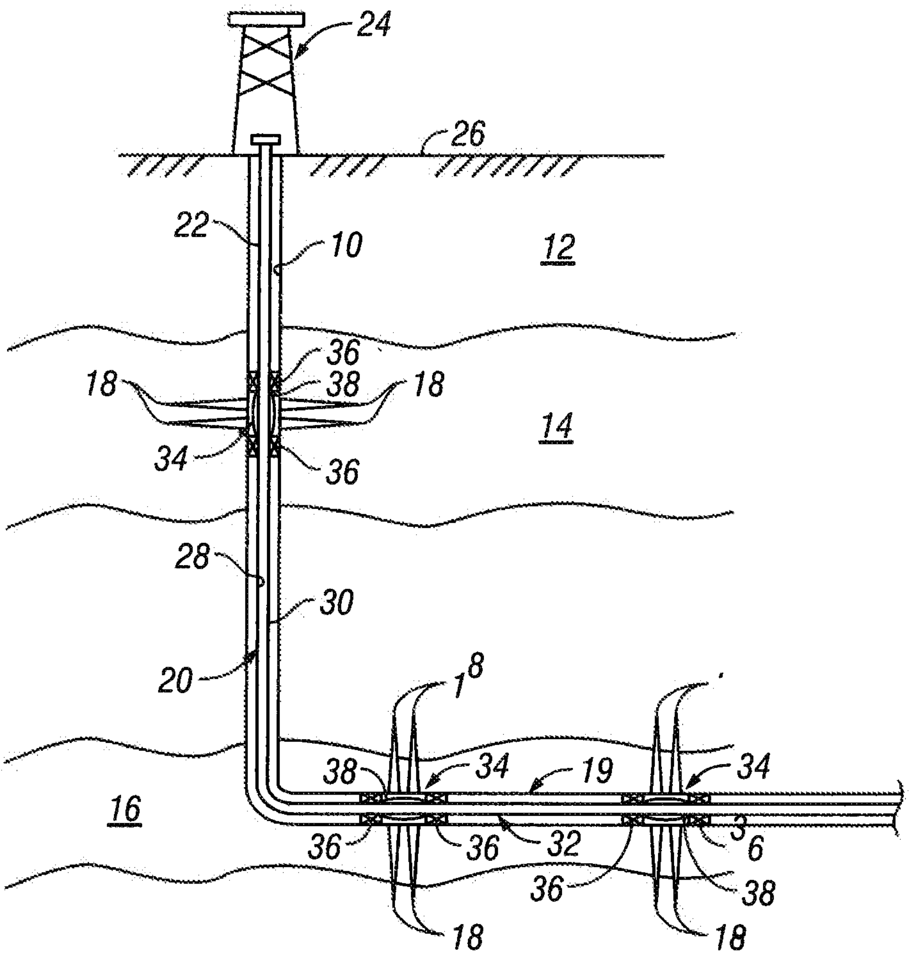
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FIG. 1

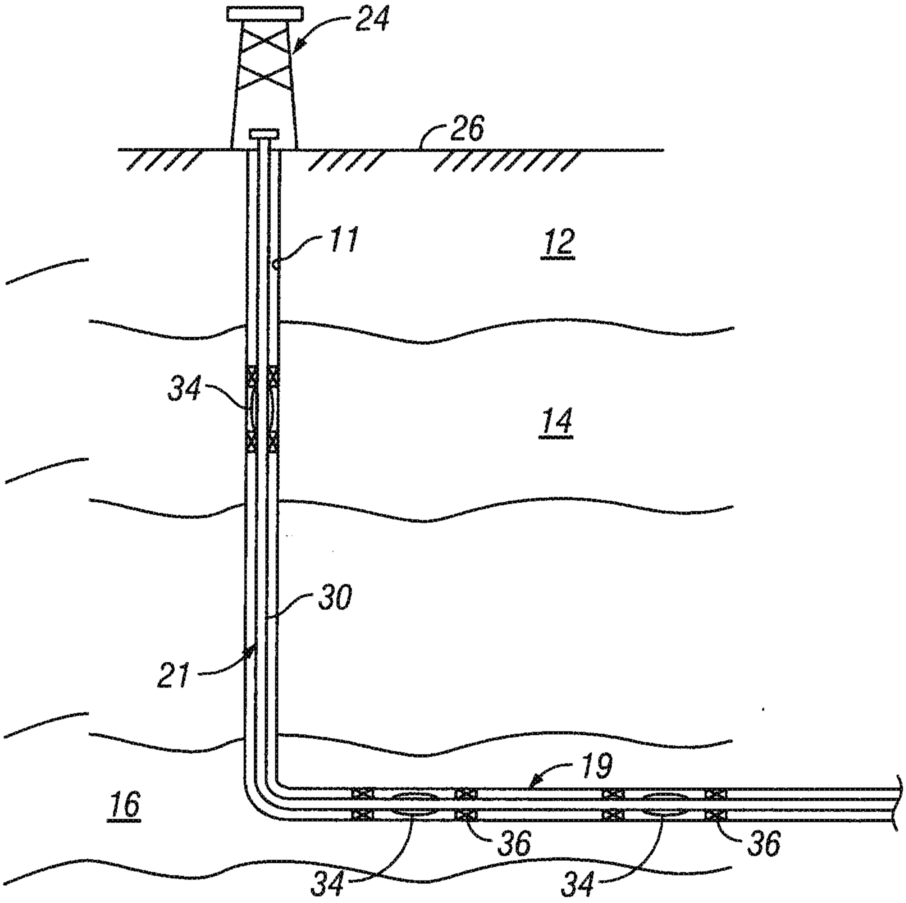
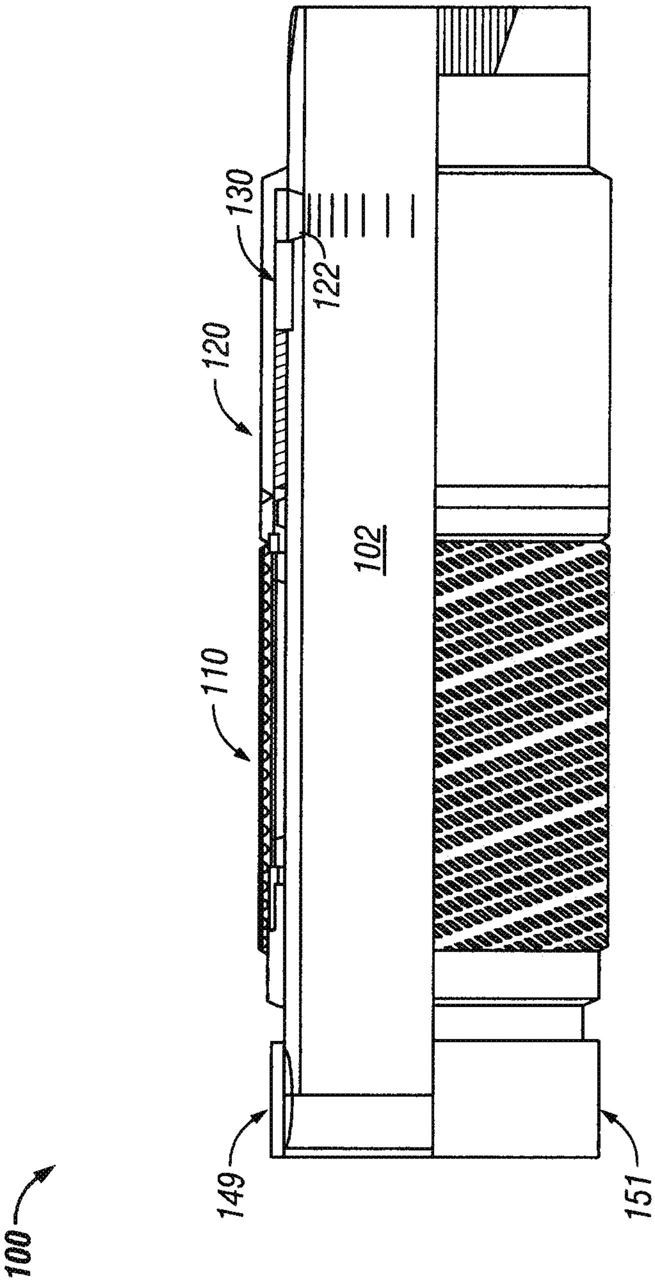


FIG. 2



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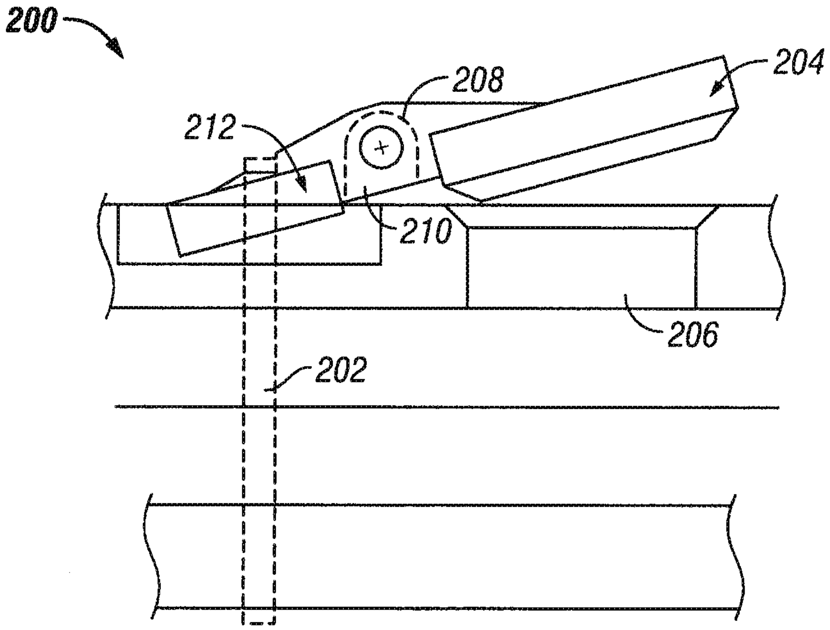

FIG. 4

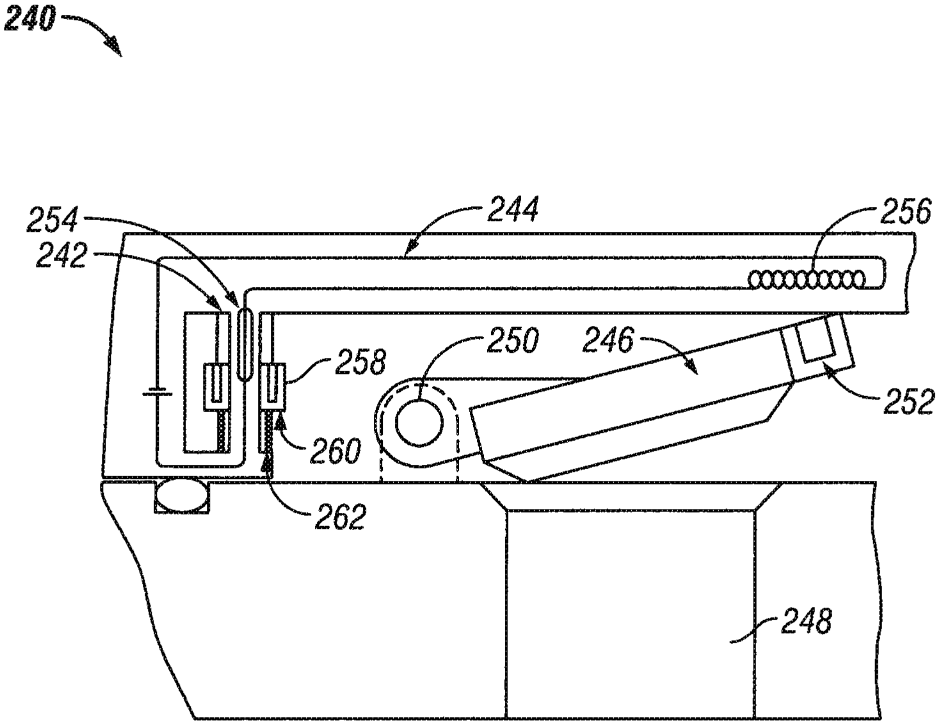

FIG. 5

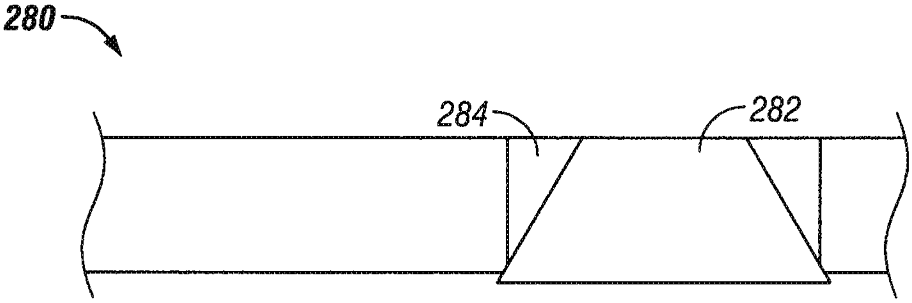

FIG. 6