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DEVICE AND METHOD FOR CONTROLLED RELEASE OF A RESTRICTION ELEMENT INSIDE A WELL

BACKGROUND

TECHNICAL FIELD

[0001] Embodiments of the subject matter disclosed herein generally relate to downhole tools for well operations, and more specifically, to a wellbore setting tool that sets a plug at a desired depth into the well and then releases, at a desired time, a restriction element to close the plug.

DISCUSSION OF THE BACKGROUND

[0002] During well exploration, various tools are lowered into the well and placed at desired positions for plugging, perforating, drilling, or measuring the well. These tools are placed inside the well with the help of a conduit, as a wireline, electric line, continuous coiled tubing, threaded work string, etc. Plugs are used to separate various sections of the well for perforating and/or fracturing purposes. The plugs block the casing so that a fluid from cannot pass the plug. The plugs need to be engineered to withstand a high pressure (thousands of psi) that is traditionally applied to the well, but also to be easily milled away after they have performed their duty.

[0003] A traditional plugging system 100 is shown in Figure 1 and includes a plug 120 that is carried with a setting tool 102 and placed in a well 110, which was drilled to a desired depth H relative to the surface 112. Note that Figure 1 shows the plug 120 already being set and detached from the setting tool 102. A casing string

114 (or simply casing herein) for protecting the wellbore 116 has been installed and cemented in place. To connect the wellbore 116 to a subterranean formation 118, the plug 120 needs to be set up in the well as shown in Figure 1 and also to be closed so that well fluids cannot pass the plug.

[0004] The typical process of connecting the casing 114 to the subterranean formation 118 may include the following steps: (1) setting the plug 120, which has a through passage 122 inside the well, (2) closing the passage 122 to block fluid flow through the plug, (3) increasing the pressure inside the casing, and (4) perforating the casing 114 with a perforating gun 126. A controller 130, located at the surface 112, is used to control the various tools and/or the fluid's pressure inside the wellbore 116. In one application, a wireline tool 124 may be used to lower the setting tool 102, the plug 120, and the gun string 126.

[0005] The structure of the traditional setting tool 102 and plug 120 is illustrated in Figure 2. The setting tool 102 has a power charge 202, which when ignited, makes a mandrel 204 to move relative to a sleeve 206 so that a rod 208 pulls a piston 210 toward the setting tool 102. Plug 120 is disposed around the rod 208 and between the sleeve 206 and the piston 210, as shown in the figure. Under the opposite forces exerted by the piston 210 and the sleeve 206, a first part 212 of the plug 120 moves toward a second part 214 of the plug so that a slip portion 216 moves over the second part 214 and engages the casing (not shown in Figure 2). After a certain force is applied to the two parts 212 and 214, the rod 208 breaks away from the plug 120 and the setting tool 102 is freed from the plug 120. At this

point, the plug 120 is set (i.e., the slip portion 216 has engaged the casing) and the setting tool 102 can be retrieved from the well. A passage (not shown) through the plug 120 allows fluid communication between the part of the casing above the plug and the part of the casing below the plug.

[0006] To close the plug for preparing the well for perforating and/or fracturing, the setting tool 102 needs to be taken out of the well, a ball is introduced into the well and pumped down until the ball sits into a seat 218 located at a proximal end of the plug 120. The ball (not shown) closes the passage and the fluid pressure inside the well and above the plug 120 can be increased. However, the operation of taking the setting tool outside the well and then pumping down the ball is time consuming and expensive. Further, the existing plugs, although made from composite materials, still require a substantial amount of time to be milled out, when the need appears to remove them.

[0007] A more efficient plug is illustrated in Figures 3A and 3B, which corresponds to Figure 14 of U.S. Patent no. 9,765,590. According to this approach, the setting tool 102 may be configured to have a sleeve 206 in which a ball 310 is positioned. As long as the sleeve 206 is attached to the plug 120, the ball 310 is trapped inside the sleeve. A shear ring 314 connects the sleeve 206 to the plug 120. After enough force is exerted by the setting tool 102, and the plug 120 is set, the shear ring 314 breaks and the setting tool 102 separates from the plug 120. When the sleeve 206 has been detached from the plug 120, as illustrated in Figure 3A, the ball 310 is free to exit the sleeve. When the well fluid is flown downstream, the ball

310 engages the plug 120 and closes its internal bore, as also illustrated in Figure 3A.

[0008] Sleeve 206 is configured to have a trap 302 for trapping the ball 310 when the well is flown back, as shown in Figure 3B. Note that the ball 310 has left the plug 120 and is flowing toward the trap 302. A catching mechanism 304 for the ball 310 is also located inside a chamber 312 defined by the sleeve 206. In this embodiment, because the ball 310 is carried inside the sleeve 206, there is no need to remove the setting tool in order to place the ball in its seating position in the plug. When the ball needs to be removed, the back flow is established inside the well so that the ball moves past the trap 302, inside the chamber 312. Once the ball has passed the trap 302, the ball cannot return to the plug 120.

[0009] Returning to Figure 1, after the plug 120 has been set, the gun string 126 is moved upward to the desired location, and they are fired, creating perforations into the casing and formation. Usually, the guns are moved up-hole and fired several times, each time, perforating the casing and the formation. The expended guns are then removed from the well. The well is now pressurized from the surface to a high enough pressure to fracture the formation. To accomplish this, the well has to be plugged. This is the function of the ball 310. As the fluid is pumped in, the ball 310 rolls from the sleeve 206 toward the plug 120 and then against the top of the plug 120 and makes a seal. The ball 310 is being used as a check valve. It will allow fluid to move upward, but it will stop fluid from moving downward.

[0010] The next string of guns, setting tool, ball, and plug is then lowered into

the well for performing further perf and fracturing operations. The reason it is possible to lower the next gun string into the well is because the fluid that is pumped into the well exits the newly created perforations. The sequence repeats, and each of these sequences are called a stage. There could be many stages per well (e.g., >40). After all of the stages are done, the balls either dissolve, or a Coiled Tubing Run is used to mill them out and remove debris from the well.

[0011] If not enough of the perforations are created in any of the stages, it is called a mis-fire. The next string of guns or anything else cannot now be pumped down to its depth because the ball is preventing the fluid from being pumped into the well. Thus, the ball needs to be removed before the next string of guns can be pumped in. If a mis-fire happens, the well pressure at the surface is dropped quickly. This causes the fluid to flow-back out of the well. This means that the fluid in the well flows in an upstream direction, which makes the ball 310 to enter the sleeve 206 and become trapped by the trap 302. Now the guns, setting tool and the ball are removed from the well and the next gun string is pumped in as the removal of the ball 310 from the plug 120 allows the fluid to be pumped into the well.

[0012] The problem with this design is that if the ball is not caught, or if it is dropped when the tool is being removed, the well remains plugged. Then, a coiled tubing run is required to get to the plug and mill-out or capture the ball. After this blockage is removed, the perforating can continue. However, the coiled tubing run is slow and costly. Other existing approaches, as the ball in place or the drop ball methods, suffer from similar problems, and/or are more time consuming, and/or uses

a large amount of water. Thus, there is a need for a setting tool and ball that have a simplified structure, are easy to be installed, and the ball can be released only when decided by the operator of the well.

SUMMARY

[0013] According to an embodiment, there is a setting tool for setting a plug in a well. The setting tool includes a housing extending along a longitudinal axis X and having a bore, a sleeve extending along the longitudinal axis of the housing, and located within the bore of the housing, and a holding mechanism located within the sleeve and configured to hold a ball within the sleeve. The holding mechanism is configured to release the ball upon receiving a signal.

[0014] According to another embodiment, there is a setting tool for setting a plug in a well, the setting tool including a sleeve extending along a longitudinal axis and configured to be attached to the plug; a ball that fits inside a bore of the sleeve; and a holding mechanism located within the sleeve and configured to hold the ball within the sleeve. The holding mechanism is configured to release the ball upon receiving a signal.

[0015] According to yet another embodiment, there is a method for releasing a ball from a setting tool in a well, the method including loading the ball into the setting tool, securing the ball to the setting tool with a holding mechanism located within the setting tool, lowering the setting tool and the ball into the well, activating the setting tool to set up a plug inside the well, and releasing the ball into the well based on a signal received by the holding mechanism.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate one or more embodiments and, together with the description, explain these embodiments. In the drawings:

[0017] Figure 1 illustrates a setting tool and plug that are used to plug a well;

[0018] Figure 2 illustrates a traditional setting tool and plug;

[0019] Figures 3A and 3B illustrate a setting tool and plug that includes a ball and the setting tool has a trap for the ball;

[0020] Figure 4 illustrates a setting tool having a mechanical holding mechanism for holding the ball inside the setting tool;

[0021] Figures 5-7 illustrate how the mechanical holding mechanism releases the ball from inside the setting tool;

[0022] Figure 8 illustrates a setting tool having an electrical holding mechanism for holding the ball inside the setting tool;

[0023] Figures 9 and 10 illustrate how the electrical holding mechanism releases the ball from inside the setting tool;

[0024] Figure 11 illustrates a setting tool having another electrical holding mechanism for holding the ball inside the setting tool;

[0025] Figure 12 illustrates the deployment of the setting tool and the holding mechanism inside of a well;

[0026] Figure 13 illustrates a setting tool having another holding mechanism for holding the ball inside the setting tool;

[0027] Figure 14 is a flowchart of a method for controlling a release of a ball from a setting tool by using a holding mechanism; and

[0028] Figure 15 illustrates a controller that can be used with an electrical holding mechanism to control the release of the ball.

DETAILED DESCRIPTION

[0029] The following description of the embodiments refers to the accompanying drawings. The same reference numbers in different drawings identify the same or similar elements. The following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims. The following embodiments are discussed, for simplicity, with regard to a setting tool for releasing a restriction element to block a plug. However, the embodiments discussed herein are also applicable to other tools that need to release a restriction element at a desired instant in time.

[0030] Reference throughout the specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described in connection with an embodiment is included in at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrases “in one embodiment” or “in an embodiment” in various places throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments.

[0031] According to an embodiment, there is a setting tool that holds a restriction element (e.g., a ball herein) and a plug that accepts the ball. The setting tool is attached to the plug. The setting tool sets the plug and then, it releases the ball to close the plug at a time that is decided by the operator of the plug. If a

decision is made that the guns have failed to perforate or that the ball should not be released, the setting tool may be retrieved from the well while the ball is still locked inside the setting tool. Thus, according to this embodiment, there is no need to drill the ball or remove it by other means that are time and/or water consuming. The ball is simply not released into the well although the plug has been set. The ball is held inside the setting tool with a holding mechanism. The holding mechanism may be implemented, as discussed next, as a mechanical device, an electronic device, or as a flexo-mechanical device.

[0032] A setting tool-plug system 400 that includes a novel setting tool 410 is now discussed with regard to Figure 4. The setting tool 410 is shown in Figure 4 being attached to a plug 480 and both elements being placed in a casing 470 of a well. The plug 480 may be any known plug. Plug 480 is shown in the figure not being set, i.e., its sealing element 482 not touching the casing 470. The plug 480 has an internal mandrel 484 that is attached with one or more shearing pins 486 to the setting tool 410. Note that a plug that does not have an internal mandrel may also be used with this novel setting tool.

[0033] The setting tool 410 includes a housing 420 and a sleeve 422 located within a bore 421 of the housing 420. The housing 420 is configured to contact the plug 480 while the sleeve 422 is attached to the inner mandrel 484 of the plug, with the shearing pins 486. When the setting tool is actuated, the housing 420 generates a reactionary force along the longitudinal axis X while the sleeve 422 is pulling the mandrel 484 along the opposite direction of the axis X, thus exerting a pulling force

opposite to the reactionary force. In this way, the mandrel 484 is biasing the sealing element 482 toward a member 486, which results in the sealing element expanding along a radial direction and eventually touching the casing 470, as illustrated in Figure 5. Note that after the plug 480 is set, the fluid inside the well cannot pass the plug only through its internal bore 488.

[0034] Returning to Figure 4, the setting tool 410 is shown having an internal holding mechanism 430, that is configured to hold the ball 432 inside the sleeve 422. The internal holding mechanism 430 is implemented in this embodiment as a mechanical device and it is located entirely inside the sleeve 422. More specifically, the holding mechanism 430 includes a swinging arm 434 that is configured to rotate about a fixed point 436, that is attached to the sleeve 422. Thus, the swinging arm 434 could pivot about the fixed point 436. However, to prevent the swinging arm 434 to pivot toward the plug 480, a hitting stop 438 is formed into the sleeve 422. Therefore, the swinging arm 434 is prevented by the hitting stop 438 to pivot to the right in Figure 4, i.e., toward the plug 480. In this way, the ball 432 cannot exit the sleeve 422. However, the swinging arm 434 can pivot toward the ball (to the left in the figure).

[0035] The swinging arm 434 has a through hole 440 through which a pushing arm 442 extends, from one side of the swinging arm to the other. The pushing arm 442 has a shoulder 444, located between the swinging arm 434 and an upstream end 410A of the setting tool 410. A downstream end 410B of the setting tool is connected to the plug 480. Note that the terms “upstream” and “downstream” in this

application refer to the head and toe of the well, respectively. Shoulder 444 is configured to pass through the hole 440 of the swinging arm 434 when the pushing arm 442 is free to move along the positive direction of the longitudinal axis X. However, as long as the plug 480 is attached to the setting tool as shown in Figure 4, the pushing arm 442 cannot move along the positive direction of the longitudinal axis X, and thus, the shoulder 444 remains on the upstream side of the swinging arm 434. Further, note that the hole 440 is selected at a given location along the swinging arm 434, so that an end 442A of the pushing arm 442 is facing and will contact the mandrel 484 of the plug 480. If the plug 480 has no mandrel, then the hole is selected so that the end 442A of the pushing arm 442 contacts a solid element of the plug.

[0036] Figure 4 further shows a first biasing mechanism 433 that is pressing on the ball 432 to push it outside the sleeve 422, toward the plug 480. The first biasing mechanism 433 may be a spring or similar element. The purpose of the first biasing element 433 is to force the ball 432 to exit the setting tool when the swinging arm 434 allows the ball to move. There is a second biasing mechanism 446 inside the sleeve 422 and the second biasing mechanism 446 presses the pushing arm 442 toward the plug 480. The second biasing mechanism 446 may also be implemented as a spring or similar element. The purpose of the second biasing mechanism 446 is to prevent the swinging arm 434 to open, which would allow the ball 432 to exit the sleeve 422.

[0037] After the plug 480 has been set as illustrated in Figure 5, and the setting tool 410 has been removed from the plug 480, the pushing arm 442 is free to move along the positive direction of the longitudinal axis X, toward the plug 480. This movement of the pushing arm 442 takes place under the biasing exerted by the second biasing mechanism 446. Note that Figure 5 shows the sleeve 422 being withdrawn inside the housing 420 while the end 442A of the pushing arm 442 extends, along the longitudinal axis X, beyond the housing 420 of the setting tool. Also note that although the setting tool 410 has been separated and pulled away from the plug 480, the ball 432 remains trapped inside the sleeve 422 by the holding mechanism 430.

[0038] At this time, the setting tool is armed for ball release. After enough perforations are made into the casing, the operator may decide to release the ball. To achieve this, the pump at the surface is used to pump the guns and the setting tool down onto the plug 480, so that the pushing arm 442 contacts the plug 480. The pushing arm 442 then starts to move along the negative direction of the longitudinal axis X, and shoulder 444 engages the swinging arm 434, which results in the swinging arm 434 being rotated about the fixed point 436, backward, i.e., in the upstream direction, as illustrated in Figure 6. At this time, the ball 432 is freed and, due to the force exerted by the first biasing mechanism 433, it moves out of the setting tool with a speed V, toward the plug 480. If the pump continues to pump the well fluid, eventually the ball 432 will end up on its seating 485, formed in the plug 480, as illustrated in Figure 7. At this time, the casing 470 is completely sealed at

the plug location, as the fluid in the well cannot move either through the bore 488 (which is blocked by the ball 432) or through the exterior of the plug 480 (which is sealed by the sealing element 482). Note that in this embodiment, the ball 432 was not released from the setting tool as soon as the setting tool was separated from the plug as is the case in the art, but rather it was released when the operator of the setting tool decided, by pushing the setting tool towards the plug and rotating the swinging arm 434 to release the ball. In this way, the release of the ball from the setting tool is controlled, which is not the case for the existing setting tools.

[0039] As previously discussed, the holding mechanism 430 that holds and controls the release of the ball 432 can be implemented as an electronic device, as now discussed with regard to Figure 8. The setting tool 410 in Figure 8 has the housing 420 and the sleeve 422 similar to the embodiment illustrated in Figures 4-7. The ball 432 is also placed inside the sleeve 422 as in the previous embodiments. What is different is the holding mechanism 430, which instead of having a pushing arm that presses against the plug 480 for releasing the ball, has electronic components that release the ball.

[0040] More specifically, the holding mechanism 430 in Figure 8 has an inner cavity 810, located toward the upstream end 410A of the setting tool. The inner cavity 810 is fluidly isolated from the remaining of the sleeve 422, by a dividing wall 812. A hole 814 is formed in the dividing wall 812 for allowing a rotating arm 820 to extend from the inner cavity 810 into the open part 422A of the sleeve 422. The rotating arm 820 is connected to a partial gear 830 located inside the inner cavity

810. A motor 840 is also located inside the inner cavity 810. A gear 842 is attached to the motor 840. The partial gear 830 is connected to the gear 842, so that the motor 840 can turn the rotating arm 820 in one of two possible angular directions. One or more O-rings 850 or other equivalent elements are placed between the rotating arm 820 and the dividing wall 812 to prevent the well fluid from the open part 422A of the sleeve 422 to enter inside the inner cavity 810. Thus, the inner cavity 810 is maintained at atmospheric pressure, so that no fluid enters inside and the motor 840 and other elements (to be discussed later) are insulated from the harsh environment that might be present inside the open part 422A of the sleeve 422. One or more thrust washers 822 may be provided between the dividing wall 812 and the rotating arm 820. The rotating arm 820 has an extending arm 824 that extends from a rotational axis RA toward the sleeve 422, to create an enclosure 826 in which the ball 432 is trapped.

[0041] A cross-section A-A through the setting tool 810 is shown in Figure 9 and illustrates the partial gear 830 being engaged with the gear 842. Note that the partial gear 830 is not a full circle, but only a slice of it. The partial gear 830 can be rotated by the full gear 842, which is rotated by the motor 840, to move from a closed position A to an open position B. The corresponding motion of the extending arm 824 is shown in Figure 10, which corresponds to the cross-section B-B through the setting tool 810 of Figure 8. Note that the extending arm 824 have been moved from the closed position A to the open position B, so that the ball 432 is freed. Due to the biasing mechanism 433 shown in Figure 8, the ball 432 is now pushed out of the

setting tool, and by controlling the pressure inside the well, the ball 432 can be placed in its seating of the plug 480, as in Figure 7.

[0042] The motor 840 may be actuated in various ways for freeing the ball 432. For example, it is possible to have a cable 844 (see Figure 8) that extends from the motor 840 all the way to the surface, to a global controller located at the head of the well. When the motor needs to be activated, the global controller supplies power along the cable 844. If such a cable is implemented along the gun string and the setting tool, it needs to be protected such that the firing of the shaped charges do not destroy the integrity of the cable.

[0043] In another embodiment, as illustrated in Figure 11, the motor 840 may be controlled by a local controller 1100, which is also located inside the inner cavity 810. Local controller 1100, which is discussed in more detail later, may be connected to a power supply 1110 (e.g., a battery), and to one or more sensors 1120. When a trigger signal is detected by the sensor 1120, the controller activates the motor 840, to release the ball 832 similar to the embodiment illustrated in Figure 8. The sensor 1120 may be implemented in various ways, as now discussed.

[0044] In one implementation, the sensor 1120 may be implemented as an acoustic sensor. After a shaped charge of a gun is fired, the noise would be detected by the acoustic sensor. The signal generated by the acoustic sensor is transmitted to the controller, which compares an intensity of the signal to a given threshold. The firing of a shaped charge generates an intense signal. The presence

of the intense signal confirms that perforations were made. Thus, the controller 1100 activates the motor 840 to release the ball 432.

[0045] In another implementation, it is possible to have a system 1200, as shown in Figure 12, in which there is an acoustic transmitter 1220 at the top of the well 1202. The acoustic transmitter 1220 is controlled by a global controller 1230 and can emit an acoustic signal that propagates through the well fluid 1204 to the acoustic sensor 1120. After the gun string 1210 has been fired, the operator at the surface 1206 could send an acoustic signal with the transmitter 1220. This acoustic signal is detected by the sensor 1120 and interpreted by the controller 1100 as a signal to activate the motor 840 and release the ball 432. The signal emitted by the transmitter 1220 may be preset into the local controller 1100 so that only for that specific acoustic signal the controller activates the motor 840.

[0046] In still another embodiment, a shaped charge 1212 associated with the gun string 1210 creates a pressure pulse when fired. This pressure pulse can be used as the signal for instructing the controller 1100 to activate the motor 840. In this case, the sensor 1120 is a pressure sensor that is located outside the inner cavity 810.

[0047] In yet another embodiment, the sensor 1120 is an accelerometer. When the gun string 1210 fires, the gun string and also the setting tool 410, which is fixedly connected to the gun string 1210, experience a sudden movement (a jump). The accelerometer 1120 detects this jump and a signal indicative of it is sent to the controller 1100. The controller 1100 stores in a memory a threshold value and

compares the jump experienced by the accelerometer with the threshold value. If the jump value is larger than the threshold value, the controller determines that the gun string has fired and motor 840 is activated to release the ball 432. Alternatively, the operator at the surface may raise or lower the setting tool 410, which is connected to a wireline 1240 or equivalent device, according to a known pattern. When the controller identifies the pattern based on the signals measured by the accelerometer 1120, the controller instructs the motor 840 to rotate to release the ball 432. In still another embodiment, the gun string and setting tool may be moved with a certain velocity pattern and the sensor 1120 may be selected to measure this velocity. When the measured pattern is identical to a stored velocity pattern, based on the signals measured by the accelerometer 1120, the controller instructs the motor 840 to rotate to release the ball 432. Other changes in well parameters may be used for communicating with the local controller 1120.

[0048] In yet another embodiment, as illustrated in Figure 13, the holding mechanism 430 is implemented as a mechanical enclosure 1310 (e.g., a collet) that has a flexible wall 1312. The wall 1312 may have first and second shoulders 1314 and 1316 that are spaced apart so that the ball 432 fits between them. The first and second shoulders are formed on the inside of the flexible wall 1312. The shoulders extend enough from the flexible wall, toward the inner space of the mechanical enclosure 1310, to prevent the ball 432 to move out of the mechanical enclosure 1310. In one application, the mechanical enclosure 1310 has both ends open, one toward the interior of the sleeve 422 and one toward the outside of the sleeve. The

mechanical enclosure 1310 is mechanically attached, through internal connecting element 1320, to the inside of the sleeve 422.

[0049] The well fluid 472 is able to enter inside the sleeve 422, through ports 420A formed in the housing of the setting tool 410 and ports 422A formed in the sleeve and move along paths 1330, from outside the setting tool to its inside. In addition, the ports are made into the housing 420 and the sleeve 422 so that the paths 1330 take the well fluid behind the ball 432, to push the ball outside the setting tool. In addition, the ports 420A and 422A are located in their corresponding housing and sleeve so that the ports are aligned with each other only when the setting tool has been separated from the plug, i.e., when the sleeve 422 has been retrieved inside the housing 420.

[0050] With this configuration, after the gun string's shaped charges have been fired, the operator moves the setting tool with a high velocity (which depends on the viscosity of the well fluid, diameter of the ports in the housing and sleeve, size of the ball, etc.) so that the well fluid 472 acts with a force against the ball and also makes the flexible walls 1312 of the mechanical enclosure 1310 to vibrate as indicated by arrows 1340, which eventually results in the mechanical enclosure flexing radially outward and the distance between the shoulders 1316 becoming larger than the diameter of the ball, so that the ball is released from the mechanical enclosure 1310 and ultimately from the setting tool 410. In one application, if the walls of the mechanical enclosure are made to be very flexible, the vibrations

generated by the firing of the shaped charges of the gun string may force the ball out of the mechanical enclosure.

[0051] A method for operating a setting tool based on one or more of the embodiments discussed above is now discussed with regard to Figure 14. The method starts in step 1400 with loading a ball 432 into a setting tool 410. In step 1402, the ball 423 is secured with a holding mechanism 430 into the setting tool 410 so that the ball cannot exit the setting tool. In step 1404, the setting tool and the ball are lowered into a well. In step 1406, the setting tool is activated to set a plug, which is originally attached to the setting tool. In step 1408, a signal is detected by a controller associated with a holding mechanism and the holding mechanism is activated to release the ball. Alternatively, the setting tool is moved by the operator of the well with a certain pattern, which is detected by the controller as a triggering signal, for releasing the ball, and the controller instructs the holding mechanism to release the ball. Another option is to move the setting tool with a certain speed or generate strong vibrations so that the holding mechanism vibrates and opens up to release the ball.

[0052] The above-discussed global and local controllers may be implemented as a computing device as illustrated in Figure 15. Hardware, firmware, software or a combination thereof may be used to perform the various steps and operations described herein. Computing device 1500 may include a server 1501. Such a server 1501 may include a central processor (CPU) 1502 coupled to a random access memory (RAM) 1504 and to a read-only memory (ROM) 1506. ROM 1506

may also be other types of storage media to store programs, such as programmable ROM (PROM), erasable PROM (EPROM), etc. Processor 1502 may communicate with other internal and external components through input/output (I/O) circuitry 1508 and bussing 1510 to provide control signals and the like. Processor 1502 carries out a variety of functions as are known in the art, as dictated by software and/or firmware instructions.

[0053] Server 1501 may also include one or more data storage devices, including hard drives 1512, CD-ROM drives 1514 and other hardware capable of reading and/or storing information, such as DVD, etc. In one embodiment, software for carrying out the above-discussed steps may be stored and distributed on a CD-ROM or DVD 1516, a USB storage device 1518 or other form of media capable of portably storing information. These storage media may be inserted into, and read by, devices such as CD-ROM drive 1514, disk drive 1512, etc. Server 1501 may be coupled to a display 1520, which may be any type of known display or presentation screen, such as LCD, plasma display, cathode ray tube (CRT), etc. A user input interface 1522 is provided, including one or more user interface mechanisms such as a mouse, keyboard, microphone, touchpad, touch screen, voice-recognition system, etc. The server may be part of a larger network configuration as in a global area network (GAN) such as the Internet 1528, which allows ultimate connection to various landline and/or mobile computing devices.

[0054] The disclosed embodiments provide methods and systems for setting a plug in a well and/or releasing a ball to close the plug. It should be understood that

this description is not intended to limit the invention. On the contrary, the exemplary embodiments are intended to cover alternatives, modifications and equivalents, which are included in the spirit and scope of the invention as defined by the appended claims. Further, in the detailed description of the exemplary embodiments, numerous specific details are set forth in order to provide a comprehensive understanding of the claimed invention. However, one skilled in the art would understand that various embodiments may be practiced without such specific details.

[0055] Although the features and elements of the present exemplary embodiments are described in the embodiments in particular combinations, each feature or element can be used alone without the other features and elements of the embodiments or in various combinations with or without other features and elements disclosed herein.

[0056] This written description uses examples of the subject matter disclosed to enable any person skilled in the art to practice the same, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the subject matter is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims.

WHAT IS CLAIMED IS:

1. A setting tool (410) for setting a plug in a well, the setting tool (410) comprising:
 - a housing (420) extending along a longitudinal axis X and having a bore (421);
 - a sleeve (422) extending along the longitudinal axis of the housing (420), and located within the bore (421) of the housing (420); and
 - a holding mechanism (430) located within the sleeve (422) and configured to hold a ball (432) within the sleeve (422),wherein the holding mechanism (430) is configured to release the ball (432) upon receiving a signal.
2. The setting tool of Claim 1, wherein the signal is a physical touch between a part of the holding mechanism and a plug set by the setting tool.
3. The setting tool of Claim 1, wherein the signal is an electrical signal sent along a wire from the surface to the holding mechanism.
4. The setting tool of Claim 1, wherein the signal is an acoustic signal detected by a local controller of the holding mechanism.

5. The setting tool of Claim 1, wherein the signal is a pressure change in a well fluid around the holding mechanism.

6. The setting tool of Claim 1, wherein the signal is related to a motion pattern.

7. The setting tool of Claim 1, wherein the signal is a velocity of the setting tool inside the well.

8. The setting tool of Claim 1, wherein the holding mechanism includes a swinging arm (434) that has a closed position for holding the ball inside the sleeve and an open position for releasing the ball.

9. The setting tool of Claim 8, wherein the swinging arm changes from the closed position to the open position when a pushing arm contacts the plug.

10. The setting tool of Claim 8, wherein the holding mechanism further comprises:

a biasing mechanism located inside the sleeve and pressing against the ball to exit the sleeve.

11. The setting tool of Claim 1, wherein the holding mechanism comprises:
a rotating arm (820) that holds the ball; and

a motor connected to the rotating arm and configured to rotate the rotating arm to release the ball.

12. The setting tool of Claim 11, wherein the motor is located inside an inner cavity (810) of the sleeve, which is insulated from the well fluid, and the rotating arm extends through a wall of the inner cavity so that a first part of the rotating arm is located inside the inner cavity and a second part of the rotating arm is located outside the inner cavity.

13. The setting tool of Claim 11, wherein the holding mechanism further comprises:

- a sensor configured to determine the signal; and
- a controller configured to release the ball upon receiving the signal.

14. The setting tool of Claim 1, wherein the holding mechanism is a mechanical enclosure having a flexible wall that holds the ball.

15. A setting tool (410) for setting a plug in a well, the setting tool (410) comprising:

- a sleeve (422) extending along a longitudinal axis and configured to be attached to the plug;
- a ball (432) that fits inside a bore of the sleeve (422); and

a holding mechanism (430) located within the sleeve (422) and configured to hold the ball (432) within the sleeve (422),

wherein the holding mechanism (430) is configured to release the ball (432) upon receiving a signal.

16. The setting tool of Claim 1, wherein the signal is a physical touch of a part of the holding mechanism with a plug set by the setting tool, or an electrical signal sent along a wire from the surface to the holding mechanism, or an acoustic signal detected by a controller of the holding mechanism, or a pressure change in a well fluid around the holding mechanism, or a motion related signal, or a velocity of the setting tool inside the well.

17. A method for releasing a ball from a setting tool in a well, the method comprising:

loading (1400) the ball (432) into the setting tool (410);

securing (1402) the ball to the setting tool with a holding mechanism (430) located within the setting tool;

lowering (1404) the setting tool and the ball into the well;

activating (1406) the setting tool to set up a plug (480) inside the well; and

releasing (1408) the ball into the well based on a signal received by the holding mechanism (430).

18. The method of Claim 17, wherein the signal is a physical touch between a part of the holding mechanism and a plug set by the setting tool, or an electrical signal sent along a wire from the surface to the holding mechanism, or an acoustic signal detected by a controller of the holding mechanism, or a pressure change in a well fluid around the holding mechanism, or a motion related signal, or a velocity of the setting tool inside the well.

19. The method of Claim 17, further comprising:
actuating a motor to release the ball.

20. The method of Claim 17, further comprising:
pushing a pushing arm to release the ball.

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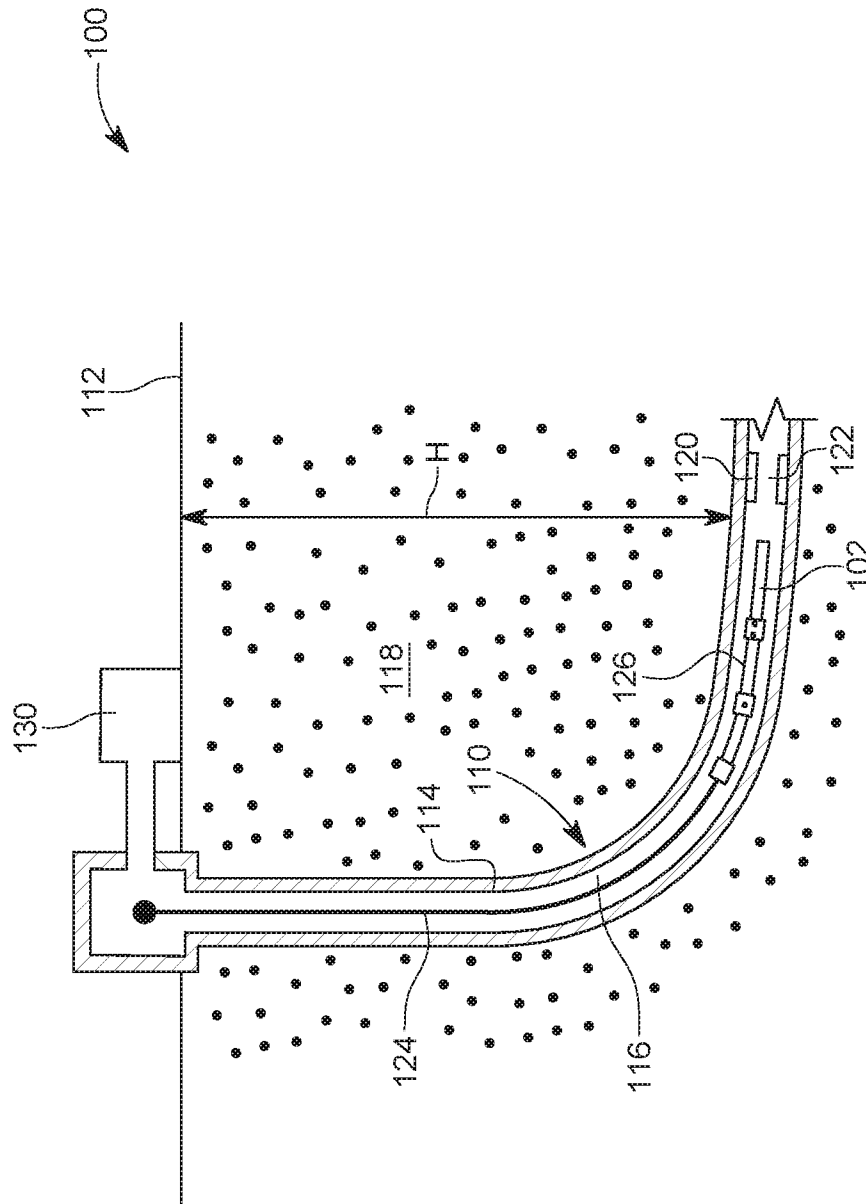


FIG. 1
(BACKGROUND ART)

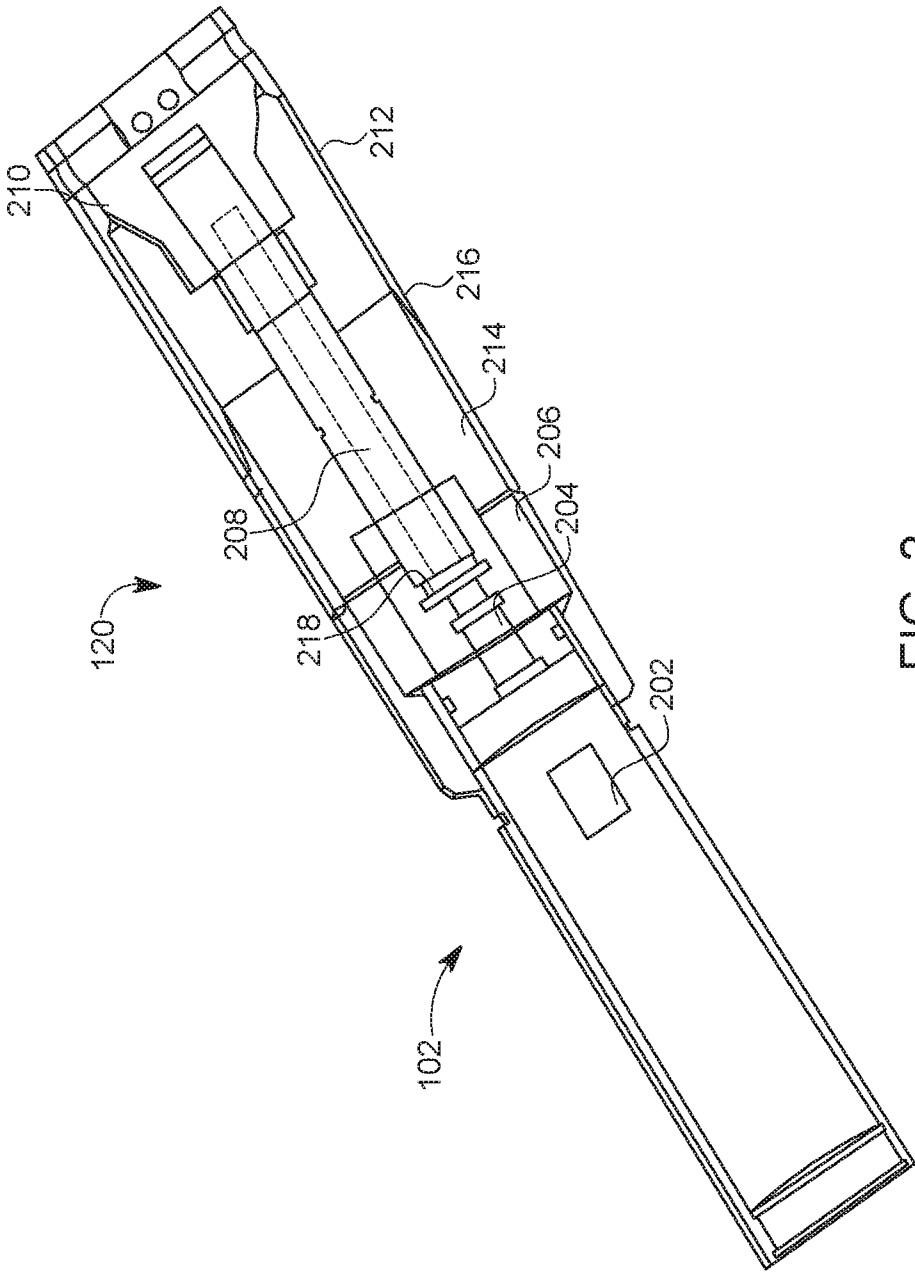


FIG. 2
(BACKGROUND ART)

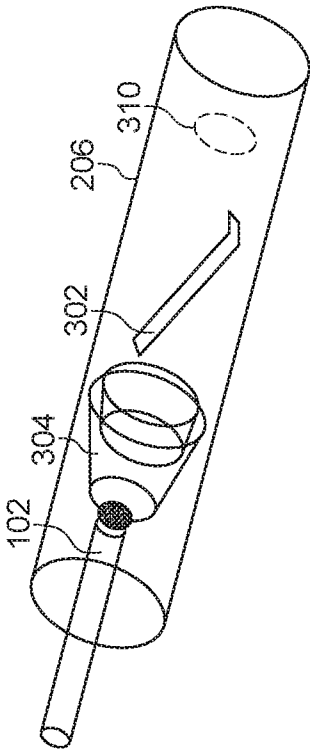


FIG. 3A
(BACKGROUND ART)

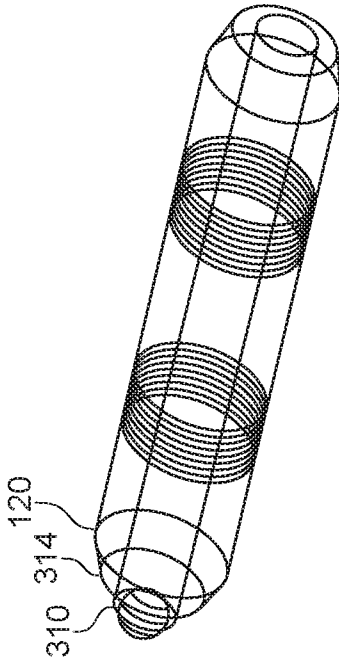
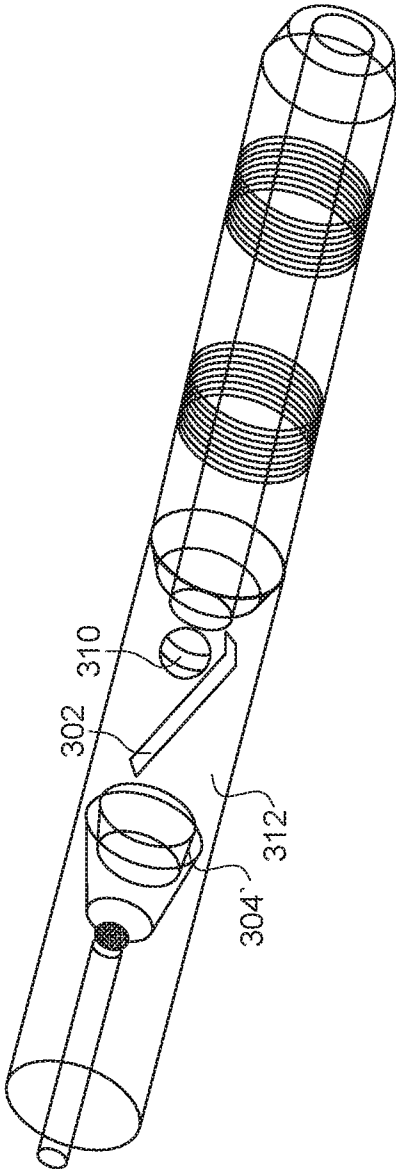


FIG. 3B
(BACKGROUND ART)



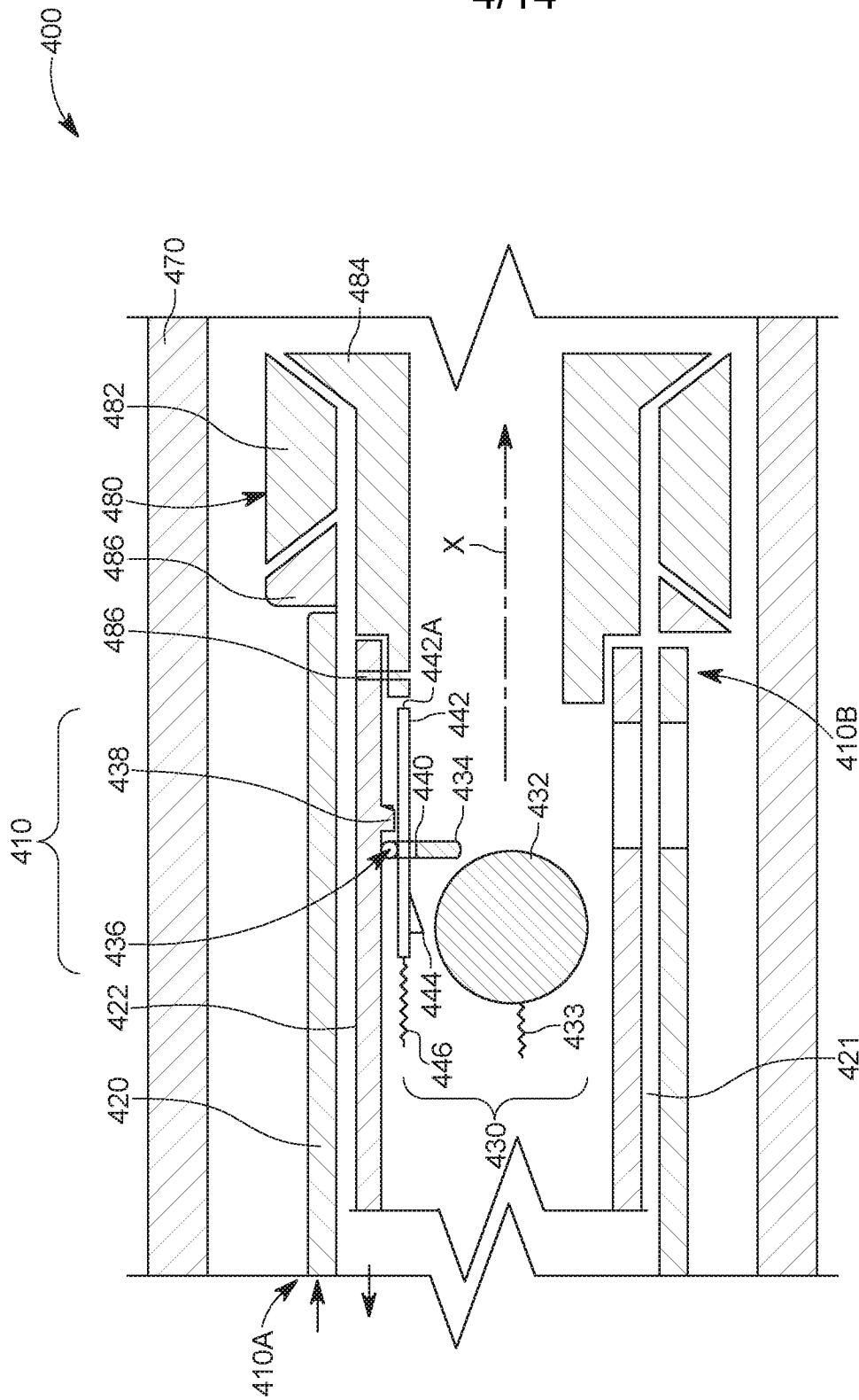


FIG. 4

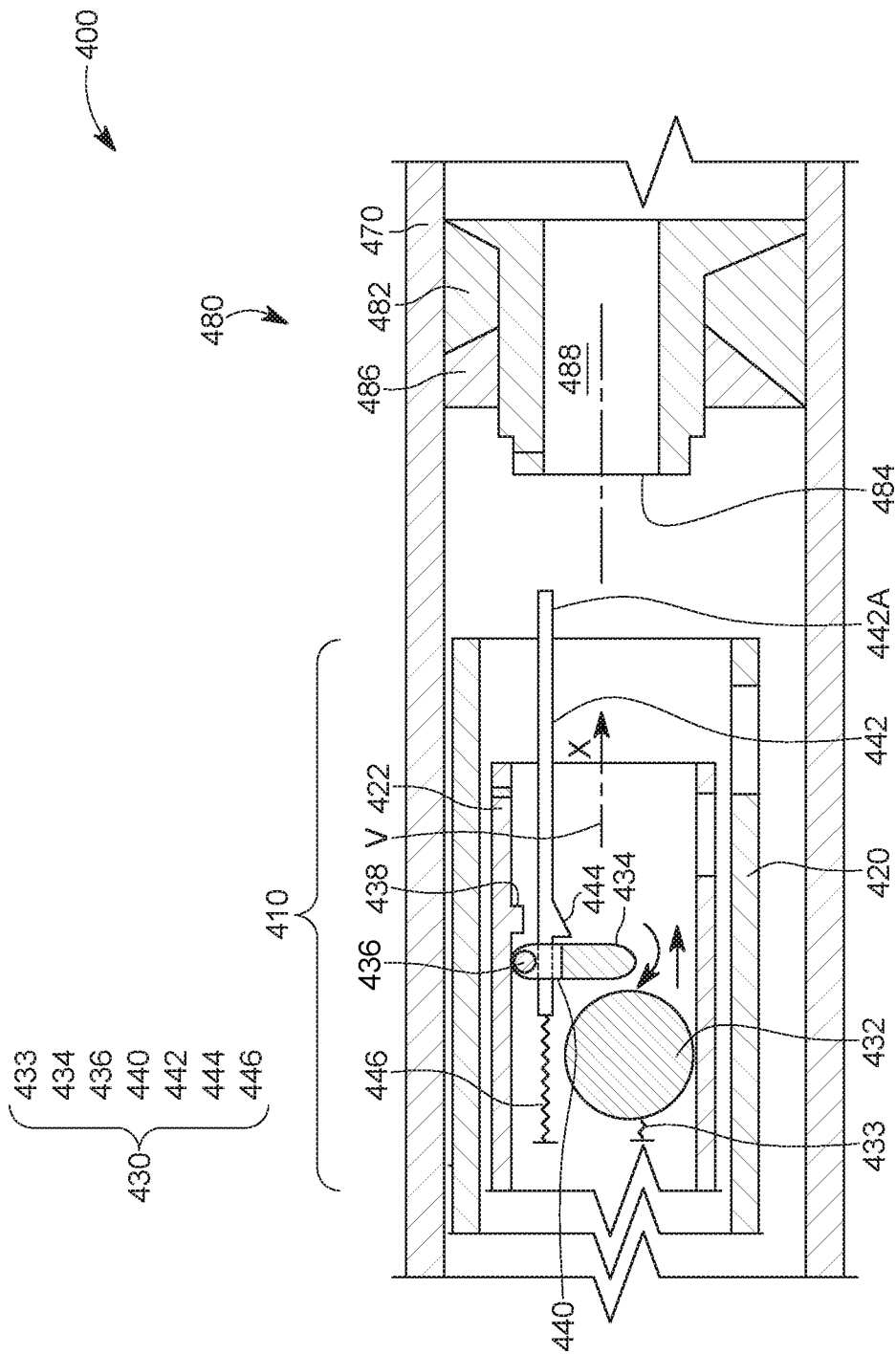


FIG. 5

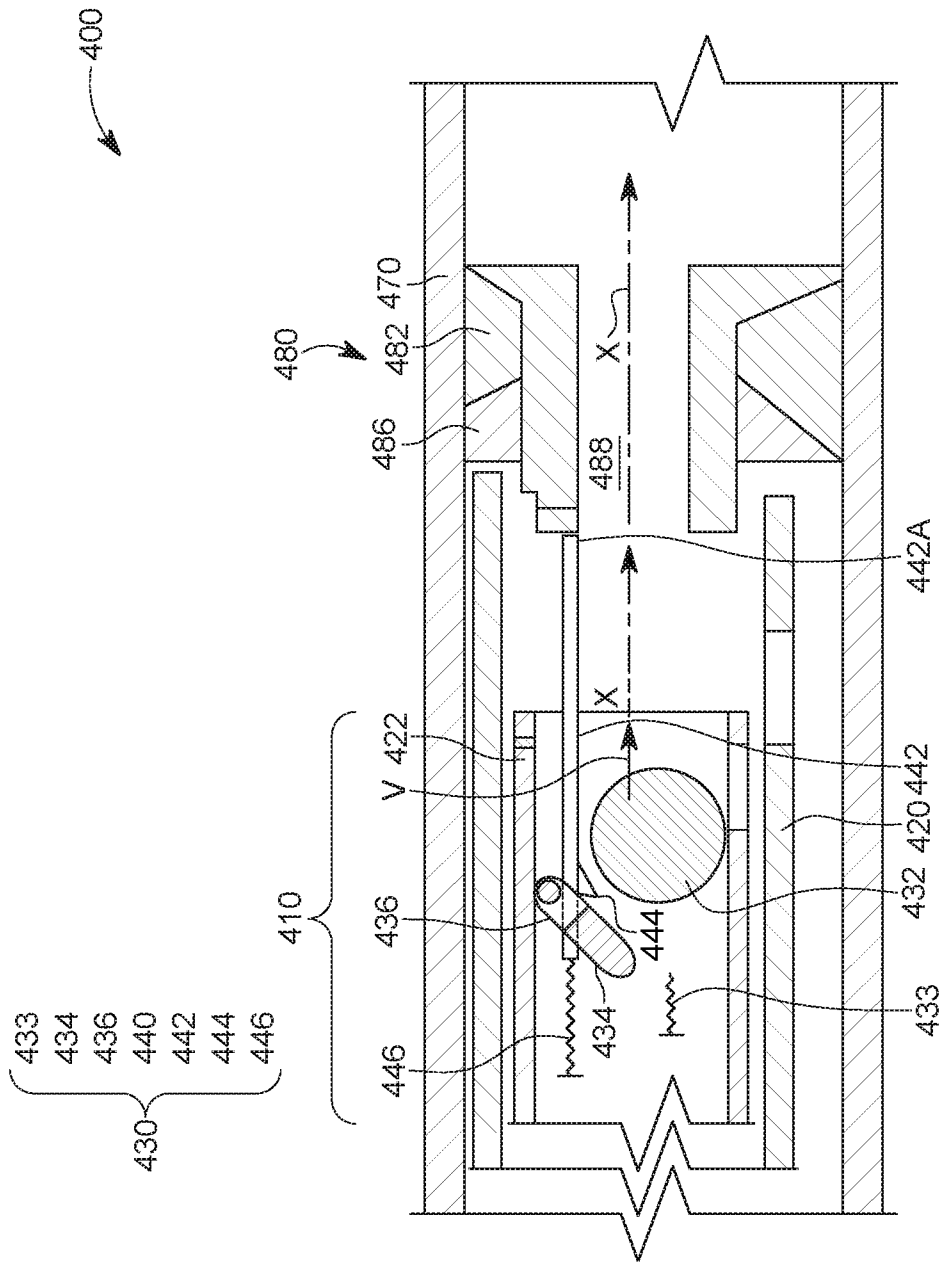
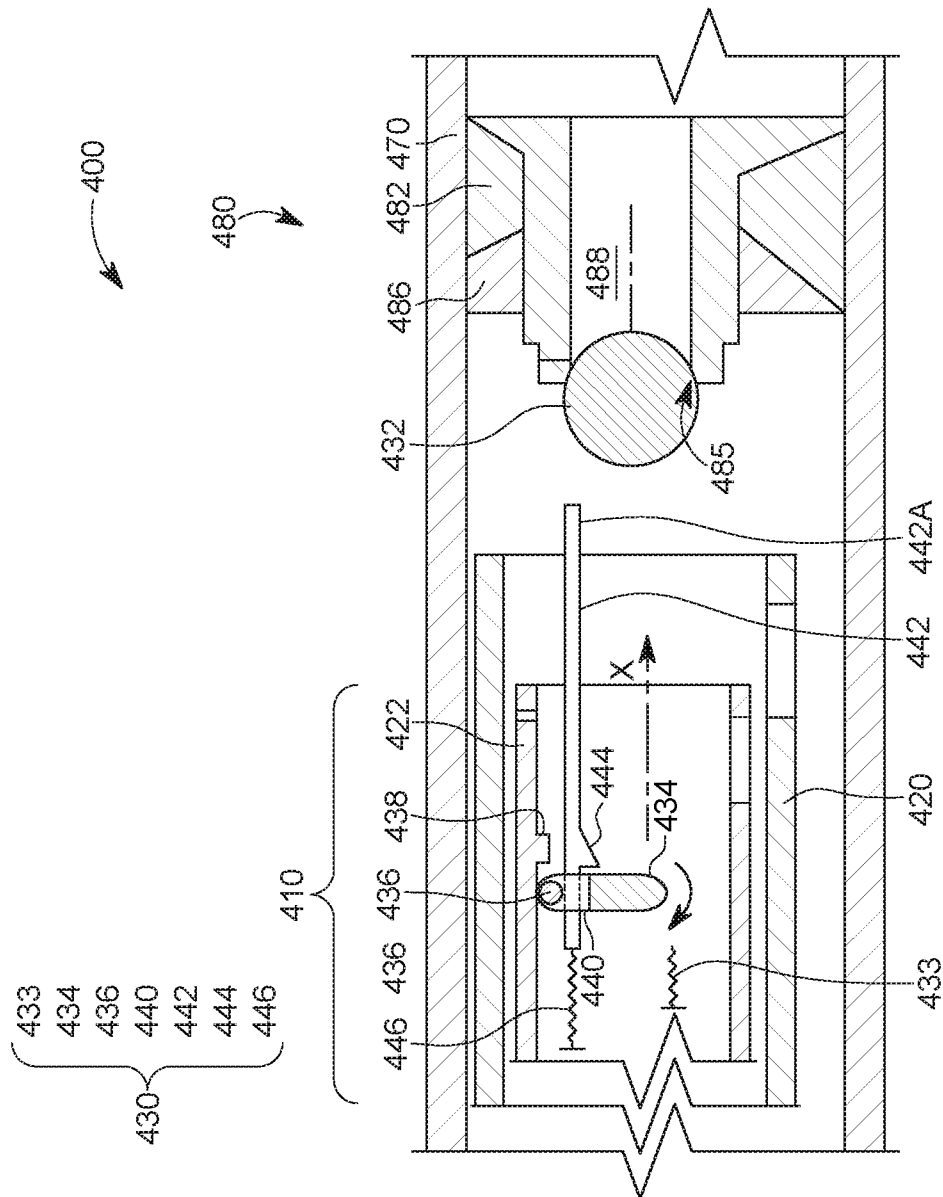


FIG. 6

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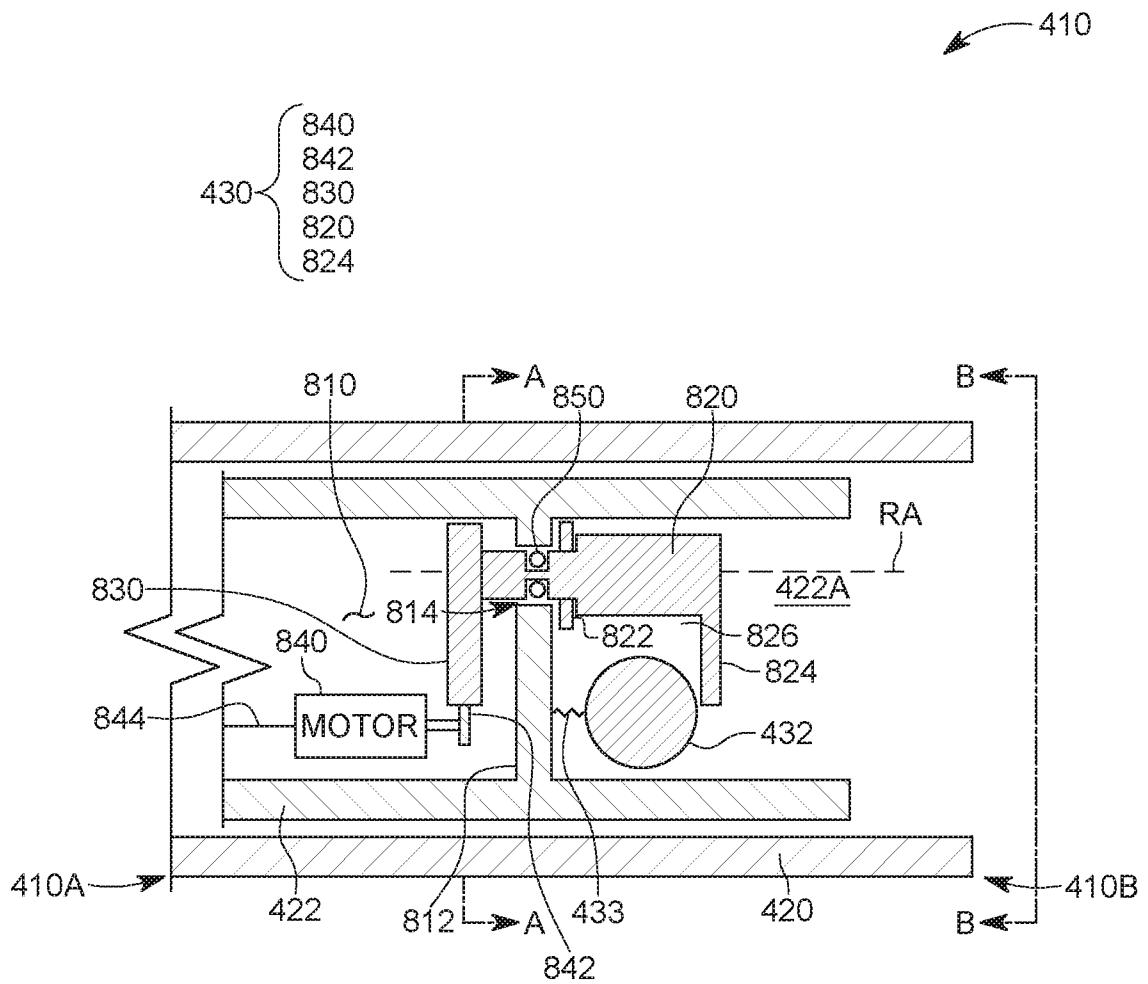


FIG. 8

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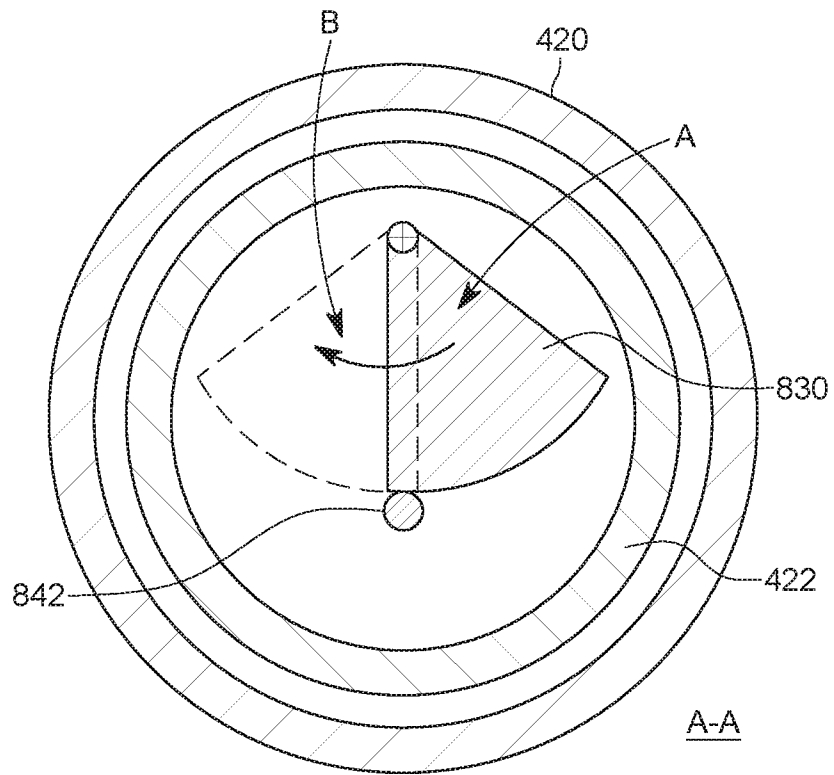


FIG. 9

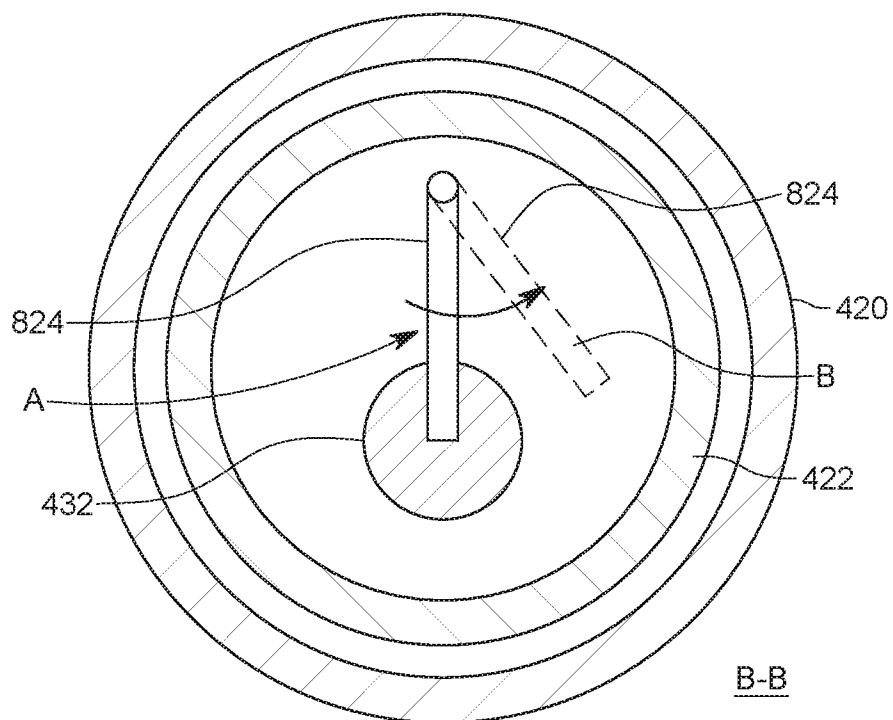


FIG. 10

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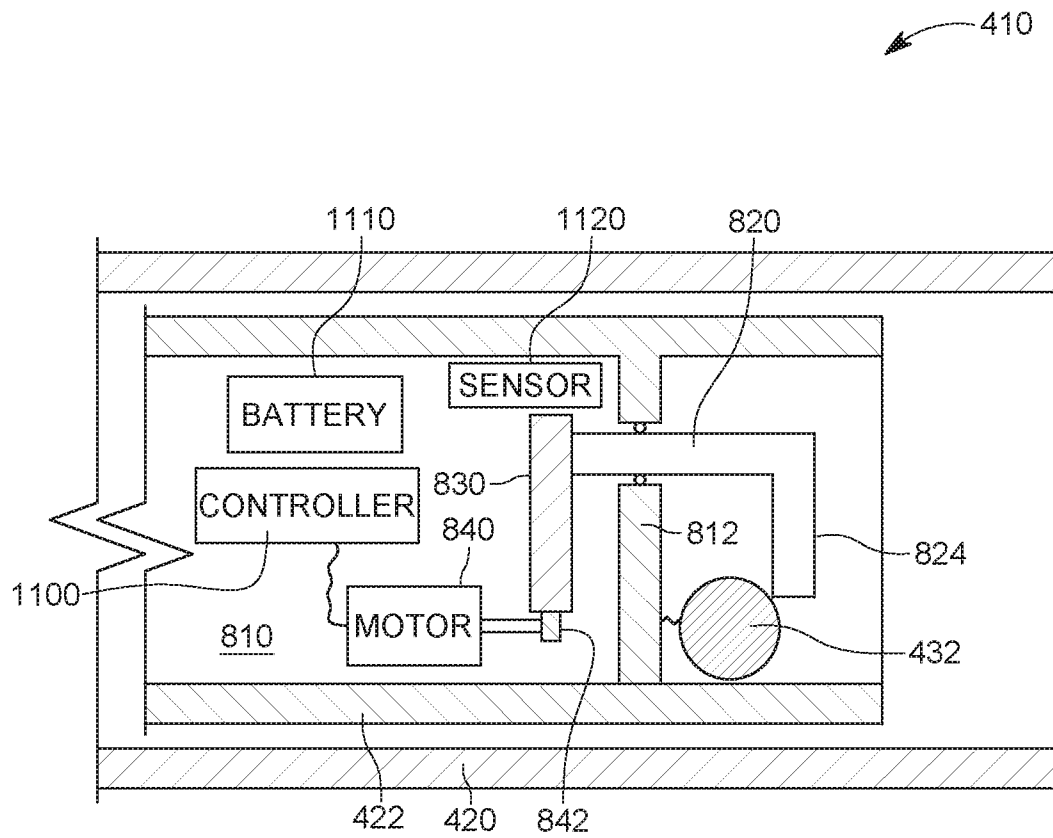


FIG. 11

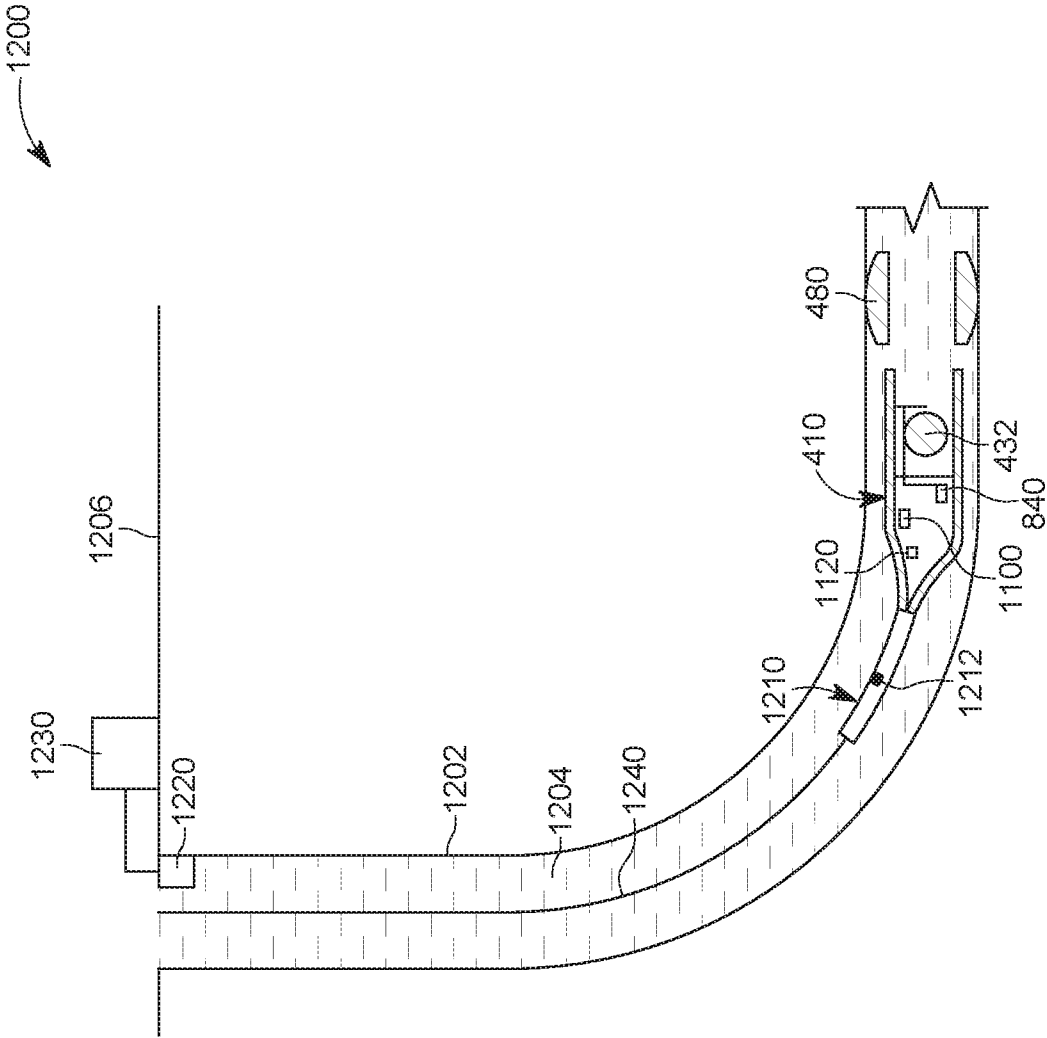


FIG. 12

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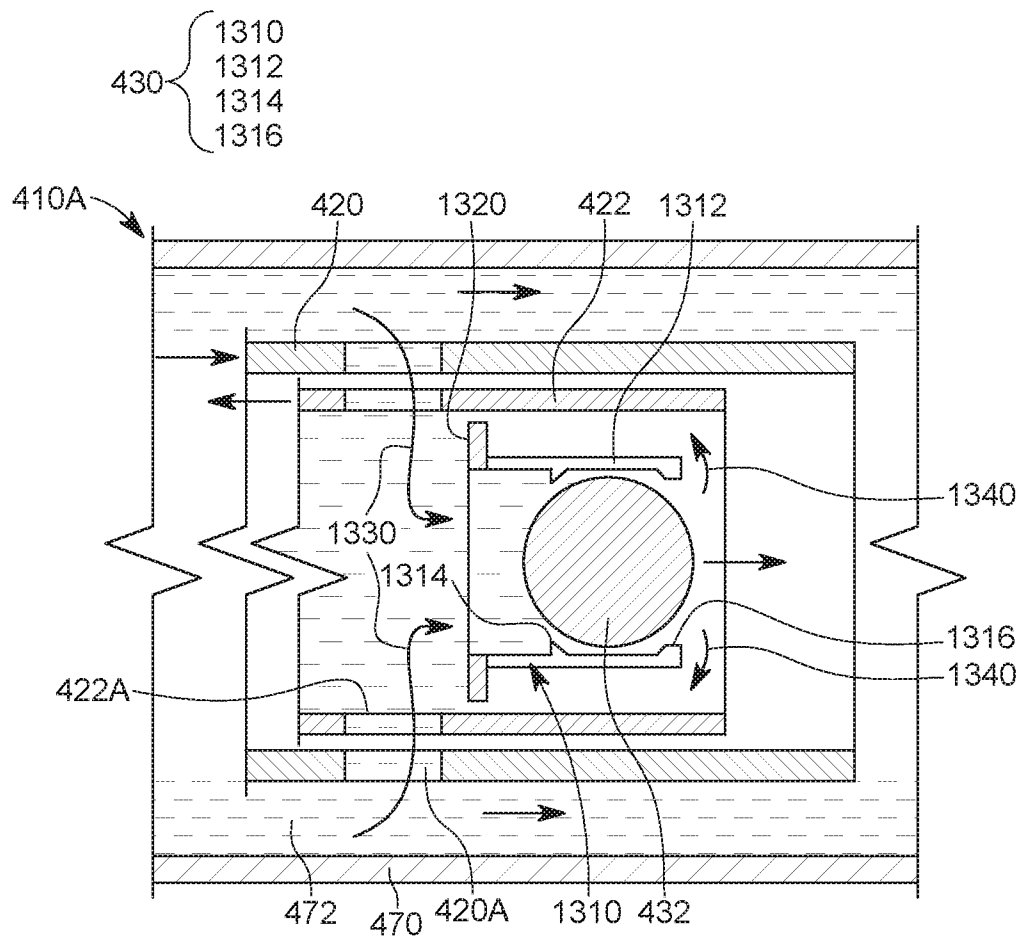


FIG. 13

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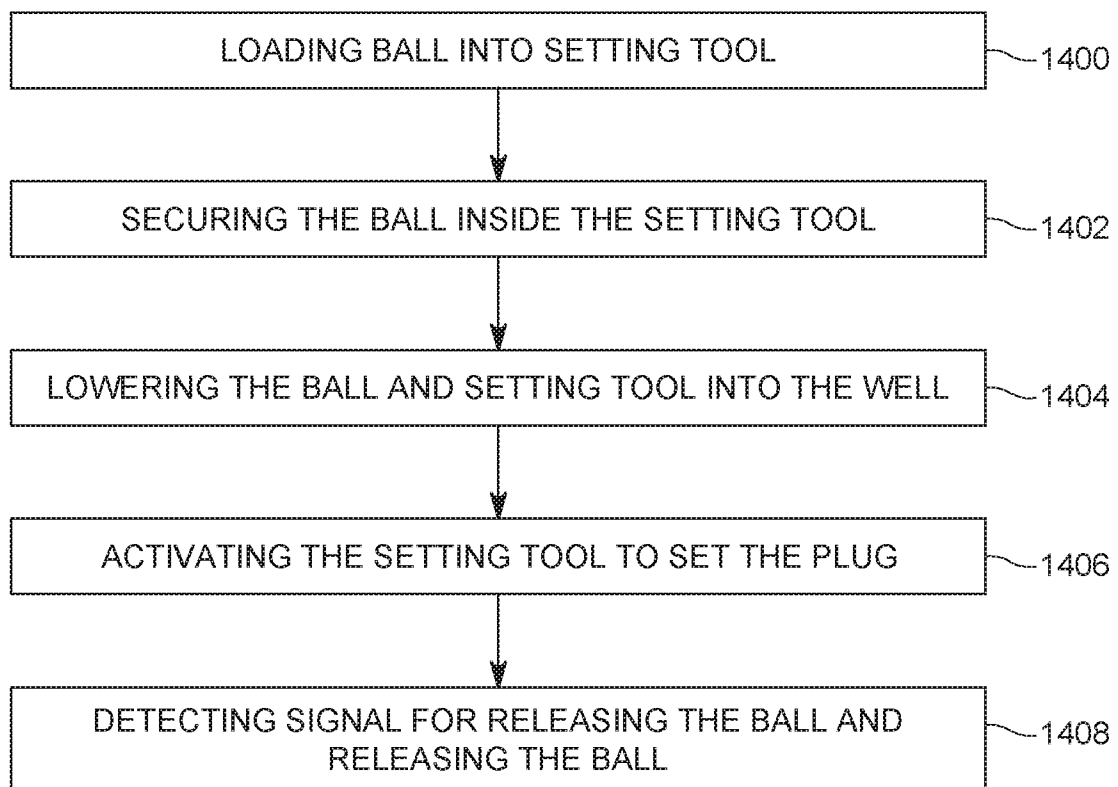


FIG. 14

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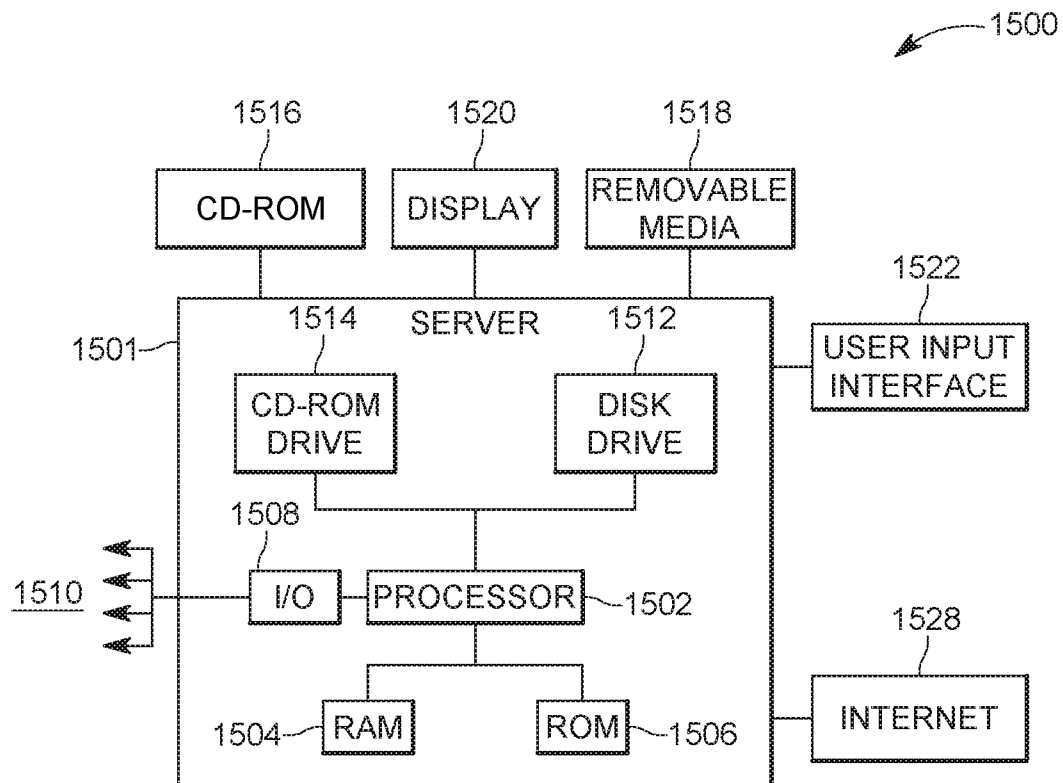


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/062754

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 34/14; E21B 33/16; E21B 34/00; E21B 34/06; E21B 34/08; E21B 34/10 (2019.01)

CPC - E21B 34/14; E21B 33/16; E21B 34/00; E21B 34/06; E21B 34/066; E21B 34/08; E21B 34/10; E21B 34/101; E21B 34/102; E21B 34/105; E21B 34/12; E21B 43/26 (2019.01)

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)

See Search History document

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

USPC - 166/192; 166/193; 166/318; 166/329; 166/374; 166/386 (keyword delimited)

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/0039925 A1 (CONNELL) 24 February 2005 (24.02.2005) entire document	1, 5, 8, 15-18, 20
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Y		3, 4, 6, 7, 10, 14, 19
Y	US 2015/0068771 A1 (HALLIBURTON ENERGY SERVICES, INC.) 12 March 2015 (12.03.2015) entire document	3, 4, 10, 19
Y	US 2015/0345240 A1 (RODERS et al) 03 December 2015 (03.12.2015) entire document	6, 7
Y	US 2016/0362962 A1 (WEATHERFORD TECHNOLOGY HOLDINGS, LLC) 15 December 2016 (15.12.2016) entire document	14
A	US 2008/0223586 A1 (BARNETT) 18 September 2008 (18.09.2008) entire document	1-20
A	US 2017/0089159 A1 (BAKKEN BALL RETRIEVAL, LLC) 30 March 2017 (30.03.2017) entire document	1-20

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 January 2019

Date of mailing of the international search report

14 FEB 2019

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