(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 663 733 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
11.01.2023 Bulletin 2023/02

(21) Application number: **11763700.9**

(22) Date of filing: **29.09.2011**

(51) International Patent Classification (IPC):
E21B 34/08 *(2006.01)* ***E21B 43/12*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
E21B 34/08; E21B 43/12

(86) International application number:
PCT/EP2011/067058

(87) International publication number:
WO 2012/095196 (19.07.2012 Gazette 2012/29)

(54) AUTONOMOUS VALVE

AUTONOMES VENTIL

SOUPAPE AUTONOME

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **14.01.2011 PCT/EP2011/050471**

(43) Date of publication of application:
20.11.2013 Bulletin 2013/47

(73) Proprietor: **Equinor Energy AS**
4035 Stavanger (NO)

(72) Inventors:
- **AAKRE, Haavard**
  N-3744 Skien (NO)
- **MATHIESEN, Vidar**
  N-3944 Porsgrunn (NO)
- **WERSWICK, Bjørnar**
  N-3970 Langesund (NO)

(74) Representative: **Lind, Robert**
Marks & Clerk LLP
2nd Floor, Wytham Court
11 West Way
Oxford OX2 0QL (GB)

(56) References cited:
WO-A1-98/20231 **WO-A1-2008/004875**
WO-A2-2010/053378 **US-A1- 2003 094 283**

- **MATHIESEN V ET AL: "The Autonomous RCP Valve - new Technology for inflow control in horizontal wells", SPE OFFSHORE EUROPE OIL AND GAS CONFERENCE AND EXHIBITION,, 6 September 2011 (2011-09-06), pages 1-10, XP007919559, [retrieved on 2011-10-10]**

EP 2 663 733 B1

Description

TECHNICAL FIELD

[0001] The present invention relates to a method of controlling the flow of a fluid into a production pipe of a well in an oil and/or gas reservoir. An autonomous valve arrangement for controlling a fluid flow is further described.

BACKGROUND ART

[0002] Devices for recovering of oil and gas from long, horizontal and vertical wells are known from US patent publications Nos. 4,821,801, 4,858,691, 4,577,691 and GB patent publication No. 2169018. These known devices comprise a perforated drainage pipe with, for example, a filter for control of sand around the pipe. A considerable disadvantage with the known devices for oil/and or gas production in highly permeable geological formations is that the pressure in the drainage pipe increases exponentially in the upstream direction as a result of the flow friction in the pipe. Because the differential pressure between the reservoir and the drainage pipe will decrease upstream as a result, the quantity of oil and/or gas flowing from the reservoir into the drainage pipe will decrease correspondingly. The total oil and /or gas produced by this means will therefore be low. With thin oil zones and highly permeable geological formations, there is also a high risk of coning, i.e. flow of unwanted water or gas into the drainage pipe downstream, where the velocity of the oil flow from the reservoir to the pipe is the greatest.

[0003] From World Oil, vol. 212, N. 11 (11/91), pages 73 - 80, it is known to divide a drainage pipe into sections with one or more inflow restriction devices such as sliding sleeves or throttling devices. However, this reference mainly deals with the use of inflow control to limit the inflow rate for up hole zones and thereby avoid or reduce coning of water and or gas.

[0004] WO-A-9208875 describes a horizontal production pipe comprising a plurality of production sections connected by mixing chambers having a larger internal diameter than the production sections. The production sections comprise an external slotted liner which can be considered as performing a filtering action. However, the sequence of sections of different diameter creates flow turbulence and prevents the running of work-over tools operated along the outer surface of the production pipe.

[0005] When extracting oil and or gas from geological production formations, fluids of different qualities, i.e. oil, gas, water (and sand) is produced in different amounts and mixtures depending on the property or quality of the formation. None of the above-mentioned known devices are able to distinguish between and control the inflow of oil, gas or water on the basis of their relative composition and/or quality.

[0006] Devices as disclosed in WO2009/088292 and WO 2008/004875 are robust, can withstand large forces and high temperatures, can prevent draw downs (differential pressure), need no energy supply, can withstand sand production, yet are reliable, simple and very cheap. However, several improvements might nevertheless be made to increase the performance and longevity of the above device in which many of the different embodiments of WO2009/088292 and WO 2008/004875 describe a disc or plate as a movable body of the valve.

[0007] One potential problem with a disc or plate as the movable body is erosion on the movable body. This is due to a very large fluid velocity between an inner seat and the movable body of the valve. The fluid is subjected to abrupt changes in its flow direction at this location. As there will always be particles in the fluid flow, even if sand screens are installed, such particles will cause erosion. The erosion problem exists both with and without the use of a stagnation chamber in the valve.

[0008] We further refer to:

- WO2010/053378 A2 (Oevland Sigbjoern, 14.5.2010) disclosing a method for reversible temperature sensitive control of the flow of fluid in oil and/or gas production, involving a control device or an autonomous valve operating by the Bernoulli principle;
- WO98/20231A (Petroenergy LLC; 14.5.98) disclosing a device wherein nozzle means in response to a pressure drop of the formation fluid automatically reduce a flow cross section of the formation fluid, or vice versa and thereby automatically maintain a pressure of the formation fluid above the saturation pressure;
- "The Autonomous RCP Valve - new Technology for inflow control in horizontal wells", Mathiesen, SPE Offshore Europe Oil and Gas Conference and Exhibition, 6.9.11, pages 1 - 10, XP007919559, describing that autonomous inflow control technology reduces the inflow of gas into a well and that preliminary evaluations indicate that even water flow is reduced;
- WO2008/004875 A1 (Aakre; 10.1.08) disclosing a control device that, depending on the composition of the fluid and its properties, automatically adjusts the flow of the fluid based on a pre-estimated flow design; and
- US2003/094283 A1 (Ivannikov; 22.5.03) describing a device for flow and liftgas production of oil-wells.

SUMMARY OF THE INVENTION

[0009] According to the present invention, there is provided a method of controlling the flow of a fluid into a production pipe of a well in an oil and/or gas reservoir, as defined by claim 1. Preferred embodiments are defined by the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Embodiments will be described in detail with reference to the attached figures. It is to be understood that the drawings are designed solely for the purpose of illustration and are not intended as a definition of the limits of the invention, for which reference should be made to the appended claims. It should be further understood that the drawings are not necessarily drawn to scale and that, unless otherwise indicated, they are merely intended to schematically illustrate the structures and procedures described herein.

Figure 1 shows a production pipe provided with an autonomous valve arrangement according to an embodiment;

Figure 2A shows an autonomous valve arrangement provided with a flow control device according to a first embodiment of the invention;

Figure 2B shows an autonomous valve arrangement provided with a flow control device according to a second embodiment of the invention;

Figure 3 shows a partially sectioned view of a second valve body as used in the embodiments of Figures 2A and 2B;

Figure 4 shows a partially sectioned view of an alternative second valve body according to an embodiment;

Figure 5 shows a partially sectioned view of a further alternative second valve body according to an embodiment; and

Figure 6 shows a schematic diagram of the different flow areas and pressure zones in a valve according to an embodiment.

DETAILED DESCRIPTION

[0011] The above problems are solved by an autonomous valve arrangement provided with a flow control device. Embodiments relate to an inflow control device which is self adjustable, or autonomous, and can easily be fitted in the wall of a production pipe. The device also allows the use of work-over tools as it does not extend outside the outer periphery of the production pipe. The device is designed to "distinguish" between the oil and/or gas and/or water and is able to control the flow or inflow of oil or gas, depending on the fluid for which such flow control is required.

[0012] A preferred embodiment relates to a self-adjustable, or autonomous, valve or flow control device for controlling the flow of a fluid from one space or area to another. The valve is particularly useful for controlling the flow of fluid from a reservoir and into a production pipe of a well in the oil and/or gas reservoir, between an inlet port on an inlet side to at least one outlet port on an outlet side of the flow control device. Such a production pipe can include a drainage pipe comprising at least two sections each including one or more inflow control devices.

[0013] A major portion of the outlet port is connected to the recess in a position located remote from the central aperture relative to a plane through the second surface. In this way, a flow from the outlet port towards the inlet port will act on the second surface of a valve body remote from the inlet port. Such a fluid flow will cause the valve body to be moved towards the central aperture of the inlet port to close the valve.

[0014] The dimensions of the valve are such that flow of the fluid past the movable body causes a drop in pressure. The fluid typically comprises a liquid with a dissolved gas. The dissolved gas has a "bubble point", a temperature or pressure at which the gas will begin to come out of solution from the liquid. It has been found that if the drop in pressure is sufficient for the bubble point of the gas to be reached, dissolved gas comes out of solution with the liquid. This in turn increases the flow rate through the valve.

[0015] In a first example, a valve as described above can have an outlet port comprising multiple apertures each connected to the recess at a location at or radially outside the outer peripheral surface of the valve body. In this example, the multiple apertures are each connected to the recess in the radial direction of the flow control device. The multiple apertures can each be connected to the recess so that each aperture faces the outer peripheral surface of the valve body. The apertures are preferably arranged to be distributed at equal distances from each other around the circumference of the valve body. The centre axis of each aperture is arranged in a plane located remote from the central aperture relative to a plane through the second surface. In this way, said centre axes extend radially into the recess towards the centre of the valve body and can be located in or out of the plane through the second surface. Consequently, a flow from the multiple apertures towards the inlet port will act on the second surface of the valve body remote from the inlet port, causing the valve body to move towards its closed position.

[0016] In a second example, a valve as described above can have an outlet port comprising multiple apertures each connected to the recess at a location at or radially outside the outer peripheral surface of the valve body as described above. In this example, the multiple apertures are each connected to the recess in the axial direction of the flow control device, parallel to the centre axis of the inlet aperture. The multiple apertures can each be connected to the recess so that each aperture faces at least a portion of an outer peripheral section of the second surface of the valve body. The apertures are preferably arranged to be distributed at equal angles from each other relative to the centre of the valve body at substantially the same distance from said centre. The multiple apertures are each connected to the recess on the opposite side of the valve body relative to the inlet port. The centre axis of each aperture is connected to the recess so that each coincides with or passes radially outside the outer peripheral surface of the valve body. Consequently, a flow from the multiple apertures towards the inlet port will act on the second surface of the valve body remote from the inlet port, causing the valve body to move towards its closed position.

[0017] A valve body as described in any of the above examples is supported by at least three projections extending axially into the recess to support the second surface of the valve body. The projections are provided to support the valve body when it in its non-activated rest position. The number of projections and the size of the surfaces contacting the second surface of the valve body are chosen to avoid or minimize sticking between the projections and the movable valve body when the movable valve body is actuated.

[0018] In a third example, a valve as described above can have an outlet port comprising an aperture connected to the recess on the opposite side of the valve body relative to the inlet port. This aperture has a cross-sectional area equal to or greater than the second surface of the valve body. In this case, the outlet port substantially comprises a single aperture. The flow area downstream of the valve body is only interrupted by the projections extending into the recess to support the valve body.

[0019] A valve body as described in the above, third example is supported by at least three projections extending radially into the recess to support the second surface of the valve body. The projections are provided to support the valve body when it in its non-activated rest position. The number of projections and the size of the surfaces contacting the second surface of the valve body are chosen to avoid or minimize sticking between the projections and the valve body when the valve body is actuated.

[0020] The valves as described can have a valve body comprising a circular disc having a predetermined thickness. In this case, both the first surface and the opposite second surface can be flat or substantially flat. Generally, the surface of the recess facing said first surface of the valve body has a surface substantially conforming to the shape of the valve body.

[0021] Alternatively, the valve body can have a first surface with a substantially conical shape with the apex facing the inlet port. The opposite second surface of the valve body can be flat or substantially flat. The first surface of the recess facing said first surface has a substantially conical shape conforming to the shape of the valve body.

[0022] A valve arrangement for a production pipe, as described above, will typically have an inlet port diameter of 2-12 mm. The diameter of the disc is typically selected 3-5 times greater than the inlet port diameter. The diameter of the recess in the assembled valve body is inherently larger in order to allow movement of the disc and to hold the disc in position. It is possible to provide means for maintaining the disc in a centred position, but typically the fluid flow past the disc will try to distribute the fluid evenly through all outlet ports and thereby centre the disc.

[0023] The total height of the valve arrangement is dependent on the wall thickness of the production pipe in which it is mounted. It is desirable that the valve does not extend outside the outer diameter of the production pipe, in order to allow work-over tools to be operated along the outer surface of the production pipe. At the same time, it is desirable that the valve does not extend further inside the inner diameter of the production pipe than necessary, as this can introduce a flow restriction and turbulence. Consequently, it is desirable to select the disc thickness as small as possible. The dimensions of the disc (thickness/diameter) and the material used are selected to maintain mechanical stability of the disc, so that is does not flex or deform when subjected to high pressure. Also, the disc must be sufficiently robust to withstand erosion and fatigue over time. Similarly, the height of the recess containing the disc within the assembled valve body is limited by the height of the assembled valve body. The distance between the disc and the upper surface of the recess, containing the inlet port, is preferably selected so that the total flow area at the periphery of the disc is at least equal to the total flow are of the outlet port or ports.

[0024] The number or positioning of the outlet ports around the assembled valve body is chosen so that the total flow area of the outlet port or ports is therefore selected equal to or greater than the flow area of the inlet port. However, due to other factors, such as valve robustness and various particles entering the valve from the well, the total flow area of the outlet port or ports is often made considerably greater than the inlet port area.

[0025] In a further aspect, there is provided a method of controlling the flow of a fluid that comprises a liquid phase and a dissolved gas phase. The fluid is allowed to pass through a valve. The valve comprises a fluid inlet and a movable body located in a flow path through the valve. The movable body is arranged to move freely relative to the opening of the inlet to vary the flow-through area through which the fluid flows by means of the Bernoulli effect. The dimensions of the valve are such that flow of the fluid past the movable body causes a drop in pressure to below the bubble point of the gas phase in the liquid phase, thereby increasing flow of the fluid through the valve.

[0026] An oil reservoir typically comprises liquid oil and gas. While a pocket of gas may be located above the liquid oil in the reservoir, gas is typically also dissolved in the liquid oil. As the temperature increases, and/or the pressure reduces, evolved gas may start to come out of solution. The 'bubble point' occurs at a certain temperature and pressure, and is the point at which the first bubble of gas comes out of solution. As oil in a reservoir is typically saturated with gas, it is very close to the bubble point.

[0027] When oil passes from a reservoir into a production pipe, the valve is designed such that the reduction in pressure on the oil causes it to fall below its bubble point. The drop below the bubble point causes gas to evolve from the oil, thereby increasing the liquid density and effectively increasing the flow rate of the liquid.

[0028] Figure 1 shows a production pipe 11 provided with an opening in which an autonomous valve arrangement 12 according to an embodiment. The valve arrangement 12 is particularly useful for controlling the flow of fluid from a subterranean reservoir and into a production pipe 11 of a well in the oil and/or gas reservoir, between an inlet port 13 on an inlet side to at least one outlet port (not shown) on an outlet side of the autonomous valve arrangement 12. The component part making up the entire autonomous valve arrangement is subsequently referred to as a "valve arrangement", while the active components required for controlling the flow are commonly referred to as a "flow control device". The inlet side of the autonomous valve arrangement 12 is located in the opening on the outer side 14 of the production pipe 11, while the outlet side is located on the inner side 15 of the production pipe 11. In the subsequent text, terms such as "inner" and "outer" are used for defining positions relative to the inner and outer surface of the valve arrangement when mounted in a pipe 11 (see Figure 1).

[0029] Figure 2A shows an autonomous valve arrangement 20 provided with a flow control device according to a first embodiment of the invention. The valve arrangement 20 comprises an annular body 21 in which the flow control device is contained. The annular body 21 is mounted in an opening through a production pipe (see Figure 1) by any suitable means, such as a force fit or a threaded connection. A first valve body 22 is located in a concentric enlarged bore in the annular body 21. An outer flange on the first valve body 22 is placed in contact with a radial surface of the bore in the annular body 21 in order to position the first valve body 22 in the axial direction of the annular body 21. The first valve body 22 is locked in place by means of a lock ring 24 acting on the opposite side of said outer flange and fixed in position in a circumferential groove in the inner surface of the bore in the annular body 21. A liquid seal is provided between the annular body 21 and the outer flange on the first valve body 22. The liquid seal comprises an O-ring located in a circumferential groove in the recess and in contact with the outer peripheral surface of the outer flange of the first valve body 22.

[0030] An axial inlet port 23 is provided through the centre of the first valve body 22. The inlet port 23 extends from an outer surface of the valve arrangement into a recess 26 in the flow control device. The recess 26 is formed in a space between the first valve body 22 and a second valve body 27. In the example shown in Figure 2A, the second valve body 27 has a general cup-shape with an opening facing the first valve body 22. The second valve body 27 is placed in sealing contact with the first valve body 22 and is attached to the first valve body 22 by means of a threaded connection. The threaded connection is located on an inner section of the first valve body 22, below the outer flange. The second valve body 27 is provided with a number of radial outlet ports 30, extending from the recess 26 radially outwards to an annular space 31between the annular body 21and the second valve body 27. This annular space 31 is in fluid connection with the internal volume of the pipe in which the valve arrangement is mounted.

[0031] The second valve body 27 can be attached to the first valve body 22 by means of any suitable connecting means, but is preferably releasably attached by a threaded connection, screws or bayonet connection. A further alternative is to attach the second valve body 27 to the inner surface of the annular body 21, while maintaining sealing contact at least with the first valve body 22.

[0032] The valve arrangement further comprises a freely movable valve body 28 located in the recess 26 in the flow control device, said movable valve body 28 has a first surface 28a facing the inlet port 23 and a second surface 28b located remote from the inlet port 23. Similarly, the recess 26 has a first surface 26a facing the first surface 28a of the movable valve body 28, and a second surface 26b facing the second surface 28b of the movable valve body 28. The movable valve body 28 comprises a circular disc having a predetermined thickness and extending to an outer periphery 28c spaced from an adjacent side wall 26c of the recess 26. In this case, both the first surface and the opposite second surface are flat or substantially flat. For this and any other embodiment described in the text, the surface of the recess facing said first surface of the movable valve body has a surface conforming to the shape of the movable valve body. The movable valve body 28 is supported by a number of projections 29. The projections 29 define a lower position for the movable valve body 28 and prevent the said body 28 from sticking to the second surface 26b of the recess 26 during actuation of the flow control device. Hence, the components making up the flow control device is the first and second valve bodies 22, 27 and the freely movable valve body 28.

[0033] In operation, the inlet port is connected to the recess by a central aperture or opening, wherein the fluid is arranged to flow into the recess through the central aperture. The fluid is then arranged to flow out of the recess radially across a first surface of the valve body, said first surface facing the central aperture, and past the outer peripheral surface of said valve body towards at least one outlet port.

[0034] The present invention exploits the effect of Bernoulli teaching that the sum of static pressure, dynamic pressure and friction is constant along a flow line:

$$\Sigma p = p_{static} + \frac{1}{2}\rho v^2 + \Delta p_{friction} \qquad (1)$$

[0035] With reference to the valve shown in Figure 2A, when subjecting the movable valve body or disc 28 to a fluid flow, which is the case with embodiments, the pressure difference over the disc 28 can be expressed as follows:

$$\Delta p_{under} = \left[p_{under(f(p3))} - p_{over(f(p1,p2))}\right] = \frac{1}{2}\rho v^2 \qquad (2)$$

[0036] Due to lower viscosity, a fluid such as gas will flow faster along the disc towards its outer periphery 28c. This results in a reduction of the pressure on the area A2 above the disc while the pressure acting on the area A3 below the disc 28 remains unaffected. As the disc 28 is freely movable within the recess it will move upwards and thereby narrow the flow path between the disc 26 and the first surface 26a of the recess 26. Thus, the disc 28 moves downwards or upwards depending on the viscosity of the fluid flowing through, whereby this principle can be used to control the flow of fluid through of the device.

[0037] Further, the pressure drop through a traditional inflow control device (ICD) with fixed geometry will be proportional to the dynamic pressure:

$$\Delta p = K\frac{1}{2}\rho v^2 \qquad (3)$$

where the constant, K is mainly a function of the geometry and less dependent on the Reynolds number. In the control device according to an embodiment the flow area will decrease when the differential pressure increases, such that the volume flow through the control device will not, or nearly not, increase when the pressure drop increases. Hence, the flowthrough volume for an embodiment is substantially constant above a given differential pressure. This represents a major advantage with an embodiment as it can be used to ensure a substantially constant volume flowing through each section for the entire horizontal well, which is not possible with fixed inflow control devices.

[0038] Furthermore, when a liquid with an entrained gas, such as oil from a reservoir, passes over the disc 28 the pressure reduces. The oil is already saturated with gas, and so approaching its bubble point. The reduction in pressure causes entrained gas to evolve from the oil, meaning the resulting oil slightly increases in density. This, along with pressure differences caused by the evolved gas, has the effect of pulling the disc 28 even further away from the inlet port 23, which increases the flow rate of oil through the autonomous valve arrangement 20.

[0039] When producing oil and gas the flow control device according embodiments may have two different applications: Using it as inflow control device to reduce inflow of water or gas, or to maintain a constant flow through the flow control device. When designing the control device according embodiments for the different applications, such as constant fluid flow, the different areas and pressure zones, as shown in Figure 6, will have impact on the efficiency and flow through properties of the device. Referring to Figure 6, the different area/pressure zones may be divided into:

- A1, P1 is the inflow area and pressure respectively. The force (P1*A1) generated by this pressure will strive to open the control device (move the disc or body 28 downwards).

- A2, P2 is the area and pressure in the zone between the first surface 28a of the disc and the recess 26, where the velocity will be largest and hence represents a dynamic pressure source. The resulting dynamic pressure will strive to close the control device by moving the disc or body 28 upwards as the flow velocity increases and the pressure is reduced.

- A3, P3 is the area and pressure behind the movable disc or body 28, between the second surface 28b of the disc and the recess 26. The pressure behind the movable disc or body should be the same as the well pressure (inlet pressure). This will strive to move the body upwards, towards the closed position of the control device as the flow velocity increases.

[0040] Fluids with different viscosities will provide different forces in each zone depending on the design of these zones, in order to optimize the efficiency and flow through properties of the control device, the design of the areas will be different for different applications, e.g. constant volume flow, or gas/oil or oil/water flow. Hence, for each application the areas needs to be carefully balanced and optimally designed taking into account the properties and physical conditions (viscosity, temperature, pressure etc.) for each design situation.

[0041] Figure 2B shows an autonomous valve arrangement provided with a flow control device according to a second embodiment of the invention. The annular body 21 identical to that of Figure 2A is mounted in an opening through a production pipe (see Figure 1) by any suitable means, such as a force fit or a threaded connection. A first valve body 32 is located in a concentric enlarged bore in the annular body 21. The first valve body 32 is locked in place in the annular body 21 in the same way as described in connection with Figure 2A above. An axial inlet port 33 is provided through the centre of the first valve body 32. A second valve body 27 substantially identical to that of Figure 2A is attached to the first valve body 32, as described above. The second valve body 27 is provided with a number of radial outlet ports 30, extending from the recess 26 radially outwards to an annular space 31between the annular body 21and the second valve body 27.

[0042] The valve arrangement further comprises a freely movable valve body 38 located in the recess 36 in the flow control device, said movable valve body 38 has a first surface 38a facing the inlet port 33 and a second surface 38b located remote from the inlet port 33. Similarly, the recess 36 has a first surface 36a facing the first surface 38a of the movable valve body 38, and a second surface 36b facing the second surface 38b of the movable valve body 38. The movable valve body 38 comprises a first surface 38a with a substantially conical shape with the apex facing the inlet port 33. The opposite second surface 38b can be flat or substantially flat. The first surface 36a of the recess 36 facing said first surface 38a of the movable valve body 38 has a substantially conical shape conforming to the shape of the valve body. In the example shown, the movable valve body 38 comprises a conical body extending to an outer periphery 38c spaced from an adjacent side wall 36c of the recess 36. The outer periphery 38c can comprise a cylindrical surface having a predetermined height, as shown in Figure 2B. Alternatively, the first and second surfaces 38a, 38b of the movable valve body 38 can merge directly at the outer periphery 38c.

[0043] Figure 3 shows a partially sectioned view of the second valve body 27 as used in the embodiments of Figures 2A and 2B. As described above, the second valve body 27 has a general cup-shape with an opening arranged to face a first valve body (see "22/32"; Figures 2A/2B). The second valve body 27 is placed in sealing contact with the first valve body and is attached to said first valve body by means of a threaded connection 35. The corresponding threaded connection on the first valve body is located on a cylindrical inner section of the first valve body. The second valve body 27 is provided with a number of radial outlet ports 30, extending radially outwards from the portion of the recess 26 delimited by the second valve body 27. The portion of the recess 26 delimited by said second valve body 27 comprises the second surface 26b and the side wall 26c of the recess 26. The side wall 26c of the recess 26 can comprise a part cylindrical cut-out coinciding with each radial outlet port 30, as shown in Figure 3, but can also comprise a cylindrical surface having a constant diameter. The surfaces 26d located between adjoining cut-outs assist in maintaining the movable valve body in its centred position in the recess 26. However, in operation, the fluid flow past the movable valve body 28, 38 will normally cause the said valve body to be centred automatically.

[0044] Figure 3 shows an embodiment provided with 12 outlet ports distributed at equal distances around the periphery of the second valve body 27. The outlet ports 30 are located radially outside the outer diameter of the movable valve body. The number and diameter of the outlet ports can be varied to fit the dimensions of the second valve body 27. The total flow area of the outlet ports must be at least equal to the flow area of the inlet port in the first valve body. The outlet ports 30 extend radially outwards through the annular wall of the second valve body 27, to reach an annular space between an annular body (see "21"; Figures 2A/2B) and the second valve body 27. This annular space is in fluid connection with the internal volume of the pipe in which the valve arrangement is mounted. The second surface 26b of the recess 26 is provided with 6 projections 29 arranged to support a movable valve body (see "29"; Figures 2A/2B). The number of projections 29 is preferably at least three and the width and radial extension of the respective upper surface of each projection determines the contact surface with the movable valve body. The number, surface area and radial location are selected to avoid or minimize sticking between the projections and the valve body when the movable valve body is actuated. Figure 4 shows a partially sectioned view of an alternative second valve body according to an embodiment. The second valve body 47 as shown in Figure 4 has a general cup-shape with an opening arranged to face a first valve body, in the same way as the second valve body in Figure 3 (cf. "22/32"; Figures 2A/2B). The second valve body 47 is placed in sealing contact with the first valve body (not shown) to form a recess 46 and is attached to said first valve body by means of a threaded connection 45. The corresponding threaded connection on the first valve body is located on a cylindrical inner section of the first valve body.

[0045] The second valve body 47 differs from the second valve body 27 in Figure 3 in that it is provided with a number of axial outlet ports 40, extending axially downwards from a lower, second surface 46b of the recess 46 delimited by the second valve body 47. As described in connection with Figure 3, the portion of the recess 46 delimited by said second valve body 47 comprises a second surface 46b and a circumferential side wall 46c of the recess 46. The side wall 46c of the recess 46 can comprise a number of part cylindrical cutouts coinciding with each axial outlet port 40, as shown in Figure 4, but can also comprise a cylindrical surface having a constant diameter. The surfaces 46d located between adjoining cut-outs assist in maintaining the movable valve body in its centred position in the recess 46.

[0046] Figure 4 shows an embodiment provided with 12 outlet ports distributed at equal distances around the periphery of the second valve body 47. The central axes of the outlet ports 40 are located so that they intersect or pass radially outside the outer diameter of the movable valve body. The number and diameter of the outlet ports can be varied to fit the dimensions of the second valve body 47. The total flow area of the outlet ports must be at least equal to the flow area of the inlet port in the first valve body. The outlet ports 40 extend axially through the bottom of the cup-shaped second valve body 47, to reach the inner volume of the production pipe in which the valve arrangement is mounted. The second surface 46b of the recess 46 is provided with 6 projections 49 arranged to support a movable valve body (see "29"; Figures 2A/2B). The number of projections 49 is preferably at least three and the width and radial extension of the respective upper surface of each projection determines the contact surface with the movable valve body. The number, surface area and radial location are selected to avoid or minimize sticking between the projections and the valve body when the movable valve body is actuated.

[0047] Figure 5 shows a partially sectioned view of a further alternative second valve body according to an embodiment. The second valve body 57 as shown in Figure 5 has a general cup-shape with a larger opening arranged to face a first valve body, as shown in Figure 3 (cf. "22/32"; Figures 2A/2B), and a smaller central opening 51 facing the inner volume of the production pipe in which the valve arrangement is mounted. The second valve body 57 is placed in sealing contact with a first valve body (not shown) to form a recess 56 and is attached to said first valve body by means of a threaded connection 55. The corresponding threaded connection on the first valve body is located on a cylindrical inner section of the first valve body.

[0048] The second valve body 57 differs from the second valve body 47 in Figure 4 in that it is provided with a central opening 51 having a number of radial recesses 50 forming a common outlet port 50, 51. The common outlet port 50, 51 extends axially downwards from a lower, second surface 56b of the recess 56 delimited by the second valve body 57. As described in connection with Figure 4, the portion of the recess 56 delimited by said second valve body 57 comprises a second surface 56b and a circumferential side wall 56c of the recess 56. The side wall 56c of the recess 56 can comprise a number of part cylindrical cut-outs around the recess 56, as shown in Figure 4, but can also comprise a cylindrical surface having a constant diameter. The surfaces 56d located between adjoining cut-outs assist in maintaining the movable valve body in its centred position in the recess 46.

[0049] Figure 5 shows an embodiment where the combined outlet port 50, 51 is provided with 6 radial recesses 50 distributed at equal distances around the periphery of the central opening 51 of second valve body 57. The radial recesses 50 of the combined outlet port 50, 51 are located so that they extend radially outside the outer diameter of the movable valve body (not shown). The number and radius of the radial recesses 50 can be varied to fit the dimensions of the second valve body 57. The total flow area of the outlet port must be at least equal to the flow area of the inlet port in the first valve body. The combined outlet port 50, 51 extends axially through the bottom of the cup-shaped second valve body 57, to reach the inner volume of the production pipe in which the valve arrangement is mounted. The radial recesses 50 are separated by 6 projections 59 extending towards the centre of the central opening 51. The projections 59 are arranged to support a movable valve body (see "29"; Figures 2A/2B). The number of projections 59 is preferably at least three and the width and radial extension of the respective upper surface of each projection determines the contact surface with the movable valve body. The number, surface area and radial location are selected to avoid or minimize sticking between the projections and the movable valve body when the movable valve body is actuated.

[0050] It is, for instance, possible to combine either of the embodiments for the movable valve body as shown in Figures 2A or 2B with any one of the alternative second valve bodies of Figures 3-5. In addition, in case of a reverse flow from the outlet to the inlet through a valve arrangement according to the above embodiments, the outlet ports are positioned relative to the movable body so that a major portion of the fluid flow through the outlets into the respective recess will pass under the movable body and cause it to close.

Claims

1. A method of controlling the flow of a fluid into a production pipe of a well in an oil and/or gas reservoir, the fluid comprising a liquid phase and a dissolved gas phase, the method comprising allowing the fluid to pass through a valve (20) in a wall of the production pipe, the valve comprising a fluid inlet (23) in an axial direction of the valve, said axial direction being a direction toward an inner volume of the production pipe, the valve comprising a movable

body (28) located in a flow path through the valve (20), the movable body (28) being arranged to move freely relative to the opening of the inlet (23) to vary a flow-through area through which the fluid flows by means of the Bernoulli effect, wherein dimensions of the valve (20) allow flow of the fluid past the movable body (28) to cause a drop in pressure to below a bubble point of the gas phase dissolved in the liquid phase, thereby increasing a volumetric rate of flow through the valve (20) of the fluid comprising the liquid phase and the dissolved gas phase,

wherein the movable body (28) is located in a recess (26) in the valve (20), the movable body (28) having a first surface (28a) facing the inlet and a second surface (28b) located remote from the inlet (23);
wherein the inlet (23) is connected to the recess by a central aperture such that the fluid flows into the recess (26) through the central aperture; and
the fluid flows out of the recess (26) in a radial direction of the valve across the first surface of the movable body (28), and past an outer peripheral surface (28c) of said movable body (28) towards at least one outlet port (30) of the valve,
wherein the outlet port (30) comprises multiple apertures (30) each connected to the recess at a location that is at the outer peripheral surface (28c) of the valve body (28), or at a location that is located, in a radial direction of the valve, outside the outer peripheral surface (28c) of the valve body (28),
wherein the multiple apertures (30) are each connected to the recess (26) in a radial direction of the valve (20), such that each aperture faces the outer peripheral surface (28c) of the movable body (28).

2. The method according to claim 1, wherein a major portion of the outlet port (30) is connected to the recess (26) in a position located remote from the central aperture relative to a plane through the second surface (28b).

3. The method according to claim 1, wherein the centre axis of each aperture is arranged in a plane located remote from the central aperture relative to a plane through the second surface (28b).

4. The method according to claim 1 or 2, wherein the outlet port (30) comprises any of multiple apertures, each aperture connected to the recess (26) in the axial direction of the valve (20), and multiple apertures, each aperture connected to the recess (26) in the axial direction of the valve (20), wherein the multiple apertures are each connected to the recess (26) on the opposite side of the movable body (28) relative to the inlet port (23).

5. The method according to claim 4, wherein the centre axis of each aperture is connected to the recess (26) so that each coincides with or passes radially outside the outer peripheral surface (28c) of the movable body (28).

6. The method according to any one claims 1 to 5, **characterised in that** the movable body is supported by at least three projections extending into the recess (26) towards the second surface of the movable body (28).

7. The method according to any of the preceding claims, **characterised in that** the movable body (28) comprises one of a circular disc, and a conical shape with the apex facing the inlet port (23).

8. The method of any preceding claim, wherein the production pipe comprises a drainage pipe, the drainage pipe comprising at least one said valve (20) that controls a flow of hydrocarbon fluids from the reservoir to an interior of the drainage pipe.

Patentansprüche

1. Verfahren zum Steuern der Strömung eines Fluids in eine Produktionsleitung eines Bohrlochs in einem Öl- und/oder Gasreservoir, wobei das Fluid eine flüssige Phase und eine gelöste Gasphase umfasst, wobei das Verfahren umfasst, dass das Fluid durch ein Ventil (20) in einer Wand des Förderrohrs strömen kann, wobei das Ventil einen Fluideinlass (23) in einer axialen Richtung des Ventils umfasst, wobei die axiale Richtung eine Richtung zu einem Innenvolumen der Produktionsleitung ist, wobei das Ventil Folgendes umfasst:

einen beweglichen Körper (28), der sich in einem Strömungsweg durch das Ventil (20) befindet, wobei der bewegliche Körper (28) angeordnet ist, um sich relativ zu der Öffnung des Einlasses (23) frei zu bewegen, um eine Durchflussfläche zu variieren, durch die das Fluid mittels des Bernoulli-Effekts strömt, wobei Abmessungen des Ventils (20) eine Strömung des Fluids an dem beweglichen Körper (28) vorbei ermöglichen, um einen Druckabfall unter einen Blasenpunkt der in der flüssigen Phase gelösten Gasphase zu bewirken, wodurch eine volumetrische Strömungsrate des Fluids, das die flüssige Phase und die gelöste Gasphase umfasst, durch das

Ventil (20) erhöht wird,

wobei sich der bewegliche Körper (28) in einer Ausnehmung (26) in dem Ventil (20) befindet, wobei der bewegliche Körper (28) eine erste Oberfläche (28a), die dem Einlass zugewandt ist, und eine zweite Fläche (28b), die sich von dem Einlass (23) entfernt befindet, aufweist;

wobei der Einlass (23) durch eine zentrale Öffnung mit der Ausnehmung verbunden ist, sodass das Fluid durch die zentrale Öffnung in die Ausnehmung (26) strömt; und

das Fluid aus der Ausnehmung (26) in einer radialen Richtung des Ventils über die erste Oberfläche des beweglichen Körpers (28) und an einer Außenumfangsfläche (28c) des beweglichen Körpers (28) vorbei zu mindestens einer Auslassöffnung (30) des Ventils strömt,

wobei die Auslassöffnung (30) mehrere Öffnungen (30) umfasst, die jeweils an einer Stelle, die an der Außenumfangsfläche (28c) des Ventilkörpers (28) ist, oder an einer Stelle, die sich in einer radialen Richtung des Ventils außerhalb der Außenumfangsfläche (28c) des Ventilkörpers (28) befindet, mit der Ausnehmung verbunden sind,

wobei die mehreren Öffnungen (30) jeweils mit der Ausnehmung (26) in einer radialen Richtung des Ventils (20) verbunden sind, so dass jede Öffnung der Außenumfangsfläche (28c) des beweglichen Körpers (28) zugewandt ist.

2. Verfahren nach Anspruch 1, wobei ein Hauptabschnitt der Auslassöffnung (30) mit der Ausnehmung (26) in einer Position verbunden ist, die sich von der zentralen Öffnung relativ zu einer Ebene durch die zweite Oberfläche (28b) entfernt befindet.

3. Verfahren nach Anspruch 1, wobei die Mittelachse jeder Öffnung in einer Ebene angeordnet ist, die sich von der zentralen Öffnung relativ zu einer Ebene durch die zweite Oberfläche (28b) entfernt befindet.

4. Verfahren nach Anspruch 1 oder 2, wobei die Auslassöffnung (30) eine von mehreren Öffnungen, wobei jede Öffnung mit der Ausnehmung (26) in der axialen Richtung des Ventils (20) verbunden ist, und mehrere Öffnungen umfasst, wobei jede Öffnung mit der Ausnehmung (26) in der axialen Richtung des Ventils (20) verbunden ist, wobei die mehreren Öffnungen jeweils mit der Ausnehmung (26) auf der gegenüberliegenden Seite des beweglichen Körpers (28) relativ zu der Einlassöffnung (23) verbunden sind.

5. Verfahren nach Anspruch 4, wobei die Mittelachse jeder Öffnung mit der Ausnehmung (26) verbunden ist, so dass jede mit der Außenumfangsfläche (28c) des beweglichen Körpers (28) zusammenfällt oder radial außerhalb davon verläuft.

6. Verfahren nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet, dass** der bewegliche Körper von mindestens drei Vorsprüngen getragen wird, die sich in die Ausnehmung (26) zur zweiten Oberfläche des beweglichen Körpers (28) hin erstrecken.

7. Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der bewegliche Körper (28) eine von einer kreisförmigen Scheibe und einer konischen Form umfasst, wobei der Scheitelpunkt der Einlassöffnung (23) zugewandt ist.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Produktionsleitung ein Drainagerohr umfasst, wobei das Drainagerohr mindestens ein Ventil (20) umfasst, das einen Strom von Kohlenwasserstofffluiden aus dem Reservoir zu einem Inneren des Drainagerohrs steuert.

Revendications

1. Procédé de contrôle de l'écoulement d'un fluide dans un tube de production d'un puits dans un réservoir de pétrole et/ou de gaz, le fluide comprenant une phase liquide et une phase gazeuse dissoute, le procédé comprenant le fait de laisser passer le fluide à travers une vanne (20) dans une paroi du tube de production, la vanne comprenant une entrée de fluide (23) dans une direction axiale de la vanne, ladite direction axiale étant une direction vers un volume interne du tube de production, la vanne comprenant

un corps mobile (28) situé dans un trajet d'écoulement à travers la vanne (20), le corps mobile (28) étant agencé pour se déplacer librement par rapport à l'ouverture de l'entrée (23) pour faire varier une zone de passage à travers laquelle le fluide s'écoule en exploitant l'effet de Bernoulli, dans lequel les dimensions de la vanne (20)

permettent l'écoulement du fluide au-delà du corps mobile (28) pour provoquer une chute de pression en dessous d'un point de bulle de la phase gazeuse dissoute dans la phase liquide, augmentant ainsi un débit volumétrique d'écoulement à travers le vanne (20) du fluide comprenant la phase liquide et la phase gazeuse dissoute,
dans lequel le corps mobile (28) est situé dans un évidement (26) dans la vanne (20), le corps mobile (28) ayant une première surface (28a) tournée vers l'entrée et une deuxième surface (28b) située à distance de l'entrée (23) ;
dans lequel l'entrée (23) est reliée à l'évidement par une ouverture centrale de sorte que le fluide s'écoule dans l'évidement (26) à travers l'ouverture centrale ; et
le fluide s'écoule hors de l'évidement (26) dans une direction radiale de la vanne à travers la première surface du corps mobile (28), et au-delà d'une surface périphérique externe (28c) dudit corps mobile (28) vers au moins un orifice de sortie (30) de la vanne,
dans lequel l'orifice de sortie (30) comprend de multiples ouvertures (30) reliées chacune à l'évidement à un emplacement qui est à la surface périphérique externe (28c) du corps de la vanne (28) ou à un emplacement qui est situé, dans une direction radiale de la vanne, à l'extérieur de la surface périphérique externe (28c) du corps de la vanne (28),
dans lequel les multiples ouvertures (30) sont chacune reliées à l'évidement (26) dans une direction radiale de la vanne (20), de sorte que chaque ouverture fait face à la surface périphérique externe (28c) du corps mobile (28).

2. Procédé selon la revendication 1, dans lequel une majeure partie de l'orifice de sortie (30) est reliée à l'évidement (26) dans une position située à distance de l'ouverture centrale par rapport à un plan passant par la deuxième surface (28b).

3. Procédé selon la revendication 1, dans lequel l'axe central de chaque ouverture est agencé dans un plan situé à distance de l'ouverture centrale par rapport à un plan passant par la deuxième surface (28b).

4. Procédé selon la revendication 1 ou 2, dans lequel l'orifice de sortie (30) comprend l'une quelconque de multiples ouvertures, chaque ouverture étant reliée à l'évidement (26) dans la direction axiale de la vanne (20), et de multiples ouvertures, chaque ouverture étant reliée à l'évidement (26) dans la direction axiale de la vanne (20), dans laquelle les multiples ouvertures sont chacune reliées à l'évidement (26) sur le côté opposé du corps mobile (28) par rapport à l'orifice d'entrée (23).

5. Procédé selon la revendication 4, dans lequel l'axe central de chaque ouverture est relié à l'évidement (26) de sorte que chacun coïncide avec ou passe radialement à l'extérieur de la surface périphérique externe (28c) du corps mobile (28).

6. Procédé selon l'une quelconque des revendications 1 à 5, **caractérisé en ce que** le corps mobile est supporté par au moins trois saillies s'étendant dans l'évidement (26) vers la deuxième surface du corps mobile (28).

7. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le corps mobile (28) comprend l'un parmi un disque circulaire et une forme conique avec le sommet faisant face à l'orifice d'entrée (23).

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel le tube de production comprend un tuyau de drainage, le tuyau de drainage comprenant au moins une dite vanne (20) qui contrôle un écoulement de fluides d'hydrocarbures du réservoir vers un intérieur du tuyau de drainage.

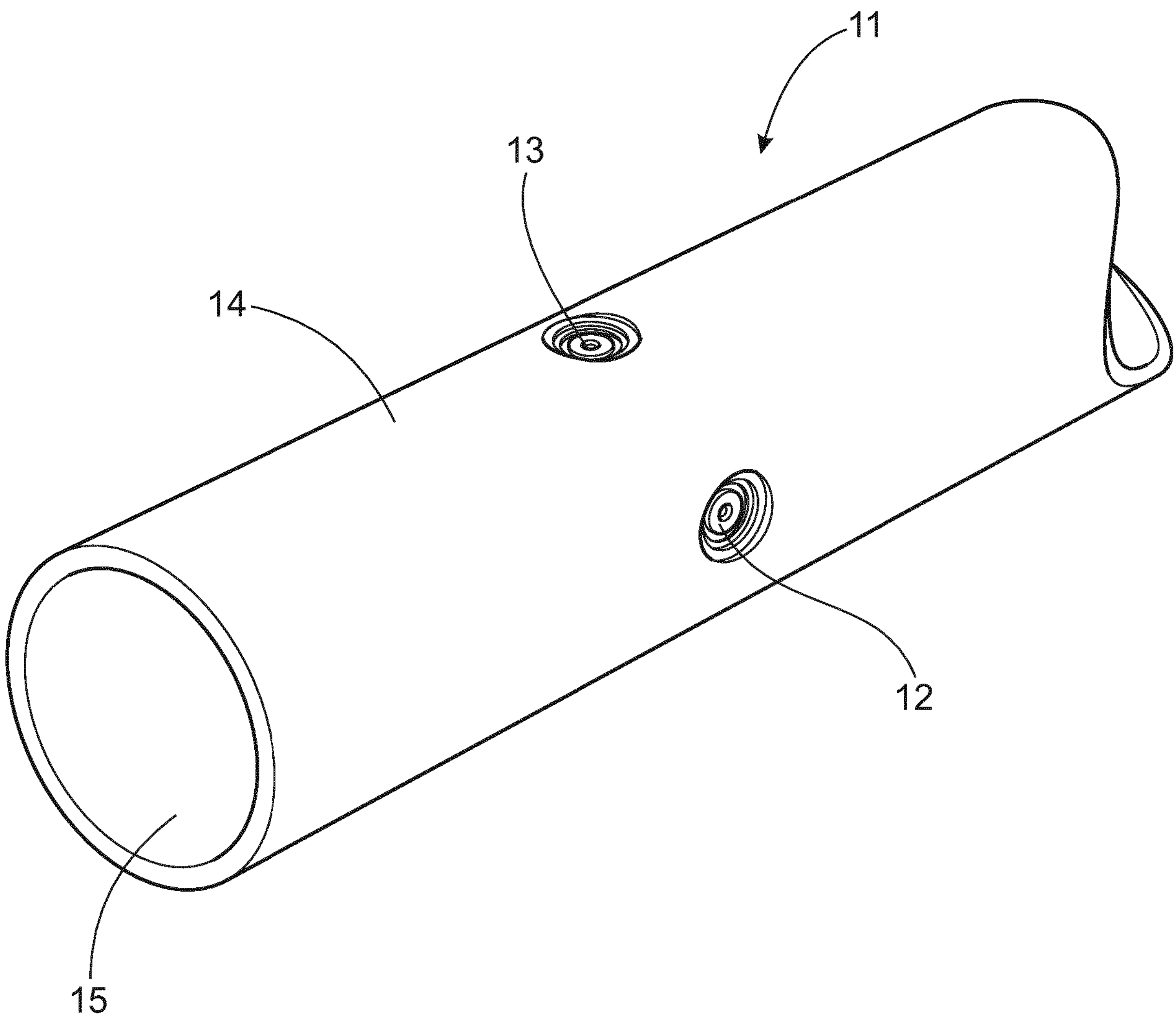


Fig.1

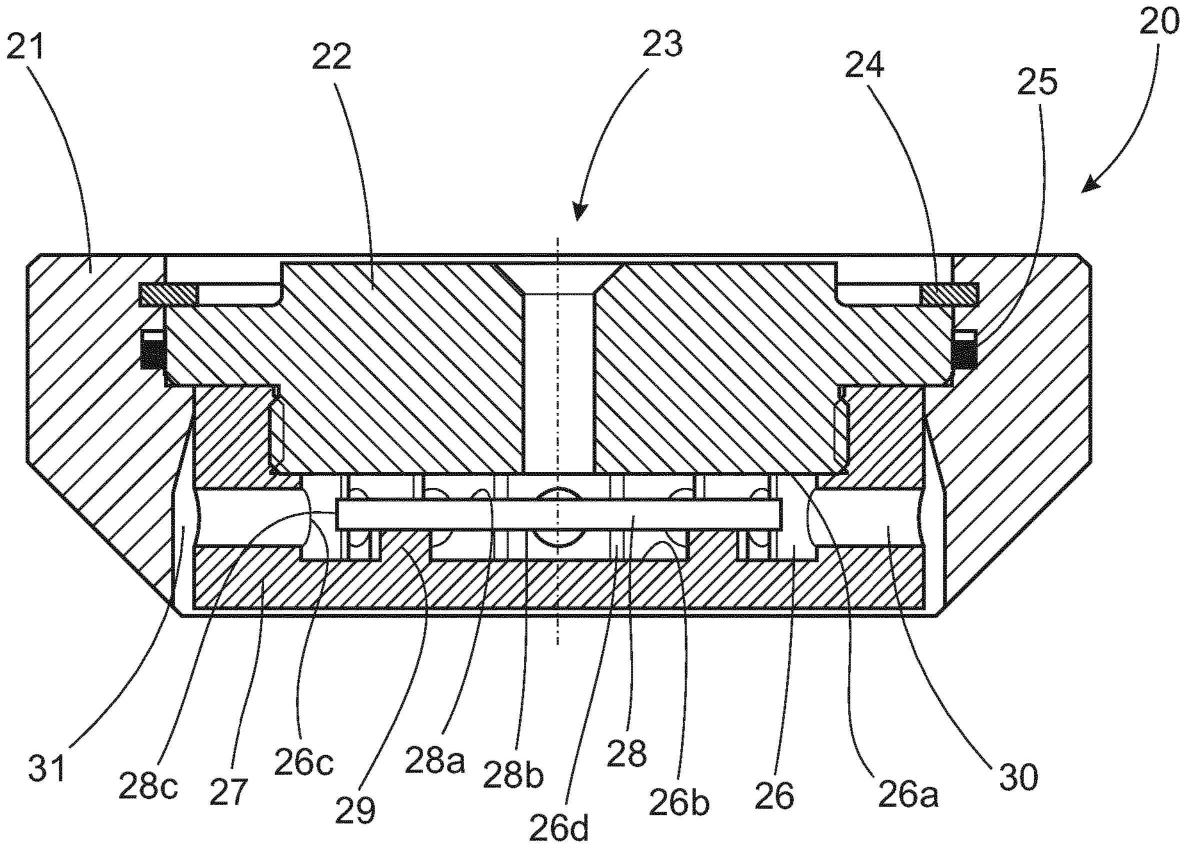


Fig.2A

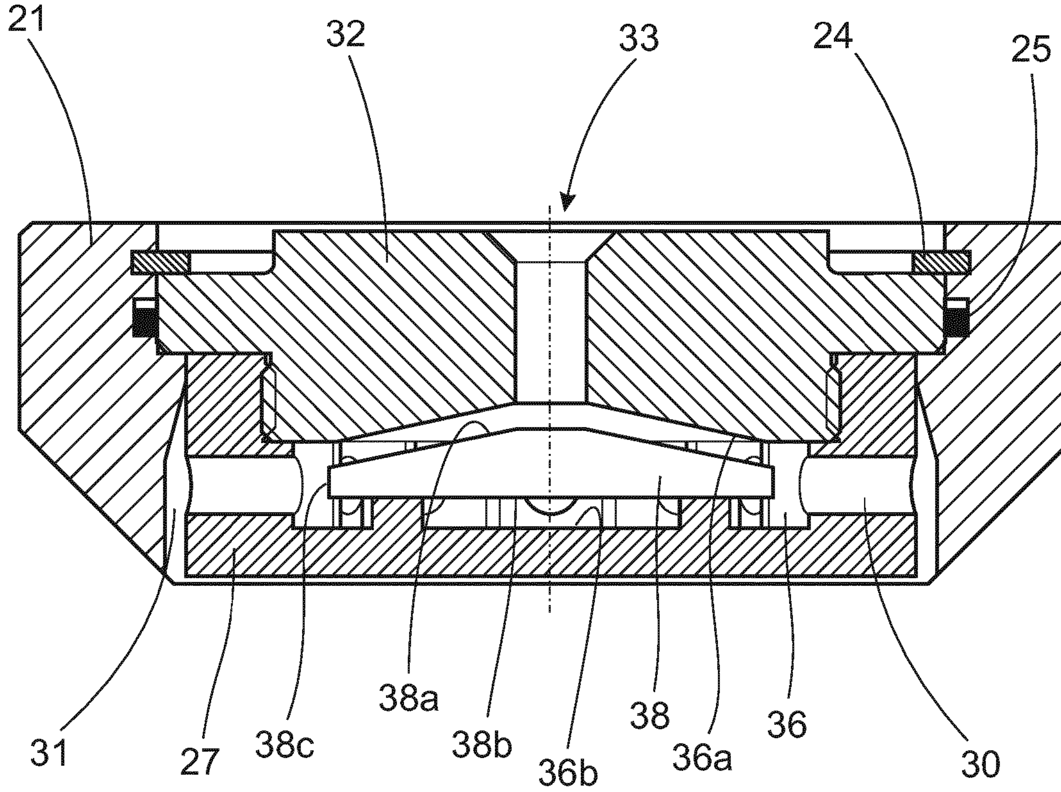


Fig.2B

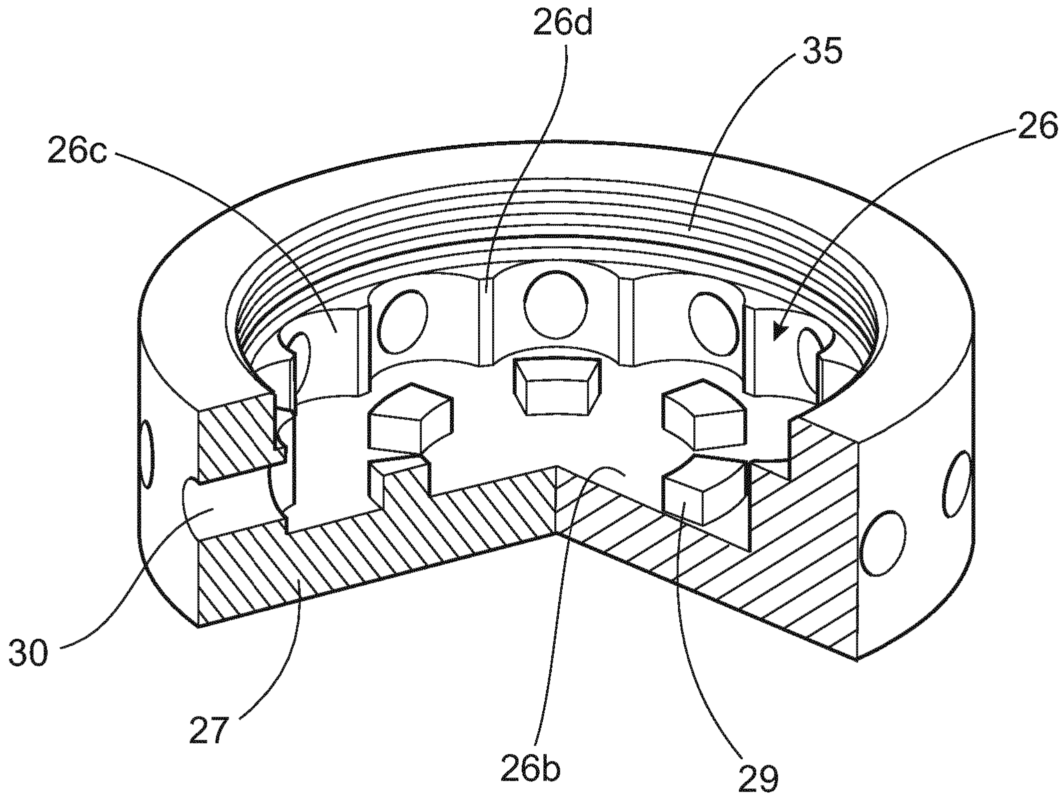


Fig.3

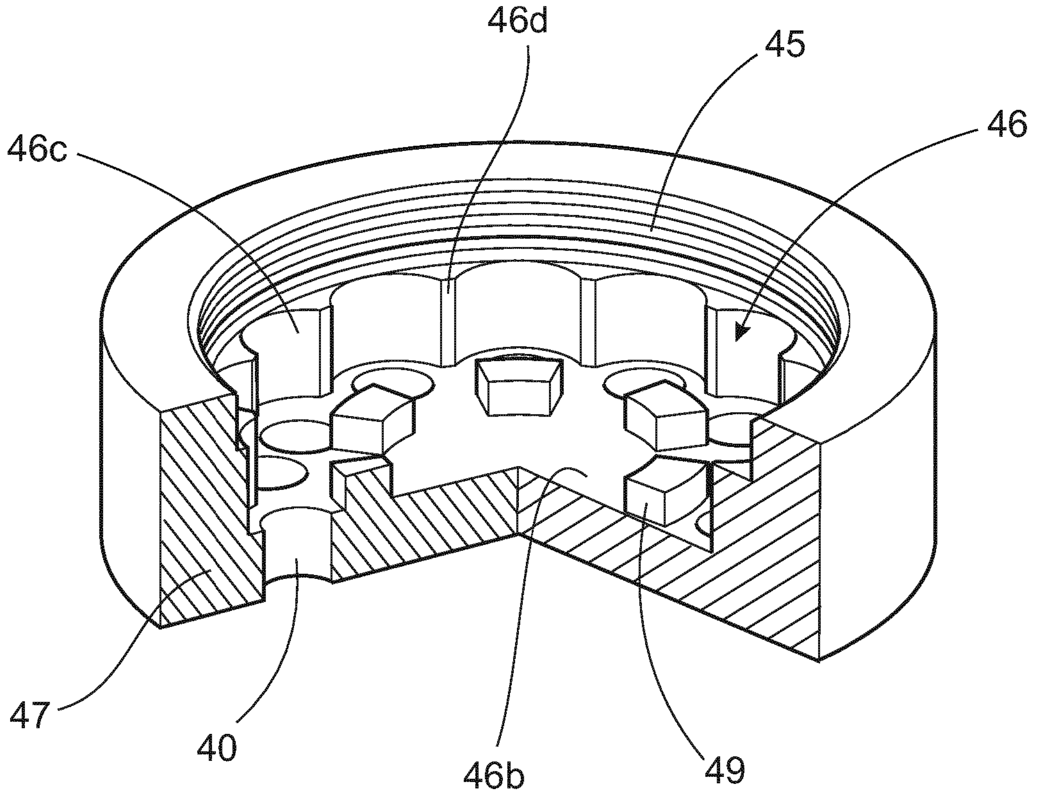


Fig.4

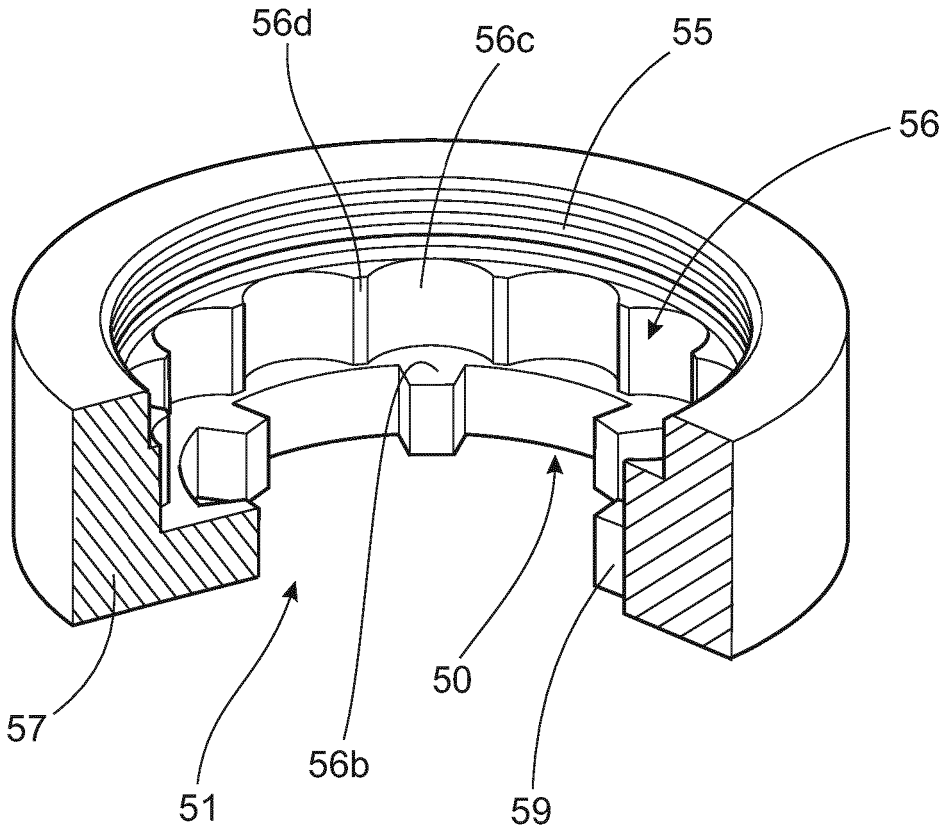
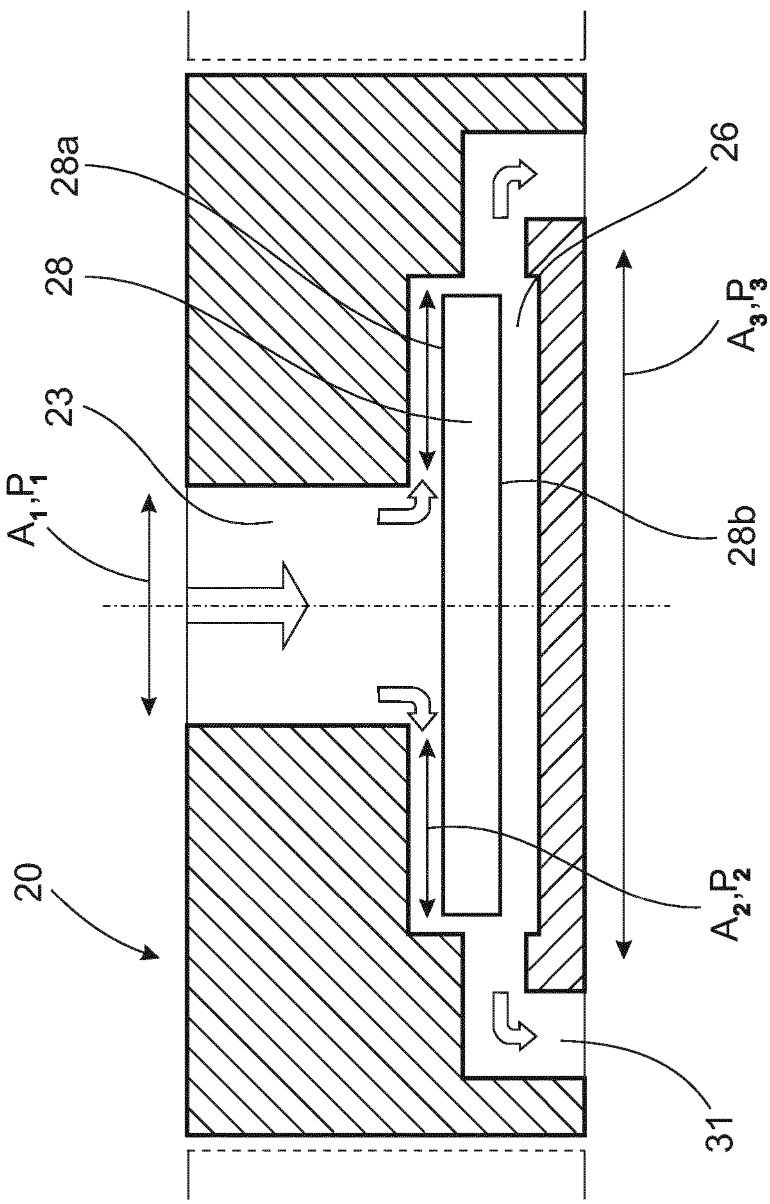


Fig.5

Fig.6



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 4821801 A **[0002]**
- US 4858691 A **[0002]**
- US 4577691 A **[0002]**
- GB 2169018 A **[0002]**
- WO 9208875 A **[0004]**
- WO 2009088292 A **[0006]**
- WO 2008004875 A **[0006]**
- WO 2010053378 A2, Oevland Sigbjoern **[0008]**
- WO 9820231 A **[0008]**
- WO 2008004875 A1, Aakre **[0008]**
- US 2003094283 A1, Ivannikov **[0008]**

Non-patent literature cited in the description

- *From World Oil,* vol. 212 (11/91), 73-80 **[0003]**
- The Autonomous RCP Valve - new Technology for inflow control in horizontal wells. *Mathiesen, SPE Offshore Europe Oil and Gas Conference and Exhibition,* 06 September 2011, 1-10 **[0008]**