A drilling method includes arranging a dual drill string (20) having an inlet fluid conduit (9) and a return fluid conduit (10) in a well (14) formed in a subsurface formation such that a well annulus (22) is formed between the dual drill string (20) and a wall (21) of the well (14). A divider element (3) is disposed in the well annulus (22) to divide the well annulus (22) into an upper annular region (5) extending above the divider element (3) to a surface of the well annulus (22) and a lower annular region (12) extending below the divider element (3) towards a bottom of the well annulus (22). The lower annular region (12) contains a first fluid (25). A second fluid (27) is fed into the upper annular region (5). The method includes configuring the second fluid such that the density of the second fluid (27) is greater than the density of the first fluid (25).
FIG. 2
METHOD AND SYSTEM FOR DRILLING WITH REDUCED SURFACE PRESSURE

FIELD

[0001] The present invention relates generally to a method and system for drilling a well.

BACKGROUND

[0002] To extract hydrocarbon fluids from reservoirs in earth formations, wells are drilled into the formations. The development of drilling techniques has evolved into the possibility of drilling wells in any direction such as to extract as much as possible of the hydrocarbon fluids present in the formations drilled. A well may for instance comprise a substantially vertical section and at least one section deviating from the vertical section, possibly a substantially horizontal section. The sections deviating from the substantially vertical section tend to be long, often extending for thousands of meters into a formation. To meet increasing demand to add energy reserves, hydrocarbon exploration is being pushed into deeper waters, and the depths of wells are increasing.

[0003] Drilling is normally performed by inserting a drill bit on the end of a drill string into the well. The weight of the drill string is proportional to the length of the drill string. When drilling at large water depths, the depth of the water also influences the pressure conditions in the well and adds to the weight of the drill string. One does not want the formation fluids to penetrate the drilled well during drilling; therefore, the pressure exerted by the drilling system on the formation should be higher than the formation pore pressure. Drilling system should also be understood as including the fluid added between the drill string and the unlined formation wall. With this one also has control of the well during drilling and will therefore prevent blowouts of the well. At the same time, there is also a need to limit the amount of drilling fluid that penetrates the unlined formation wall, and also a need to prevent fracturing the side wall of the drilled bore before production starts. This gives that the pressure exerted by the drilling system must not exceed the fracturing pressure of the formation. The formation pore pressure is also dependent on the hydrostatic column, and at larger water depths the formation pore pressure increases. When the pressure exerted by the drilling system moves towards the boundaries defined by the formation pore pressure and formation fracturing pressure, the well has to be cased by casing or liner before drilling can be continued. It is therefore a need to provide a method of drilling where the drilling can proceed for a longer period of time in the allowed pressure range between the formation pore pressure and the formation fracturing pressure, i.e., broader drilling window.

[0004] The term “drilling” should be understood to refer to establishing a hole in the ground by the means of a drill string. It particularly applies for drilling in the crust of the earth for hydrocarbon recovery, tunnels, canals or for recovery of geothermal energy, both offshore and onshore.

[0005] WO 2010/039043 A1 describes a downhole well tool comprising a tool unit. The tool unit comprises at least one first fluid conduit and a return fluid conduit, and the tool unit is arranged to be placed in well bore defining an annular space between the well unit and the well bore or cased well bore. The return fluid conduit may be arranged in the first fluid conduit, leaving an annular space in between the first fluid conduit and the return fluid conduit for the flow of the first fluid, and wherein the return fluid conduit passes in the centrally arranged space of the return fluid conduit.

[0006] From document WO 94/13925 A1 it is known to drill with dual pipes arranged next to each other, where one pipe is used for the pumping of fluids from the surface to the drill bit, and the other pipe serves as a return line for the drilled cuttings and fluids from the bit to the surface facility. At a lower part of the drill string, above the bit, is arranged a sealing piston. Above the piston is a seal closing the space between the pipes and the borehole wall or casing, defining a volume between said piston and the seal. Pressurized fluid, such as hydraulic fluid, pumped into this volume, urges the piston, and thereby the bit, hydraulically against the bottom of the hole. When drilling in a formation, trying to reach the potential hydrocarbon reservoir, zones having higher formation pore pressures than the surrounding formation may be encountered. These zones might be pockets or reservoirs of high pressure gas or water. Drilling through such zones may be difficult, or even impossible, by conventional drilling technologies as it is very difficult to keep control on the pore pressure at the same time as drilling underbalanced (UBD) or using managed pressure drilling (MPD) and still reaching further down the high pressure formation zone. UBD is referred to as a drilling state where the hydrostatic pressure inside the casing or liner is less than the reservoir pressure, while MPD is a suited method if the difference between the formation pore pressure and the formation fracturing pressure is low. MPD is an adaptive drilling method used to more precisely control the annular pressure profile throughout the wellbore.

[0007] To be able to drill, the weight of the drilling system has to be higher than the formation pore pressure. It might be possible to pump pressurized fluid, such as hydraulic fluid, above the piston, but then the rotating control device (RCD), typically arranged at the top of the well, and defining the upper boundary of an annular volume between the piston and the top of the well, would have to withstand the pressures from the pumped pressurized fluid. As the drill string rotates through the RCD with mud, there will always be a limited pressure/rotation range for these products.

SUMMARY

[0008] In one aspect of the present invention, a drilling method includes arranging a dual drill string having one inlet fluid conduit and one return fluid conduit in a well drilled in a formation such that a well annulus is formed between the dual drill string and a wall of the well. The method includes arranging a divider element in the well annulus to divide the well annulus into an upper annular region, which extends above the divider element to a surface of the well annulus, and a lower annular region, which extends below the divider element towards a bottom of the well annulus. The method includes feeding a second fluid having a second density into the upper annular region. The feeding includes configuring the second fluid such that the second density is greater than the first density.

[0009] In one embodiment, at least a portion of the first fluid is fluid from the formation.

[0010] In one embodiment, feeding the second fluid includes providing the second fluid as an unpressurized fluid.

[0011] In one embodiment, the method further includes measuring pressure at or near at least one of an upper surface
of the divider element exposed to the upper annular region and a lower surface of the divider element exposed to the lower annular region.

[0012] In one embodiment, the method further includes using the measured pressure to selectively adjust the second density such that the second density remains greater than the first density during drilling of the well.

[0013] In one embodiment, the method includes arranging a rotating control unit near the surface of the well annulus. Pressure acting on the rotating control unit will be determined by pressure in the well and density of the fluid in the well annulus.

[0014] In another aspect of the present invention, a drilling system includes a dual drill string having one inlet fluid conduit and one return fluid conduit. The dual drill string is arranged in a well formed in a formation such that a well annulus is formed between the drill string and a wall of the well. A divider element arranged in the annulus divides the well annulus into an upper annular region extending above the divider element to a surface of the well annulus and a lower annular region extending below the divider element towards the bottom of the well annulus. The lower annular region contains a first fluid having a first density. A second fluid having a second density is disposed in the upper annular region, where the second density is greater than the first density.

[0015] In one embodiment, the drilling system further includes a fluid inlet through which the second fluid is fed into the upper annular region.

[0016] In one embodiment, the drilling system further includes a rotating control unit arranged near the surface of the well annulus, where the rotating control unit is in communication with the fluid inlet.

[0017] In one embodiment, the drilling system further includes a blowout preventer arranged near the surface of the well annulus in connection with the rotating control unit, the blowout preventer forming an upper boundary of the upper annular region.

[0018] In one embodiment, the drilling system further includes means for measuring pressure at or near a lower surface of the divider element exposed to the lower annular region.

[0019] In one embodiment, the drilling system further includes means for measuring pressure at or near an upper surface of the divider element exposed to the upper annular region.

[0020] In one embodiment, the divider element is a piston.

[0021] In one embodiment, the divider element is fixed to the dual drill string.

[0022] In another embodiment, the divider element is movable relative to the dual drill string.

[0023] In one embodiment, the two fluid conduits of the dual drill string are concentric.

[0024] In one embodiment, at least a portion of the first fluid is fluid from the formation.

[0025] In one embodiment, the second fluid is unpressurized.

[0026] It is to be understood that both the foregoing summary and the following detailed description are exemplary of the invention and are intended to provide an overview or framework for understanding the nature and character of the invention as it is claimed. The accompanying drawings are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification. The drawings illustrate various embodiments of the invention and together with the description serve to explain the principles and operation of the invention.

**BRIEF DESCRIPTION OF THE DRAWING**

[0027] The following is a description of the figures in the accompanying drawings. 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.

[0028] FIG. 1 shows a well with a drilling system according to one embodiment of the invention.

[0029] FIG. 2 is a graph showing pressure as a function of depth in a well annulus for two different weight fluids.

**DETAILED DESCRIPTION**

[0030] In the following detailed description, numerous specific details may be set forth in order to provide a thorough understanding of embodiments of the invention. However, it will be clear to one skilled in the art when embodiments of the invention may be practiced without some or all of these specific details. In other instances, well-known features or processes may not be described in detail so as not to unnecessarily obscure the invention. In addition, like or identical reference numerals may be used to identify common or similar elements.

[0031] The present invention relates to a method of controlling pressure in a well annulus such that pressure at a rotating control unit (RCU) near the well annulus is kept low. The method involves use of a divider element, typically a piston, arranged in the well annulus. The arrangement is such that there is fluid below the divider element and fluid above the divider element, where the fluid above the divider element is a heavy fluid and the fluid below the divider element is a light fluid, i.e., the fluid above the divider element has a higher density than the fluid below the divider element. In FIG. 2, line A represents the pressure in the well annulus as a function of depth for the system where light fluid is below the divider element and heavy fluid is above the divider element. For comparison, line B represents the pressure in the well annulus as a function of depth if the fluid above and below the divider element are both light fluids, e.g., having substantially equal densities, or if there is no divider element in the well annulus. As illustrated in FIG. 2, lines A and B have the same bottom-hole pressure, as indicated at P1. Right below the divider element, at P2, the pressures for lines A and B are also the same. Above the divider element, line A diverges from line B. The surface pressures of lines A and B are shown at P3 and P4, respectively. As shown, the surface pressure for line A is lower than the surface pressure for line B. This is due to the heavy fluid above the divider element in the system represented by line A. This means that the RCU in the system represented by line A will experience a lower surface pressure than the RCU in the system represented by line B. This reduction in the pressure acting on the RCU will enable a broader drilling window. If the heavy fluid in the system represented by line A is unpressurized, the pressure acting on the RCU can be as low as zero.

[0032] FIG. 1 shows a drilling system according to one aspect of the present invention. The drilling system would exhibit a pressure in the well annulus similar to line A of FIG. 2, as described above. The drilling system is shown in the context of offshore drilling, but it may also be applied to land
drilling. A well 14 has been drilled through formation 32 and is being drilled through a high pressure formation 34 overlying a hydrocarbon formation 36. The upper part of the well 14 is provided with casing 2. The lower part of the well 14 is not cased. The drilling system 1 consists of a drill string 20 having dual pipes. The pipes can be concentric or positioned next to each other. In the shown embodiment the pipes are concentric. A first pipe 29 has an inlet fluid path A connected to an inlet fluid conduit 10. A second pipe 30 has a return fluid path B connected to a return fluid conduit 9. The return fluid conduit 9 is on the inside of the inlet fluid conduit 10, but in an alternative embodiment the inlet fluid conduit 10 may be on the inside of the return fluid conduit 9. The lower part of the drill string 20 has a bottom hole assembly (BHA) 15 and a drill bit 4 having a drilling fluid outlet 18 in its lower end. The BHA 15 may be provided with a crossover valve 16. A cuttings inlet 17 is positioned on the upper part of the BHA 15.

[0033] The drill string 20 is arranged in the well 14 such that a well annulus 22 is formed between the drill string 20 and a wall 21 of the well 14. A divider element 3, such as a piston, plunger or ram 3, is arranged in the well annulus 22 on the outside of the drill string 20. The divider element 3 divides the well annulus 22 into an upper annular region 5 above the divider element 3 and a lower annular region 12 below the divider element 3. The upper annular region 5 extends from an upper surface 3b of the divider element 3 to the surface of the well annulus 22, while the lower annular region 12 extends from a lower surface 3a of the divider element 3 towards the bottom of the well annulus 22. In one embodiment, the lower annular region 12 extends all the way to the bottom of the well 14. The divider element 3 can be set in an area of the well 14 with casing 2 or in an open hole. In one embodiment, the divider element 3 is fixed to the drill string 20. In this case, if the force acting on the upper surface 3b of the divider element 3 is greater than the force acting on the lower surface 3a of the divider element 3, the divider element 3 will tend to move downwards. If the net force on the divider element 3 overcomes the weight of the drill string 20, the drill string 20 will be urged downwards, i.e., towards the bottom of the well 14, by motion of the divider element 3. In another embodiment, the divider element 3 is not fixed to the drill string 20 and is free to move relative to the drill string 20.

[0034] Near the surface of the well 14 or well annulus 22, in the area close to the sea floor 13, is arranged a blowout preventer (BOP) 8 and a rotating control device (RCD) 7. The RCD 7 is in communication with a tank (not shown) or similar storing facility for storage of fluid, such as drilling fluid, through a fluid inlet 6. The fluid inlet 6 also leads to the upper annular region 5 defined above the divider element 3. A top drive adapter 11, for rotating or driving the drill string, is arranged at a surface vessel or platform (not shown).

[0035] When performing drilling operations in the well 14, the drilling system 1 also includes a lower annular region fluid 25 contained in the lower annular region 12 and an upper annular region fluid 27 disposed in the upper annular region 5. In one embodiment, at least a portion of the lower annular region fluid 25 is from the formation(s) in which the well 14 is drilled. The remainder of the lower annular region fluid 25 may be from fluid discharged from the drill string 20 into the bottom of the well 14. The lower annular region fluid 25 will apply a first pressure on the lower surface 3a of the divider element 3.

[0036] The upper annular region fluid 27 may be fed into the upper annular region 5 through the fluid inlet 6. The upper annular region fluid 27 will apply a second pressure on the upper surface 3b of the divider element 3. The upper annular region 5 may be filled partially or entirely with the upper annular region fluid 27. The pressure at the surface of the column of fluid in the upper annular region 5 will determine the pressure at the surface of the well annulus 22. The pressure acting on the RCD 7 will be determined by the pressure in the well 14 and the density of fluid in the well annulus 22, which is related to the pressure in the well annulus 22.

[0037] In one embodiment, the density of the upper annular region fluid 27 is greater than the density of the lower annular region fluid 25. In this case, the hydrostatic pressure at the upper surface 3b of the divider element 3 will be greater than the hydrostatic pressure at the lower surface 3a of the divider element 3. In one embodiment, the upper annular region fluid 27 is “unpressurized,” i.e., does not have raised pressure that is produced or maintained artificially. If the upper annular region fluid 27 is unpressurized, the pressure at the surface of the well annulus 22 and acting on the RCD 7 will be essentially zero. The upper annular region fluid 27 may be a drilling fluid, for example. In general, the upper annular region fluid 27 can be a liquid, a mixture of one or more liquids, or a mixture of one or more liquids and one or more types of solid particulates. The composition of the upper annular region fluid 27 will be selected to achieve a desired density, which would preferably be greater than that of the lower annular region fluid 25. Typically, the density of the upper annular region fluid 27 will be greater than 1.0 kg/litre.

[0038] In one embodiment, a pressure sensor 24 is arranged at or near the upper surface 3b of the divider element 3 to measure pressure at or near the upper surface 3b. Alternately, or additionally, a pressure sensor 26 may be arranged at or near the lower surface 3a of the divider element 3 to measure pressure at or near the lower surface 3a. As mentioned earlier, the density of the upper annular region fluid 27 needs to be greater than the density of the lower annular region fluid 25. If the density of the upper annular region fluid 27 is greater than the density of the lower annular region fluid 25, the pressure measured at or near the upper surface 3b of the divider element 3 will be greater than the pressure measured at or near the lower surface 3a of the divider element 3. If the outputs of the sensors 24, 26 indicate that the density of the upper annular region fluid 27 is not greater than the density of the lower annular region 25, the density of the upper annular region fluid 27 can be increased. Monitoring of pressure at or near the surfaces 3a, 3b may be carried out at various times during the drilling process. This is because the conditions in the lower annular region 12 can change at any time, e.g., due to formation fluid influx or change in the composition of the fluid pumped down the drill string 20. Adjustment of the density of the upper annular region fluid 27 may be manual or automated.

[0039] The method of reducing the pressure acting on the RCD 7 through use of a heavy fluid above the divider element 3, as described above, can be used with any drilling mode, such as underbalanced, managed pressure, and overbalanced drilling modes. This means that selection of the density of the upper annular region fluid 27 may be influenced by the formation pore pressure.

[0040] Although the present invention is described in terms of some preferred embodiments, alterations can be made. For example, the fluid flow directions, and the inlets and outlets of the cuttings and drilling fluid, can be swapped. A person skilled in the art will understand that there are other alter-
atations and modifications that could be made that are within the scope of the invention as defined in the attached claims.

1. A drilling method, comprising:
   arranging a dual drill string having one inlet fluid conduit and one return fluid conduit in a well drilled in a formation such that a well annulus is formed between the dual drill string and a wall of the well;
   disposing a divider element in the well annulus to divide the well annulus into an upper annular region, extending above the divider element, to a surface of the well annulus and a lower annular region extending below the divider element towards the bottom of the well annulus, the lower annular region containing a first fluid having a first density; and
   feeding a second fluid having a second density into the upper annular region, the feeding comprising configuring the second fluid such that the second density is greater than the first density.

2. A method according to claim 1, wherein at least a portion of the first fluid is fluid from the formation.

3. A method according to claim 1, further comprising providing the second fluid as an unpressurized fluid.

4. A method according to claim 1, further comprising measuring pressure at or near at least one of an upper surface of the divider element exposed to the upper annular region and a lower surface of the divider element exposed to the lower annular region.

5. A method according to claim 1, further comprising using the measured pressure to selectively adjust the second density such that the second density remains greater than the first density during drilling of the well.

6. A method according to claim 1, further comprising arranging a rotating control unit near the surface of the well annulus, wherein pressure acting on the rotating control unit is determined by pressure in the well and density of fluid in the well annulus.

7. A drilling system comprising:
   a dual drill string arranged in a well formed in a formation such that a well annulus is formed between the dual drill string and a wall of the well, the dual drill string having one inlet fluid conduit and one return fluid conduit;
   a divider element arranged in the well annulus, to divide the well annulus into an upper annular region extending above the divider element to a surface of the well annulus and a lower annular region below the divider element towards a bottom of the well annulus, the lower annular region containing a first fluid having a first density; and
   a second fluid having a second density disposed in the upper annular region, the second fluid being configured such that the second density is greater than the first density.

8. A drilling system according to claim 7, further comprising a fluid inlet through which the second fluid is fed into the upper annular region.

9. A drilling system according to claim 8, further comprising a rotating control unit arranged near the surface of the well annulus the rotating control unit being in communication with the fluid inlet.

10. A drilling system according to claim 9, further comprising a blowout preventer arranged near the surface of the well annulus in connection with the rotating control unit, the blowout preventer forming an upper boundary of the upper annular region.

11. A drilling system according to claim 7, further comprising means for measuring pressure at or near a lower surface of the divider element exposed to the lower annular region.

12. A drilling system according to claim 7, further comprising means for measuring pressure at or near an upper surface of the divider element exposed to the upper annular region.

13. A drilling system according to claim 7, wherein the divider element is a piston.

14. A drilling system according to claim 7, wherein the divider element is fixed to the dual drill string.

15. A drilling system according to claim 7, wherein the divider element is movable relative to the dual drill string.

16. A drilling system according to claim 7, wherein the two fluid conduits of the dual drill string are concentric.

17. A drilling system according to claim 7, wherein at least a portion of the first fluid is fluid from the formation.

18. A drilling system according to claim 7, wherein the second fluid is unpressurized.

* * * * *