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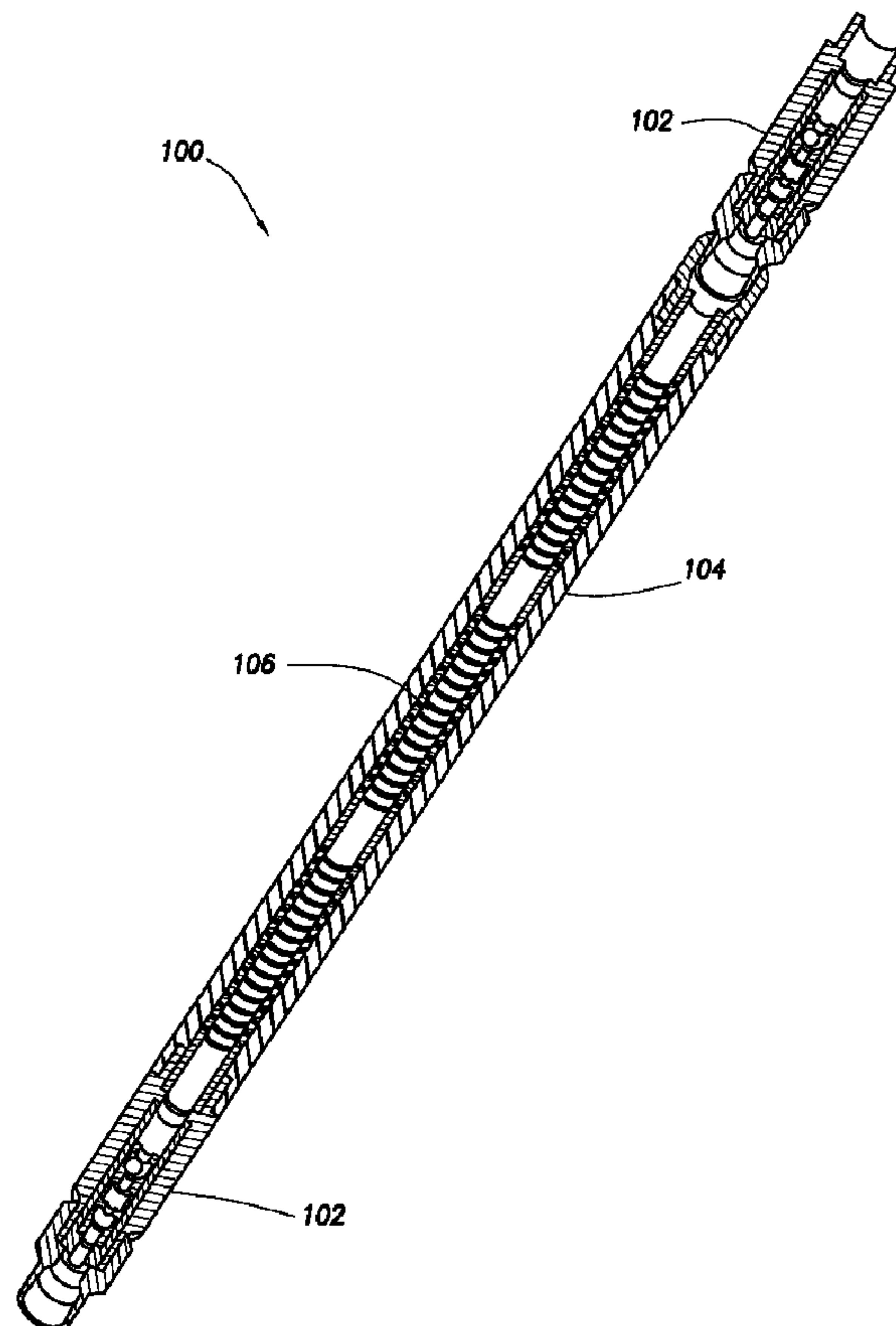
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(54) Title: METHODS AND EQUIPMENT TO IMPROVE RELIABILITY OF PINPOINT STIMULATION OPERATIONS



(57) Abrégé/Abstract:

Apparatuses and methods for improving the reliability of pinpoint stimulation operations are disclosed. The pinpoint stimulation improvement apparatus includes an elastomeric element and a spring positioned on an inner surface of the elastomeric element. A flow limiter is coupled to the elastomeric element.

METHODS AND EQUIPMENT TO IMPROVE RELIABILITY OF PINPOINT STIMULATION OPERATIONS

ABSTRACT OF THE INVENTION

Apparatuses and methods for improving the reliability of pinpoint stimulation operations are disclosed. The pinpoint stimulation improvement apparatus includes an elastomeric element and a spring positioned on an inner surface of the elastomeric element. A flow limiter is coupled to the elastomeric element.

METHODS AND EQUIPMENT TO IMPROVE RELIABILITY OF PINPOINT STIMULATION OPERATIONS

BACKGROUND

[0001] The present invention relates to subterranean stimulation operations and, more particularly, to apparatuses and methods for improving the reliability of pinpoint stimulation operations.

[0002] To produce hydrocarbons (*e.g.*, oil, gas, etc.) from a subterranean formation, well bores may be drilled that penetrate hydrocarbon-containing portions of the subterranean formation. The portion of the subterranean formation from which hydrocarbons may be produced is commonly referred to as a "production zone." In some instances, a subterranean formation penetrated by the well bore may have multiple production zones at various locations along the well bore.

[0003] Generally, after a well bore has been drilled to a desired depth, completion operations are performed. Such completion operations may include inserting a liner or casing into the well bore and, at times, cementing a casing or liner into place. Once the well bore is completed as desired (lined, cased, open hole, or any other known completion) a stimulation operation may be performed to enhance hydrocarbon production into the well bore. Where methods of the present invention reference "stimulation," that term refers to any stimulation technique known in the art for increasing production of desirable fluids from a subterranean formation adjacent to a portion of a well bore. Examples of some common stimulation operations involve hydraulic fracturing, acidizing, fracture acidizing, and hydrazetting. Stimulation operations are intended to increase the flow of hydrocarbons from the subterranean formation surrounding the well bore into the well bore itself so that the hydrocarbons may then be produced up to the wellhead.

[0004] One suitable hydrazet stimulation method, introduced by Halliburton Energy Services, Inc., is known as the SURGIFRAC and is described in U.S. Pat. No. 5,765,642. The SURGIFRAC process may be particularly well suited for use along highly deviated portions of a well bore, where casing the well bore may be difficult and/or expensive. The SURGIFRAC hydrazetting technique makes possible the generation of one or more independent, single plane hydraulic fractures. Furthermore, even when highly deviated or horizontal wells are cased,

hydramjetting the perforations and fractures in such wells generally result in a more effective fracturing method than using traditional perforation and fracturing techniques.

[0005] Another suitable hydramjet stimulation method, introduced by Halliburton Energy Services, Inc., is known as the COBRAMAX-H and is described in U.S. Pat. No. 7,225,869. The COBRAMAX-H process may be particularly well suited for use along highly deviated portions of a well bore. The COBRAMAX-H technique makes possible the generation of one or more independent hydraulic fractures without the necessity of zone isolation, can be used to perforate and fracture in a single down hole trip, and may eliminate the need to set mechanical plugs through the use of a proppant slug.

[0006] Current pinpoint stimulation techniques suffer from a number of disadvantages. For instance, during hydramjetting operations, the movements of the hydramjetting tool generally reduces the tool performance. The movements of the hydramjetting tool may be caused by the extension or shrinkage of the pipe or the tremendous turbulence around the tool. The reduction in tool performance is generally compensated by longer jetting times so that a hole is eventually created. However, the increase in jetting times leads to an inefficient and time consuming hydramjetting process.

[0007] The COBRAMAX-H process also suffers from some drawbacks. Specifically, the COBRAMAX-H process involves isolating the hydramjet stimulated zones from subsequent well operations. The primary sealing of the previous regions in the COBRAMAX-H process is achieved by placing sand plugs in the zones to be isolated. The placement of sand plugs, particularly in horizontal well bores, requires a very low flow rate which is difficult to achieve when using surface pumping equipment. Moreover, when the operating pressures are high, the orifices of the tool must be very small to create a low flow rate. The small size of the orifices makes them susceptible to plugging.

[0008] Finally, the SURGIFRAC process which uses the Bernoulli principle to achieve sealing between fractures poses certain challenges. During the SURGIFRAC process, the primary flow goes to the fracture while the secondary, leakoff flow, is supplied by the annulus. In some instances, such as in long horizontal well bores, a large number of fractures may be desired. The formation of each fracture results in some additional leakoff. Consequently, with the increase in the number of fractures, the amount of the secondary, leakoff

flow increases and eventually exceeds the amount of the primary flow to the fracture. The increased fluid losses reduces the efficiency of the operations and increases the cost.

SUMMARY

[0009] The present invention relates to subterranean stimulation operations and, more particularly, to apparatuses and methods for improving the reliability of pinpoint stimulation operations.

[0010] In one embodiment, the present invention is directed to a pinpoint stimulation improvement apparatus comprising: an elastomeric element; a spring positioned on an inner surface of the elastomeric element; and a flow limiter coupled to the elastomeric element.

[0011] In another embodiment, the present invention is directed to a flow limiter device, comprising: an inner tubing; a pressure reducing channel on an outer surface of the inner tubing; an inlet from the inside of the inner tubing to the pressure reducing channel; and an outlet from the pressure reducing channel to the inside of the inner tubing.

[0012] In yet another embodiment, the present invention is directed to a pressure control module comprising: a seat body, wherein the seat body may be sealed within an outer body; an opening on the seat body; and a ball, wherein the ball is inserted in to the seat body through the opening.

[0013] In another embodiment, the present invention is directed to a method of creating a sand plug comprising: pumping a process fluid through a pinpoint stimulation improvement apparatus; passing the process fluid through a flow limiter device, wherein passing the process fluid through a flow limiter device comprises passing the process fluid through a pressure reduction channel; introducing the process fluid at a desired location; and creating a sand plug at the desired location.

[0014] In one embodiment, the present invention is directed to a method of improving the performance of a stimulation jetting tool comprising: pumping a process fluid through the stimulation jetting tool; passing a portion of the process fluid through a pinpoint stimulation improvement apparatus, wherein the pinpoint stimulation improvement apparatus comprises: an elastomeric element; a spring positioned on an inner surface of the elastomeric

element; and a flow limiter coupled to the elastomeric element; and expanding the elastomeric element to form a hold down mechanism for the stimulation jetting tool.

[0015] The features and advantages of the present invention will be apparent to those skilled in the art from the description of the preferred embodiments which follows when taken in conjunction with the accompanying drawings. While numerous changes may be made by those skilled in the art, such changes are within the spirit of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] These drawings illustrate certain aspects of some of the embodiments of the present invention, and should not be used to limit or define the invention.

[0017] FIGURE 1 is a perspective view of a Pinpoint Stimulation Improvement Apparatus in accordance with an exemplary embodiment of the present invention.

[0018] FIGURE 2 is a cross-sectional comparison of an inflatable packer with a hold down implementation of a Pinpoint Stimulation Improvement Apparatus in accordance with an exemplary embodiment of the present invention.

[0019] FIGURE 3 is a flow limiter in accordance with an exemplary embodiment of the present invention.

[0020] While embodiments of this disclosure have been depicted and described and are defined by reference to example embodiments of the disclosure, such references do not imply a limitation on the disclosure, and no such limitation is to be inferred. The subject matter disclosed is capable of considerable modification, alteration, and equivalents in form and function, as will occur to those skilled in the pertinent art and having the benefit of this disclosure. The depicted and described embodiments of this disclosure are examples only, and not exhaustive of the scope of the disclosure.

DETAILED DESCRIPTION

[0021] The present invention relates to subterranean stimulation operations and, more particularly, to apparatuses and methods for improving the reliability of pinpoint stimulation operations.

[0022] Turning now to Figure 1, a Pinpoint Stimulation Improvement Apparatus (PSIA) in accordance with an exemplary embodiment of the present invention is denoted generally by reference numeral 100. The PSIA 100 may comprise one or more flow limiters 102, an elastomeric element 104 and a spring-mandrel 106 placed on the inner surface of the elastomeric element. The spring-mandrel 106 is stiff and provides some flexure, while acting as a resetting mechanism to the elastomeric element 104. Additionally, the spring-mandrel 106 provides a free flow between the area behind and inside the mandrel. In one exemplary embodiment, "blanked" areas may be placed strategically to allow installation of chokes to promote flow through the outside section of the spring-mandrel 106, thereby continuously clearing the area from sand or proppants. Specifically, chokes are placed a few places (as at the blanked sections) to insure that a portion of the flow always goes through the outside of the spring-mandrel 106 and hence, that no sand or proppants are trapped in the elastomeric cavity.

[0023] The elastomeric element 104 performs as a hold down device. Figure 2 depicts a cross sectional comparison of an elastomeric element used as an inflatable packer configuration with the elastomeric element hold down configuration in accordance with an exemplary embodiment of the present invention. Specifically, Figure 2 is divided into two regions: the traditional packer implementation 202 (above the centerline) and the new hold down configuration 204 (below the centerline). In the packer implementation 202 the elastomeric element 206 is pressurized such that a total seal occurs between the top and bottom (right and left of Figure 2) of the packer. The pressure achieved must be high enough so that the elastomeric element 206 is completely deformed, forming a competent seal. The slats 208 in the packer implementation 202 are permanently deformed, with the deformation becoming more pronounced after each cycle. The pressurization of the packer implementation 202 may be achieved using a clean fluid 210. The clean fluid 210 is placed in the cavity 212 through the cavity opening 214 and the cavity opening 214 is closed, leaving the packer set. To unset the packer, the cavity opening 214 must be manually opened.

[0024] In contrast, with the hold down implementation 204, the elastomeric element 216 may be pressurized by a process fluid 218 such as a sand slurry or an acid, often containing sand or other particles. The pressure of the process fluid 218 is pro-rated using a pressure reduction system, discussed in more detail below. Because the pressure is pro-rated, the low pressure of the process fluid 218 inflates the elastomeric element 216 just enough to touch

the outside walls (not shown), without causing a complete seal. Sealing is not the primary object of the hold down implementation and unlike the packer implementation, fluid flow remains continuous through the tool, as well as around the tool, from the top to the bottom (from right to left in Figure 2) of the tool. Moreover, in the hold down implementation, the elastomeric element 216 is not deformed. The elastomeric element 216 is strengthened and protected by slats 220 which are either outside of the elastomeric element 216 or covered within it (not shown). The outer slats 220 are stretched by the spring-mandrel 106. As a result, the elastomeric element 216 deflates as soon as the process fluid 218 ceases to be pumped through the tool. Thus, the hold down capabilities of the PSIA 100 perform as an anchoring mechanism allowing the tool to be maintained at a fixed position for a desired period before deflating and allowing it to move to a second desired location. As the elastomeric element 216 deflates, the spring-mandrel 106 collapses the elastomeric element 216 back in position and the PSIA 100 is dislodged from its location.

[0025] In one embodiment, the PSIA 100 in accordance with an exemplary embodiment of the present invention may be utilized to improve the performance of a hydrajetting tool. Specifically, the tool movements due to pipe extension/shrinkage, temperature and/or pressure can be minimized by engaging the hold down implementation of the PSIA 100. As would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, the strength requirements for the hold-down device are minimal. For instance, in a vertical well, a 10000 ft. tubing, 2-3/8" - 4.7 lb./ft. would only need 3800 lbs. to stretch a full 1 ft.; or about 319 lb./in. As would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, in reality, this value will have to be subtracted by some large unknown value, representing friction with the wellbore wall. Note that, even in "vertical" wells, wells are never truly vertical; some slants occur during the drilling of the well. In horizontal wells, movement can sometimes be large due to the "jerkiness" of the system. However, the pipe friction negates some of this movement. For instance, for a 2000 ft. tubing as in the above example, in a horizontal well, assuming a friction factor of 0.35 between the pipe and the well bore wall, the friction force may be close to 3290 lbs, thus needing an additional help of only 500 lbs to prevent the tool's movement. Similarly, the jet reaction force causes some small side movements of the tool. For instance, a 0.25" jet at a pressure of 5000 psi may produce a 400 lb. thrust. Consequently, some small additional force will suffice in preventing the movements of a

hydrajetting tool during operation. When in the hold down implementation, the PSIA 100 provides a flexible, elastomeric hold down system which minimizes the tool movements and improves the efficiency of the hydrajetting process.

[0026] As depicted in Figure 1, the PSIA 100 comprises one or more flow limiting devices 102. Figure 3 depicts a flow limiting device 102 in accordance with an exemplary embodiment of the present invention. As depicted in Figure 3, the fluid is routed through a pressure reducing channel 300, which wraps around the outer surface of the inner tubing 302 a multitude of times. The fluid enters the pressure reducing channel through the inlet 304. The friction pressure drop due to the continuous turn becomes very high, even though the channel size is quite big. As the fluid flows through the pressure reducing channel 300, the fluid flow rate is also reduced. The fluid, now having a lower flow rate, then exits the pressure reducing channel 300 through an outlet (not shown) and flows back into the inside of the inner tubing 302. In one exemplary embodiment, as depicted in Figure 3, the channel may be intercepted at three points (e.g., 306), thus bypassing a portion of the channel for pressure control.

[0027] As depicted in Figure 3, in one exemplary embodiment, the flow limiting device 102 may further comprise one or more pressure control modules 308a, 308b, and 308c. In one embodiment, the pressure control modules 308a, 308b, and 308c may be ball seat arrangements. The ball seat arrangement includes a seat body 310. The seat body 10 is arranged so that it can be sealed within the flow limiting device 102. A ball 312 may be inserted into the seat body 310 through an opening (not shown). Once the ball 312 is inserted into the seat body 310, it is caged therein. Although Figure 3 depicts three ball seat modules 308a, 308b, and 308c, as would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, a different number of ball seat modules may be utilized. Removing each ball seat module 308 bypasses a portion of the pressure reducing channel 300 through ports located just above each potential ball seat module position. These ports connect the channel 300 to the inside of the inner tubing. Although the pressure control modules 308 are discussed in conjunction with the flow limiting device 102, as would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, the pressure control modules 308 may be used independently as a general purpose check valve.

[0028] In one exemplary embodiment, the ball seat arrangement of the pressure control modules 308a, 308b, and 308c may also perform as a check valve. Specifically, the ball seat arrangement may permit fluid flow from the bottom to the top of the PSIA 100 of Figure 1 for cleaning purposes. Moreover, the ball seat modules 308 may provide a high flow rate return line for the fluids that are pumped down the annulus while maintaining a low flow rate for the fluids being pumped down through the PSIA 100.

[0029] In one embodiment, it may be desirable to control the pressure of the fluid flowing through the elastomeric element. In one exemplary embodiment, two or more flow limiting devices 102 may be used as shown in Figure 1. The pressure control units may be set with multiple combinations so that the intended pressure and flow is reached.

[0030] In one embodiment, the present invention may be utilized in conjunction with the COBRAMAX-H process where the creation of solid sand plugs are required for the process. This sand plug creation depends upon the ability to pump sand slurries at a very low flow rate. Typically, the high pressure of the fluids results in a high flow rate. The flow limiting device 102 may be used to reduce the flow rate to as low as 1/2 bpm (barrels per minute) without using extra small chokes that would tend to plug when exposed to sand. Therefore, the PSIA 100 allows the placement of competent sand plugs at desired locations. To achieve a similar result using conventional chokes, a 0.09" choke must be utilized which would potentially plug with sand that is 30 Mesh or greater. Although a flow limiting device 102 in accordance with an exemplary embodiment of the present invention has some size limitations, it can be designed to accept 8 Mesh or even larger particles.

[0031] In another exemplary embodiment, the present invention may be used in conjunction with SURGIFRAC operations. Specifically, once a first fracture is created during the SURGIFRAC operations, the hydramjetting tool is moved to a second location to create a second fracture. However, some of the fluids that are being pumped into the annulus will leak off into the already existing fracture. As the number of fractures increases, the amount of fluid that leaks off also increases. The hold down implementation of the PSIA 100 reduces the amount of leak off fluid flow through the annulus from the hydramjetting tool (not shown) to the existing fractures. Specifically, as the elastomeric element 206 inflates, it restricts the path of the leak of fluid flow, thereby reducing the amount of fluids leaked off. Consequently, the PSIA 100 will reduce the annulus flow requirement while maintaining pore-pressure and limited flow influx to

let the fracture slowly close without producing proppants back into the wellbore after fluid injection has stopped.

[0032] As would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, the term “pinpoint stimulation” is not limited to a particular dimension. For instance, depending on the zones to be isolated, the area subject to the “pinpoint stimulation” may be a few inches or in the order of tens of feet in size. Moreover, although the present invention is disclosed in the context of “stimulation” processes, as would be appreciated by those of ordinary skill in the art, the apparatuses and methods disclosed herein may be used in conjunction with other operations. For instance, the apparatuses and methods disclosed herein may be used for non-stimulation processes such as cementing; in particular squeeze cementing or other squeeze applications of chemicals, fluids, or foams.

[0033] As would be appreciated by those of ordinary skill in the art, although the present invention is described in conjunction with a hydrajetting tool, it may be utilized with any stimulation jetting tool where it would be desirable to minimize tool movement and/or fluid leak off. Moreover, as would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, any references to the term “sand” may include not only quartz sand, but also other proppant agents and granular solids. Additionally, as would be appreciated by those of ordinary skill in the art, with the benefit of this disclosure, although the present invention is described as using one PSIA, two or more PSIAs may be used simultaneously or sequentially in the same application to obtain desired results, without departing from the scope of the present invention.

[0034] Therefore, the present invention is well-adapted to carry out the objects and attain the ends and advantages mentioned as well as those which are inherent therein. While the invention has been depicted and described by reference to exemplary embodiments of the invention, such a reference does not imply a limitation on the invention, and no such limitation is to be inferred. The invention is capable of considerable modification, alteration, and equivalents in form and function, as will occur to those ordinarily skilled in the pertinent arts and having the benefit of this disclosure. The depicted and described embodiments of the invention are exemplary only, and are not exhaustive of the scope of the invention. Consequently, the invention is intended to be limited only by the spirit and scope of the appended claims, giving

full cognizance to equivalents in all respects. The terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

CLAIMS:

1. A pinpoint stimulation improvement apparatus comprising:
an elastomeric element;
a spring positioned on an inner surface of the elastomeric element; and
a flow limiter coupled to the elastomeric element.
2. The pinpoint stimulation improvement apparatus of claim 1, wherein the elastomeric element is inflatable.
3. The pinpoint stimulation improvement apparatus of claim 2, wherein the elastomeric element is inflated by a process fluid.
4. The pinpoint stimulation improvement apparatus of claim 3, wherein the elastomeric element is deflated by ceasing the process fluid flow.
5. The pinpoint stimulation improvement apparatus of claim 4, wherein the spring collapses the elastomeric element as the process fluid flow ceases.
6. The pinpoint stimulation improvement apparatus of claim 2, wherein the inflatable elastomeric element does not seal against a wellbore wall.
7. The pinpoint stimulation improvement apparatus of claim 1, wherein the flow limiter comprises:
an inner tubing;
a pressure reducing channel on an outer surface of the inner tubing;
an inlet from the inside of the inner tubing to the pressure reducing channel;
and
an outlet from the pressure reducing channel to the inside of the inner tubing.
8. The pinpoint stimulation improvement apparatus of claim 7, wherein the flow limiter further comprises a pressure control module.

9. The pinpoint stimulation improvement apparatus of claim 8, wherein the pressure control module comprises:

a seat body,

wherein the seat body is sealed within the inner tubing;

an opening on the seat body; and

a ball,

wherein the ball is inserted in to the seat body through the opening.

10. A method of improving the performance of a stimulation jetting tool comprising:

pumping a process fluid through the stimulation jetting tool;

passing a portion of the process fluid through a pinpoint stimulation improvement apparatus,

wherein the pinpoint stimulation improvement apparatus comprises:

an elastomeric element;

a spring positioned on an inner surface of the elastomeric element; and

a flow limiter coupled to the elastomeric element; and

expanding the elastomeric element to form a hold down mechanism for the stimulation jetting tool.

11. The method of claim 10, wherein the stimulation jetting tool is a hydrajetting tool.

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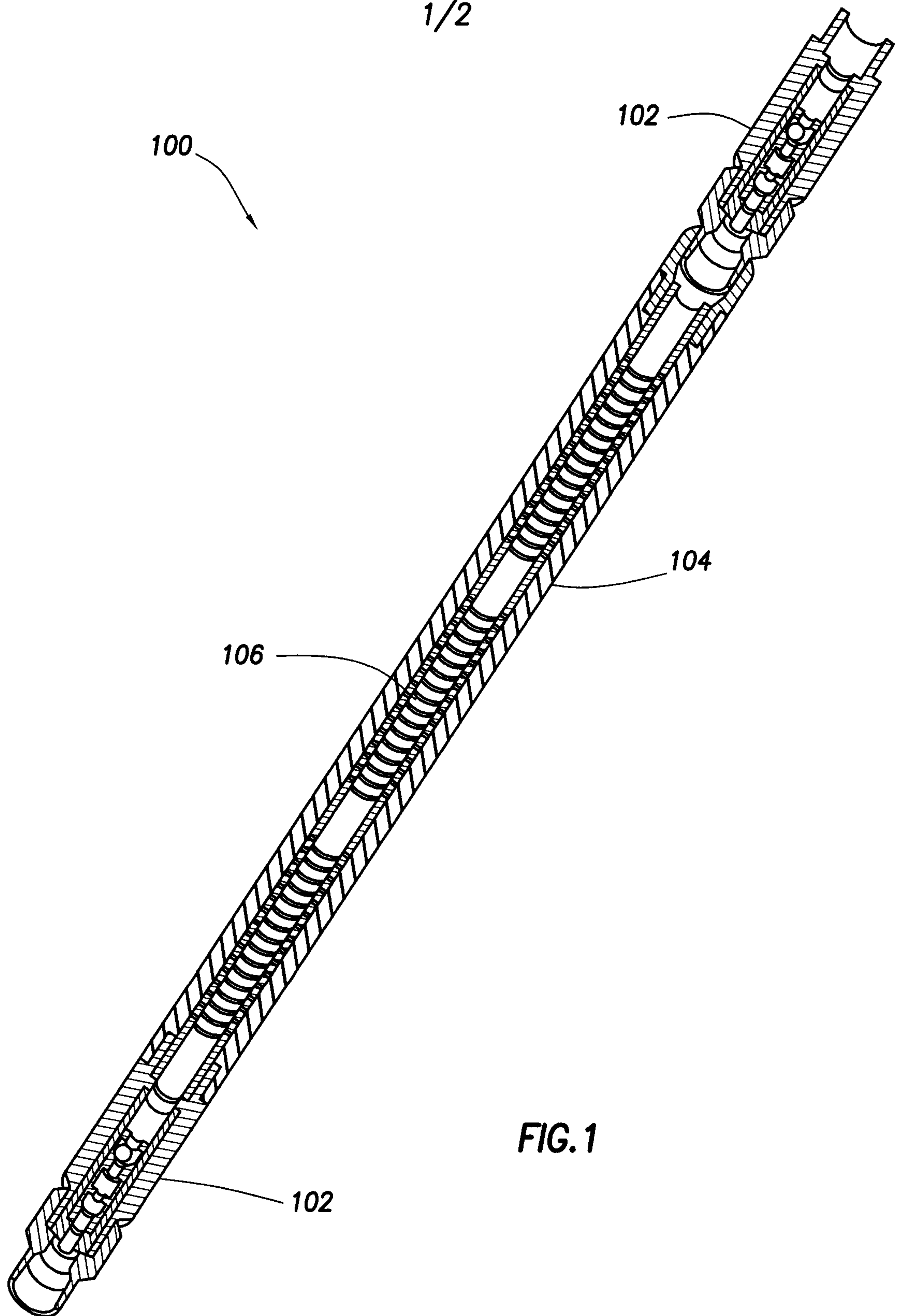


FIG. 1

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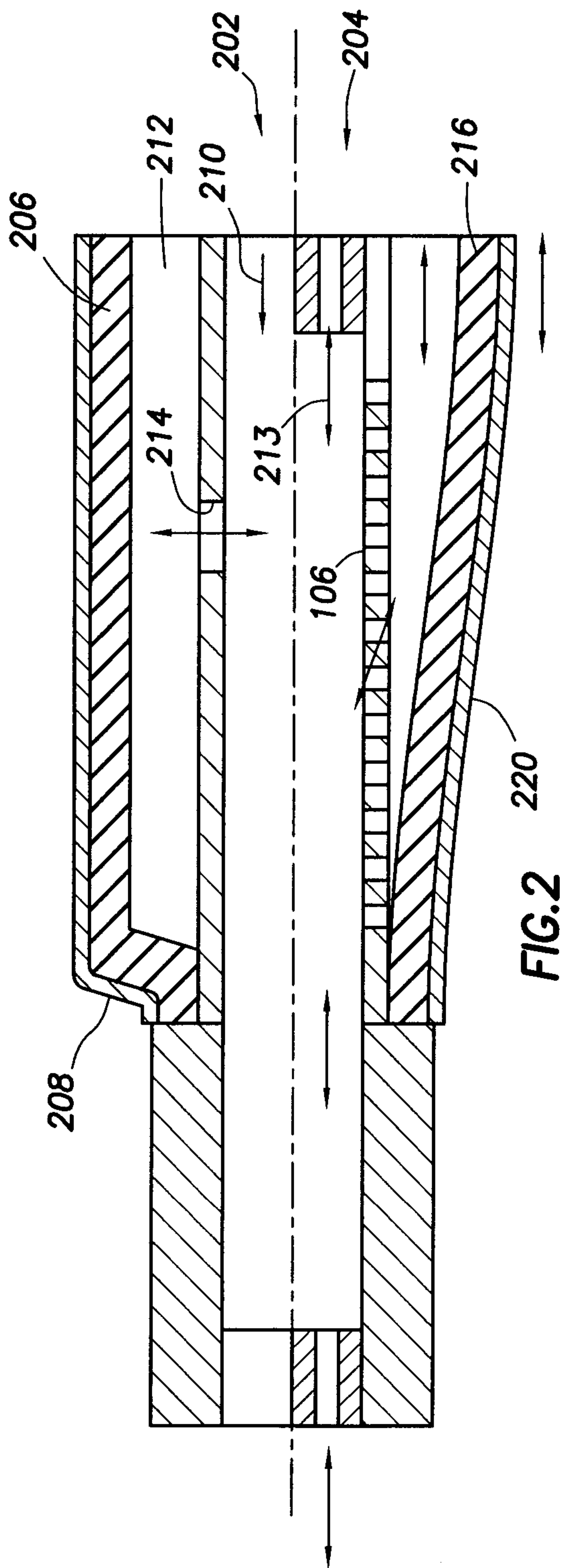


FIG. 2

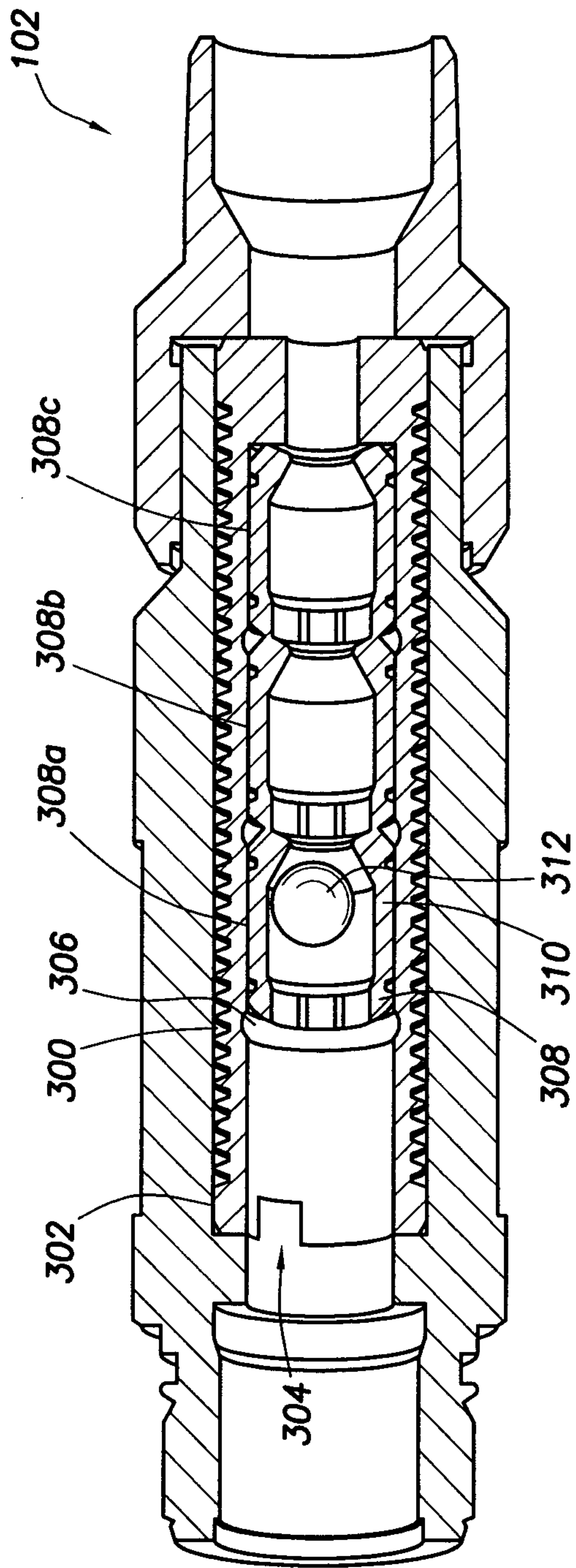


FIG. 3

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