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(54) **Downhole pressure compensator**

(57) The techniques herein relate to a pressure compensation system. The system includes a downhole tool (104) and one or more pressure compensators (112) positionable in the downhole tool. Each pressure compensator includes a first compensating fluid section having a first compensating fluid, at least one second compensating fluid section having a second compensating fluid, and a convoluted membrane (246) between the first and second fluids in the first and second compensating fluid sections, respectively. The first or second compensating fluid sections, or both, may include a porous disk positioned at a hole in the fluid section. The pressure compensator may also include a switch (256) configured to indicate a fluid condition in the pressure compensator and a relief valve configured to release fluid from the pressure compensator.

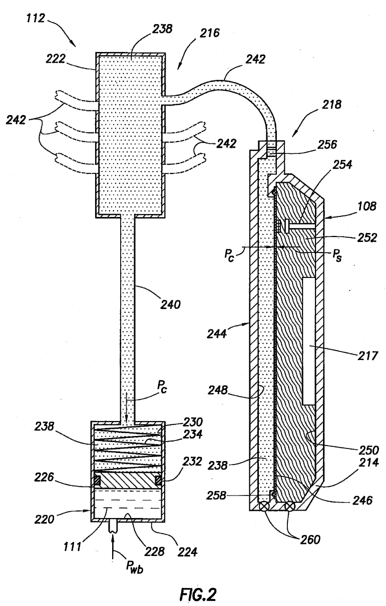

FIG.2

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Description

BACKGROUND

1. Field

[0001] This disclosure relates to techniques for performing wellsite operations. More particularly, this disclosure relates to techniques for compensating for downhole conditions, such as pressure.

2. Related Art

[0002] Oil rigs are positioned at wellsites to locate and gather valuable downhole fluids, such as hydrocarbons. Various oilfield operations are performed at the wellsites, such as drilling a wellbore, performing downhole testing and producing downhole fluids. Downhole drilling tools are advanced into the earth from a surface rig to form a wellbore. Drilling fluids, such as drilling muds, are often pumped into the wellbore as the drilling tool is advanced into the earth. The drilling muds may be used, for example, to remove cuttings, to cool a drill bit at the end of the drilling tool and/or to line a wall of the wellbore.

[0003] During wellsite operations, measurements are often taken to determine downhole conditions. In some cases, the drilling tool may be removed so that a downhole tool may be lowered into the wellbore to take additional measurements of the wellbore. The downhole measurements may be taken by drilling, testing, production and/or other tools for determining downhole conditions and/or to assist in locating subsurface reservoirs containing valuable hydrocarbons. Such wellsite tools may be used to measure downhole parameters, such as pressure, temperature, permittivity, resistivity, etc. Such measurements may be useful in directing oilfield operations and/or for analyzing downhole conditions.

[0004] In some cases, pressures and/or temperatures may rise to levels that affect the operation of downhole devices, such as sensors. Some techniques for protecting sensors may involve providing an interface, such as a bellows or piston between the sensor and wellbore fluids to protect the sensors from the harsh conditions.

SUMMARY

[0005] One or more embodiments relates to a pressure compensation system having one or more pressure compensators. Each pressure compensator includes a first fluid compensating section having a first fluid, a second fluid compensating section having a second fluid, and a convoluted membrane disposed between the first fluid in the first fluid compensating section and the second fluid in the second fluid compensating section. The convoluted membrane may have ridges, waves, folds, etc. The convoluted membrane may be suitable for separating the first fluid from the second fluid and for adjusting a pressure of the second fluid compensating section based on a pressure of the first fluid compensating section. The pressure compensator may also include a second convoluted membrane disposed between the first fluid and a wellbore fluid in the wellbore. The second convoluted membrane is suitable for separating the wellbore fluid from the first fluid and for adjusting a pressure of the first fluid based on a wellbore pressure of the wellbore fluid.

[0006] In some embodiments, the second fluid compensating section includes a hole, and a porous disk may be positioned to cover or expand through the dimensions of the hole. The porous disk may allow fluid flow and may also be a smooth surface for contacting the first or second convoluted membranes (or both).

[0007] The pressure compensator may also include a switch for providing an indication corresponding to a fluid condition in the pressure compensator. For example, the switch may indicate when a fluid level in the first fluid compensating section, the second fluid compensating section, or both, is below an acceptable level. The pressure compensator may also include a relief valve to release fluid from the first fluid compensating section, the second fluid compensating section, or both, based on an indication of the switch. Furthermore, the relief valve may release fluid from the first fluid compensating section, the second fluid compensating section, or both, when the corresponding fluid compensating section is above an acceptable level.

[0008] Some embodiments include a method of compensating pressure in a downhole tool. The method includes deploying a downhole tool into the wellbore and receiving an indication of a pressure condition in the downhole tool. The downhole tool includes a pressure compensator having a first fluid compensating section having a first fluid, a second fluid compensating section having a second fluid, and a pressure indicator for providing an indication corresponding to a fluid condition in the pressure compensator.

[0009] In some embodiments, the method includes releasing the first fluid from the first fluid compensating section, the second fluid from the second fluid compensating section, or both, through a release valve. The release may be based on a volume of fluid in the first fluid compensating section, the second fluid compensating section, or both. In some embodiments, the fluid may be released based on the indication from the pressure indicator. The pressure compensator may include a convoluted membrane disposed between the first fluid in the first fluid compensating section and the second fluid in the second fluid compensating section. The pressure compensator may also include a convoluted membrane disposed between a wellbore fluid and the first fluid in the first fluid compensating section.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the above recited features and advantages of the techniques herein can be understood in detail, a more particular description thereof, briefly summarized above, may be had by reference to the embodiments thereof that are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments and are, therefore, not to be considered limiting of its scope, for the techniques herein may admit to other equally effective embodiments. The figures are not necessarily to scale, and certain features and certain views of the figures may be shown exaggerated in scale or in schematic in the interest of clarity and conciseness.

Figure 1 is a schematic view, partially in cross section, of a wellsite having a downhole tool deployable into a wellbore, the downhole tool having a pressure compensator and a sensing unit therein.
Figure 2 is a schematic view of a portion of the downhole tool of Figure 1 depicting the pressure compensator and the sensing unit in greater detail.
Figure 3A is a schematic view of a pressure compensator having indirect interfaces.
Figure 3B is a schematic view of a pressure compensator having direct and indirect interfaces.
Figure 4 is a flow chart depicting a method of compensating pressure of a sensor of a downhole tool.
Figure 5 is a perspective view of an elastomer membrane having a convoluted shape for separating fluids in a chamber of the downhole tool.
Figure 6 is a perspective view of a disk for smoothing a contact surface in the downhole tool.
Figure 7 is a cross-sectional view of a portion of the downhole tool depicting a switch for indicating a condition of the pressure compensator.

DETAILED DESCRIPTION OF THE INVENTION

[0011] The description that follows includes exemplary systems, apparatuses, methods, techniques and instruction sequences that embody the present inventive subject matter. However, it is understood that the described embodiments may be practiced without these specific details.

[0012] The techniques herein are designed to protect downhole devices (e.g., sensors and/or sensing systems) from exposure to harsh conditions (e.g., high temperature, high pressure and/or corrosive materials), while still enabling measurement of downhole parameters. In some cases, the downhole devices cannot withstand the downhole conditions of a wellbore and/or exposure to wellbore fluids (e.g., drilling or production fluids). In particular, pressure in the wellbore may increase with the drilled depth and increase the risk of damage to downhole devices.

[0013] It may be desirable to provide an interface between the wellbore fluids and the downhole devices to transmit pressure without exposing the downhole devices to the wellbore fluids. An additional (or indirect) interface may be provided between the downhole devices and the downhole environment to further isolate the downhole devices from exposure to the harsh downhole conditions in the wellbore. The indirect interface may be used, for example, to limit exposure to wellbore fluids (e.g., to enhance maintenance, reduce cleaning, reduce degradation of the direct interface, reduce clogging, etc.), to provide a compensation media with known properties, to prevent leakage/mud entry, to prevent component damage (e.g., mud entry, seal degradation, membrane perforation, etc.), and/or to provide a single interface with the wellbore fluid for multiple sensors.

[0014] Figure 1 is a schematic view of a wellsite 100 having a rig 102 with a downhole tool 104 deployed into a wellbore 106. The downhole tool 104 is depicted as having a sensing unit 108 positionable along a wall 110 of the wellbore 106 having a wellbore fluid 111 therein. The sensing unit 108 may be, for example, an imaging sensor for measuring downhole parameters and/or generating downhole images, such as that described in US

[0015] Patent No. 7242192. The downhole tool 104 also has a pressure compensator 112 usable for protecting the sensing unit 108 during operation. At least a portion of the pressure compensator 112 and/or the sensing unit 108 may be positioned in the downhole tool 104 and/or extendable therefrom via one or more arms 109.

[0016] As shown, the downhole tool 104 is a wireline tool positioned in a land based rig, but could be any downhole tool (e.g., drilling, coiled tubing, testing, measurement while drilling, logging while drilling, etc.) deployed from a land based rig or offshore platform. Also, the sensing unit 108 is depicted as being used with a specific type of sensing unit 108, such as an imaging tool positionable in the downhole tool 104, but may be used with any downhole sensor, sensing unit or other downhole device.

[0017] Figure 2 is a schematic view of a portion of the downhole tool of Figure 1 depicting the pressure compensator 112 and sensing unit 108 in greater detail. The sensing unit 108 is depicted as including a sensor housing 214 with electrodes (or wellbore sensors) 217 for taking downhole measurements. The sensor housing 214 may be positioned in various parts of the downhole tool 104, such as housing, arms, pads, etc. (as shown in Figure 1).

[0018] In this illustrative example, the pressure compensator 112 includes two pressure compensation sections, i.e., a first pressure compensation section 216 and a second pressure compensation section 218. It should be appreciated that the pressure compensator 112 may include one or more pressure compensation sections. The first pressure compensation section 216 is fluidly exposed to a wellbore fluid 111, such as oil-based mud, water-based mud, or other downhole fluid, in the wellbore 106. The first pressure compensation section 216 includes a first pressure regulation section 220 and a compensating fluid section 222. The first pressure regulation section 220 includes a cylinder 224 with a first pressure regulating device, such as a piston 226 slidably positionable therein to define a wellbore fluid cavity 228 and a compensating fluid cavity 230. The piston 226 may be provided with a seal (or gasket) 232 to prevent the passage of fluid between the wellbore fluid cavity 228 and the compensating fluid cavity 230, and a spring 234 having a spring tension configured to apply an overpressure ΔP_1 as it translates a wellbore pressure P_{wb} of the wellbore fluid 111 received in the wellbore fluid cavity 228 to a compensation pressure P_c of a first compensating fluid 238 in the compensating fluid cavity 230.

[0019] The compensating fluid cavity 230 is in fluid communication with the compensating fluid section 222 via flowline 240 for passing the first compensating fluid 238 therebetween. The compensating fluid section 222 may be fluidly coupled to one or more second pressure compensation sections 218 via flowline(s) 242. For descriptive purposes, only one second pressure compensation section 218 is depicted. While flowlines 240, 242 may be depicted as a tube or hose, the second pressure compensation section 218 may optionally be directly coupled to the compensating fluid cavity 230. In cases where flowlines are provided, the first and/or second pressure compensation sections 216, 218 may be movable, for example, where positioned in moving parts, such as sensor pads extendable by arms (see, e.g., 109 of Figure 1).

[0020] Referring still to Figure 2, the second pressure compensation section 218 may be a separate component coupled to the sensor 217 (e.g., pressure, temperature, or other gauge) or a measuring pad for measuring downhole parameters, or may be formed as an integral part of the sensor or the measuring pad. The second pressure compensation section 218 also includes a pressure regulation section 244 that has a second pressure regulating device, such as a membrane 246 flexibly positionable in the sensor housing 214 and defining a first compensating fluid cavity 248 and a second compensating fluid cavity (or section) 250. A seal 258 may be provided about the membrane 246 to further prevent fluid passage between the first compensating fluid cavity 248 and the second compensating fluid cavity 250. The membrane 246 may be made of an elastomeric, metallic or other flexible material to prevent the passage of fluid. The second pressure regulating device (e.g., membrane 246) applies an overpressure ΔP_2 while allowing the compensation pressure P_c of the first compensating fluid 238 in the first compensating fluid cavity 248 to apply to a sensor pressure P_s of a second compensating fluid 252 in the second compensating fluid cavity 250.

[0021] The second pressure compensation section 218 may also be provided with a sensing device 254, such as a piston, for evaluating the position of the membrane 246. One or more sensing devices 254 may be provided about the pressure compensator 112 to determine operation of one or more pressure regulating devices. The sensing device(s) 254 may be used to determine, for example, the longitudinal displacement of the piston 226 and/or the expansion/retraction position of the membrane 246. The sensing device(s) 254 may be, for example, a capacitive/resistive measurement sensor for continuous position information, or a switch for discrete position information.

[0022] A disconnect 256 may also be provided in the sensor housing 214 for selectively disconnecting the second pressure compensation section 218 from the first pressure compensation section 216. The disconnect 256 may have a switch to detect if the second pressure compensation section 218 is intentionally or unintentionally disconnected from the first pressure compensation section 216. The switch may prevent the first compensating fluid 238 from flowing out and/or impairing the functioning of other portions of the pressure compensator 112 and/or the downhole tool 104. This disconnect switch may be, for example, a mechanical contact self-closing valve or a mechanical check valve.

[0023] Plugs 260 may also be provided in the sensor housing 214 for selectively permitting addition or removal of fluids. The plugs 260 may be, for example, fill/empty plugs added to various portions of the second pressure compensation section 218 or other portions of the pressure compensator 112 for filling and/or emptying fluids.

[0024] As shown in Figure 2, the pressure regulation sections 220, 244, and the compensating fluid sections 222, 250 are in fluid communication for regulating pressure therebetween. For example, the wellbore pressure P_{wb} balances with the compensation pressure P_c of the first compensating fluid 238 and the sensor pressure P_s of the second compensating fluid 252. The first pressure regulation section 220 provides a first interface in direct contact with the wellbore fluid 111, and the second pressure regulation section 244 provides a second interface indirectly providing pressure communication between the sensor 217 and the wellbore fluid 111. In this manner, the pressure compensator 112 provides a compensation chain that enables the wellbore pressure P_{wb} to be indirectly applied to the wellbore sensor 217.

[0025] The first compensating fluid 238 and the second compensating fluid 252 may be any suitable fluids or media, such as oil (e.g., dielectric, silicon, mineral or other oil), gel, foam, non-conducting fluids, etc. For example, such fluid may be a liquid with good lubrication properties, low expansion/compression set towards temperature/pressure, and any other desired properties to facilitate operation of the pressure compensator 112 and/or the sensing unit 108 (e.g., power transmission for a hydraulic circuit, good insulation, purity, etc.) In some cases, the compensating fluid may be different from the hydraulic oil or other fluids used in the downhole tool 104.

[0026] The pressure regulation section(s) 220 and/or 244 may be provided with any suitable pressure regulating device (e.g., a piston, bellows, membrane, etc.) capable of providing a tight barrier between the wellbore fluid 111 and the first compensating fluid 238 and/or between the first compensating fluid 238 and the second compensating fluid 252, while allowing movement in response to the fluid(s) and regulating pressure therebetween. The pressure regulating devices are preferably gas tight to avoid fluid/solid/gas entry in and/or out of such devices. The pressure regulating devices may have static or dynamic seals 232, 258, such as welded/soldered membranes, gaskets, elastomers, etc. By way of example, when the pressure and/or temperature vary, the pressure and/or temperature may expand and/or retract the compensating fluids 238, 252. The pressures P_{wb}, P_c, P_s may be in a range of from about 1 to about 3000 bar (about 0.1 MPa to about 300 MPa), the overpressures ΔP_1, ΔP_2 may be in the range of from about 1 to about 10 bar (about 0.1 to about 1 MPa), and/or the temperature may be in a range of from about -50 to about 250 degrees C.

[0027] Figures 3A and 3B schematically depict various configurations of a pressure compensator 112a,112b, respectively, usable as the pressure compensator 112 of Figure 1 or 2. The pressure compensator 112a of Figure 3A has multiple second pressure compensation sections 218a with an indirect interface configuration for compensating the pressure of the wellbore fluid 111. The pressure compensator 112a is similar to the pressure compensator 112 of Figure 2, except that multiple pressure compensation sections 218a are depicted as being linked to the compensating fluid section 222 by flowlines 242, and that various pressure regulating devices 246, 246a, 246b are depicted. The pressure compensation sections 218a of Figure 3A include a membrane 246, bellows 246a, and piston 246b as the second pressure regulating device for transferring the pressure P_c of the first compensating fluid 238 to the second compensating fluid 252. As demonstrated by this figure, the pressure regulating device may be any device, such as a membrane 246, bellows246a, piston 246b, or other device capable of regulating pressure between fluids.

[0028] In the indirect interface configuration of Figure 3A, each second pressure compensation section 218a has its own second pressure regulating device 246, 246a, or 246b with its own second compensating fluid 252 for providing its own individual pressure compensation system. Each of these individual indirect interfaces is coupled to the shared first compensating fluid 238 of compensating fluid section 222. This configuration allows each pressure compensation section 218a to have pressure communication with the wellbore fluid 111 through the shared first compensation fluid 238. This provides a single interface between the wellbore fluid 111 and multiple second pressure compensation sections 218a.

[0029] The pressure compensator 112b of Figure 3B provides multiple pressure compensation sections 320, 218a with a combined direct and indirect interface configuration for compensating the pressure of the wellbore fluid 111. The pressure compensator 112b is similar to the pressure compensator 112a of Figure 3A, except that three of the pressure compensation sections are depicted as a third (or direct) pressure compensation section 320 with a direct interface with the wellbore fluid 111, and one of the pressure compensation sections is depicted as a second pressure compensation section 218a with an indirect configuration with an indirect interface with the wellbore fluid 111. The second pressure compensation section 218a has a pressure regulating device 246, such as a membrane, coupled to the compensating fluid section 222 as previously described for Figure 3A. As demonstrated by this figure, the pressure compensator 112b may have one or more direct interfaces and one or more indirect interfaces with the wellbore fluid 111.

[0030] The combined direct and indirect configuration of Figure 3B allows each of the third pressure compensation sections 320 to have individual pressure communication with the wellbore fluid 111, and a fluid compensation section 318. Each of the third pressure compensation sections 320 has a third pressure regulation device and is similar to the pressure regulation device 226 previously described herein, except that the first compensating fluid 238 in the fluid compensation section 318 is exposed directly to a sensor for applying the wellbore pressure directly thereto.

[0031] A separate first pressure regulation section 220 is also depicted for indirectly providing pressure compensation to various portions of the downhole tool, such as for second pressure compensation section 218a. One or more pressure compensation sections 218, 218a, 318 may be provided in various configurations as desired. Redundant pressure compensation sections may be used , for example, in case certain pressure compensation sections are affected by exposure to wellbore fluids or otherwise malfunction.

[0032] Referring to Figures 1-3B, in operation, the pressure compensator 112, 112a, 112b adjusts pressure to in situ conditions. Wellbore fluid (e.g., mud) 111 surrounds the downhole tool 104, the sensing unit 108 and the pressure compensator 112. The wellbore fluid 111 has a pressure P_{wb}. This wellbore pressure P_{wb} may vary with the movement of the downhole tool 104 in the wellbore and/or variations in the wellbore pressure P_{wb}.

[0033] The wellbore fluid 111 enters the first pressure regulation section 220 and applies pressure P_{wb} to the first pressure regulation device (e.g., piston) 226. The wellbore pressure P_{wb} applied to the piston 226 may compress the spring 234 and translate the pressure to the first compensation fluid 238. The spring 234 ensures a positive displacement of the piston 226 and the seal 232, and adds an overpressure ΔP_1 inside the first compensating fluid 238. This overpressure ΔP_1 may be used to avoid wellbore fluid 111 entry through the first pressure regulation section 220 if potential leaks occur at the seal 232. The compensation pressure P_c of the first compensating fluid 238 may be determined by the following Equation (1):

$$P_c = P_{wb} + \Delta P_1 \qquad \text{(Equation 1)}$$

[0034] The first compensating fluid 238 is communicated to all second pressure compensation sections 218, 218a via flowlines 242 (or directly where no flowlines are present). The first compensating fluid 238 and the second compensating fluid 252 are isolated by the second pressure regulation device 246 with a seal 258 to avoid fluid transfer therebetween. The second pressure regulation device 246 allows for transmission of the compensating pressure P_c of the first compensating fluid 238 to the sensor pressure P_s of the second compensating fluid 252. The second pressure regulation device 246 has a resilience which adds an overpressure ΔP_2 from the first compensating fluid 238 to the second compensating fluid 252. The sensor pressure P_s of the second compensating fluid 252 may be determined by the following Equation (2):

$$P_s = P_c + \Delta P_2 \qquad \text{(Equation 2)}$$

[0035] From Equations (1) and (2), the following Equation (3) may be derived:

$$P_s = P_m + \Delta P_1 + \Delta P_2 \qquad \text{(Equation 3)}$$

[0036] The first pressure regulation section 220 and the second pressure regulation section 244 may allow some positive or negative movement of the pressure regulation device 226, 246 itself. For example, the first pressure regulation device 226 may translate longitudinally inside its cylinder 224 or the second pressure regulation device 246 may expand or retract similar to a balloon. This movement may allow the first and/or second pressure regulation section 220, 244 to adapt for fluid volume changes due to pressure and/or temperature changes (e.g., expansion, contraction or other changes, such as small leaks to a certain point).

[0037] As shown in Figure 2, the pressure regulation devices 226, 246 are positioned in a central (or released) position at ambient pressure and/or ambient temperature. Higher temperatures may cause the first compensation fluid 238 and the second compensation fluid 252 to expand, thereby causing pressure regulation devices 226,246 to move to an extended position. The first pressure regulation device 226 is in the extended position as it advances to expand the compensation fluid cavity 230. The second pressure regulation device 246 is moved to the extended position as it expands to enlarge the second compensating fluid cavity (or section) 250.

[0038] Higher pressures may cause the first compensation fluid 238 and the second compensating fluid 252 to retract, thereby causing the first pressure regulation device 226 and the second pressure regulation device 246 to move to a retracted position. The first pressure regulation device 226 is in the retracted position as it moves to reduce the compensating fluid cavity 230. The second pressure regulation device 252 is moved to the retracted position as it deflates to reduce the second compensating fluid cavity (or section) 250.

[0039] The sensing device 254 may be used to determine the position of the second pressure regulation device 246. If the second pressure regulation device 246 and the first pressure regulation device 226 move together, the position of the first pressure regulation device 226 may also be determined accordingly. This information may be used, for example, to detect failures or to know when refills may be necessary for the first compensating fluid 238 and/or the second compensating fluid 252. This information may also be used to determine, for example, a measurement of the position of one or more of the second pressure regulation devices 246 to determine the different volumes of first compensating fluid 238. Pressure may also be compensated through the third pressure compensation sections 320. The amount of first compensating fluid 238 may be used to evaluate maintenance needs and/or refill needs. Information gathered by the pressure compensator 112 and/or the sensing unit 108 may be passed to a surface unit (not shown).

[0040] Figure 4 depicts a method 400 of compensating pressure of a wellbore fluid. The method involves deploying (450) a downhole tool into a wellbore (the downhole tool having at least one sensor for measuring downhole parameters and at least one pressure compensator coupled to the sensor), and exposing (452) the sensor(s) to a wellbore pressure of the wellbore fluid by adjusting a compensation pressure of a first compensating fluid based on the wellbore pressure and adjusting a sensor pressure of a second compensating fluid based on the compensation pressure of the first compensating fluid. The method may also involve directly exposing (454) the sensor to the wellbore pressure by adjusting a sensor pressure of a third compensating fluid based on the wellbore pressure of the wellbore fluid.

[0041] As previously discussed, a downhole tool 104 may include a pressure compensator 112 having one or more pressure compensation sections which may each be exposed to mud, other downhole fluid, compensating fluid, etc., and may be suitable for compensating for the different pressures in the different sections or fluids of the downhole tool 104 in the wellbore 106. The pressure compensation sections may include pressure regulating devices, such as a membrane which separates and/or defines different pressure compensating cavities.

[0042] One example of a pressure regulating device is provided in Figure 5. Figure 5 is a perspective view of a membrane 500, which may include elastomeric material, metallic material, other flexible materials, or combinations thereof, which may be suitable for interfacing between two different types of fluid and sufficiently elastic to accommodate pressure and/or volume changes from either side.

[0043] The membrane may be susceptible to high stress levels due to constant adjustments in its form, as well as possible contact between the membrane and the walls of the cavities (e.g., first and second compensating fluid cavities 248 and 250 of Figure 2, respectively). Furthermore, in some situations, the membrane may also be exposed to environmental elements or human errors which result in stresses on the membrane beyond its predicted compensation abilities.

[0044] In some embodiments, and as depicted in Figure 5, the membrane 500 may have a convoluted shape, such as folds, waves, or ridges 502. Such ridges 502 may be implemented to increase the compensation ability of the membrane 500, as ridged membrane 500 may have more material to expand with decreased stress, compared to a flat membrane.

[0045] In some embodiments, the pressure compensator 112 may include smooth surfaces at possible contact areas between the membrane 500 and surfaces of the pressure compensator 112. For example, if one cavity has a hole for fluid flow or fluid exchange, the size of the hole may be limited such that the membrane will not be extruded inside, which may cause additional stress on the membrane. If a contact surface has a relatively large diameter hole, a porous disk may be used to plug the hole to allow fluid flow while maintaining a smooth contact surface for the membrane 500. For example, a smooth porous disk 600 is provided in Figure 6. In some embodiments, the disk 600 may include metal or any other suitable material shaped to have appropriate porosity for fluid flow and smoothness for constant contact with the membrane 500.

[0046] A cross-sectional diagram illustrating the membrane 500 and disk 600 is provided in Figure 700. The portion of the downhole tool 104 includes a convoluted membrane 500 implemented between two fluid cavities 702 and 704. A porous metal disk 600 may be impleneted at a hole in the lower fluid cavity 702 to allow fluid flow while providing a smooth contact with the convoluted membrane 500.

[0047] Additionally, embodiments may include safety features for indicating a pressure condition in the downhole tool 104, or a pressure compensator 112 of the downhole tool 104. As also illustrated in Figure 7, the downhole compensator portion 700 may include a switch 706 configured to provide an indication of a fluid level of one or more fluid chambers (e.g., lower or upper fluid cavities 702 and/or 704). For example, the switch 706 may indicate that a compensating fluid in the upper chamber 704 is below an acceptable fluid level. In some embodiments, the indication may be received on the downhole tool 104 or at the surface, and an operator of the tool may refill the compensating fluid to maintain pressure compensating levels in the downhole tool 104.

[0048] The downhole compensator portion 700 may also include a relief valve 708 configured to release excess fluid in one or more fluid chambers (e.g., the lower or upper fluid cavities 702 and/or 704) if a detected fluid pressure or fluid volume is beyond the compensation abilities of the membrane 500. For instance, the relief valve 708 may release excess fluid from the upper cavity 704 when volume expansion of the compensating fluid in the upper cavity 704 exceeds the compensation abilities of the membrane. Releasing the excess fluid may prevent damage to the membrane 500, which may prevent other resulting malfunctions of the downhole tool 104.

[0049] While the embodiments are described with reference to various implementations and exploitations, it will be understood that these embodiments are illustrative and that the scope of the inventive subject matter is not limited to them. Many variations, modifications, additions and improvements are possible. For example, one or more sensing units may be positioned about various portions of the downhole tool and have one or more direct or indirect compensation units operatively coupled thereto for compensating for pressure thereabout.

[0050] Plural instances may be provided for components, operations or structures described herein as a single instance. In general, structures and functionality presented as separate components in the exemplary configurations may be implemented as a combined structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements may fall within the scope of the inventive subject matter.

Claims

1. A pressure compensation system comprising:

one or more pressure compensators, each pressure compensator comprising:

a first fluid compensating section comprising a first fluid;
a second fluid compensating section comprising a second fluid; and
a convoluted membrane disposed between the first fluid in the first fluid compensating section and the second fluid in the second fluid compensating section.

2. The pressure compensating system of claim 1, wherein the second fluid compensating section comprises:

a hole; and
a porous disk coupled to the hole.

3. The pressure compensating system of claim 1, wherein the pressure compensator comprises a switch configured to provide an indication corresponding to a fluid condition in the pressure compensator.

4. The pressure compensating system of claim 3, wherein the switch is configured to indicate when a fluid level in the first fluid compensating section, the second fluid compensating section, or both, is below an acceptable level.

5. The pressure compensating system of claim 3, wherein the pressure compensator comprises a relief valve configured to release fluid from the first fluid compensating section, the second fluid compensating section, or both, based on an indication of the switch.

6. The pressure compensating system of claim 1, wherein the pressure compensator comprises a relief valve configured to release fluid from the first fluid compensating section, the second fluid compensating section, or both, when the corresponding fluid compensating section is above an acceptable level.

7. The pressure compensating system of claim 1, comprising a downhole tool positionable in a wellbore, wherein the one or more pressure compensators is positionable in the downhole tool.

8. The pressure compensating system of claim 7, wherein the pressure compensator comprises a second convoluted membrane disposed between the first fluid and a wellbore fluid in the wellbore.

9. The pressure compensating system of claim 8, wherein the second convoluted membrane is suitable for separating the wellbore fluid from the first fluid and for adjusting a pressure of the first fluid based on a wellbore pressure of the wellbore fluid.

10. The pressure compensating system of claim 1, wherein the convoluted membrane disposed between the first fluid and the second fluid is suitable for separating the first fluid from the second fluid and for adjusting a pressure of the second fluid based on a pressure of the first fluid compensating section.

11. A method of compensating pressure in a downhole tool, the method comprising:

deploying a downhole tool into the wellbore, the downhole tool having a pressure compensator comprising:

a first fluid compensating section comprising a first fluid;
a second fluid compensating section comprising a second fluid; and
a pressure indicator configured to provide an indication corresponding to a fluid condition in the pressure compensator;

receiving an indication of a pressure condition.

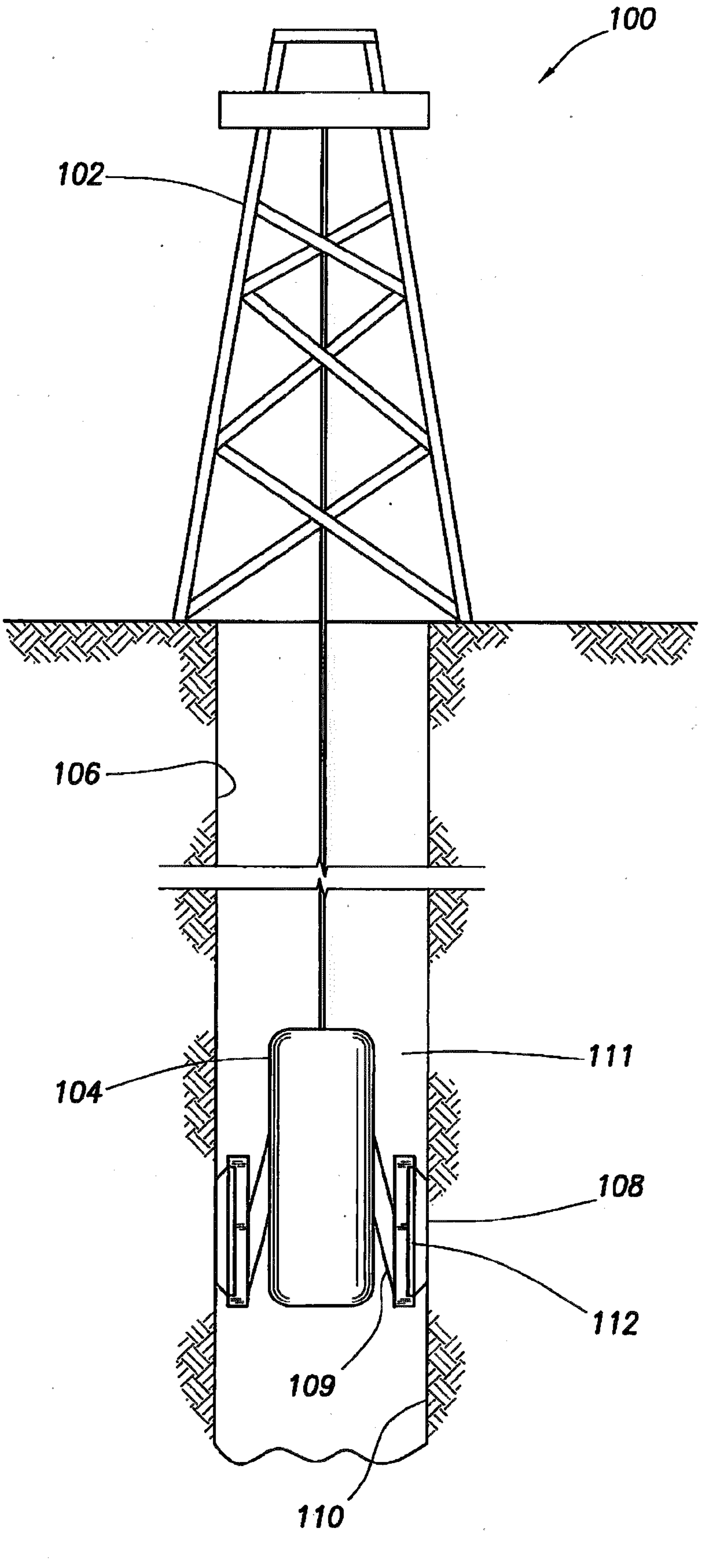
12. The method of claim 11, comprising releasing via a release valve, the first fluid from the first fluid compensating section, the second fluid from the second fluid compensating section, or both, based on a volume of fluid in the first fluid compensating section, the second fluid compensating section, or both.

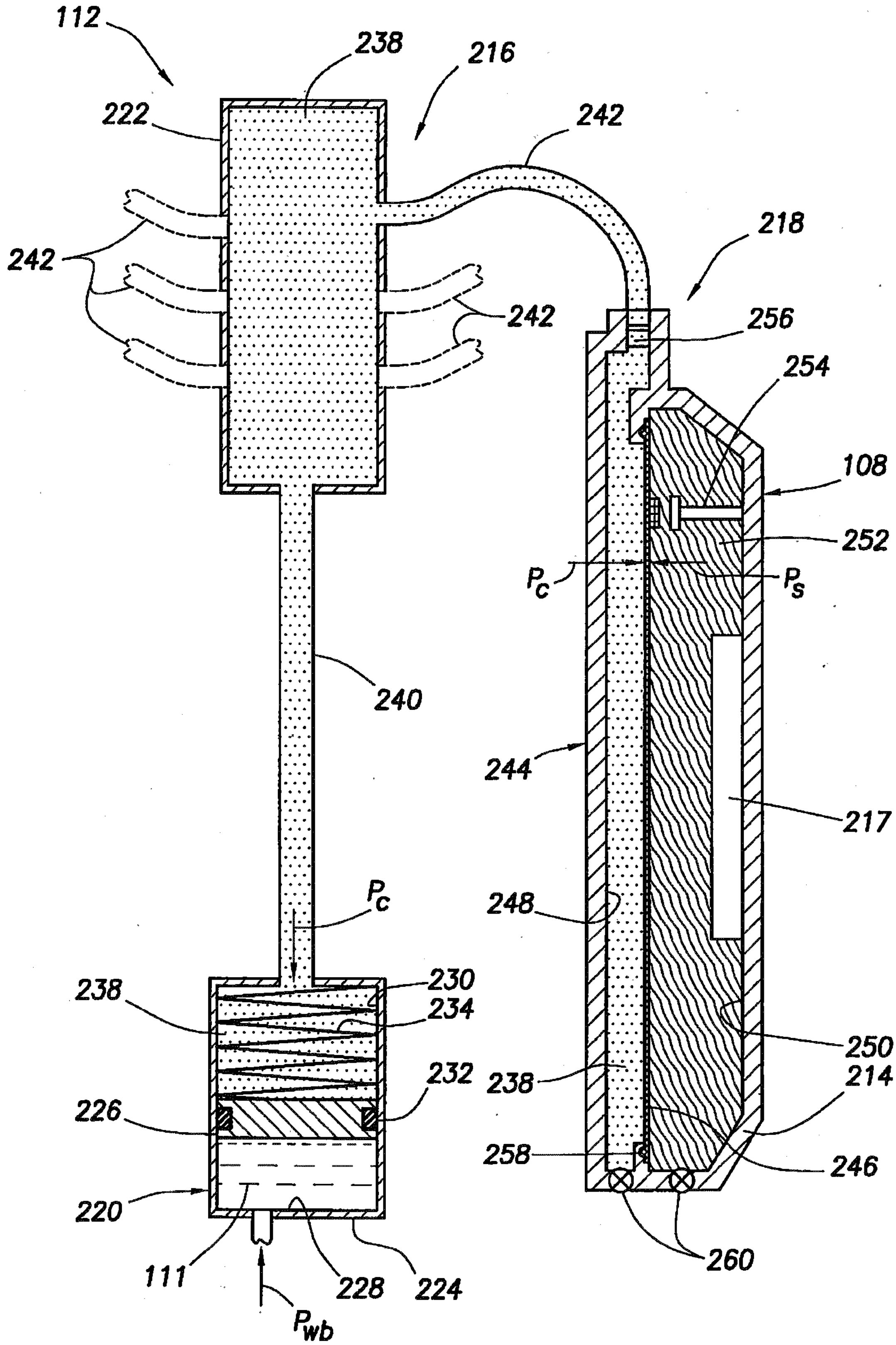
13. The method of claim 11, comprising releasing via a release valve, the first fluid from the first fluid compensating section, the second fluid from the second fluid compensating section, or both, based on the indication from the pressure indicator.

14. The method of claim 11, wherein the pressure compensator comprises a convoluted membrane disposed between the first fluid in the first fluid compensating section and the second fluid in the second fluid compensating section.

15. The method of claim 11, wherein the pressure compensator comprises a convoluted membrane disposed between a wellbore fluid and the first fluid in the first fluid compensating section.

FIG. 1

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217
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P_c
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230
234
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232
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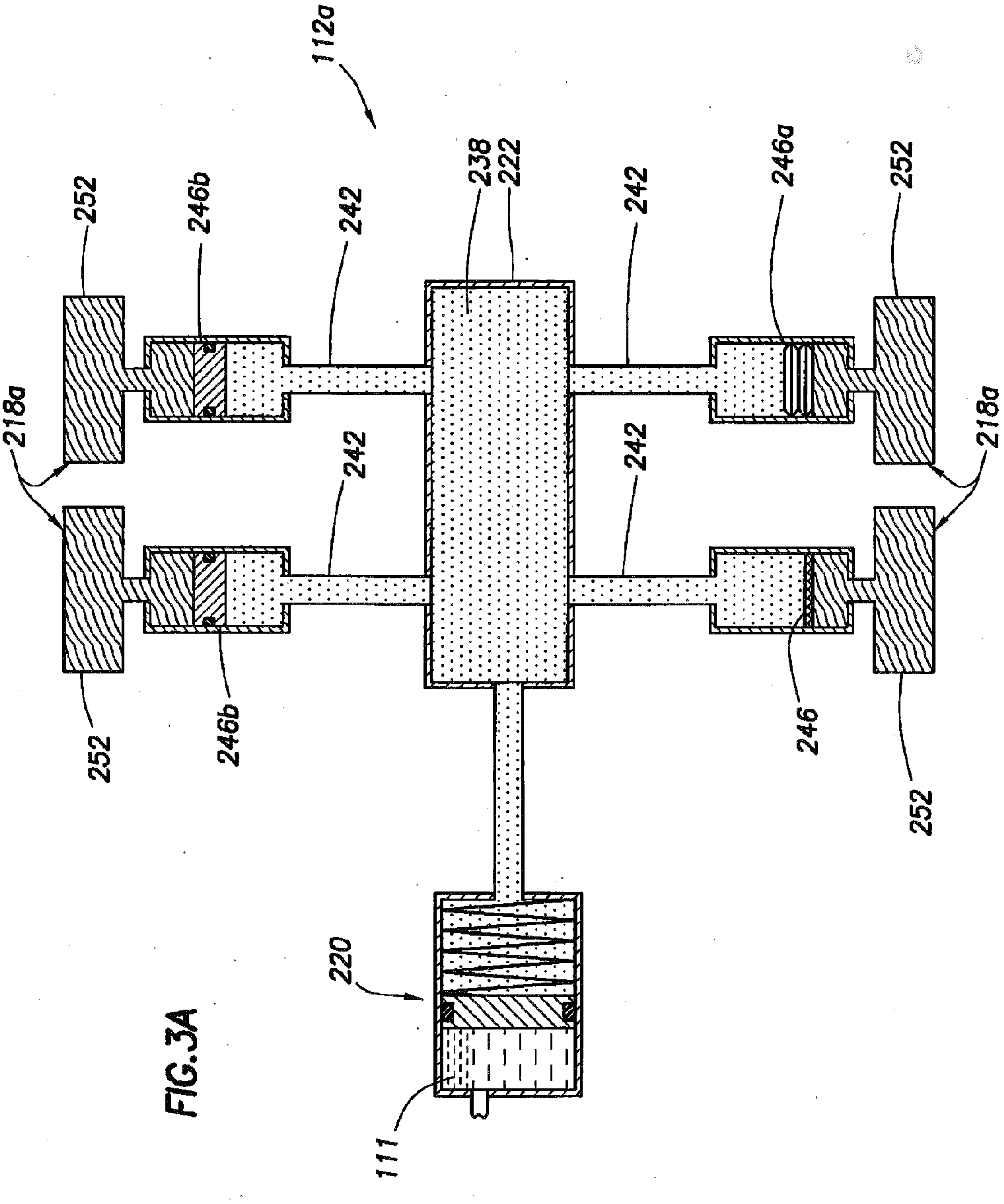
214
226
258
246
220
260
111
228
224
P_{wb}

FIG.2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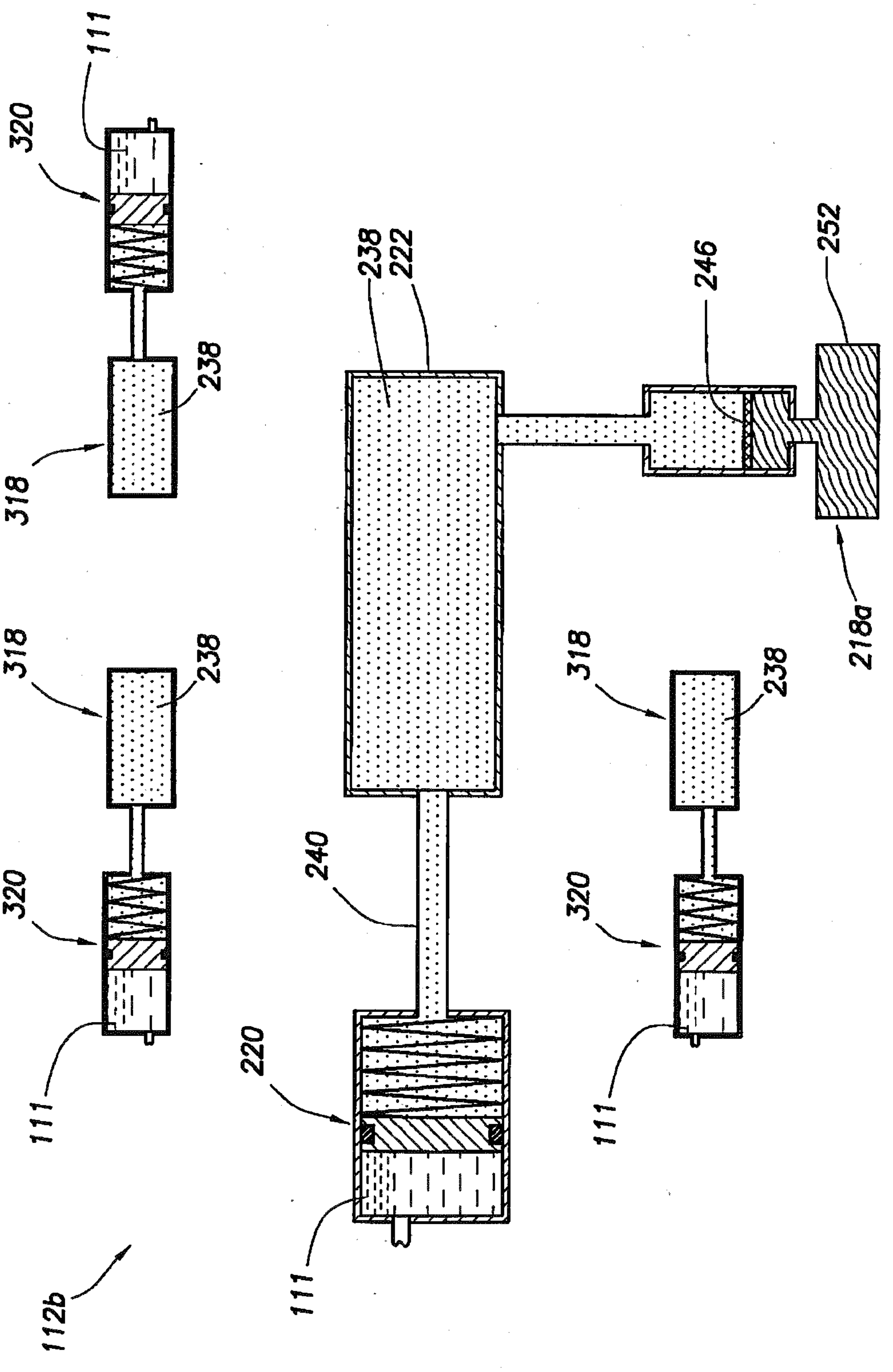
111

FIG.3A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112b

FIG.3B

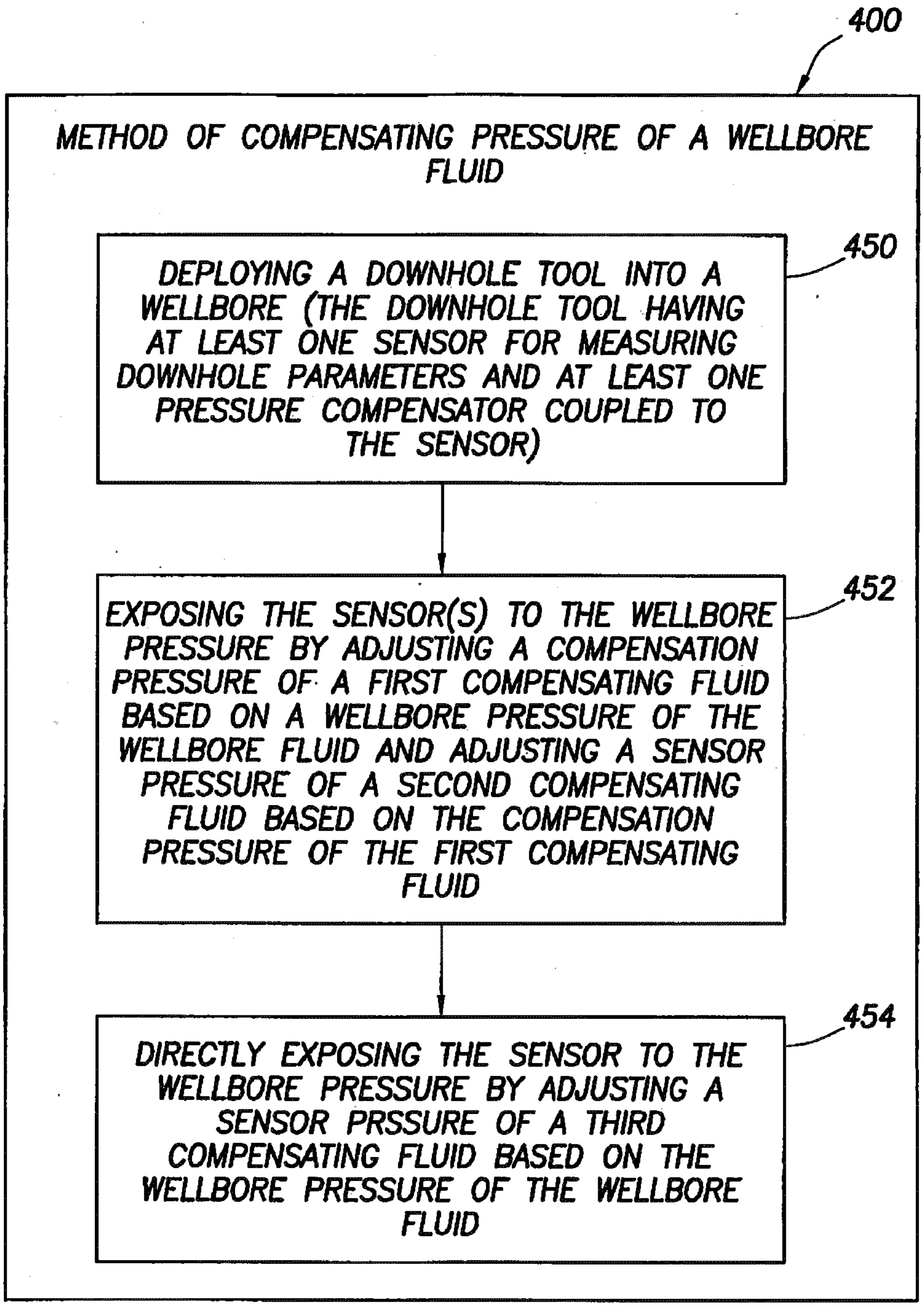
400
METHOD OF COMPENSATING PRESSURE OF A WELLBORE FLUID
DEPLOYING A DOWNHOLE TOOL INTO A WELLBORE (THE DOWNHOLE TOOL HAVING AT LEAST ONE SENSOR FOR MEASURING DOWNHOLE PARAMETERS AND AT LEAST ONE PRESSURE COMPENSATOR COUPLED TO THE SENSOR)
450
EXPOSING THE SENSOR(S) TO THE WELLBORE PRESSURE BY ADJUSTING A COMPENSATION PRESSURE OF A FIRST COMPENSATING FLUID BASED ON A WELLBORE PRESSURE OF THE WELLBORE FLUID AND ADJUSTING A SENSOR PRESSURE OF A SECOND COMPENSATING FLUID BASED ON THE COMPENSATION PRESSURE OF THE FIRST COMPENSATING FLUID
452
DIRECTLY EXPOSING THE SENSOR TO THE WELLBORE PRESSURE BY ADJUSTING A SENSOR PRSSURE OF A THIRD COMPENSATING FLUID BASED ON THE WELLBORE PRESSURE OF THE WELLBORE FLUID
454

FIG.4

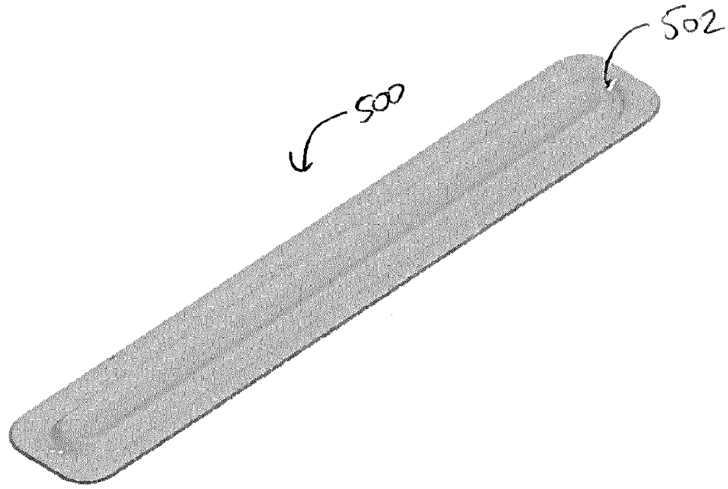

Figure 5

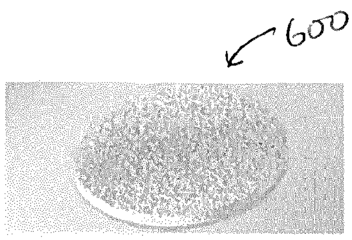

Figure 6

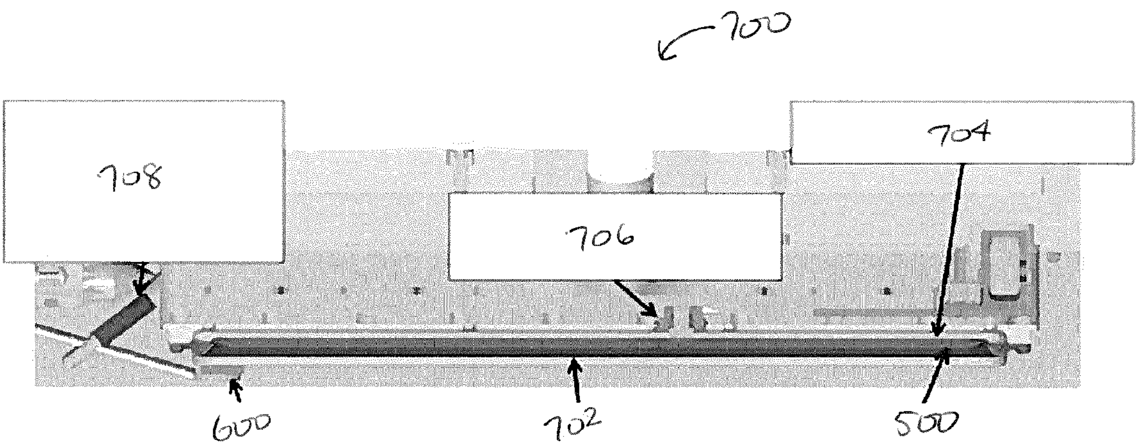

Figure 7

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EUROPEAN SEARCH REPORT

Application Number
EP 13 30 5035

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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	-/--		

1

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
Munich	21 May 2013	Georgescu, Mihnea

CATEGORY OF CITED DOCUMENTS

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Y : particularly relevant if combined with another document of the same category
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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EUROPEAN SEARCH REPORT

Application Number
EP 13 30 5035

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

~~The present search report has been drawn up for all claims~~

1

Place of search	Date of completion of the search	Examiner
Munich	21 May 2013	Georgescu, Mihnea

CATEGORY OF CITED DOCUMENTS

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D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

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Application Number
EP 13 30 5035

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-10

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 13 30 5035

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-10

A pressure compensation system comprising: one or more pressure compensators, each pressure compensator comprising: a first fluid compensating section comprising a first fluid;a second fluid compensating section comprising a second fluid; and a convoluted membrane disposed between the first fluid in the first fluid compensating section and the second fluid in the second fluid compensating section.

1.1. claims: 1, 2

System of claim 1, wherein (potential special technical feature of claim 2) the second fluid compensating section comprises: a hole; and a porous disk coupled to the hole.

1.2. claims: 3-5

System of claim 1, wherein (potential special technical feature of claim 3) the pressure compensator comprises a switch configured to provide an indication corresponding to a fluid condition in the pressure compensator.

1.3. claim: 6

System of claim 1, wherein (potential special technical feature of claim 6) the pressure compensator comprises a relief valve configured to release fluid from the first fluid compensating section, the second fluid compensating section, or both, when the corresponding fluid compensating section is above an acceptable level.

1.4. claims: 7-9

System of claim 1, wherein (potential special technical feature of claim 7) comprising a downhole tool positionable in a wellbore, wherein the one or more pressure compensators is positionable in the downhole tool.

1.5. claim: 10

System of claim 1, wherein (potential special technical feature of claim 10) the convoluted membrane disposed between the first fluid and the second fluid is suitable for separating the first fluid from the second fluid and for adjusting a pressure of the second fluid based on a pressure of the first fluid compensating section.

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2. claims: 11-15

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 13 30 5035

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

A method of compensating pressure in a downhole tool, the method comprising: deploying a downhole tool into the wellbore, the downhole tool having a pressure compensator comprising: a first fluid compensating section comprising a first fluid;a second fluid compensating section comprising a second fluid; and a pressure indicator configured to provide an indication corresponding to a fluid condition in the pressure compensator; receiving an indication of a pressure condition.

Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

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