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(54) DEVICE FOR CONTROLLING A PASSAGE OF FLUID IN A TUBING STRING AND METHOD OF OPERATING IT

(57) The present application discloses a device for controlling a passage of fluid in a tubing string. The device comprises a fluid chamber and two pistons for interacting with a fluid inside the fluid chamber. Each piston is adapted for catching an object received through the tubing string from an uphole side of the device. Also, at least one of the pistons is adapted for controlling the passage of fluid, and the pistons and the fluid chamber are arranged so that the pistons are directed in the same direction along the tubing string.

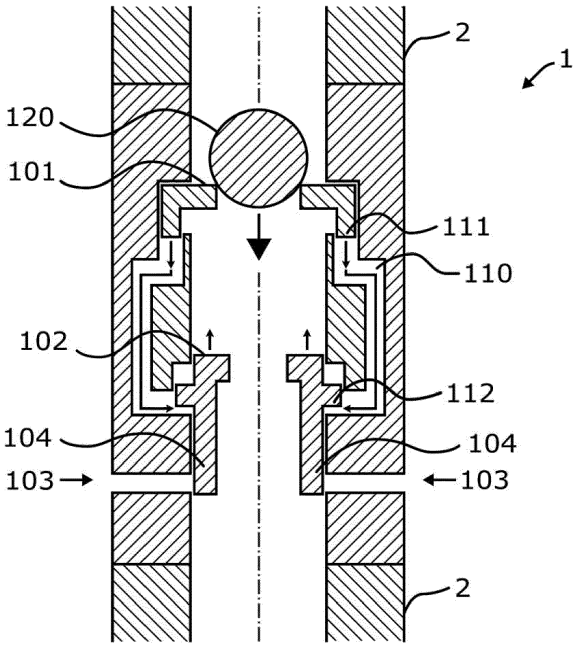

Fig. 2

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Description

[0001] The present invention relates to a device for controlling a passage of fluid in a tubing string and a method of operating it.

[0002] When choosing tools for controlling injection or production flows in a well, there is a preference for tools that minimize the risk of having to perform an intervention. An intervention may be necessary, for example, for moving a part of a tool, such as a sleeve of a valve, using a wireline. The major drawback of having to perform an intervention is that it takes time while the execution of other tasks in the well is stopped. The operator, however, is still paying for operational costs during the intervention.

[0003] A tool normally used for controlling injection or production flows in a well is a device provided on a tubing string for controlling a passage of fluid, such as a passage between the interior and the exterior of the tubing string. This device is useful for various purposes such as selectively injecting water into a reservoir layer or shutting off excessive water being produced from a layer in an oil producing well. However, it can be challenging to provide a device as this that can be opened and closed multiple times without requiring a well intervention.

[0004] A known solution is a type of valve that is hydraulically actuated using two control lines. The valve opens and closes by controlling the hydraulic pressure in wire-lines. The use of this type of valve is problematic for several reasons, such as the risk of damaging a control line during installation and this type of valve being an expensive solution and having a time-consuming installation process.

[0005] Another known solution is a device that makes use of a mechanism for converting axial movement to rotating movement, the axial movement being provided by an object that is deployed inside the tubing string. The mechanism includes a seat inside the device onto which the object lands and exerts an axial force. This mechanism has a behaviour similar to the one of a retractable pen. An example of such a mechanism is the J-slot, which includes a profile creating a track for an actuating cam or pin that combines rotation and up or down movement. This type of solution is expensive and complex, having many parts and requiring a spring, or similar compressing means, for creating a force in the uphole direction.

[0006] The present invention will now be disclosed.

[0007] According to an aspect of the invention, there is provided a device for controlling a passage of fluid in a tubing string, the device comprising:

- a fluid chamber; and
- at least two pistons for interacting with a fluid inside the fluid chamber, each piston being adapted for catching an object received through the tubing string from an uphole side of the device,

wherein at least one of the pistons is adapted for controlling the passage of fluid, and wherein the pistons and the fluid chamber are arranged so that the pistons are directed in the same direction along the tubing string.

[0008] The pistons and the fluid chamber may be arranged so that a downhole motion of either of the pistons increases the pressure of the fluid in the fluid chamber. Also, the pistons may be arranged so that the passage of fluid is downhole in relation to both positions at which each of the pistons are adapted to catch the object.

[0009] The device may be configured to operate in at least one mode in which the passage of fluid is closed and another mode in which the passage of fluid is open.

[0010] One of the pistons may be adapted to catch the object at a downhole position in relation to the position at which the other piston is adapted to catch the object.

[0011] Each piston may include a portion for acting as a seat for catching the object. The seat may include a hole with a section for catching the object. The hole may include a section for catching a ball with a diameter larger than the diameter of the hole.

[0012] The seat of the downhole piston may be adapted for catching an object that is passable through the seat of the uphole piston. The downhole piston may have a hole with a smaller diameter than the diameter of the hole of the other seat.

[0013] Each piston may be a portion of a sleeve adapted for moving along the device.

[0014] The object may be made of a dissolvable material and/or include an outer shell filled with sand, metallic particles, or a dissolvable internal structure.

[0015] According to another aspect of the invention, there is provided a method of operating a device as described above, the method comprising:

- providing a tubing string inside a wellbore with the top end protruding from the wellhead, the tubing string comprising the device inside the wellbore;
- selecting an object for getting caught by one of the two pistons; and
- pumping down the object until it gets caught, and further pumping down the object so that a downhole axial force is transmitted to the one of the pistons.

[0016] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a device embodiment on a tubing string

Figure 2 is a schematic cross-sectional view of a device embodiment being opened

Figure 3 is a schematic view of the two seats of the device embodiment of Figure 2

Figure 4 is a schematic cross-sectional view of the device embodiment of Figure 2 being closed

Figure 5 is a schematic view of part of the device embodiment of Figures 2 and 4

Figure 6 is schematic cross-section view of the device

embodiment of Figures 2 and 4 without the seats and ball being shown

Figure 7 is a schematic view of three device embodiments arranged along a tubing string

[0017] For the purposes of simplifying the present description, these Figures are shown with the uphole and downhole directions aligned with the height of the page; that is, the top of a Figure is the uphole side of the device 1 and the bottom is the downhole side. The Figures are shown in a schematic and highly simplified manner, and various features shown in the drawings are not necessarily drawn to scale.

[0018] Turning now to Figure 1, the tubing string 2 is shown including the device embodiment 1 on it. During the completion of a well, the tubing string 2 may be inside the wellbore with only the top end protruding from the wellhead. Also, the distance from the top end of the tubing string 2 to the device 1 may be in the range between a few hundred meters to a couple of kilometres.

[0019] The device 1 is being used for controlling the passage of fluid between the interior and the exterior of the tubing string 2 at the openings 103. This passage of fluid may be useful during the completion of the well for various purposes, such as providing bore completion control and zone isolation for completion operations such as gravel packing, spot acidizing and fracturing, killing a well, or directing flow from the casing to the tubing string 2 in alternate or selective completion operations.

[0020] The device 1 is operated from the top end of the tubing string 2 to open or close the openings 103. This is achieved by inserting an object here in the form of a ball 120 into the interior of the tubing string 2 and have it pumped down until it reaches the interior of the device 1. Instead of being pumped, the ball 120 may also move through the tubing string 2 by free falling. Then, the ball 120 exerts an axial force on the device 1 that causes the latter to either open or close the openings 103, and thus to alter the flow of fluid to pass between the interior and the exterior of the tubing string 2.

[0021] As it will be explained below, the device 1 is provided so that the openings 103 are opened or closed depending on the diameter of the ball 120 that is inserted in the tubing string 2.

[0022] The device 1 can be operated multiple times to open or close, without requiring an intervention such as running a wireline with a shifting tool key to reopen the openings 103. Also, the device 1 is provided on the tubing string 2 without requiring further components such as control lines extending from the top end. Moreover, the operation of the device 1 by pumping balls through the tubing string 2 has the advantage of being a simple method requiring the pumping of a fluid into the top end of the tubing string 2 until the ball reaches the device 1.

[0023] Figure 2 shows a cross-sectorial view of the device 1 illustrating one possibility of what happens inside the device 1 after a ball has been inserted into the tubing string 2 as shown in Figure 1 and travelled until it reached the device 1. In this possibility, the ball 120 is actuating on the device 1 so that it opens the openings 103.

[0024] The device 1 controls the passage of fluid through the openings 103 using the sleeve 104. This sleeve slides in both the uphole and the downhole direction and in Figure 2 it is shown in its downhole end position, completely closing the openings 103. The actuation of the ball 120 will cause the sleeve 104 to move in the uphole direction and open the openings 103. This is achieved by converting a downhole motion of the ball 120 into an uphole motion of the sleeve 104.

[0025] The device 1 includes the fluid chamber 110 and the two pistons 111 and 112, one uphole and the other downhole, for interacting with the fluid inside the fluid chamber 110. Also, the uphole piston 111 is adapted for catching the ball 120 and the piston 112 is adapted with the portion 104 that acts as the sleeve.

[0026] The uphole piston 111 includes a uphold seat 101 extending inwards to the interior of the tubing string 2, the seat being suitable for catching the ball 120 when the latter reaches the device 1 from the uphole side. The seat 101 includes a hole that has a diameter smaller than the diameter of the ball 120. Thus, when the ball reaches the seat 101 from an uphole side, it gets blocked at the seat 101 because it cannot pass through the hole of the seat 101.

[0027] The ball 120 exerts an axial force on the seat 101 due to its weight and also, if the contact surface between the ball 120 and the seat 101 forms a seal, to pressure created on the uphole side of the seat 101.

[0028] The axial force exerted on the seat actuates the uphole piston 111, and the latter performs a downhole motion. Due to the arrangement of the uphole piston 111 and the fluid chamber 110 directing the uphole piston 111 in a downhole direction of the tubing string 2, the uphole piston 111 increases the pressure of the fluid inside the fluid chamber 110.

[0029] The pressure increase is transmitted to the other piston 112 through the fluid chamber 110. As the pressure of the fluid inside the fluid chamber 110 increases, the downhole piston 112 reacts to the fluid pushing it. Since the only degree of freedom available to the downhole piston 112 is in the uphole direction, the downhole piston 112 reacts in that direction. Thus, the downhole motion of the uphole piston 111 actuating on the fluid chamber 110 results in the downhole piston 112 reacting in an uphole motion.

[0030] As the downhole piston 112 moves in the uphole direction, the portion of the downhole piston 112 that provides the sleeve 104 will also move, and the openings 103 will be open to allow a passage of fluid between the interior and the exterior of the tubing string 2.

[0031] The ball 120 then needs to be removed from uphole seat 101, in order to allow fluid to pass through the interior of the tubing string 2. This may be achieved by having the ball 120 comprising a dissolvable material, such as metallic powder that disintegrates over time in salt containing ions. Also, the ball 120 does not need to

fully disintegrate, only requiring that it becomes small enough to pass. This may also be achieved by having the ball 120 comprise an outer shell filled with sand, metallic particles, or a dissolvable internal structure. In this case, when submitted to pressure above a predetermined threshold, the ball 120 crushes into smaller pieces and disintegrates from the inside.

[0032] Once the device 1 in open mode, ie. with the openings 103 open, has been used for its purpose during the completion procedure, there may be a need for operating it to shift to closed mode. As mentioned above, this is achieved by inserting a new ball into the tubing string 2 as shown in Figure 1, but now the ball has a different diameter than the previous ball 120. In particular, the new ball has a smaller diameter than ball 120. This difference in diameter makes it possible for the new ball to move through the tubing string 2 until the position of the device 1, and then continue to move through tubing string 2 after having passed through the hole of the uphole seat 101.

[0033] Figure 3 shows a schematic view of the two seats of the device 1, the seats being arranged coaxially but at different positions in the tubing string 2. For the purposes of simplicity, only the uphole side of the seats 101 and 102 and some abstract alignment lines are shown.

[0034] The seats 101 and 102 have holes with different diameters, in particular the downhole seat 102 has a smaller diameter than the uphole seat 101. This configuration allows performing one of three operations when a ball moves through the tubing string 2. One operation happens when the ball has a diameter that is larger than the diameter of the hole of the uphole seat 101 (and smaller than the diameter of the tubing string 2). In this case, the ball gets caught by the uphole seat 101, as explained above for Figure 2. Another operation happens when the ball has a diameter that is smaller than the diameter of the hole in the downhole seat 101, but larger than the diameter of the hole in the uphole seat 102. For this situation, the ball passes through the hole in uphole seat 101 and gets caught by the seat 102. A further operation happens when the ball has a diameter that is smaller than the diameters of the holes in both seats 101 and 102, resulting in the ball passing through both seats and continuing its trip along the downhole portion of the tubing string 2.

[0035] Figure 4 shows a cross-sectorial view of the device 1 of Figure 2, illustrating another possibility of what happens inside the device 1 after a ball has been inserted into the tubing string 2 as shown in Figure 1 and travelled until it reached the device 1. In this possibility, the ball 121 is actuating the downhole piston 112 so that it closes the openings 103.

[0036] The ball 121 has a diameter that allows it to pass through the seat 101 and get caught by the seat 102. That is, the diameter of the ball 121 is smaller than the hole in the seat 101 but larger than the hole in seat 102 (see the arrows and abstracts lines in the middle of the seat 101 in Figure 4, illustrating the gap between the ball 102 and the hole in the seat 101).

[0037] After having moved through the tubing string 2 and passed the seat 101, the ball 121 gets caught by the seat 102 where it exerts an axial force in the downhole direction. This results in a downhole motion being carried out by both the piston 112 and the sleeve 104. That is, due to the downhole motion of the ball 121, the sleeve 104 closes the openings 103 and the piston 112 increases the pressure in the fluid chamber 110.

[0038] The pressure in the fluid chamber 110 is transmitted to the piston 111, in a path opposite to the one that is explained above for Figure 2. The piston 111 has only one degree of freedom for moving, and it reacts to the pressure increase inside the fluid chamber 110 by moving in the uphole direction.

[0039] After the ball 121 has moved the piston 112 to its downhole end position, the device achieves the state shown in Figure 2 with the openings 103 closed/covered and the seats 101 and 102 in position to catch a new ball at the uphole seat 101.

[0040] The device 1 thus provides a solution for opening or closing the openings 103 multiple times without requiring an intervention. Although the balls 120 and 121 inserted in the tubing string 2 only move in the downhole direction, the device 1 is capable of converting that motion in either an uphole or a downhole motion for opening/covering or closing/uncovering its openings 103. Thus, this makes it easy for the operators to control how they want the device 1 to operate the passage of fluid through the openings 103, simply requiring them to change the diameter of the ball being pumped through the tubing string 2 depending on which mode of operation they wish the device 1 to have.

[0041] Figure 5 shows a part of the device 1 with a possible design of the openings 103. As mentioned above, the openings 103 enable a passage of fluid between the exterior 201 of the tubing string 2 and the interior 202. This can be achieved by having a circular strip of block ribs 1032 creating intermediary spaces 1031.

[0042] The openings may also be created by providing a tubular body and then drilling, or perforating in any other way, holes perpendicularly on its surface. In that case, the openings through which the fluid may pass may have a circular shape.

[0043] A plurality of openings arranged all around at a position of the tubing string 2, besides allowing fluid to be exchanged through that position, also provides a mechanical connection between the uphole and the downhole parts of the device 1.

[0044] Moreover, the passage of fluid controlled by the device embodiment may be implemented in many other ways. For example, instead having several openings 103, the device 1 may be provided so that there is only one opening implementing the passage of fluid.

[0045] Figure 6 shows a device embodiment illustrating how a fluid chamber 110 may be formed.

[0046] The fluid chamber 110 is delimited by an outer

part 113, an interior part 114, and the two pistons 111 and 112 (none of the pistons is shown). The inner part 114 is mechanically connected to the outer part 113 by two circular strips of block ribs 115, similar to the one shown in Figure 5. These strips of block ribs 115 serve the purpose of providing the fluid chamber 110 connecting the two pistons, at the same time that it establishes a mechanical connection between the inner and the outer parts 114 and 113 of the fluid chamber.

[0047] The fluid used inside the fluid chamber 110 may comprise oil or any other incompressible fluid. The main purpose of the fluid inside the fluid chamber 110 is to provide a liquid medium that can transmit forces between the two pistons 111 and 112.

[0048] Figure 7 shows a tubing string 2 including three device embodiments. The seats of the three devices 701, 702, and 703 are configured so that they have different diameters between not only the seats of each device but also the seats of the other devices. In particular, the uphole seat inside the device 701 is the one which has the hole with the largest diameter, and the downhole seat inside the device 703 is the one which has the hole with the smallest diameter. The intermediate holes have a decreasing diameter as further in the downhole direction they are positioned.

[0049] This configuration allows providing several device embodiments on a tubing string that can be operated independently of each other using different sized balls. This is quite useful for defining different well zones during completion operations.

[0050] Embodiments of the invention may have some or all of the following advantages:

- A passage of fluid is operable in a tubing string between open and closed positions multiple times without the need for interventions
- A device for controlling a passage of fluid in a tubing string that is simple to operate
- Completion tasks that require a device as described above are performed faster than with known solutions
- Reduced cost and risk compared to known solutions

[0051] Generally, the terms used in this description and claims are interpreted according to their ordinary meaning the technical field, unless explicitly defined otherwise. Notwithstanding, the terms "comprises" and "comprising" and variations thereof mean that the specified features, steps or integers are included. These terms are not interpreted to exclude the presence of other features, steps or integers. Furthermore, the indefinite article "a" or "an" is interpreted openly as introducing at least one instance of an entity, unless explicitly stated otherwise. An entity introduced by an indefinite article is not excluded from being interpreted as a plurality of the entity.

[0052] The features disclosed in the foregoing description, or in the following claims, or in the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for obtaining the disclosed results, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

[0053] While the invention has been described in conjunction with the embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given this disclosure. Accordingly, the embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the invention.

Claims

1. A device (1) for controlling a passage of fluid (103) in a tubing string (2), the device (1) comprising:

   - a fluid chamber (110); and
   - at least two pistons (111, 112) for interacting with a fluid inside the fluid chamber (110), each piston (111, 112) being adapted for catching an object (120, 121) received through the tubing string (2) from an uphole side of the device (1),

   wherein at least one of the pistons (111, 112) is adapted for controlling the passage of fluid (103), and
   wherein the pistons (111, 112) and the fluid chamber (110) are arranged so that the pistons (111, 112) are directed in the same direction along the tubing string (2).

2. A device according to claim 1, wherein the pistons and the fluid chamber are arranged so that a downhole motion of either of the pistons increases the pressure of the fluid in the fluid chamber.

3. A device according to any of the previous claims, wherein the pistons are arranged so that the passage of fluid is downhole in relation to both positions at which each of the pistons are adapted to catch the object.

4. A device according to any of the previous claims, the device being configured to operate in at least one mode in which the passage of fluid is closed and another mode in which the passage of fluid is open.

5. A device according to any of the previous claims, wherein one of the pistons is adapted to catch the object at a downhole position in relation to the position at which the other piston is adapted to catch the object.

6. A device according to any of the previous claims, wherein each piston comprises a portion for acting as a seat for catching the object.

7. A device according to claim 6, wherein the seat comprises a hole with a section for catching the object.

8. A device according to claim 7, wherein the hole comprises a section for catching a ball with a diameter larger than the diameter of the hole.

9. A device according to claim 5 and any of the claims 7 or 8, wherein the seat of the downhole piston is adapted for catching an object that is passable through the seat of the uphole piston.

10. A device according to claims 5 and 8, wherein the downhole piston has a hole with a smaller diameter than the diameter of the hole of the other seat.

11. A device according to any of the previous claims, wherein each piston is a portion of a sleeve adapted for moving along the device.

12. A device according to any of the previous claims, wherein the object comprises a dissolvable material and/or comprises an outer shell filled with sand, metallic particles, or a dissolvable internal structure.

13. A method of operating a device (1) as described in any of the claims 1 to 12, the method comprising:

- providing a tubing string (2) inside a wellbore with the top end protruding from the wellhead, the tubing string (2) comprising the device (1) inside the wellbore;
- selecting an object (120, 121) for getting caught by one of the two pistons (111, 112); and
- pumping down the object (120, 121) until it gets caught, and further pumping down the object (121) so that a downhole axial force is transmitted to the one of the pistons (111, 112).

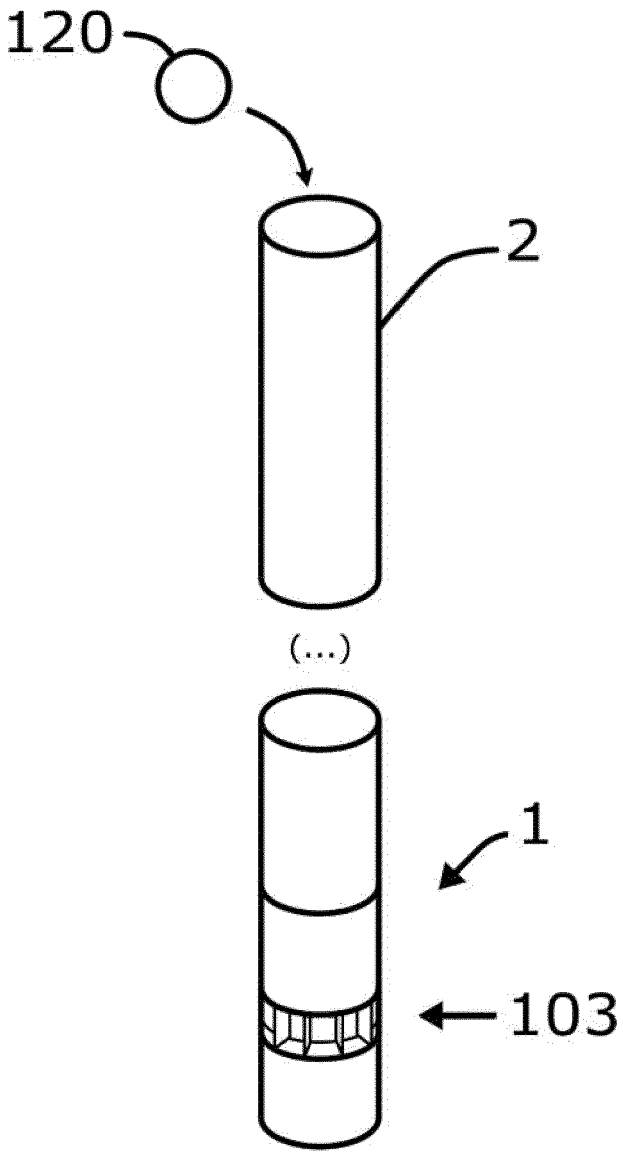

Fig. 1

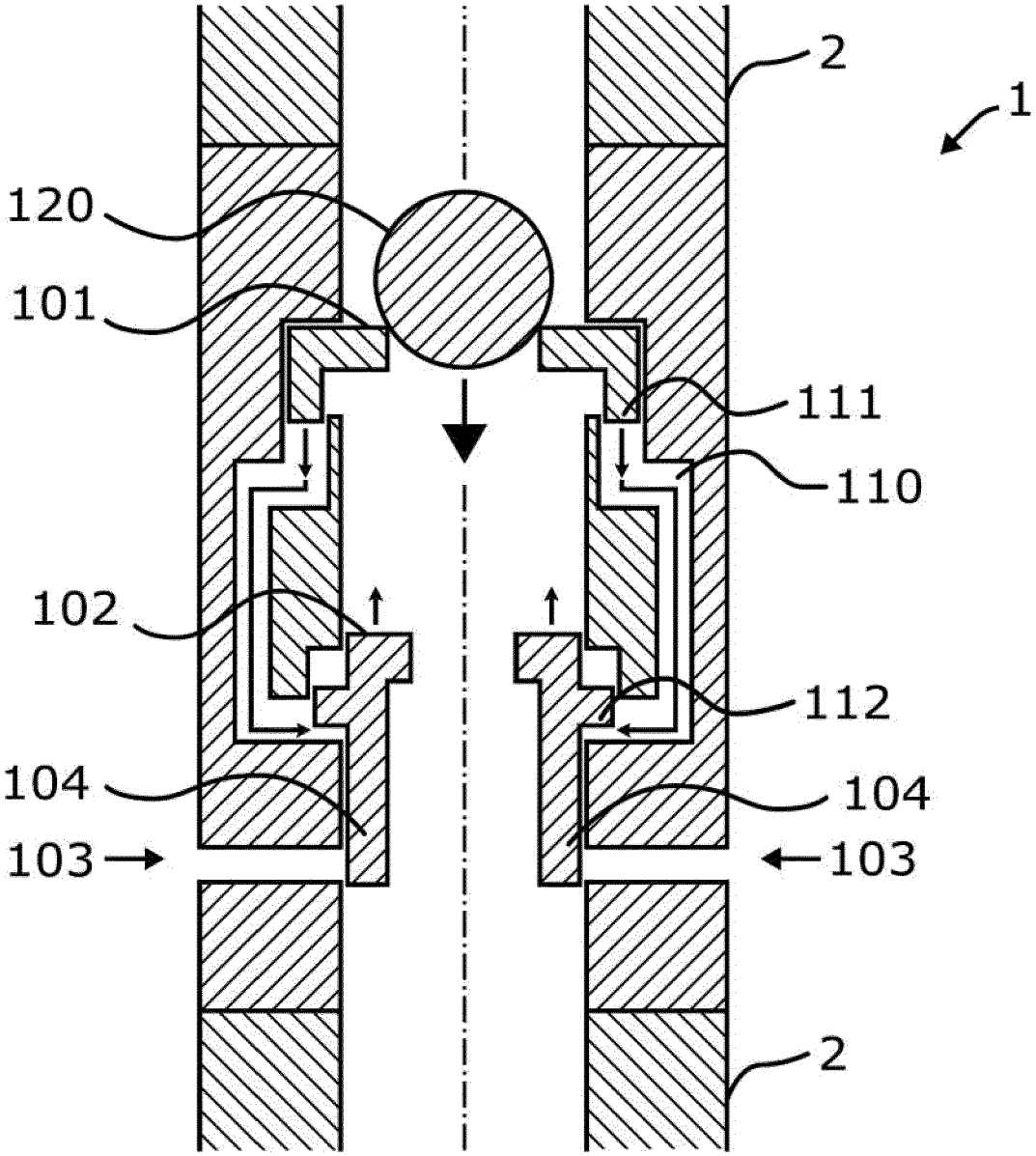

Fig. 2

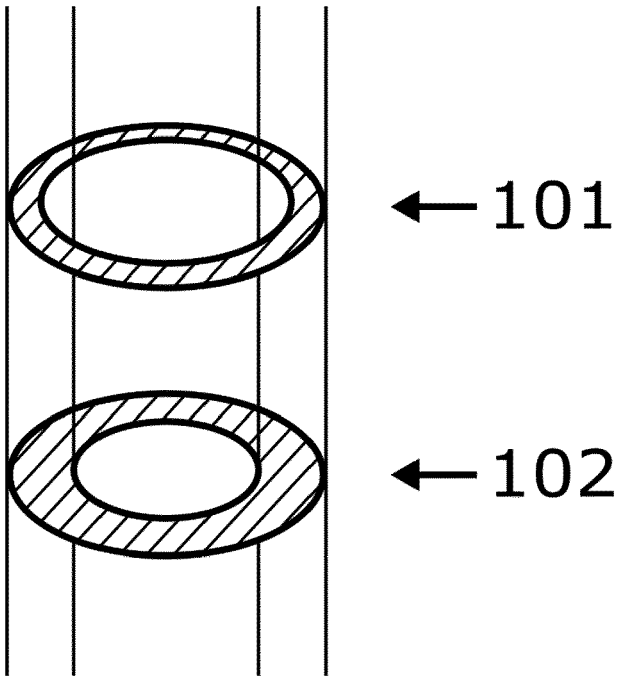

Fig. 3

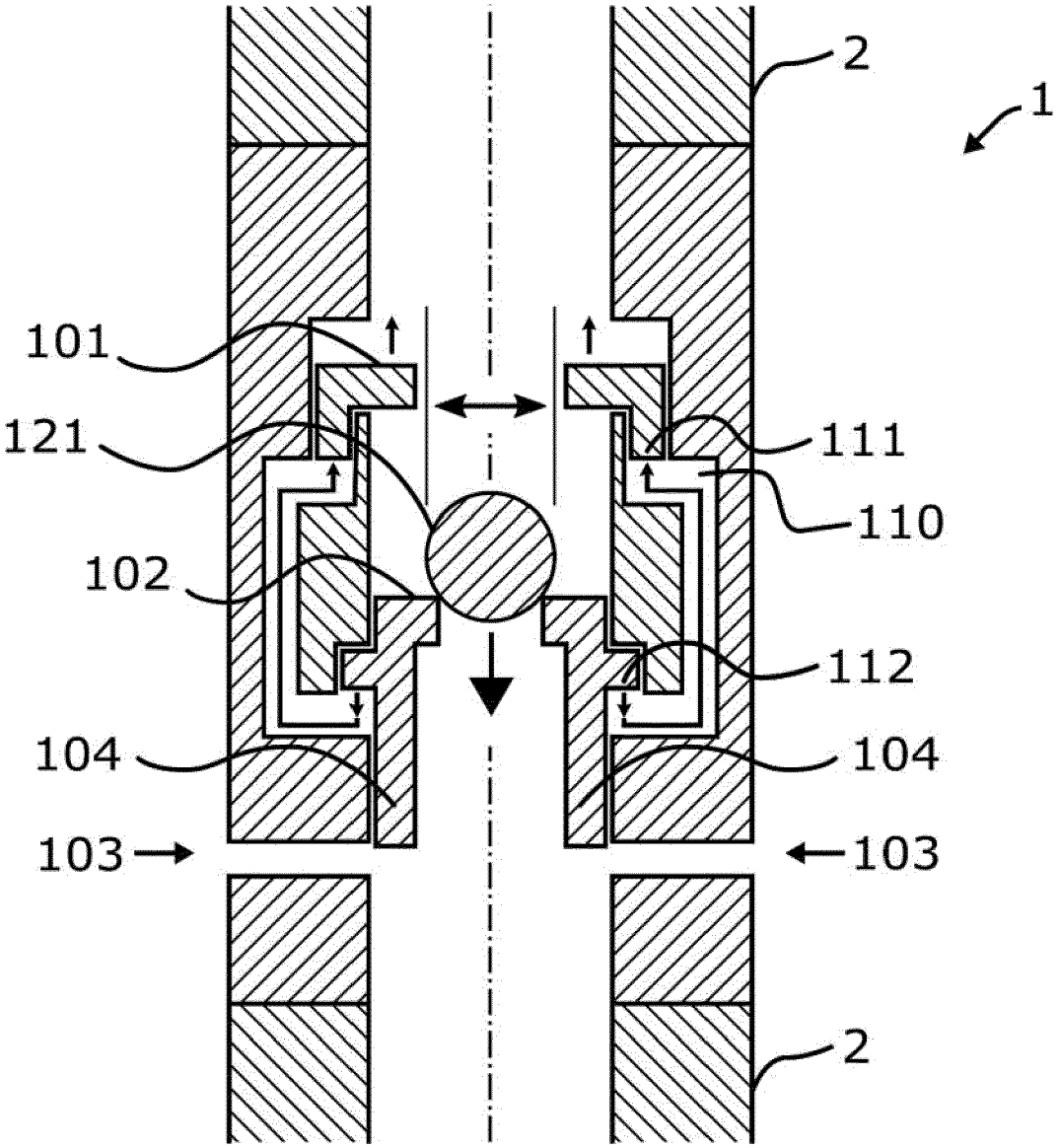

Fig. 4

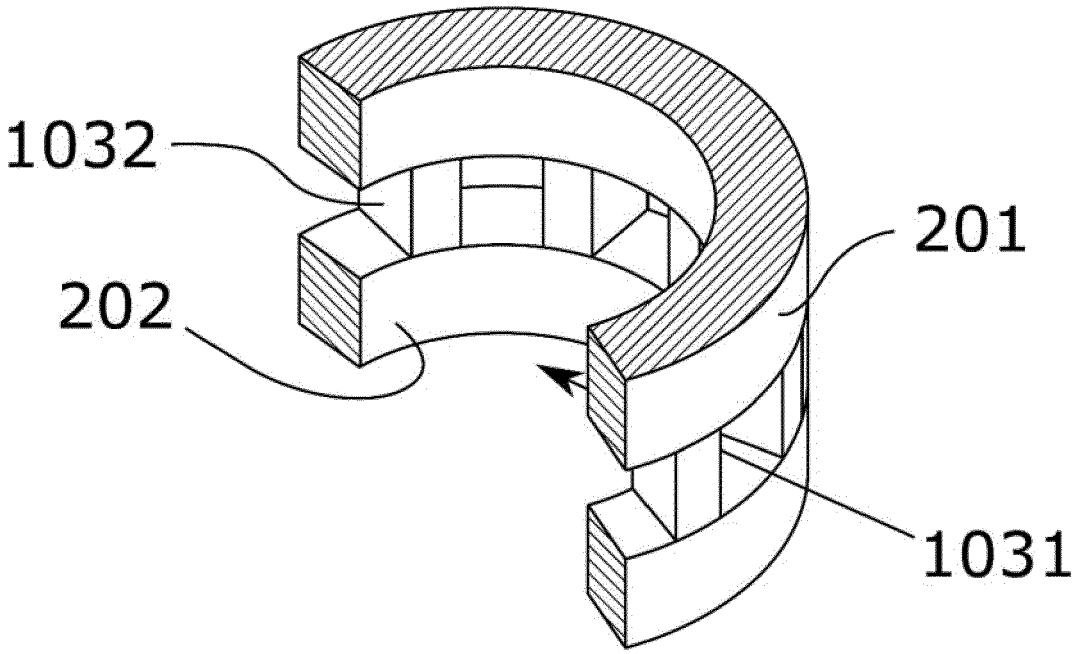

Fig. 5

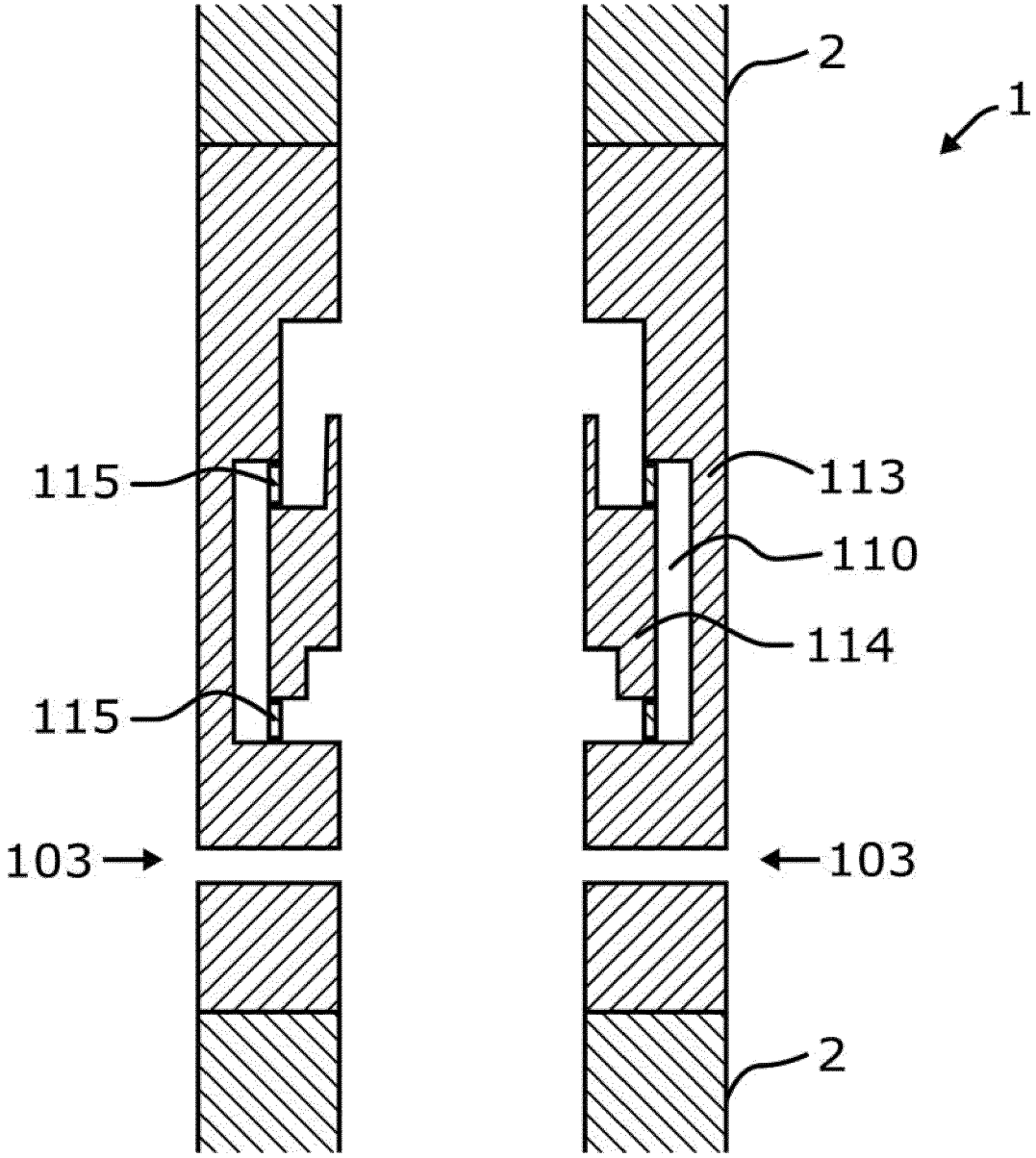

Fig.6

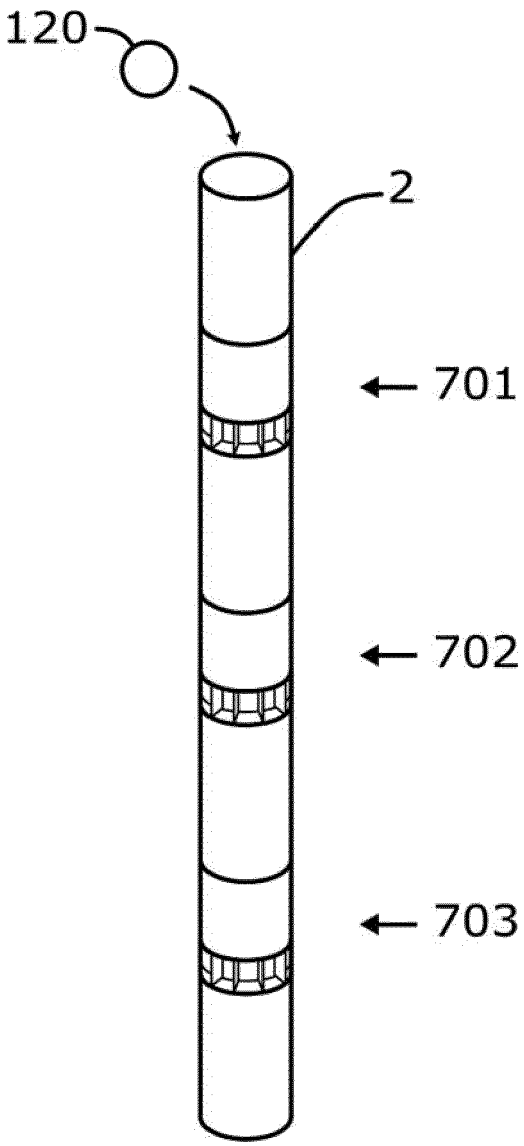

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 18 19 8607

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2016/326833 A1 (LUKE MIKE A [US]) 10 November 2016 (2016-11-10) * page 1, paragraph 18 - page 2, paragraph 19; figure 2 *	1-13	INV. E21B23/04 E21B21/10 E21B34/14
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A	US 2013/302193 A1 (GABDULLIN RIVENER MUSAVIROVICH [RU]) 14 November 2013 (2013-11-14) * the whole document *	1-13	

TECHNICAL FIELDS SEARCHED (IPC)

E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	12 March 2019	Morrish, Susan

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 19 8607

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