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- (71) Applicant (for all designated States except US):  
STATOIL PETROLEUM AS [NO/NO]; N-4035  
Stavanger (NO).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): AAKRE, Haavard  
[NO/NO]; Lille Einaren 21, N-3744 Skien (NO). WER-  
SWICK, Bjørnar [NO/NO]; Baneåsen 24, N-3970 Lange-  
sund (NO). MATHISEN, Vidar [NO/NO]; Øvaldveien  
14, N-3944 Porsgrunn (NO).
- (74) Agent: Zacco Norway AS; P.O. Box 2003 Vika, N-0125  
Oslo (NO).

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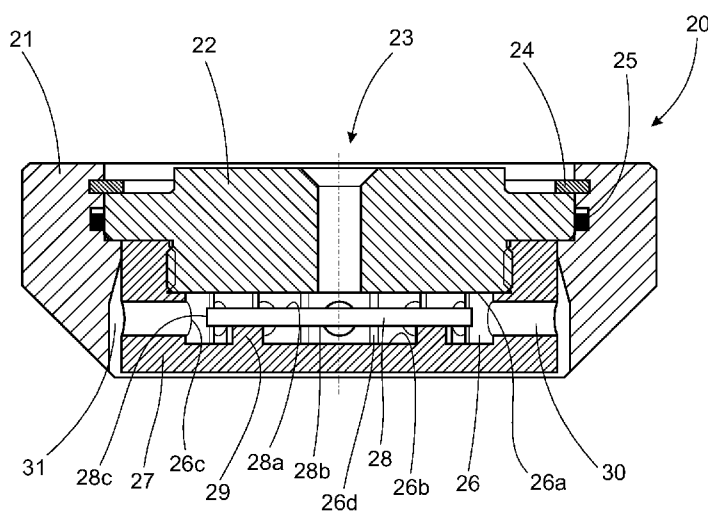


Fig.2A

(57) Abstract: The invention 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. A freely movable valve body is located in a recess in the flow control device, wherein the fluid is 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. Such a production pipe can include a drainage pipe comprising at least two sections each including one or more inflow control devices.

## AUTONOMOUS VALVE

### TECHNICAL FIELD

The present invention relates to an autonomous valve arrangement provided  
5 an inflow control device for achieving constant mass flow of hydrocarbons into a production line in a wellbore.

### BACKGROUND ART

Devices for recovering of oil and gas from long, horizontal and vertical wells  
10 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  
15 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  
20 produced by this means will therefore be low. With thin oil zones and highly permeable geological formations, there is further a high risk that 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.

25 From World Oil, vol. 212, N. 11 (11/91), pages 73 - 80, is previously 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 is mainly dealing 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.

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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  
5 outer surface of the production pipe.

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.  
10 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.

Device as disclosed in WO2009/088292 and WO 2008/004875 are robust,  
15 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  
20 WO2009/088292 and WO 2008/004875 describe a disc as the movable body of the valve.

One potential problem with a disc as the movable body is erosion on the movable body. This is due to a very large fluid velocity between an inner seat  
25 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. The present invention provides an improved  
30 valve which aims to minimize this problem.

## SUMMARY OF THE INVENTION

The above problems are solved by an autonomous valve arrangement provided with a flow control device according to the appended claims.

5 The present invention relates 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 which of these fluids such flow control is required.

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According to a preferred embodiment, the invention 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.

20 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 the 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.

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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

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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.

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.

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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.

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.

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.

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.

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.

5 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  
10 flow past the disc will try to distribute the fluid evenly through all outlet ports and thereby centre the disc.

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  
15 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.  
20 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 it 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  
25 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 area of the outlet port or ports.

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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.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention 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 the invention;

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 the invention;

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

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

#### DETAILED DESCRIPTION



Figure 1 shows a production pipe 11 provided with an opening in which an autonomous valve arrangement 12 according to the invention. 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).

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.

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  
5 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  
10 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 31 between the annular body 21 and the second valve body 27. This annular space 31 is in fluid connection with the internal volume of the pipe in  
15 which the valve arrangement is mounted.

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  
20 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

The valve arrangement further comprises a freely movable valve body 28  
25 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  
30 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.

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.

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:

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

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 the present invention, the pressure difference over the disc 28 can be expressed as follows:

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

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  
5 through of the device.

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

$$10 \quad \Delta p = K \frac{1}{2} \rho v^2 \quad (3)$$

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

When producing oil and gas the flow control device according to the invention 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  
25 control device. When designing the control device according to the invention 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 ( $P1 \cdot A1$ ) 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.

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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.

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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

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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 31 between the annular body 21 and the second valve body 27.

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.

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 5 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 10 the movable valve body 28, 38 will normally cause the said valve body to be centred automatically.

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 15 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 20 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 25 (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 30 movable valve body is actuated.

Figure 4 shows a partially sectioned view of an alternative second valve body according to the invention. 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.

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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 cut-outs 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.

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.

- 5 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 5 shows a partially sectioned view of a further alternative second valve body according to the invention. The second valve body 57 as shown in  
10 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  
15 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.

20 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  
25 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  
30 surfaces 56d located between adjoining cut-outs assist in maintaining the movable valve body in its centred position in the recess 46.

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  
5 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  
10 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  
15 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.

20

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  
25 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 self-adjustable (autonomous) valve or flow control device for controlling the flow of a fluid from one space or area to another, in particular to control the flow of fluid from a reservoir and into a production pipe of a well in the oil and/or gas reservoir where the production pipe includes a drainage pipe comprising at least two sections including one or more inflow control devices, between an inlet port on an inlet side to at least one outlet port on an outlet side of the flow control device *characterised in* that
- 10 - a freely movable valve body is located in a recess in the flow control device, said valve body having a first surface facing the inlet port and a second surface located remote from the inlet port;
- the inlet port is connected to the recess by a central aperture (opening);
- the fluid is arranged to flow into the recess through the central aperture
- 15 ;and that
- the fluid is 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.
- 20
2. A self-adjustable valve according to claim 1, characterised in that 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.
- 25
3. A self-adjustable valve according to claim 1 or 2, *characterised in* that the outlet port comprises multiple apertures each connected to the recess at a location at or radially outside the outer peripheral surface of the valve body.
- 30
4. A self-adjustable valve according to claim 3, *characterised in* that the multiple apertures are each connected to the recess in the radial direction of the flow control device.

5. A self-adjustable valve according to claim 4, *characterised in* that the multiple apertures are each connected to the recess so that each aperture faces the outer peripheral (circumferential) surface of the valve body.

5

6. A self-adjustable valve according to any one of claims 3-5, characterised in that 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.

10 7. A self-adjustable valve according to claim 1 or 2, *characterised in* that the outlet port comprises multiple apertures each connected to the recess in the axial direction of the flow control device.

15 8. A self-adjustable valve according to claim 7, *characterised in* that the multiple apertures are each connected to the recess on the opposite side of the valve body relative to the inlet port.

20 9. A self-adjustable valve according to claim 7 or 8, *characterised in* that 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.

25 10. A self-adjustable valve according to any one of the above claims, *characterised in* that the valve body is supported by at least three projections extending into the recess towards the second surface of the valve body.

11. A self-adjustable valve according to claim 1 or 2, *characterised in* that the outlet port comprises an aperture connected to the recess on the opposite side of the valve body relative to the inlet port.

30

12. A self-adjustable valve according to claim 11, *characterised in* that the aperture has a cross-sectional area equal to or greater than the second surface of the valve body.

5 13. A self-adjustable valve according to claim 11 or 12, *characterised in* that the valve body is supported by at least three projections extending radially outwards from the peripheral circumference of the recess.

14. A self-adjustable valve according to any one of the above claims 1-13,  
10 *characterised in* that the valve body comprises a circular disc.

15. A self-adjustable valve according to any one of the above claims 1-13  
*characterised in* that the valve body has a conical shape with the apex facing  
the inlet port.

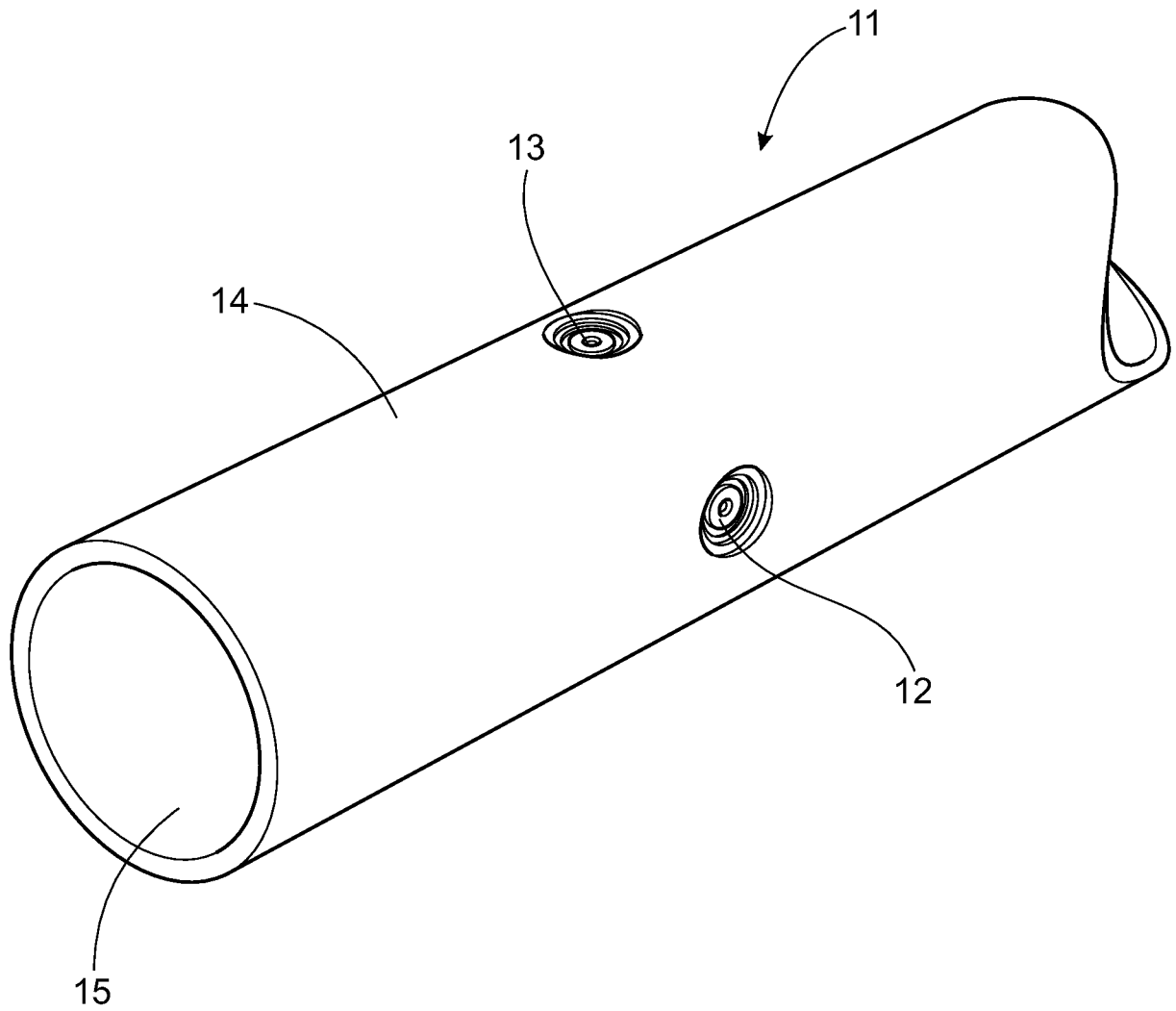


Fig.1

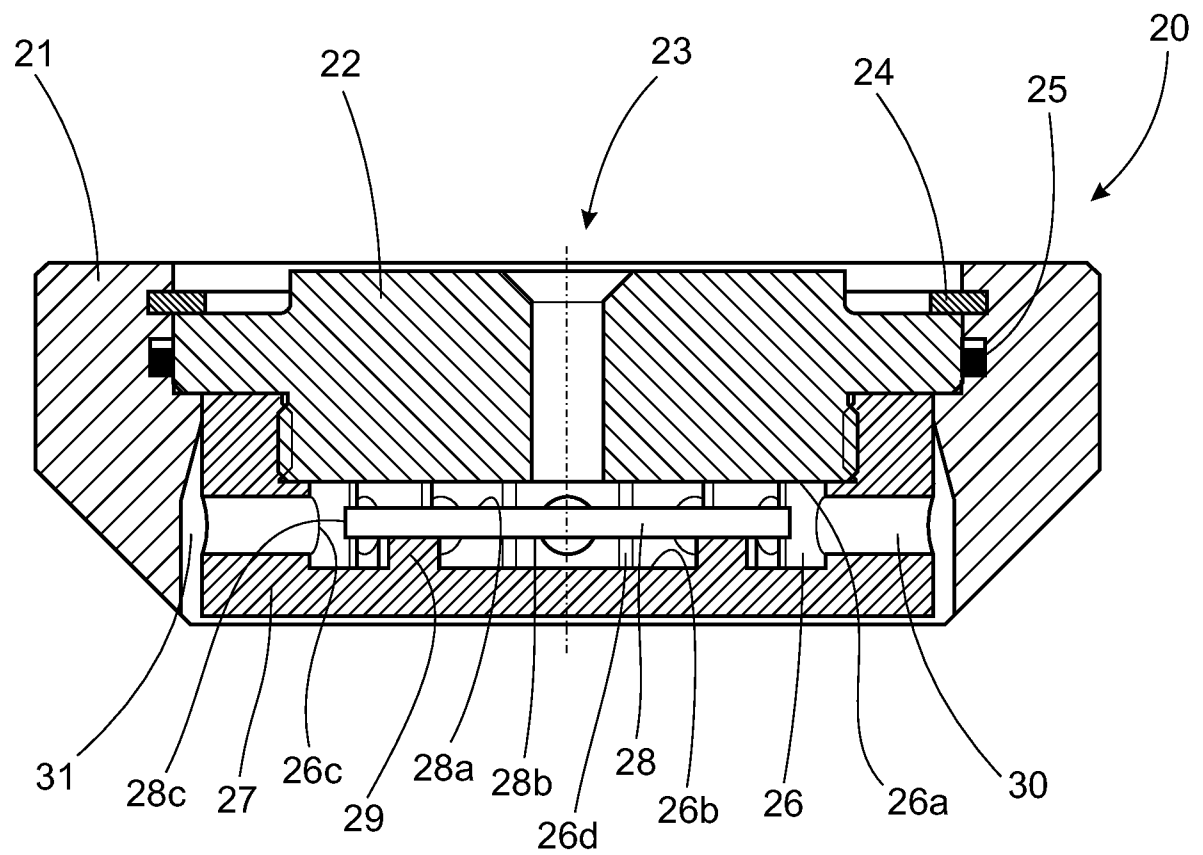
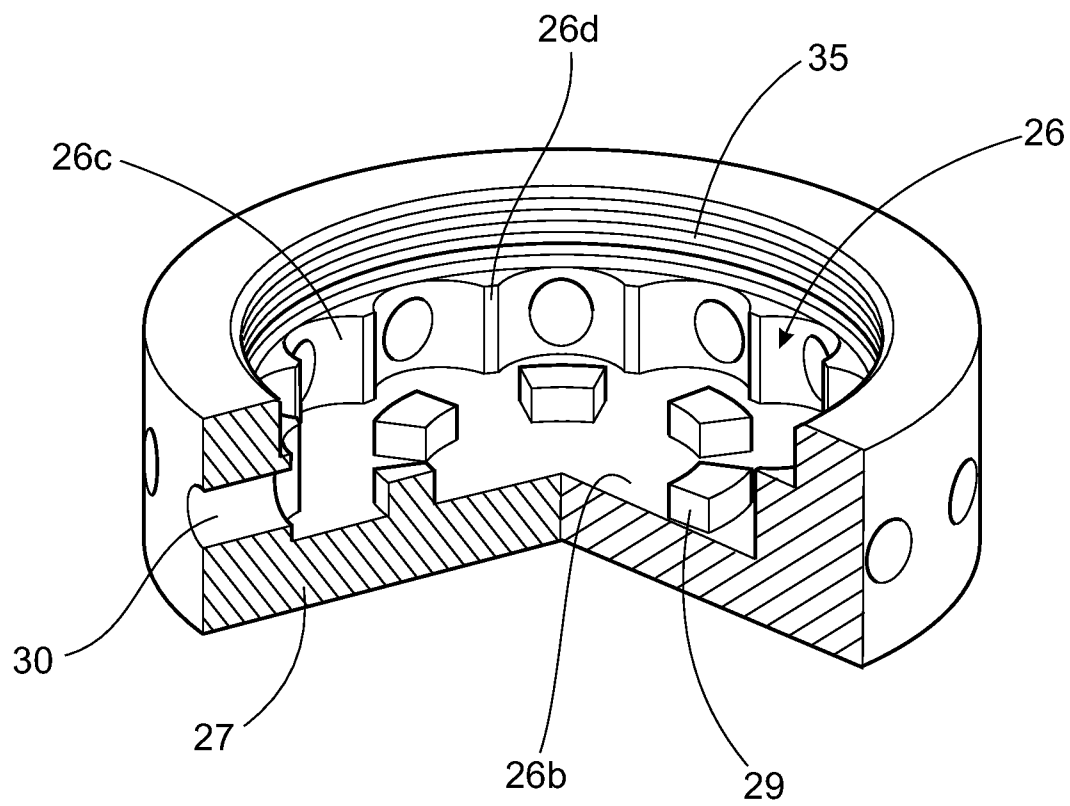


Fig.2A



**Fig.3**



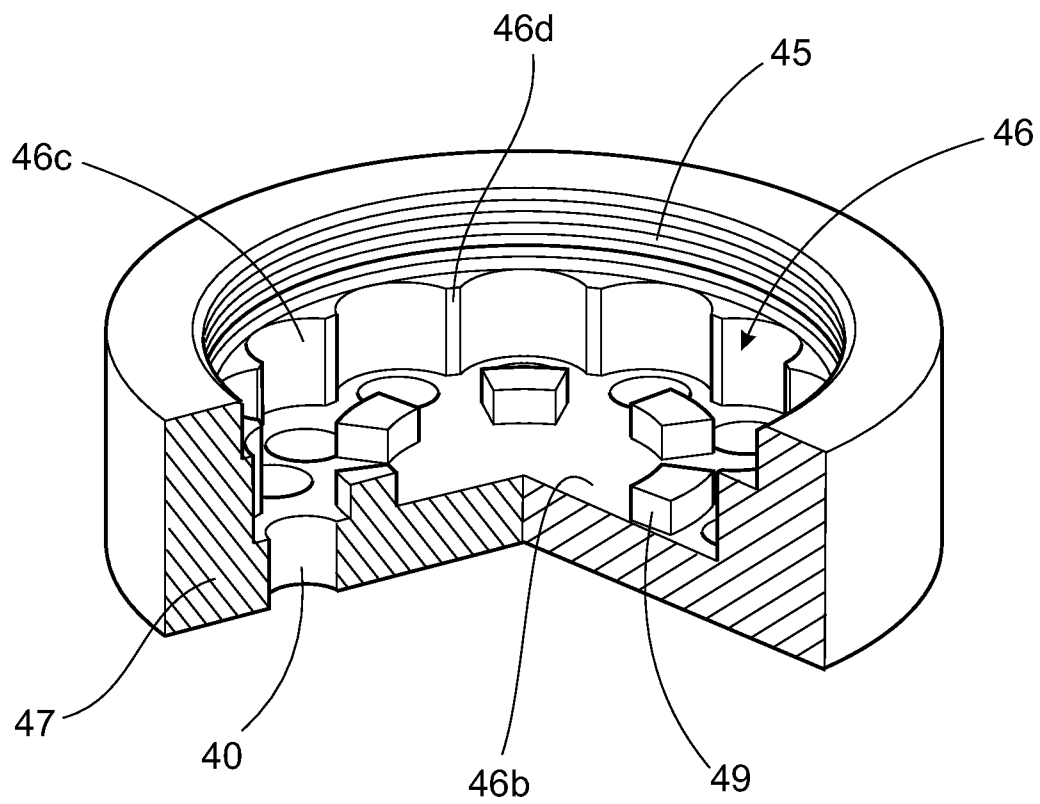


Fig.4

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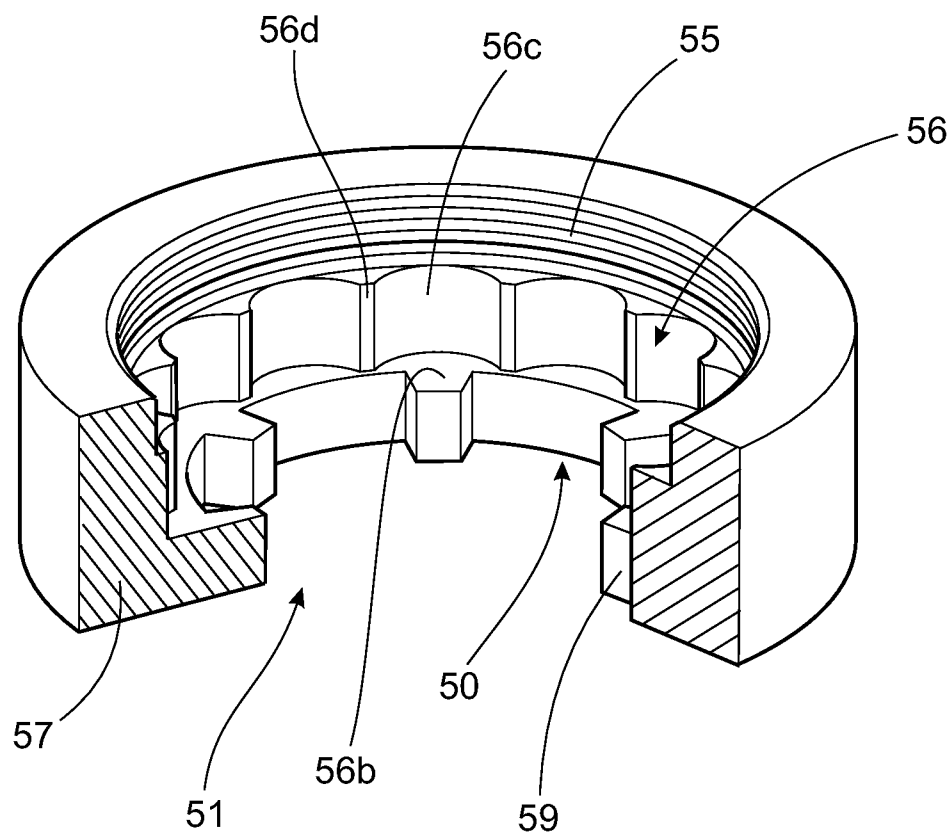


Fig.5

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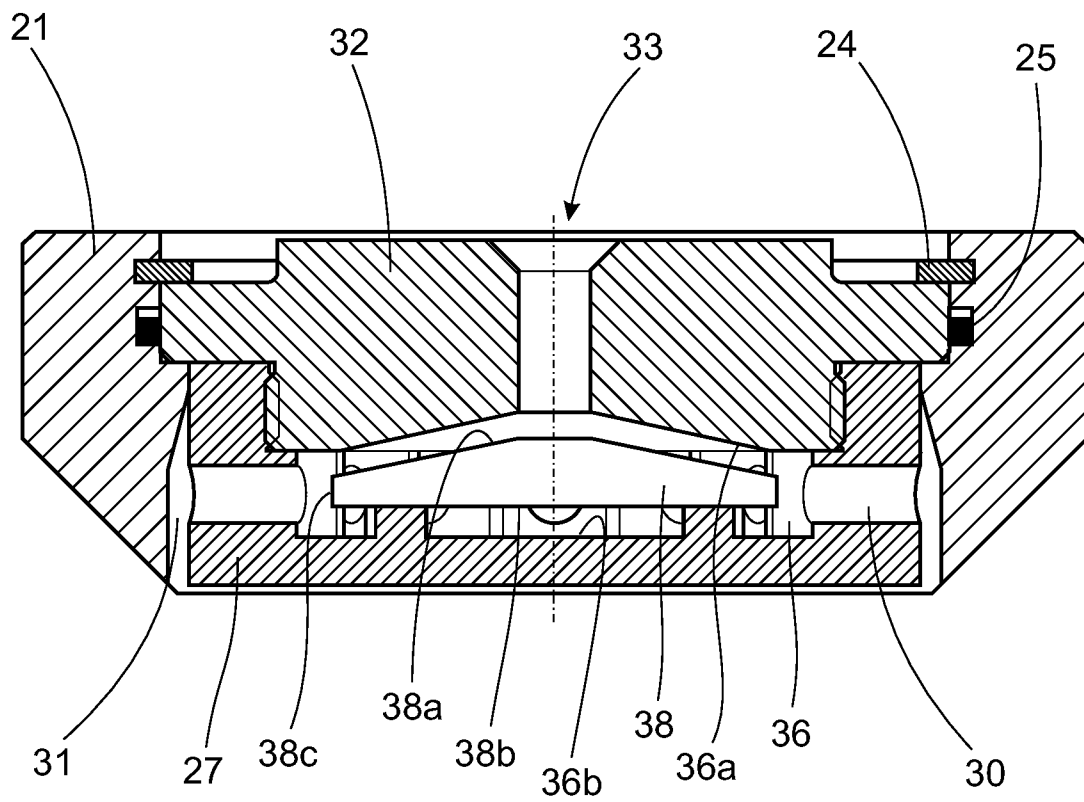


Fig.2B

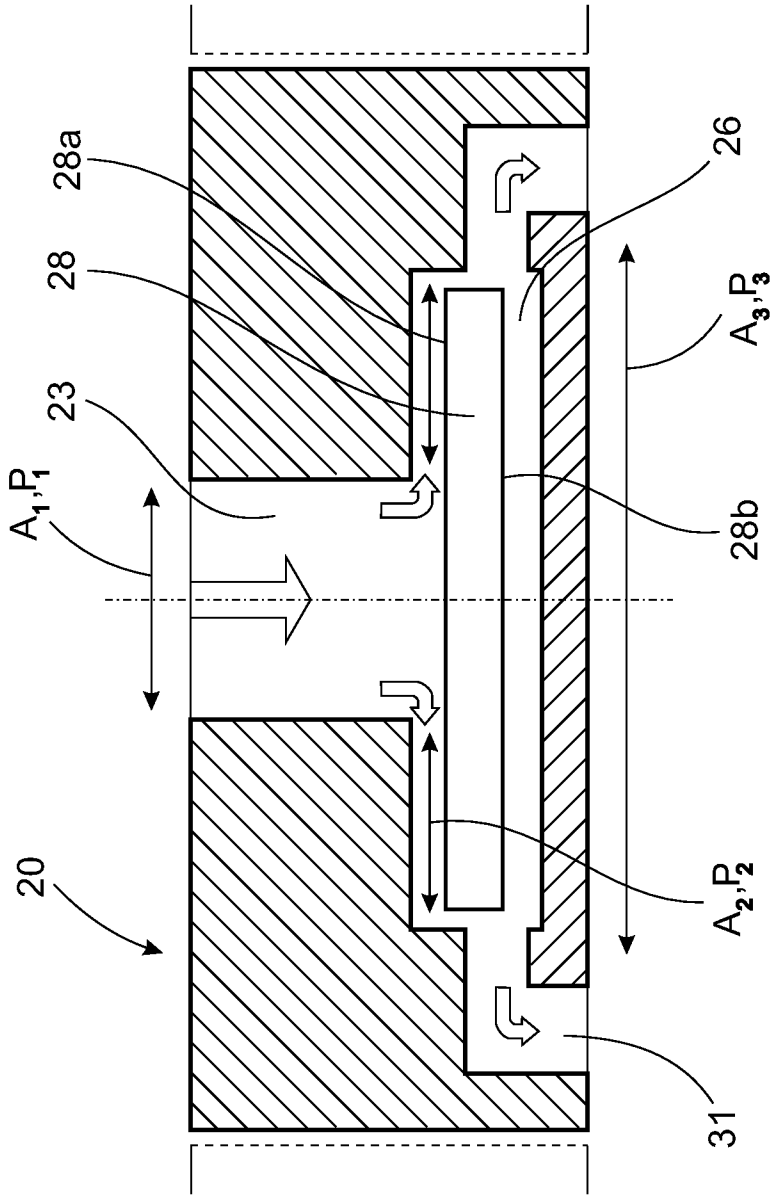


Fig.6

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2011/050471

A. CLASSIFICATION OF SUBJECT MATTER  
INV. E21B34/08 E21B43/12  
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
E21B

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

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

EP0-Internal, WPI Data

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/282476 A1 (TESSIER LYNN P [CA] ET AL) 11 November 2010 (2010-11-11) figure 2 the whole document -----	1-15
X	WO 91/03781 A1 (PALMER DAVID W [US]) 21 March 1991 (1991-03-21) page 10, line 30 - page 12, line 8; figure 6 the whole document -----	1-6,15
X	WO 2008/004875 A1 (NORSK HYDRO AS [NO]; AAKRE HAAVARD [NO]; MATHIESEN VIDAR [NO]) 10 January 2008 (2008-01-10) cited in the application figure 5 the whole document figures 1,2 ----- -/--	1,2, 10-15



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

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Date of the actual completion of the international search

12 October 2011

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040,  
Fax: (+31-70) 340-3016

Authorized officer

van Berlo, André

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2011/050471

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No

PCT/EP2011/050471

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