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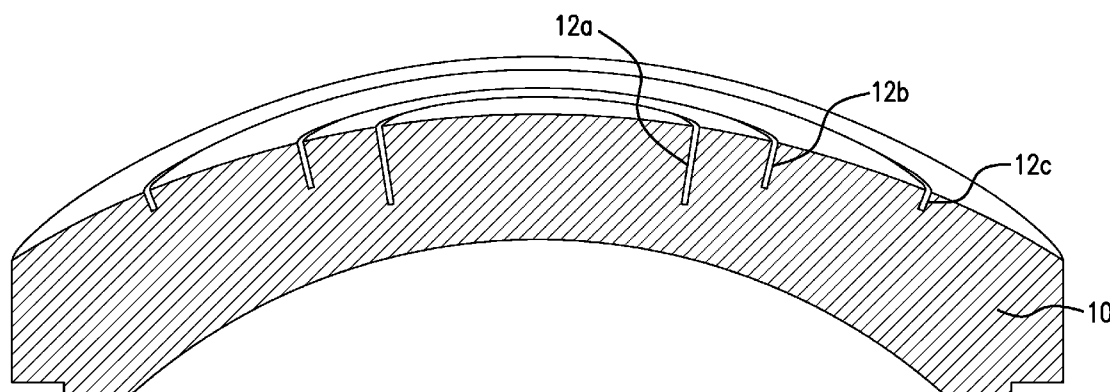


FIG. 2

(57) Abstract: A downhole component includes a body and a stress riser formed in the body. The stress riser being positioned and shaped to promote a full fracture of the body while maintaining a structure of the body to bear force in at least one direction. A downhole system having a tubular string disposed in a borehole.



COMPONENT AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 15/189821, filed on June 22, 2016, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] In downhole industries including hydrocarbon production, CO₂ sequestration, etc. sequences of operations are used to accomplish intended results. Some operations require that components used in the borehole for one operation must be removed from the borehole for other operations. Such components may according to the prior art be retrieved to surface, broken or dissolved away. These methods are effective but carry penalties. Retrieval requires a run in at least one direction, breakup of the component often results in pieces of the component being hazardous to other components due to incomplete breakage and dissolution has a time component that must be selected and if done wrongly for a host of reasons, could occur at a time that is, while expect, inopportune. The art is always receptive to alternative apparatus and methods that improve outcomes.

SUMMARY

[0003] A downhole component includes a body; and a stress riser formed in the body, the stress riser being positioned and shaped to promote a full fracture of the body while maintaining a structure of the body to bear force in at least one direction.

[0004] A downhole system having a tubular string disposed in a borehole including at least one component having a body a stress riser formed in the body, the stress riser being positioned and shaped to promote a full fracture of the body while maintaining a structure of the body to bear force in at least one direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0006] Figure 1 is a perspective representation of a component illustrating stress risers therein in a pattern that supports structural soundness of the component in at least one direction subsequent to fracture along the stress risers;

[0007] Figure 2 is a perspective cross section of Figure 1;

[0008] Figure 3 is essentially the same view of the component as Figure 2 but in place in a safety valve configuration;

[0009] Figure 4 is the view of Figure 3 with the component in a fully fractured condition;

[0010] Figure 5 is a cross sectional representation of another embodiment where the component is flat rather than dome shaped;

[0011] Figure 6 is a perspective view of a holed tubular with another embodiment of the component disclosed herein visible through the holes;

[0012] Figure 7 is a sectional illustration of the view of Figure 6 with one embodiment of the component therein;

[0013] Figure 8 is a sectional illustration of the view of Figure 6 with another embodiment of the component therein;

[0014] Figure 9 is a perspective view of a tubular section having another embodiment of the component disclosed herein illustrated thereon; and

[0015] Figure 10 is a sectional view of Figure 9.

DETAILED DESCRIPTION

[0016] Referring to Figure 1, a component 10 that may be useable in a downhole system is illustrated by itself. In particular the component shown is in the form of a flapper of a flapper valve configuration (visible in figures 3 and 4). It is to be understood that the disclosure hereof is not limited to a flapper as the component 10 but that any component configuration that might benefit from the condition that is taught herein is contemplated and is intended to be encompassed in this disclosure.

[0017] The component 10 comprises a body 11 including a number of stress risers 12. Stress risers 12 may be continuous or discontinuous and may be formed from a plurality of perforations extending at least partially through the body, or may be formed by scoring the body, etc. Patterns and number of the stress risers may vary and are not limited to those illustrated. There may be more or fewer stress risers for a particular iteration of the component 10 as needed provided they are patterned, positioned and oriented to promote full fracture of enough of the stress risers in a particular component 10 to make remaining pieces easily removable without intervention of another tool while maintaining structural integrity in at least one direction after full fracture occurs. Specifically, the pattern and particular degree of stress risers 12 are selected to promote, upon being subjected to an impetus, a full fracture

of stress risers 12 (enough of them to make remaining pieces easily removable without intervention of another tool and in some embodiments all of the stress risers) rather than allowing the component 10 to fracture in one or just a few locations before the magnitude of the impetus is dispersed. Structural integrity as noted is maintained in at least one direction which is important to the full fracture requirement of this disclosure. Because the structure is maintained in at least one direction, the component is capable of maintaining its position in opposition to the force exerted thereon. This means that the stress in the component is also maintained and that therefore all stress risers will form fractures at their threshold values. In an embodiment, the direction is the same direction in which the impetus acts.

[0018] Turning to Figures 2 and 3, the component 10 is shown in cross section such that the stress riser depth is illustrated. The depths 12a, 12b, 12c are selected to promote contemporaneous (close in time) failure of each stress riser. It is noted that it is not necessarily required that the fractures occur in a linear manner such as most radially inward to most radially outward (as shown) or vice versa but rather could be in other orders providing that full fracture of enough of the stress risers does occur that removal of the remaining pieces is achieved without intervention with another tool and structural integrity is maintained in at least one direction after fracture. The stress risers comprise two principal considerations: 1) they are to be spaced out so that the part will separate into a desired number and size of fragments and 2) the stress risers are to be calibrated so that they fail contemporaneously at the same desired force loading. For example, the flapper in Figure 4 is intended to separate into four concentric rings upon application of hydraulic pressure. The diameters of the rings are selected to be small enough to pass through other equipment. The stress risers are then formed (e.g. by cutting, etc.) so that the shear strength of the remaining material in the fracture propagation area around each ring is proportional to the area of that ring. The result for the illustrated embodiment is that all three ring-shaped stress risers fail contemporaneously at about 4000psi. The following formula is derived for cylindrical or frustoconical stress risers on a flat flapper by setting the strength of each riser equal to the hydraulic force acting upon it. The formula is as follows:

[0019] *Equation 1* $A_h = \pi \times r^2$

[0020] A_h = Area that hydraulic pressure is working on

[0021] $\pi = 3.14159...$

[0022] r = radius of circular stress riser.

[0023] This is the formula for force acting on the enclosed area:

[0024] *Equation 2* $F_h = A_h \times P$

[0025] F_h = Hydraulic Force

[0026] P = desired pressure loading to fracture the part (4,000 psi)

[0027] This is the formula for the area of the material that must be sheared, which is a circular band:

[0028] *Equation 3* $A_s = t \times \pi \times 2r$

[0029] A_s = Area of material to shear

[0030] t = thickness of material

[0031] The strength of the stress riser is:

[0032] *Equation 4* $F_s = \tau \times A_s$

[0033] F_s = Force required to shear the material

[0034] τ = shear strength of the material

[0035] For hydraulic actuation, we want F_s (force to shear) to equal F_h (hydraulic force). Solving equations 1 - 4 for t (thickness), we get:

[0036] *Equation 5* $t = \frac{P \times r}{2 \times \tau}$

[0037] t = thickness of remaining material at stress riser

[0038] P = desired pressure loading to fracture the part (4,000 psi)

[0039] r = radius of the stress riser

[0040] τ = shear strength of the material (10,000 psi)

[0041] It is to be understood that if the shape of the component changes from circular to some other shape, corresponding changes in the area formulae will be needed. This will be well understood by one of ordinary skill in the art having been exposed to the derivation set forth above. In some embodiments, one or more additional failure points may be created to fail at a higher loading, to ensure the part will lose structural integrity at a selected time. For the flapper embodiment illustrated in Figure 4, the outermost ring may be configured to break in half along the convex “spine,” 14 (see Figure 1) allowing the other pieces to lose structural integrity.

[0042] Still referring to Figure 4, the component 10 is fully fractured, meaning that all stress risers 12 have reacted to the impetus (imposition of force) whether that force be hydraulic, mechanical, etc. The component 10 illustrated is a flapper of a safety valve 13 disposed in a downhole string 15. For this iteration then, the force is a hydraulic one that acts

against the flapper to close the same. With a pressure delta reaching a threshold such as, for example, 4000 psi the stress risers 12 (Figure 3) cause component comminution into several pieces, 16, 18, 20, and 22. In the Figure, the pieces are annular but this is not required.

[0043] Due to the positioning and shape (dictated by the location and angle of the stress risers) of each piece and its interaction with each adjacent piece, the structure of the component 10 is maintained. More particularly, in Figure 4, the component 10 is a dome (an arch in cross section) and the pieces act as arch stones and a keystone. Consequently, the flapper illustrated will still hold substantial pressure in the direction that closes the flapper. Upon a change of pressure though, or a flow of fluid in the opposite direction, the flapper will break apart into small pieces and can be disposed of by dissolution, entrainment with fluid flow, falling to the bottom of the well, etc.

[0044] In another embodiment, referring to Figure 5 component 30 having a body 31 is configured as another flapper embodiment that is flat rather than dome shaped yet still be capable of operating according to the principles hereof. In one iteration, the stress risers 32 are frustoconical in shape with a wider portion 34 of the frustocone being against the direction of the application of force on the flapper. The stress risers may initially be complete frustocones or may be intermittent such that they will produce a frustoconical fracture of the component 30 when subjected to the force. The structure remains intact because the wider portion 34 of the frustocones is physically urged against an inner surface 36 of the next radially outward frustocone as illustrated. Continued application of the force maintains the flapper in the same position. Application of increased force above a threshold causes the component 30 to break up. Alternatively, a flow in the opposite direction as in the previously described embodiment will also result in the flapper 30 breaking up into small pieces.

[0045] For each embodiment hereof, the material of the component may be dissolvable or nondissolvable. Where dissolvable material is employed, the breaking up of the component will expose a greater surface area of the dissolvable material and hence increase the speed of dissolution. Where the material is not dissolvable, the component still will break up into small enough pieces to not represent a problem to other operations.

[0046] In other embodiments (see Figures 6-10), the body 40(a, b, and c) is a sleeve comprising a dissolvable material that includes stress risers 42. The sleeve is positioned adjacent (inside for Figures 6-7 (40a) and 6 and 8 (40b) and outside for Figures 9-10 (40c)) a tubular 44 having ports 46 therein. The tubular 44 may be a part of a borehole string. The body 40 initially occludes flow through the ports 46 and will hold a pressure differential. In

Figures 6-8, the tubular 44 will radially outwardly bound the body 40a or 40c while in Figures 9-10 the body 40b is radially outwardly bound by rings 48 positioned at an outside diameter of the body 40b to hold the body together after fracture and until dissolution. Upon fracturing of the body 40, it will still hold pressure from within the tubular 44 but dissolution time will decrease due to surface area rise and the pieces of body 40 will fall away leaving the ports 46 unencumbered after the pressure from the tubular 44 is relieved. Stress risers 42 may be continuous or discontinuous and may be formed from a plurality of perforations extending at least partially through the body, or may be formed by scoring the body, etc. Patterns, angles, and number of the stress risers may vary and are not limited to those illustrated. There may be more or fewer stress risers for a particular iteration of the body 40 as needed provided they are patterned, positioned and oriented to promote full fracture of enough of the stress risers in a particular body 40 to make remaining pieces easily removable without intervention of another tool while maintaining structural integrity in at least one direction after full fracture occurs. When the body 40 is broken by pressure, the individual pieces are small but still capable of holding pressure due to their shapes being directed by the stress risers so that multiple zones can be pressurized at the same time and actuated. The patterning of the stress risers ensures that the body 40 will when fractured hold pressure from the inside. It will be appreciated from Figures 6-10 that stress risers 42 may be radially oriented 50 or may be axially oriented 52. Others are also contemplated. In some iterations, fluid flow from the outside to the inside is permitted with some minor sand screen effect. In a period of time that is pre-selected the broken up pieces will dissolve leaving the ports open for flow.

[0047] In each of the foregoing embodiments, it is further contemplated to add a coating 60 on a surface of the component such as the “face” of the flapper shown partially in Figure 1 that acts to hold the pieces together until the desired time of structural integrity loss and improve pressure holding capability of the component post fracture and pre structural loss. The coating may be in the form of a layer of material such as rubber, some other polymer, an epoxy, etc.

[0048] In each of the foregoing embodiments may be incorporated into a downhole system that comprises a string such that the component may be used in conjunction with the production of hydrocarbons for example.

[0049] Set forth below are some embodiments of the foregoing disclosure:

[0050] Embodiment 1: A downhole component comprising: a body; and a stress riser formed in the body, the stress riser being positioned and shaped to promote a full fracture of the body while maintaining a structure of the body to bear force in at least one direction.

[0051] Embodiment 2: The component of any of the preceding embodiments wherein the stress riser is continuous.

[0052] Embodiment 3: The component of any of the preceding embodiments wherein the stress riser is discontinuous.

[0053] Embodiment 4: The component of any of the preceding embodiments wherein the stress riser is a plurality of perforations extending at least partially through the body.

[0054] Embodiment 5: The component of any of the preceding embodiments wherein the stress riser is a score.

[0055] Embodiment 6: The component of any of the preceding embodiments wherein the stress riser is shaped as a ring.

[0056] Embodiment 7: The component of any of the preceding embodiments wherein the stress risers are positioned configured and dimensioned such that remaining shear strength of material in a fracture propagation area of the stress riser around each ring is proportional to an area of that ring.

[0057] Embodiment 8: The component of any of the preceding embodiments wherein the stress riser is shaped, as a frustocone.

[0058] Embodiment 9: The component of any of the preceding embodiments wherein the body is a flapper.

[0059] Embodiment 10: The component of any of the preceding embodiments wherein the flapper is dome shaped.

[0060] Embodiment 11: The component of any of the preceding embodiments wherein the flapper is flat.

[0061] Embodiment 12: The component as of any of the preceding embodiments where in the body is a sleeve.

[0062] Embodiment 13: The component of any of the preceding embodiments where in the sleeve includes axially oriented stress risers.

[0063] Embodiment 14: The component of any of the preceding embodiments where in the sleeve includes radially oriented stress risers.

[0064] Embodiment 15: The component of any of the preceding embodiments where in the body includes a coating to enhance pressure holding capability.

[0065] Embodiment 16: The component of any of the preceding embodiments where in the coating is a rubber, other polymer or epoxy.

[0066] Embodiment 17: A downhole system having a tubular string disposed in a borehole comprising at least one component having a body a stress riser formed in the body, the stress riser being positioned and shaped to promote a full fracture of the body while maintaining a structure of the body to bear force in at least one direction.

[0067] Embodiment 18: The system of any of the preceding embodiments wherein the body is a flapper.

[0068] Embodiment 19: The system of any of the preceding embodiments wherein the body is a sleeve.

[0069] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Further, it should further be noted that the terms “first,” “second,” and the like herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the particular quantity).

[0070] The teachings of the present disclosure may be used in a variety of well operations. These operations may involve using one or more treatment agents to treat a formation, the fluids resident in a formation, a wellbore, and / or equipment in the wellbore, such as production tubing. The treatment agents may be in the form of liquids, gases, solids, semi-solids, and mixtures thereof. Illustrative treatment agents include, but are not limited to, fracturing fluids, acids, steam, water, brine, anti-corrosion agents, cement, permeability modifiers, drilling muds, emulsifiers, demulsifiers, tracers, flow improvers etc. Illustrative well operations include, but are not limited to, hydraulic fracturing, stimulation, tracer injection, cleaning, acidizing, steam injection, water flooding, cementing, etc.

[0071] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this

invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited.

CLAIMS:

1. A downhole component (10) comprising:
a body (11); and
a stress riser (12, 32, 42) formed in the body (11), the stress riser (12, 32, 42) being positioned and shaped to promote a full fracture of the body (11) while maintaining a structure of the body (11) to bear force in at least one direction.
2. The component (10) as claimed in claim 1 wherein the stress riser (12, 32, 42) is continuous.
3. The component (10) as claimed in claim 1 wherein the stress riser (12, 32, 42) is shaped as a ring (48).
4. The component (10) as claimed in claim 3 wherein the stress risers (12, 32, 42) are positioned configured and dimensioned such that remaining shear strength of material in a fracture propagation area of the stress riser (12, 32, 42) around each ring (48) is proportional to an area of that ring (48).
5. The component (10) as claimed in claim 1 wherein the stress riser (12, 32, 42) is shaped, as a frustocone.
6. The component (10) as claimed in claim 1 wherein the body (11) is a flapper (30).
7. The component (10) as claimed in claim 6 wherein the flapper (30) is dome shaped.
8. The component (10) as claimed in claim 1 where in the body (11) is a sleeve.
9. The component (10) as claimed in claim 8 where in the sleeve includes axially oriented (52) stress risers (12, 32, 42).
10. The component (10) as claimed in claim 8 where in the sleeve includes radially oriented (50) stress risers (12, 32, 42).
11. The component (10) as claimed in claim 1 where in the body includes a coating (60) to enhance pressure holding capability.
12. The component (10) as claimed in claim 11 where in the coating (60) is a rubber, other polymer or epoxy.
13. A downhole system having a tubular string disposed in a borehole comprising at least one component (30) having a body (40) a stress riser (12, 32, 42) formed in the body (31), the stress riser (12, 32, 42) being positioned and shaped to promote a full fracture of the body (31) while maintaining a structure of the body (31) to bear force in at least one direction.

14. The system as claimed in claim 13 wherein the body (40) is a flapper (30).
15. The system as claimed in claim 13 wherein the body (40) is a sleeve.

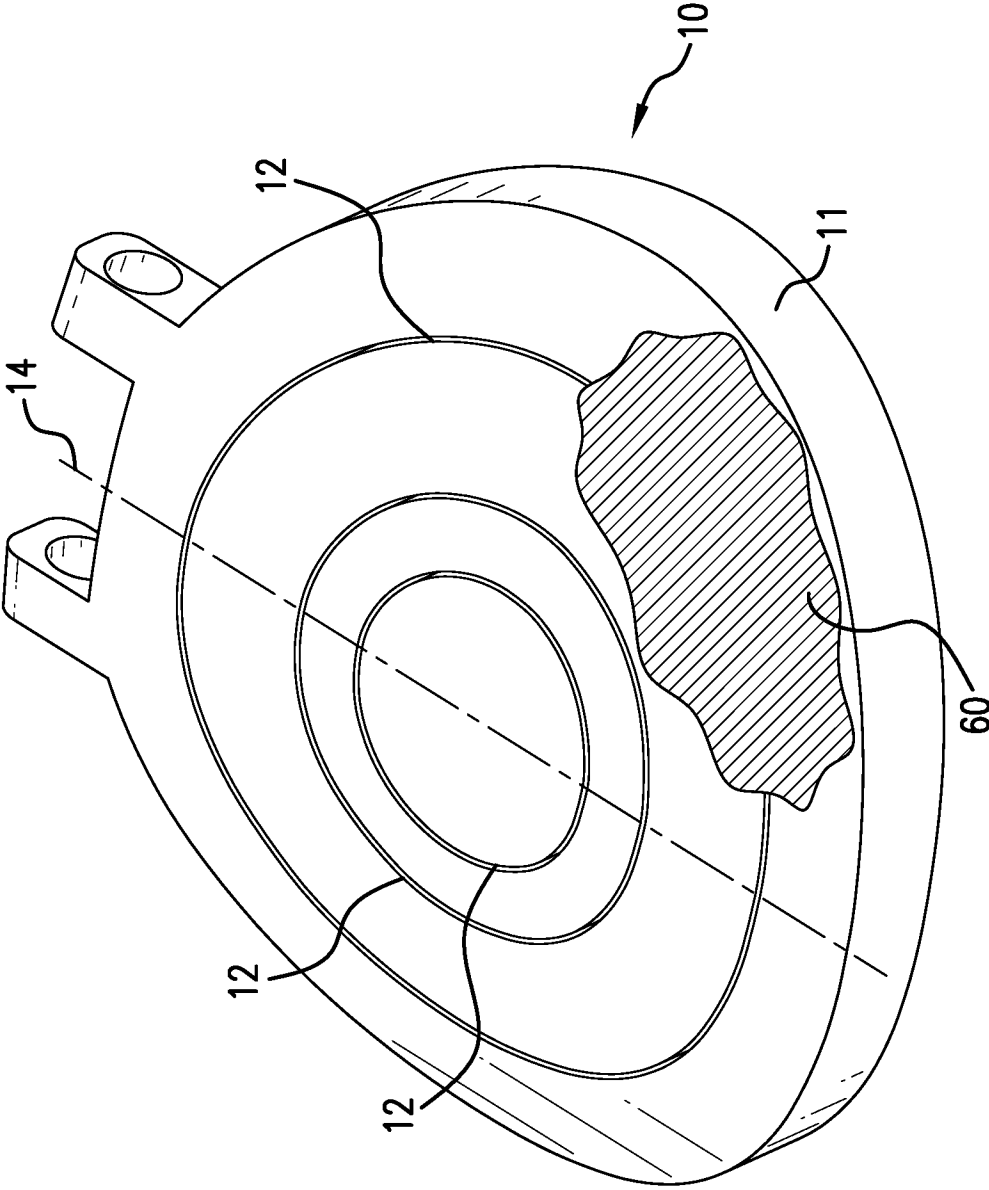


FIG. 1

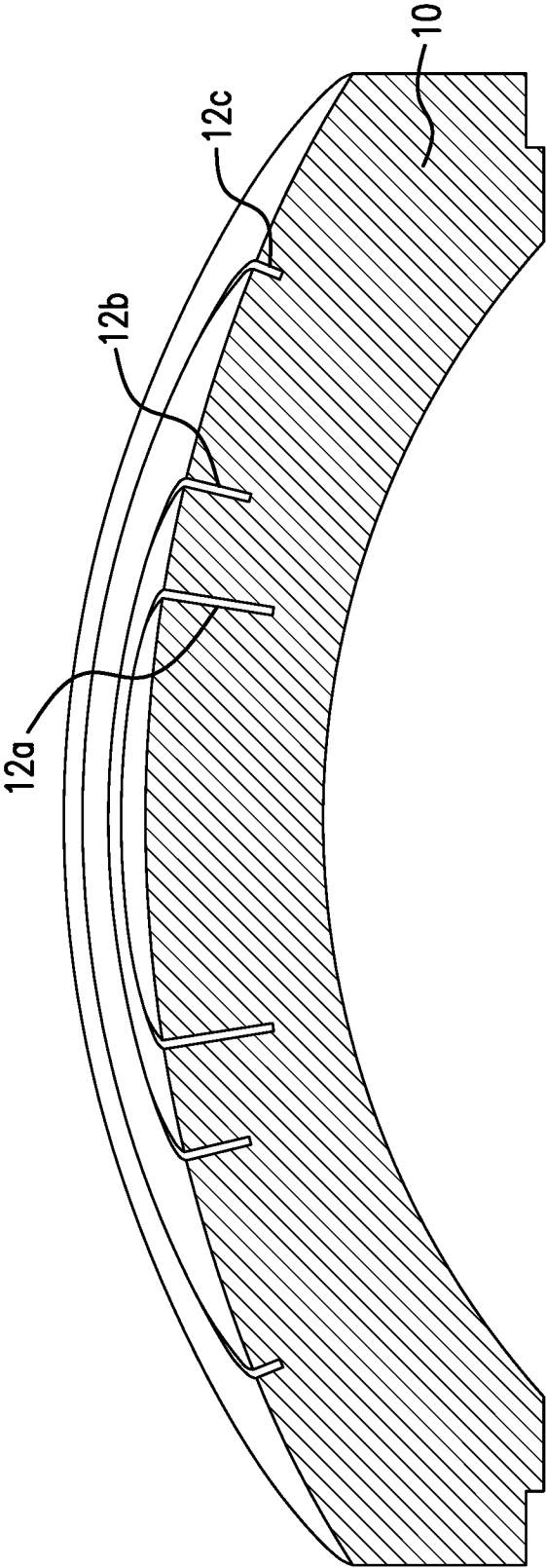


FIG. 2

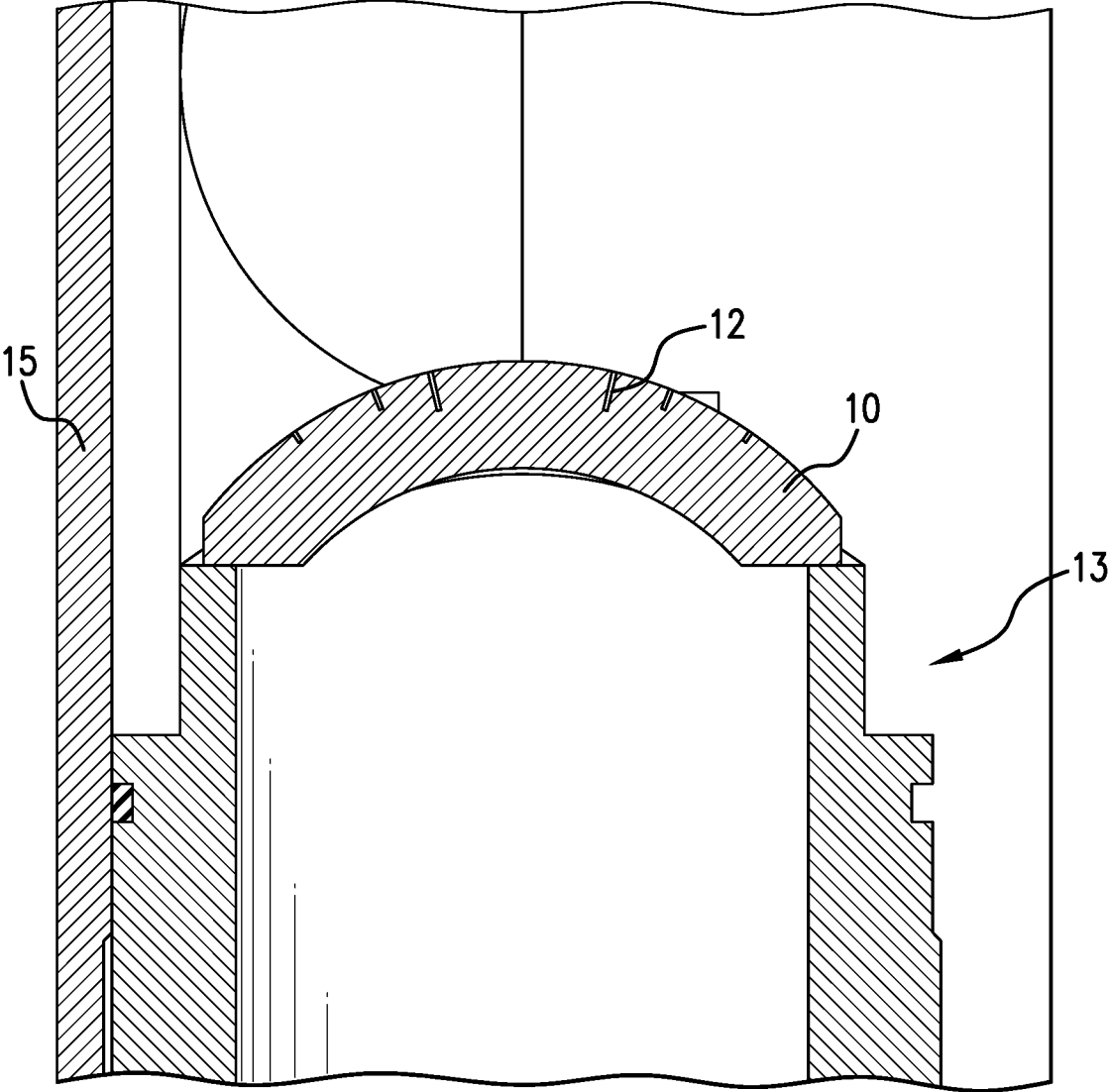


FIG.3

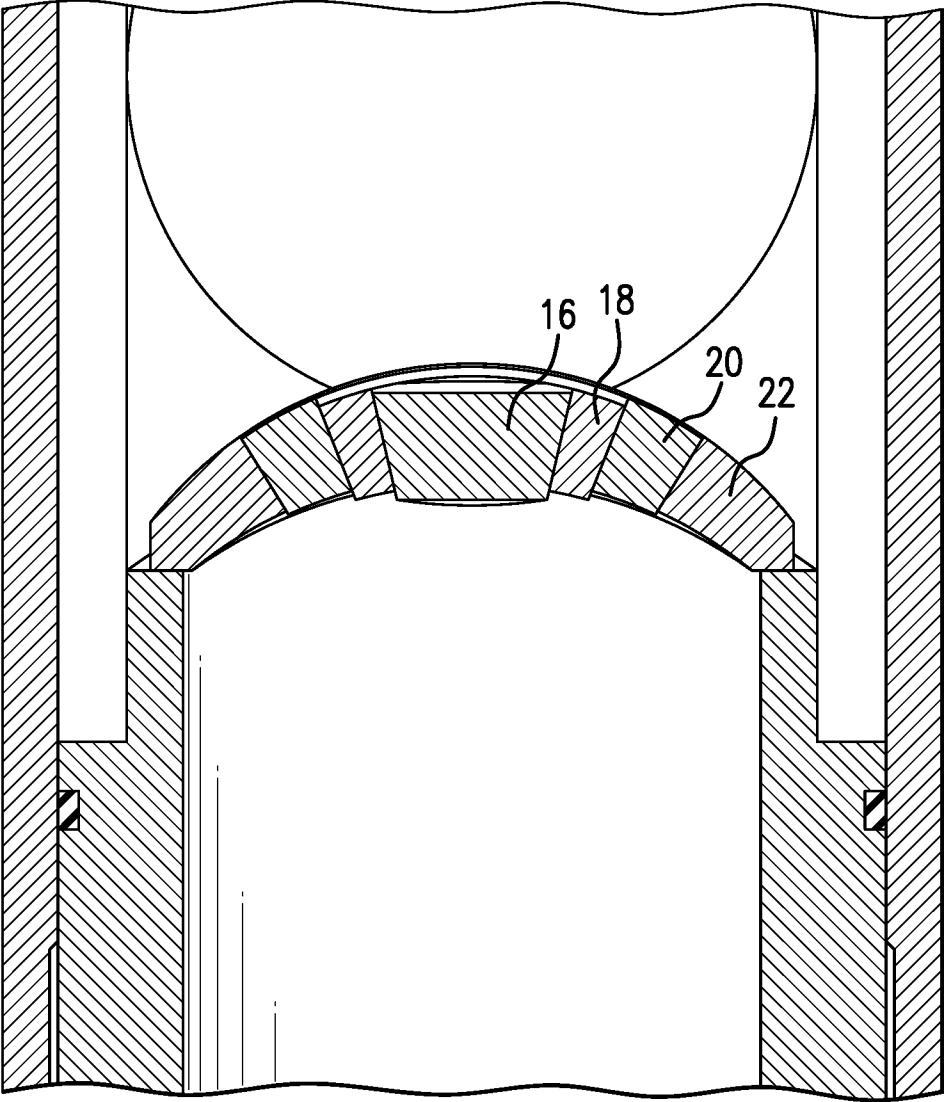


FIG.4

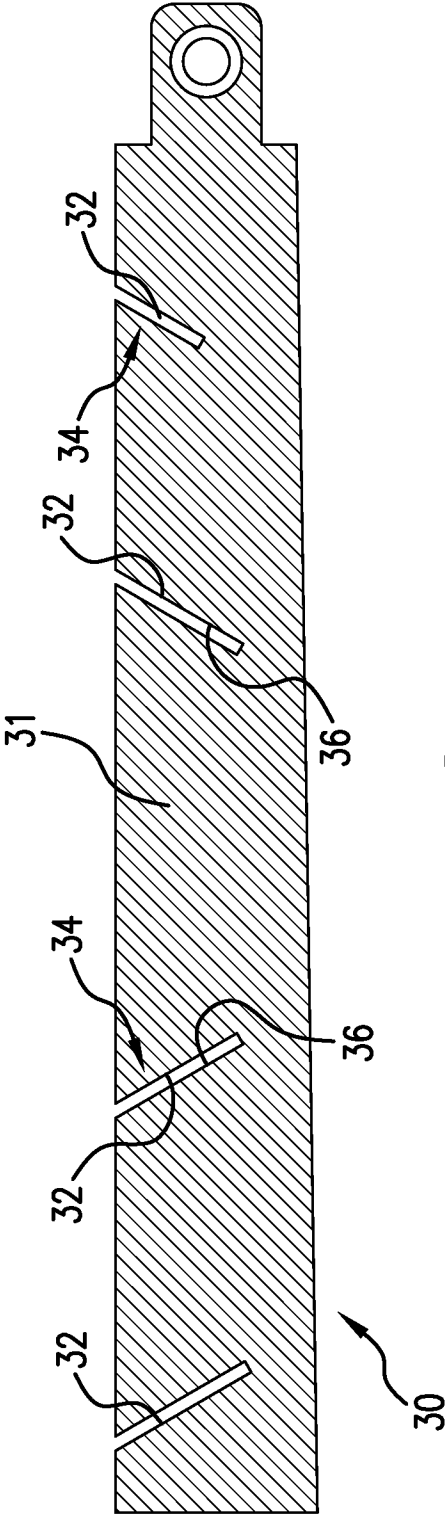


FIG. 5

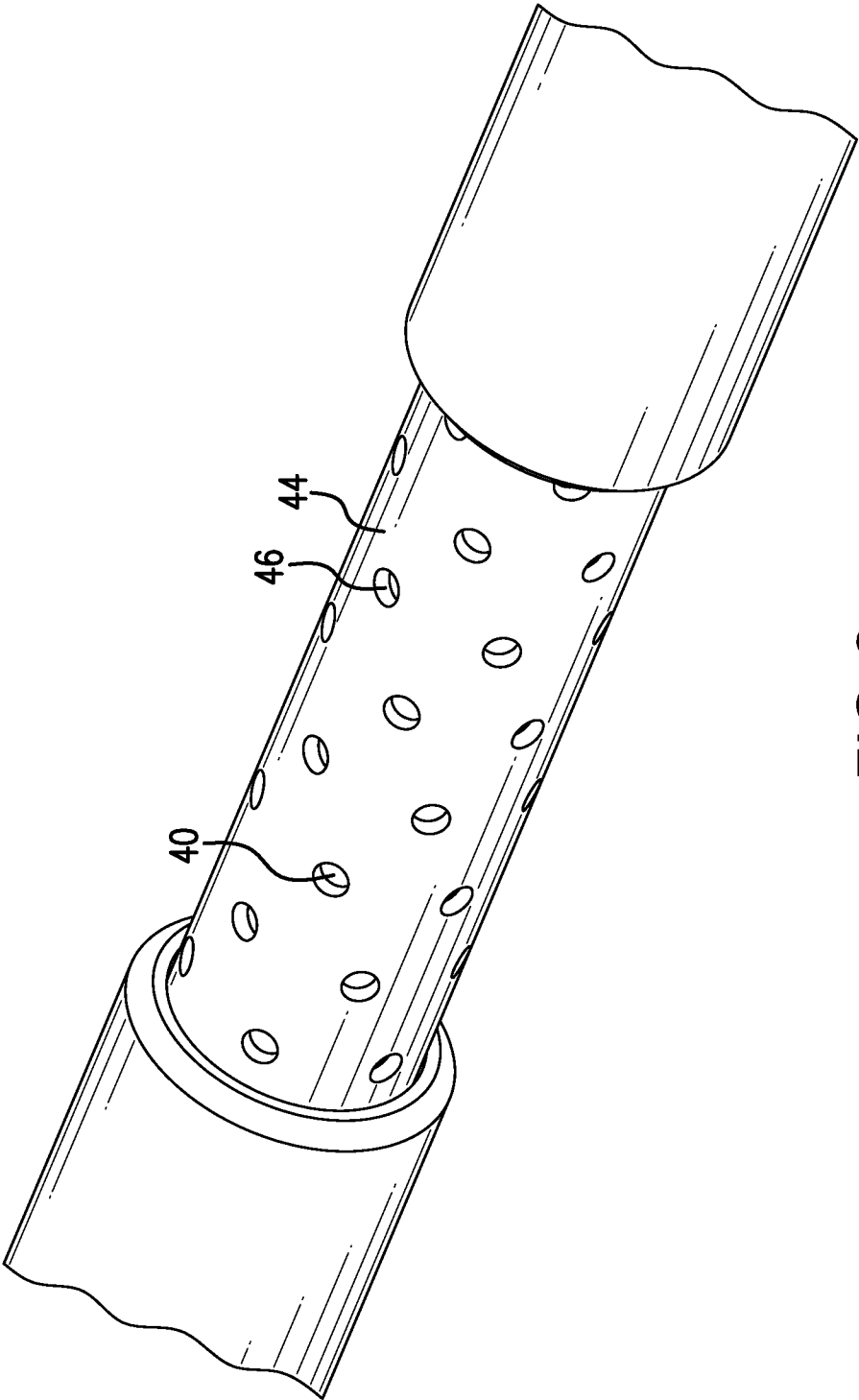


FIG. 6

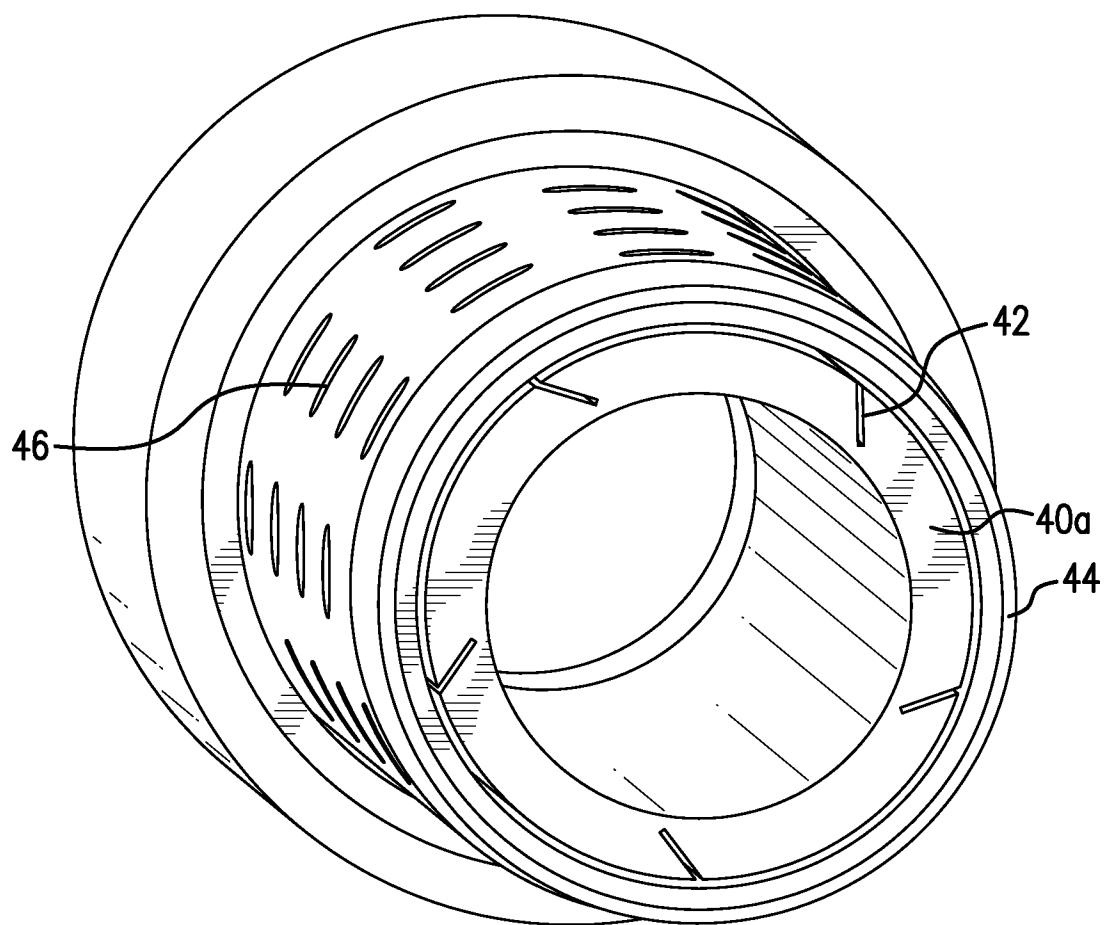


FIG. 7

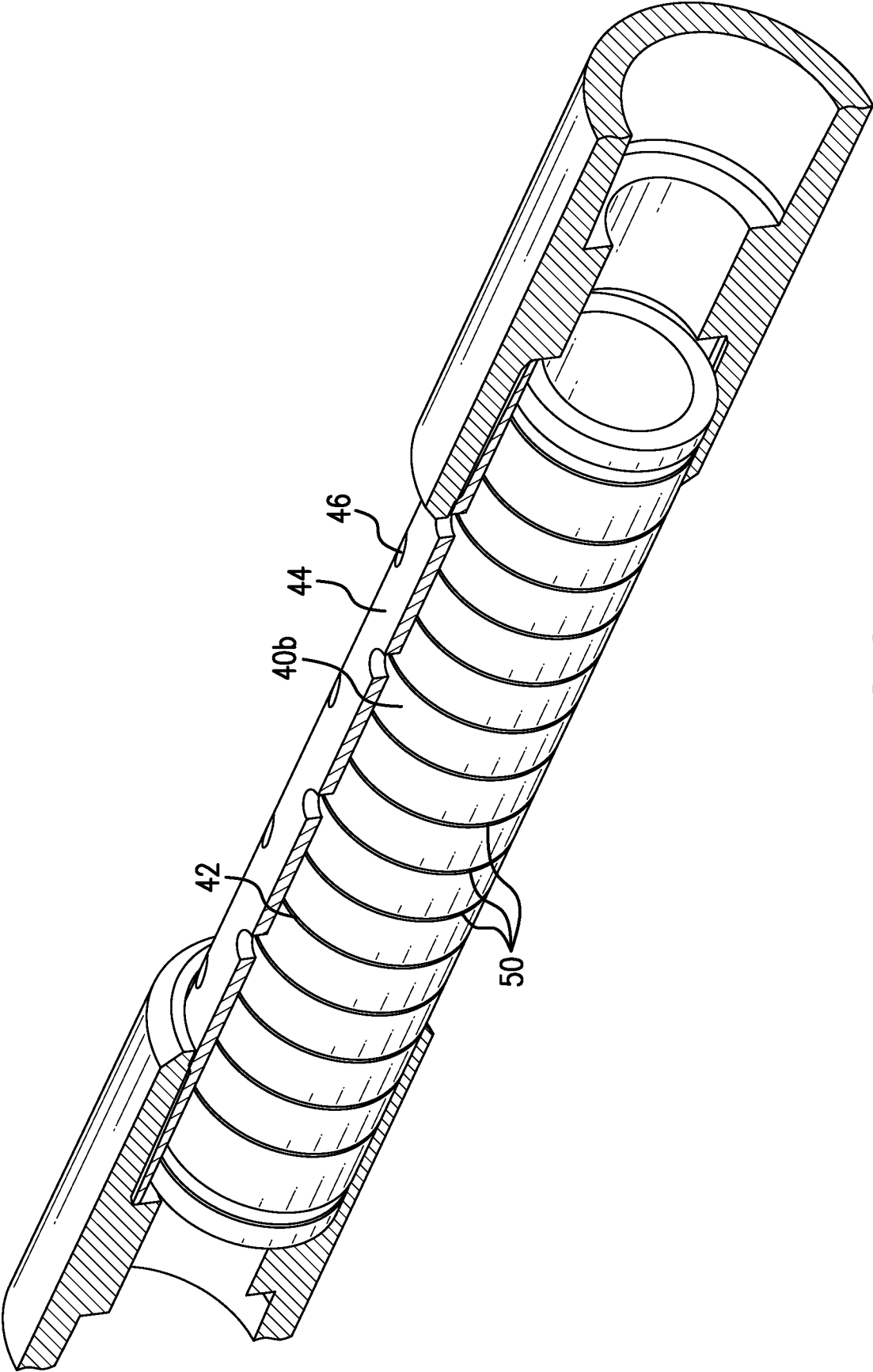


FIG. 8

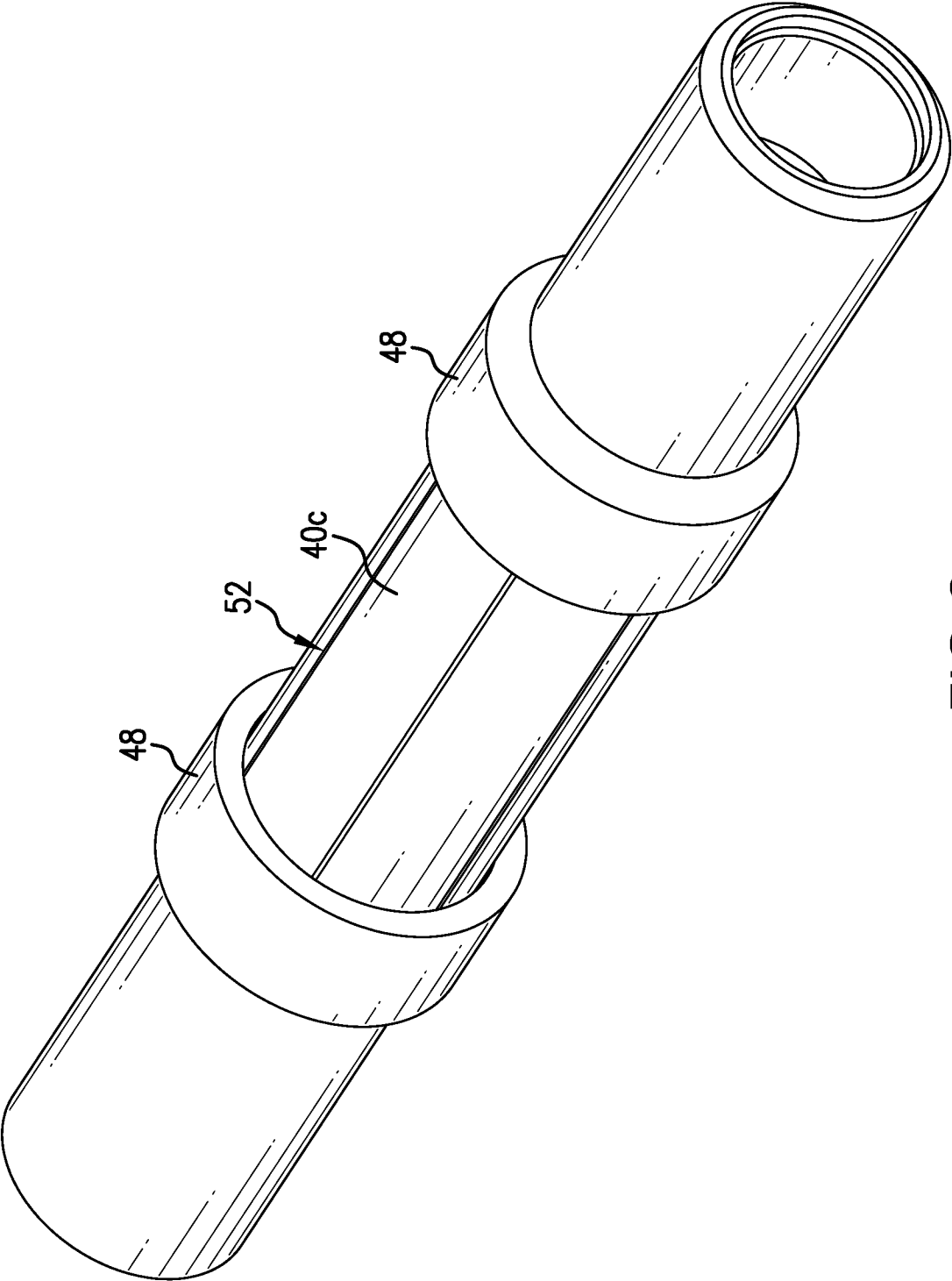


FIG. 9

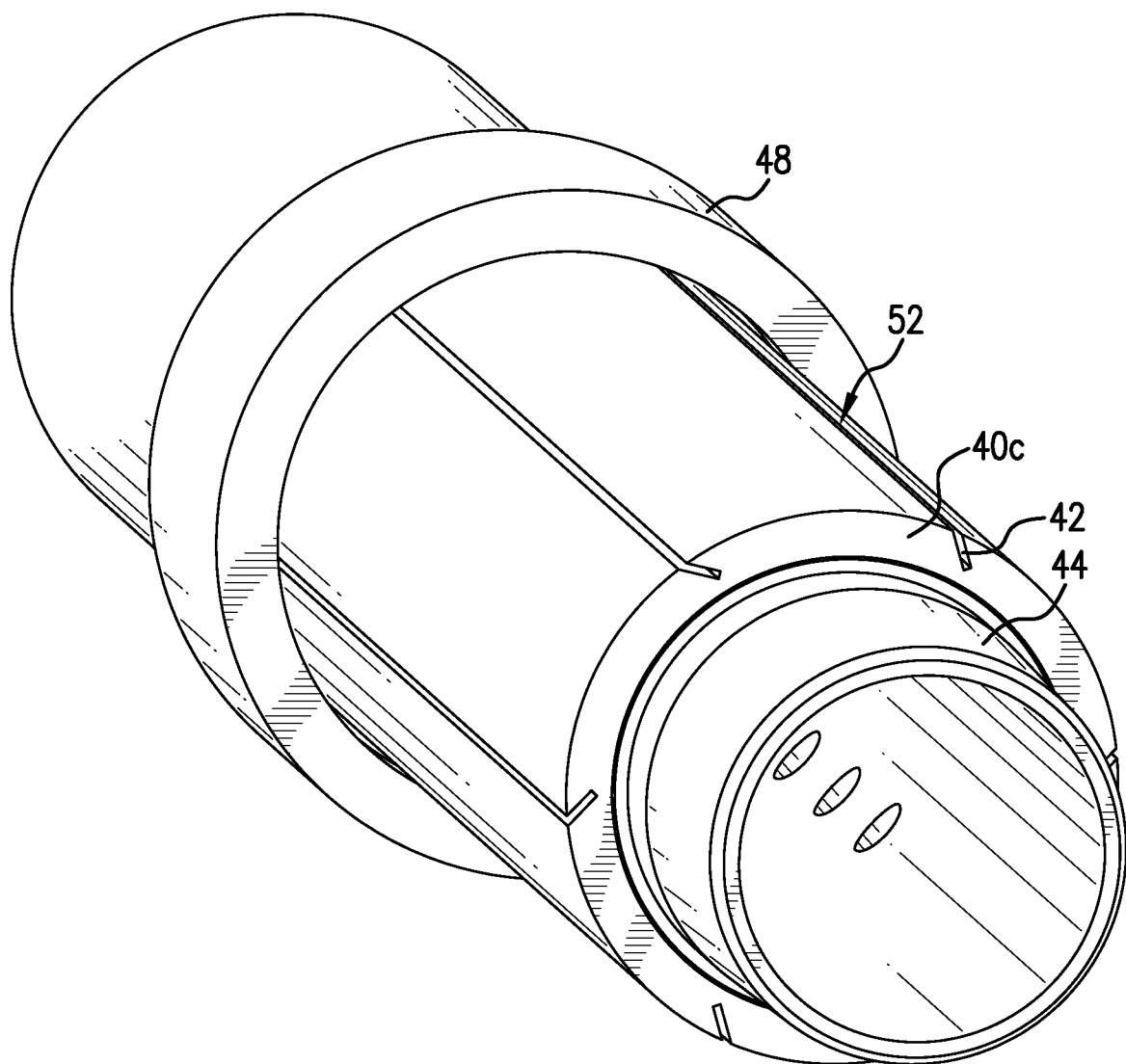


FIG. 10

A. CLASSIFICATION OF SUBJECT MATTER**E21B 17/01(2006.01)i, E21B 34/02(2006.01)i, E21B 34/00(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 17/01; E21B 43/263; E21B 34/06; E21B 43/116; E21B 19/00; E21B 29/00; E21B 23/00; B21K 5/04; E21B 34/02; E21B 34/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: stress, riser, raiser, concentration, flapper, sleeve and coating

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015-0191986 A1 (DENG, GUIJUN et al.) 09 July 2015 See paragraphs [0011]–[0017] and figures 1–4.	1–8, 13–15
Y		9–12
Y	US 2016-0153272 A1 (LOS ALAMOS NATIONAL SECURITY, L.L.C.) 02 June 2016 See paragraphs [0120]–[0121], [0146]–[0151] and figures 10, 27–32.	9–12
A	US 2011-0132619 A1 (AGRAWAL, GAURAV et al.) 09 June 2011 See paragraphs [0024]–[0062] and figures 1–10.	1–15
A	US 2011-0056702 A1 (SHARMA, ASHISH et al.) 10 March 2011 See paragraphs [0021]–[0042] and figures 1–7.	1–15
A	US 2010-0300690 A1 (AL BUSAIDY, ADIL MAHALLAB) 02 December 2010 See paragraphs [0024]–[0038] and figures 1–11.	1–15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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