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

(11) EP 2 479 376 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
25.07.2012 Bulletin 2012/30

(51) Int Cl.:
E21B 33/127 *(2006.01)*

(21) Application number: **11152135.7**

(22) Date of filing: **25.01.2011**

(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
Designated Extension States:
BA ME

(71) Applicant: **Welltec A/S**
3450 Allerød (DK)

(72) Inventors:
- **Hallundbæk, Jørgen**
3230, Græsted (DK)
- **Hazel, Poul**
Aberdeen, AB41/7JQ (GB)
- **Stæhr, Lars**
2600, Glostrup (DK)

(74) Representative: **Hoffmann Dragsted A/S**
Rådhuspladsen 16
1550 Copenhagen V (DK)

(54) Annular barrier with a diaphragm

(57) The present invention relates to an annular barrier arranged in a borehole for providing zone isolation between a first zone and a second zone. Furthermore, the present invention relates to an annular barrier system as well as to a method of placing an annular barrier in an annulus and a method of using annular barriers in an annulus to seal off an inflow control section.

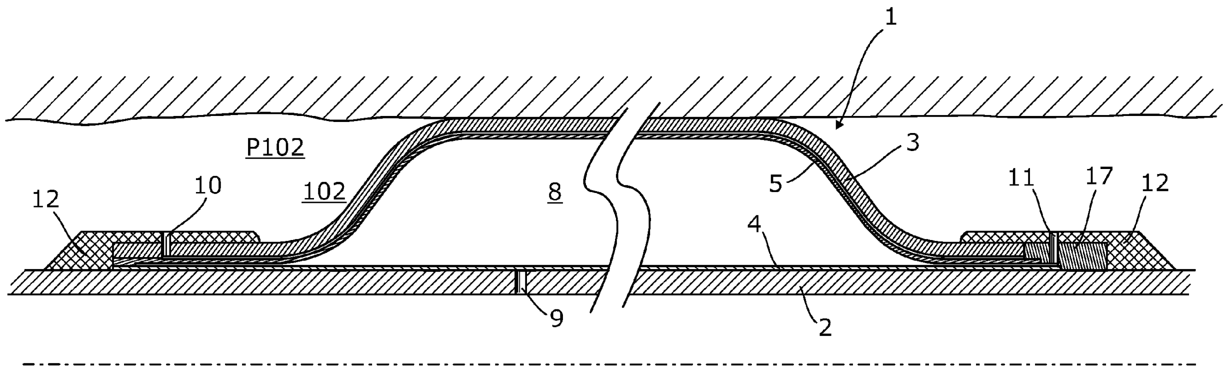

Fig. 7

EP 2 479 376 A1

Description

Field of the invention

[0001] The present invention relates to an annular barrier arranged in a borehole for providing zone isolation between a first zone and a second zone. Furthermore, the present invention relates to an annular barrier system as well as to a method of placing an annular barrier in an annulus and a method of using annular barriers in an annulus to seal off an inflow control section.

Background art

[0002] In wellbores, annular barriers are used for different purposes, such as for providing an isolation barrier. An annular barrier has a tubular part mounted as part of the well tubular structure, such as the production casing, which is surrounded by an annular expandable sleeve. The expandable sleeve is typically made of an elastomeric material, but may also be made of metal. The sleeve is fastened at its ends to the tubular part of the annular barrier.

[0003] In order to seal off a zone between a well tubular structure and the borehole or an inner and an outer tubular structure, a second annular barrier is used. The first annular barrier is expanded on one side of the zone to be sealed off, and the second annular barrier is expanded on the other side of that zone, and in this way, the zone is sealed off.

[0004] The pressure envelope of a well is governed by the burst rating of the tubular and the well hardware etc. used within the well construction. In some circumstances, the expandable sleeve of an annular barrier may be expanded by increasing the pressure within the well, which is the most cost-efficient way of expanding the sleeve. The burst rating of a well defines the maximum pressure that can be applied to the well for expanding the sleeve, and it is desirable to minimise the expansion pressure required for expanding the sleeve in order to minimise the exposure of the well to the expansion pressure.

[0005] When expanded, annular barriers may be subjected to a continuous pressure or a periodic high pressure from the outside, either in the form of hydraulic pressure within the well environment or in the form of formation pressure. In some circumstances, such pressure may cause the annular barrier to collapse, which may have severe consequences for the area which is to be sealed off by the barrier as the sealing properties are lost due to the collapse. A similar problem may arise when the expandable sleeve is expanded by expansion means, e.g. a pressurised fluid. If the fluid leaks from the sleeve, the back pressure may fade, and the sleeve itself may thus collapse.

[0006] The ability of the expanded sleeve of an annular barrier to withstand the collapse pressure is thus affected by many variables, such as strength of material, wall thickness, surface area exposed to the collapse pressure, temperature, well fluids, etc.

[0007] A collapse rating currently achievable for the expanded sleeve within certain well environments is insufficient for all well applications. Thus, it is desirable to increase the collapse rating to enable annular barriers to be used in all wells, specifically in wells with a high drawdown pressure during production and depletion. The collapse rating may be increased by increasing the wall thickness or the strength of the material; however, this would increase the expansion pressure, which, as already mentioned, is not desirable.

[0008] It is thus desirable to provide a solution wherein the annular barrier is improved so that it does not collapse, without having to increase the thickness of the expandable sleeve.

Summary of the invention

[0009] It is an object of the present invention to wholly or partly overcome the above disadvantages and drawbacks of the prior art. More specifically, it is an object to provide an improved annular barrier solution which does not collapse without having to increase the thickness of the expandable sleeve.

[0010] The above objects, together with numerous other objects, advantages, and features, which will become evident from the below description, are accomplished by a solution in accordance with the present invention by an annular barrier arranged in a borehole for providing a zone isolation between a first zone and a second zone of the borehole, comprising:

- a tubular part for mounting as part of a well tubular structure and having an expansion opening,
- an expandable sleeve surrounding the tubular part, each end of the expandable sleeve being connected with the tubular part,
- an annual barrier space between the tubular part and the expandable sleeve,

wherein a first diaphragm arranged in the annual barrier space divides the annual barrier space into a barrier compartment and an expansion compartment, and wherein the expansion compartment is in fluid communication with an inside of the tubular part through the expansion opening, and the barrier compartment is in fluid communication with the borehole through a first barrier opening.

[0011] By having a diaphragm, the annular barrier is capable of withstanding an outside pressure that is higher than the pressure in the well tubular structure without changing the pressure inside the well tubular structure since the diaphragm seals off the inside of the well tubular structure from the outside of the well tubular structure.

[0012] In one embodiment, the annular barrier may further comprise a second diaphragm, wherein the first and second diaphragms may divide the annual barrier space into the first barrier compartment, a second barrier compartment and an expansion compartment, and wherein the expansion compartment may be in fluid communication with an inside of the tubular part through the expansion opening, and the first barrier compartment may be in fluid communication with the first zone of the borehole through the first barrier opening, and the second barrier compartment may be in fluid communication with the second zone of the borehole through a second barrier opening.

[0013] Furthermore, the diaphragm may be made from a deformable material.

[0014] Moreover, the diaphragm may be made from an elastically/plastically deformable material.

[0015] Also, the diaphragm may be made from an expandable material.

[0016] Also, the diaphragm may be cylindrical or corrugated.

[0017] Finally, the diaphragm may be made from metal, alloy, plastic, elastomers or natural or synthetic rubber, or any combination thereof.

[0018] The annular barrier may further comprise a connection part connecting the expandable sleeve to the tubular part.

[0019] Additionally, the annular barrier may comprise a spacer which may be a part of the connection part, a part of the expandable sleeve or a separate part.

[0020] Furthermore, the second barrier opening may be arranged in the spacer.

[0021] In addition, at least one of the expansion pressure opening, the first pressure opening and/or the second pressure opening may comprise a valve.

[0022] Said at least one valve may be a one-way valve.

[0023] In another embodiment, the annular barrier may further comprise a restriction element arranged on an outside of the expandable sleeve restricting the sleeve from expanding freely. Alternatively, the restriction element may be arranged on the inside of the sleeve.

[0024] In yet another embodiment, the annular barrier may further comprise sealing elements arranged on an outside of the expandable sleeve for sealing against an inside of the borehole.

[0025] Moreover, the diaphragm in an unexpanded state may substantially be shaped as a hollow cylinder.

[0026] The annular barrier according to the present invention may further comprise an anti-collapsing element connected with the expandable sleeve at predetermined positions along the sleeve.

[0027] The expandable sleeve may be capable of expanding to an at least 10% larger diameter, preferably an at least 15% larger diameter, more preferably an at least 30% larger diameter than that of an unexpanded sleeve, and it may have a wall thickness which is thinner than a length of the expandable sleeve, the thickness preferably being less than 25% of its length, more preferably less than 15% of its length, and even more preferably less than 10% of its length.

[0028] In one embodiment, the expandable sleeve may have a varying thickness along the periphery and/or length.

[0029] In addition, at least one of the connection parts may be slidable in relation to the tubular part of the annular barrier, and at least one sealing member, such as an O-ring or chevron seal, may be arranged between the slidable connection part and the tubular part.

[0030] In one embodiment, more than one sealing member may be arranged between the slidable fastening means and the tubular part.

[0031] At least one of the connection parts may be fixedly fastened to the tubular part or be part of the tubular part.

[0032] In one embodiment, the sleeve may comprise a plurality of sections arranged along the non-inclining part of the sleeve and having a mutual distance between them.

[0033] The expandable sleeve may have an outer face onto which at least one sealing element is arranged opposite a section of the sleeve having an increased thickness.

[0034] The sealing elements may have a tapering or triangular cross-sectional shape.

[0035] The sealing elements may have a sealing surface facing the inner side of the borehole. The sealing surface may be serrated or another kind of deformable surface.

[0036] The sealing elements may be made of polymers, elastomers, natural or synthetic rubber or silicone.

[0037] The present invention may further relate to an annular barrier system comprising:

- a well tubular structure, and
- at least an annular barrier according to any of the preceding claims arranged as part of the well tubular structure.

[0038] The system may further comprise an inflow control section.

[0039] Further, the system may comprise a second annular barrier, wherein the inflow control section is arranged between the two annular barriers.

[0040] The present invention may further relate to a method of placing an annular barrier according to the invention in an annulus comprising the steps of:

- connecting the annular barrier with a well tubular structure,
- placing the unexpanded annual barrier in a desired position downhole, and
- expanding the sleeve by pressurised fluid from within the tubular part.

[0041] The method of placing an annular barrier may further comprise the step of pressurising the well tubular structure in order to provide the pressurised fluid for expanding the sleeve.

[0042] The method of placing an annular barrier may comprise the step of placing a pressure tool in the vicinity of the annual barrier for expanding the sleeve by providing a pressurised fluid locally in the well tubular structure.

[0043] Moreover, said method may comprise the step of opening the inflow control section.

[0044] The present invention may further relate to a method of using annular barriers according to the invention in an annulus to seal off an inflow control section, comprising the steps of:

- connecting two annular barriers with a well tubular structure and in between them an inflow control section,
- placing the two annual barriers and the inflow control section in a desired position downhole,
- pressurising the tubular part and expanding the annual barriers by pressurised expansion fluid from within the tubular part for providing a zone isolation between a first zone and a second zone of the borehole, the first zone having a first fluid pressure and the second zone having a second fluid pressure,
- stopping the pressurising of the tubular part,
- activating the inflow control section for starting a production of fluid into the well tubular structure, and
- equalising the pressure between the first and/or second fluid pressure and the pressure within the space by letting fluid into the space.

Brief description of the drawings

[0045] The invention and its many advantages will be described in more detail below with reference to the accompanying schematic drawings, which for the purpose of illustration show some non-limiting embodiments and in which

Fig. 1 shows a cross-sectional view along a longitudinal extension of an annular barrier in its unexpanded condition,

Fig. 2 shows the annular barrier of Fig. 1 in its expanded condition,

Fig. 3 shows the annular barrier of Fig. 2 in a situation where a first zone pressure has exceeded a pressure inside the well tubular structure,

Fig. 4 shows the annular barrier of Fig. 1 in an intermediate situation,

Fig. 5 shows an annular barrier having two diaphragms in its unexpanded condition,

Fig. 6 shows the annular barrier of Fig. 5 in its expanded condition,

Fig. 7 shows the annular barrier of Fig. 5 in a situation where a first zone pressure has exceeded a pressure inside the well tubular structure,

Fig. 8 shows the annular barrier of Fig. 5 in a situation where a second zone pressure has exceeded a pressure inside of the well tubular structure,

Fig. 9 shows the annular barrier of Fig. 5 in an intermediate situation,

Fig. 10A shows another embodiment of the annular barrier having two diaphragms in its expanded condition,

Fig. 10B shows yet another embodiment of the annular barrier having two diaphragms in its expanded condition,

Fig. 11 shows yet another embodiment of the annular barrier having two diaphragms in its expanded condition,

Fig. 12 shows the annular barrier having projections restricting free expansion of the expandable sleeve,

Fig. 13 shows another embodiment of an annular barrier,

Fig. 14 shows yet another embodiment of an annular barrier,

Fig. 15 shows an annular barrier in which the expandable sleeve has circumferential reinforcement rings,

Fig. 16 shows an annular barrier in which the expandable sleeve has circumferential sealing elements and reinforcement rings, and

Fig. 17 shows an annular barrier system.

[0046] All the figures are highly schematic and not necessarily to scale, and they show only those parts which are necessary in order to elucidate the invention, other parts being omitted or merely suggested.

Detailed description of the invention

[0047] Annular barriers 1 according to the present invention are typically mounted into a well tubular structure, such as a production casing, before lowering the well tubular structure 300 into the borehole downhole. The well tubular structure 300 is constructed by well tubular structure parts assembled as a long well tubular structure string. The annular barriers 1 are mounted between the well tubular structure parts when mounting the well tubular structure string.

[0048] The annular barrier 1 is used for a variety of purposes, all of which require that an expandable sleeve 3 of the annular barrier 1 is expanded so that the sleeve abuts the inside wall 101 of the borehole. The annular barrier 1 comprises a tubular part 2 surrounded by the expandable sleeve 3. The unexpanded sleeve has a cylindrical shape and at its ends it is connected with the tubular part. The expandable sleeve 3 is expanded by letting pressurised fluid in through an expansion opening 9 of the tubular part into an annual barrier space 6 between the expandable sleeve 3 and the tubular part 2.

[0049] The tubular part 2 is connected with the well tubular structure parts, e.g. by means of a thread connection, and forms part of the well tubular structure 300. Thus, the tubular part 2 and the well tubular structure parts together form the inside wall 301 of the well tubular structure 300, enclosing an inside space 302 of the well tubular structure. The expandable sleeve 3 may be expanded by pressurising the inside space 302 fully or partly opposite the expansion opening 9 of the tubular part 2.

[0050] The annular barrier 1 furthermore has a first diaphragm 4 arranged in the annual barrier space 6, 7, which divides the annual barrier space into a barrier compartment 7 and an expansion compartment 6. The expansion compartment 6 is in fluid communication with an inside 302 of the tubular part 2 through an expansion opening 9, and the barrier compartment 7 is in fluid communication with the borehole 100 through a first barrier opening 10. The annular barrier 1 of Fig. 1 is shown as a cross-section along a longitudinal extension of the expandable sleeve 3 and in its unexpanded and relaxed position, the line 22 is the centreline 22 of the annular barrier 1. The centreline indicates a rotation symmetry around this line, such as the tubular part 2 in Fig. 1 is a cylinder in three dimensions. In order to expand the expandable sleeve 3, pressurised fluid is injected into an expansion opening 9 expanding a cavity referred to as the expansion compartment 6 between the expandable sleeve 3 and the first diaphragm 4 of the annular barrier 1, so that the first diaphragm 4 and the expandable sleeve 3 are expanded. Thus, the first diaphragm 4 follows the shape of the expandable sleeve 3 during expansion of the sleeve as shown in Fig. 2.

[0051] The pressurised fluid used to expand the annual barrier may either be pressurised from the top of the borehole 100 and fed through the well tubular structure 300, or be pressurised in a locally sealed off zone in the well tubular structure. The pressurised fluid having an expansion pressure $P_{expansion}$ is injected (illustrated by an arrow) into the expansion compartment until the expandable sleeve 3 abuts the inside wall 101 of the borehole, which is shown in Fig. 2. The expandable sleeve 3 and the first diaphragm 4 are connected with the tubular part 2 using a connection part 12 at each end of the expandable sleeve 31, 32. When the annual barrier 1 has been expanded using a pressurised fluid and abuts the inside of the borehole wall 101, the annular barrier provides a seal between a first zone 102 and a second zone 103 of the borehole. Thus, the first zone 102 is on one side of the annular barrier 1 and the second zone 103 is on the other side of the annular barrier 1.

[0052] When the pressure $P_{expansion}$ of the pressurised fluid is released in order to start production, the annual barrier 1 must be capable of withstanding a certain pressure P100 from the borehole 100 in order to prevent a collapse which would lead the barrier to become leaky. As an example, the annual barrier 1 is used to seal off a production zone 400 (shown in Fig. 17), and a pressure P400 in the production zone might build up inside the production zone 400 when a fluid, such as oil, starts to enter the production zone 400 from the surrounding formation 200. When the pressure P400 builds up in the production zone, the pressure against the annual barrier increases, and the seal made by the annual barrier may become leaky. This is due to the fact that the pressure inside the annular barrier is no longer the expansion pressure $P_{expansion}$, and that the pressure inside the well tubular structure P302 under normal operating conditions is typically much lower than the expansion pressure $P_{expansion}$ and the pressure from the borehole P100 might then exceed the pressure P302 inside the well tubular structure. However, the annular barrier 1 comprises a barrier compartment 7 which is in fluid communication with the borehole 100 through a first barrier opening 10, and since the barrier space 7 is in fluid communication with the first zone 102 of the borehole, the pressure P7 in the barrier compartment will build up as fluid flows from the first zone 102 and into the barrier compartment 7 (illustrated by an arrow) equalising the pressure in the barrier compartment 7 with the pressure in the first zone P102.

[0053] The first diaphragm 4 ensures that the first zone pressure P102 is sealed from the inside 302 of the well tubular structure 300. When the annual barrier is exposed to a pressure increase from the first zone 102 of the borehole 100, the pressure increases equivalently inside the barrier compartment 7, and therefore the expandable sleeve 3 will not be exposed to an increased difference in pressure between P102 and P7, causing the annual barrier to break its seal between the first zone 102 and second zone 103 of the borehole.

[0054] In order for a diaphragm to withstand the pressure exerted on the diaphragm, it has to be made from a deformable material in order that it can be deformed and abut either the expandable sleeve or the tubular part in the annual barrier 1. Thus, the diaphragm is made of a material being more flexible and/or deformable than the material of the expandable sleeve 3 and/or the tubular part 2. A diaphragm is typically much thinner than the expandable sleeve 3 and the tubular part 2 and therefore incapable of withstanding the pressures without being supported by an abutting element, such as the tubular part 2 or the expandable sleeve 3. In annual barriers using more than one diaphragm, the diaphragms may abut each other, the outermost diaphragm being supported by an abutting element, such as the tubular part 2 or the expandable sleeve 3. The deformation of a diaphragm material may be elastic, plastic or a combination thereof. The deformation of both diaphragms and sleeves may also be referred to as expansion or expandable, since compared to the relaxed position, the material of the sleeve and diaphragms will be expanded during use.

[0055] Fig. 3 shows a situation in which the first zone pressure P102 has exceeded the pressure P302 of the inside of the well tubular structure 300. Then fluid is entering the barrier compartment 7 from the first zone 102 through the first barrier opening 10, leading to pressure equalisation between the first zone pressure P102 and the barrier compartment pressure P7 and furthermore forcing the first diaphragm towards the tubular part 2. Fig. 4 shows the first diaphragm 4 in an intermediate position, which illustrates a typical situation during pressure equalisation when fluid is flowing from the first zone 102 of the borehole and into the barrier compartment 7, before the first diaphragm 4 abuts the tubular part 2.

[0056] The diaphragms and the sleeve may be connected with the tubular part 2 by means of a connection part 12. The connection part may be connected with the sleeve and the diaphragms by means of welding or thread connections.

[0057] As shown in Fig. 6, the expandable sleeve 3 is at its ends connected with a connection part 12. During expansion, the expandable sleeve 3 shortens in length, which is why one of the two connection parts is slidably connected with the tubular part and provided with sealing members 20 which may be arranged in grooves. The other of the two connection parts is fixedly connected with the tubular part.

[0058] When the expandable sleeve 3 of the annular barrier 1 is expanded, the diameter of the sleeve is expanded from its initial unexpanded diameter to a larger diameter. The expandable sleeve 3 has an outside diameter D and is capable of expanding to an at least 10% larger diameter, preferably an at least 15% larger diameter, more preferably an at least 30% larger diameter than that of an unexpanded sleeve.

[0059] Furthermore, the expandable sleeve 3 has a wall thickness t which is thinner than a length L of the expandable sleeve, the thickness preferably being less than 25% of the length, more preferably less than 15% of the length, and even more preferably less than 10% of the length.

[0060] The expandable sleeve 3 of the annular barrier 1 may be made of metal, polymers, an elastomeric material, silicone, or natural or synthetic rubber.

[0061] In order to increase the thickness of a section 14 of the sleeve 3, additional material is applied onto an outer face 33 of the expandable sleeve, e.g. by adding welded material onto the outer face. This section 14 is also referred to, in some embodiments, as a reinforcement ring 14.

[0062] In another embodiment, the thickness of the section 14 of the sleeve 3 is increased by fastening a ring-shaped part onto the sleeve. The ring-shaped part is the section 14 and is fastened onto the inner surface by means of welding or similar suitable fastening process.

[0063] In yet another embodiment, the thickness of the section 14 of the sleeve 3 is facilitated using a varying thickness sleeve 3. To obtain a sleeve of varying thickness 3, 14, techniques such as rolling, extrusion or diecasting may be used.

[0064] The annular barrier of Fig. 5 has a first diaphragm 4 and a second diaphragm 5, wherein the first 4 and second 5 diaphragms divide the annual barrier space 30 into the first barrier compartment 7, a second barrier compartment 8 and the expansion compartment 6. In situations in which the annual barrier may suddenly experience an unexpected high pressure in both the first zone 102 and the second zone 103 of the borehole, one more diaphragm may be arranged inside the annular barrier 1. In situations in which the annual barrier may suddenly experience an unexpected high pressure, a production zone 400 on one side of the annular barrier is a first zone 102 of the borehole with a first zone pressure P102, and on the other side of the annular barrier is the second zone 103 of the borehole not forming part of the production zone 400. As an example of such a situation in which the second zone pressure P103 suddenly increases substantially, may be due to a gas leak further down the borehole 100, the annual barrier 1 may suddenly experience an unexpected high pressure from the second zone pressure P103 even though the barrier was set up to seal a high production zone pressure P400. To avoid a potential breakdown of the seal due to an increased second zone pressure P103, the second diaphragm 5 is provided in the annular barrier 1. The expansion compartment 6 is in fluid communication with an inside 302 of the well tubular structure 300 through an expansion opening 9, and the first barrier compartment 7 is in fluid communication with the first zone 102 of the borehole through a first barrier opening 10, and the second barrier compartment 8 is in fluid communication with the second zone 103 of the borehole through a second barrier opening 11. When the second zone pressure P103 builds up as shown in Fig. 7, fluid will flow (illustrated by an arrow) into the second barrier compartment 8, forcing the first diaphragm to abut the expandable sleeve 3 and the second diaphragm 5 to abut the tubular part 2, thereby obtaining the second zone pressure P103 inside the annular barrier 1. When the pressures on both sides of the expandable sleeve 3 are substantially equal, the annular barrier 1 will be capable of withstanding high pressures and still abut the inside of the borehole wall to make a tight seal, since the annual barrier 1 can maintain the same pressure inside the annual barrier as the highest pressure experienced by the annual barrier from the outside of the annular barrier 1.

[0065] The annual barrier comprising both a first diaphragm 4 and a second diaphragm 5 is shown in four different situations in Figs. 5 to 9. Fig. 5 shows the unexpanded state of the annual barrier 1. Fig. 6 shows an expanded state of the annular barrier 1, where a pressurised fluid (illustrated by an arrow) is injected through the expansion opening 9 in order to force the expandable sleeve to abut the inside of the borehole 101. In this situation, the two diaphragms follow the shape of the expandable sleeve 3 during expansion of the sleeve. As already explained, Fig. 7 shows the situation in which the second zone pressure P103 is the highest pressure, thereby forcing the second diaphragm 5 to abut the expandable sleeve 3 and the first diaphragm 4 to abut the tubular part 2. Fig. 8 shows the situation in which the first zone pressure P102 is the highest, thereby forcing a fluid to enter the first barrier compartment 7 from the first zone 102 of the borehole 100 (illustrated by the arrow). When fluid enters the first barrier compartment 7, the first diaphragm 4 is forced towards the tubular part in that the first diaphragm 4 is forced to abut the second diaphragm 5 which is forced to abut the tubular part 2. Fig. 9 shows the first and second diaphragms 4, 5 in intermediate positions not abutting each other, nor abutting the expandable sleeve 3 or the tubular part 2.

[0066] By having two diaphragms, the annular barrier can withstand a higher outside pressure from either the first zone 102 or the second zone 103.

[0067] By using diaphragms instead of valves, the lifetime of an annular barrier may be increased significantly. Typical lifetimes of valves in downhole environments are around 5 years, and valve systems will then have to be replaced. Annular barriers are exposed to very few pressure changes, typically not many more than 20 pressure changes during the lifetime of an annular barrier. Therefore, annular barrier diaphragms can maintain their functionality for many years due to the absence of moving parts. The lifetime of the annular barrier using diaphragms will therefore only be limited by fatigue in the diaphragm materials, which, given the very few pressure changes, is a minor problem. Furthermore, it should be noted that a typical annual barrier has a length of 5 to 15 metres and preferably 10 metres to match standard well tubular parts and equipment for inserting well tubular parts into boreholes. The difference between the diameter of an expanded and an unexpanded annular barrier may typically be less than 10 centimetres, and even less than 5 centimetres, which over a length of 5 to 15 metres applies very little stress to the diaphragm. With this in mind, it is evident that an annular barrier using diaphragms is a very robust structure.

[0068] When the outside pressure drops again, the pressure inside the annular barrier 1 is equalised again by letting fluid out of the annular barrier into to the first zone 102 or the second zone 103.

[0069] In Fig. 5-9, the diaphragms are shaped as hollow cylinders fastened at their ends to the connection parts and surrounding the tubular part which is surrounded by the expandable sleeve.

[0070] Figs. 10A and 10B show the annular barrier 1 having two diaphragms; each diaphragm is shaped as a hollow cylinder fastened at its one end to a connection part and at its other end to the tubular part 2. The tubular part 2 has an expansion opening 9 arranged in a middle part, and the ends of the diaphragms are connected with the tubular part 2 on opposite sides of the expansion opening 9 when seen in the cross-sectional view of Fig. 10. At its ends nearest the expansion opening, the diaphragms are welded to the tubular part, and at its other ends the diaphragms are connected with the connection parts by means of a thread connection. The diaphragms may also be welded to the connection pa rts.

[0071] In the annular barrier of Fig. 10A, both the first barrier opening 10 and the second barrier opening 11 are provided penetrating the connection part, the expansion sleeve 3 and the diaphragm providing fluid communication between the first zone 102 and the first barrier compartment and the second zone 103 and the second barrier compartment, respectively.

[0072] In Fig. 10B, the first barrier opening 10 and the second barrier opening 11 are provided penetrating only the connection part. In this way, the expandable sleeve 3 and the diaphragms are not penetrated, resulting in a more simple design.

[0073] The diaphragms in Figs. 10A and 10B may also manufactured from one cylinder fastened at its ends to the connection parts and at a middle part welded to the tubular part and subsequently, the expansion openings are provided therein and through the tubular part.

[0074] By having two diaphragms connected on opposite sides of the expansion opening 9, the connection parts do not necessarily have a sealing member 20 and to provide a seal towards the tubular part since the diaphragms provide the seal so that fluid from the first or second zone 102, 103 does not enter into the well tubular structure.

[0075] The annular barrier of Fig. 11 also has two diaphragms; a first diaphragm connected at its ends to the connection part and a second diaphragm which in its one end is connected with one connection part and in its other end is connected with the tubular part 2 near the expansion opening 9. The expansion opening 9 is provided in the tubular part 2 near the connection part in which only the first diaphragm is fastened. Thus, the expansion opening 9 is not arranged in the middle part of the tubular as in Fig. 10A and 10B.

[0076] Even though Figs. 10A and 10B show a first barrier opening 10 and a second barrier opening 11, the barrier openings may be replaced by a non-sealing connection between the connection part and the tubular part. In Fig. 11, the first barrier connection may be replaced in the same way by a leaky connection between the connection part and the tubular part.

[0077] In the same way as in Fig. 10A and 10B, the first diaphragm shown in Fig. 11 allows that a completely tight sealing connection is not needed between the connection part 12 and the tubular part 2 at the end of the annular barrier 1, where the first diaphragm 4 is connected to the connection part. Thus, the first diaphragm arranged in this way results in this connection part possibly being the sliding end of the annular barrier, thereby complying with the need for a movable end due to the shortening of the sleeve during expansion while still providing a seal between the outside pressure and the inside of the well tubular structure, and then the other end can be fixedly connected to the tubular part 2.

[0078] Furthermore, the first diaphragm of Fig. 11 has the ability to expand substantially the entire volume of the annual barrier 1, equivalently to if it was connected with both connection parts due to the fact that its connection with the tubular part 2 can be arranged so close to the connection part in which only the second diaphragm is connected that the first diaphragm can be expanded in substantially the entire volume of the annual barrier 1.

[0079] As shown in Fig. 12, the annular barrier has a restriction element 13 in the form of a projecting part 13 as a prolongation of each of the connection parts and overlapping the expandable sleeve 3. The connection part 12 is welded together with the expandable sleeve 3 in a connection. The projecting part 13 of the connection part 12 increasingly tapers towards the expandable sleeve 3 until the projecting part 13 does not overlap the expandable sleeve 3 anymore and the expandable sleeve 3 is free to expand.

[0080] In Fig. 12, a spacer 16 is separating the expandable sleeve 3 from the first diaphragm 4 to allow fluid to pass between them. Spacers 16 can be used to impose a gap between the expandable sleeve 3, the first 4 and second diaphragm 5 and the tubular part 2. The spacer may be flat or a step structure. The spacer may be a separate part or an integral part of the expandable sleeve, the diaphragms, the tubular part, the connection part or the welding 21.

[0081] The projecting part 13 has the purpose of restricting the expansion of the expandable sleeve 3 so that the curvature of the expandable sleeve 3 when expanded is more S-shaped when seen in the cross-sectional view along the longitudinal extension of the sleeve. It is hereby obtained that the expandable sleeve 3 does not fracture during expansion and that the cross-sectional profile of the expandable sleeve 3 is capable of withstanding a higher collapse pressure than a known annular barrier. Thus, the expandable sleeve 3 is more restricted in expanding at the first point than at the second point. Furthermore, due to the fact that the projecting part 13 may be made from a less flexible metal alloy and tapers from the connection towards the second point, the expandable sleeve 3 is less restricted in expanding along with the decreasing thickness of the projecting part.

[0082] The first barrier opening 10 may also be arranged directly in the expandable sleeve 3 as shown in Fig. 13, resulting in a very simple design which is easy to manufacture and implement in existing manufacturing procedures.

[0083] Also shown in Fig. 13 is a welding of the first diaphragm 4 and the expandable sleeve 3. The diaphragms, the sleeve, the connection element 12, the tubular part 2 may be welded as best suited in a specific annual barrier. As examples, the diaphragms and sleeves may be welded if the connection part is slidably connected to the tubular part, or they may be welded to the tubular part if the connection part is fixedly connected to the tubular part, etc.

[0084] The expandable sleeve and the diaphragm/-s may also be fastened directly to the tubular part without use of connection parts as shown in Fig. 14. Even though not shown, the expandable sleeve of the annular barrier may have one end fastened by means of a connection part and the other end welded directly to the tubular part together with a diaphragm. As an alternative, both ends can be fixed by welding or both ends can be sliding along the tubular part 2.

[0085] In order to increase the collapse pressure, an anti-collapsing element 14 is arranged on the outside of the sleeve which is a section 14 of the expandable sleeve may have an increased thickness when seen in a cross-sectional view along the longitudinal extension of the sleeve as shown in Fig. 15. When expanding the sleeve, this section of the sleeve is expanded less than other sections of the sleeve along a non-inclining part of the expandable sleeve in its expanded state, resulting in a corrugated shape of the sleeve as seen in Fig. 16.

[0086] Also in Fig. 15 is shown the possibility of using a valve 19 instead of the barrier opening 10. The expansion opening 9, the first barrier opening 10 and/or the second barrier opening 11 may in some embodiments be replaced by a valve to control the flow from the borehole into the barrier compartments or to control the flow from the inside of the well tubular structure 300 and into the expansion compartment 6. Also the flow direction may be restricted using one-way valves.

[0087] In order to increase the thickness of a section of the sleeve, additional material may be applied onto an inner or outer face of the sleeve, e.g. by adding welded material onto the inner face.

[0088] In another embodiment, the thickness of the section of the sleeve is increased by fastening a ring-shaped part onto the sleeve. The ring-shaped part is the section 14 and is fastened onto the inner surface by means of welding or similar suitable fastening process.

[0089] As shown in Fig. 16, on the outer face of the expandable sleeve 3, sealing elements 15 are arranged opposite the sections of the sleeve having an increased thickness. When the sleeve is expanded, the sealing elements 15 fill up the gap occurring during expansion. In order to fit the gap better, the sealing elements 15 have a tapering or triangular cross-sectional shape.

[0090] When the annular barrier is installed, it forms part of a well tubular structure as shown in Fig. 17, providing an annular barrier system 500. In Fig. 17, the system comprises two annular barriers sealing a production zone 400. The barriers are arranged in a horizontal part of the well and seen in its expanded condition.

[0091] An inner ring may also be arranged between the expandable sleeve 3 and the tubular part 2 and may be welded to the connection part 12.

[0092] In the event that the tool cannot move forward in the well tubular structure 3, the tool may comprise a downhole tractor, such as a Well Tractor®.

[0093] An expansion tool may be used to expand the annular barrier and may comprise an isolation device for isolating a first section outside the passage or valve between an outside wall of the tool and the inside wall of the well tubular structure. The pressurised fluid is obtained by increasing the pressure of the fluid in the isolation device. When a section of the well tubular structure outside the passage of the tubular part is isolated, it is not necessary to pressurise the fluid in the entire well tubular structure, just as no additional plug is needed as is the case in prior art solutions. When the fluid has been injected into the space, the passage or valve is closed.

[0094] The tool may also use coiled tubing for expanding the expandable sleeve 3 of an annular barrier 1 or of two annular barriers at the same time. A tool with coiled tubing can pressurise the fluid in the well tubular structure without having to isolate a section of the well tubular structure. However, the tool may need to plug the well tubular structure further down the borehole from the two annular barriers or barriers 1 to be operated. The annular barrier system of the present invention may also employ a drill pipe or a wireline tool to expand the sleeve.

[0095] In one embodiment, the tool comprises a reservoir containing the pressurised fluid, e.g. when the fluid used for expanding the sleeve 3 is cement, gas or a two-component compound.

[0096] An annular barrier 1 may also be called a packer or similar expandable means. The well tubular structure can be the production tubing or casing or a similar kind of tubing downhole in a well or a borehole. The annular barrier 1 can be used both between the inner production tubing and an outer tubing in the borehole or between a tubing and the inner wall of the borehole. A well may have several kinds of tubing, and the annular barrier 1 of the present invention can be mounted for use in all of them.

[0097] The valve may be any kind of valve capable of controlling flow, such as a ball valve, butterfly valve, choke valve, check valve or non-return valve, diaphragm valve, expansion valve, gate valve, globe valve, knife valve, needle valve, piston valve, pinch valve or plug valve.

[0098] The expandable tubular metal sleeve 3 may be a cold-drawn or hot-drawn tubular structure. The sleeve may be seamless or welded.

[0099] The expandable tubular metal sleeve 3 may be extruded, die-cast or rolled, e.g. hot rolled, cold rolled, roll bended etc., and subsequently welded.

[0100] The fluid used for expanding the expandable sleeve 3 may be any kind of well fluid present in the borehole surrounding the tool and/or the well tubular structure. Also, the fluid may be cement, gas, water, polymers, or a two-component compound, such as powder or particles mixing or reacting with a binding or hardening agent. Part of the fluid, such as the hardening agent, may be present in the space before injecting a subsequent fluid into the space.

[0101] Although the invention has been described in the above in connection with preferred embodiments of the invention, it will be evident for a person skilled in the art that several modifications are conceivable without departing from the invention as defined by the following claims.

Claims

1. An annular barrier (1) arranged in a borehole (100) for providing zone isolation between a first zone (102) and a second zone (103) of the borehole, comprising:

- a tubular part (2) for mounting as part of a well tubular structure (300) and having an expansion opening (9),
- an expandable sleeve (3) surrounding the tubular part, each end (31, 32) of the expandable sleeve being connected with the tubular part,
- an annual barrier space (30) between the tubular part (2) and the expandable sleeve (3),

wherein a first diaphragm (4) arranged in the annual barrier space divides the annual barrier space into a barrier compartment (7) and an expansion compartment (6), and wherein the expansion compartment (6) is in fluid communication with an inside (302) of the tubular part (2) through the expansion opening (9), and the barrier compartment (7) is in fluid communication with the borehole (100) through a first barrier opening (10).

2. An annular barrier (1) according to claim 1, further comprising a second diaphragm (5), wherein the first (4) and second (5) diaphragms divide the annual barrier space into the first (7) barrier compartment, a second (8) barrier compartment and an expansion compartment (6), and wherein the expansion compartment (6) is in fluid communication with an inside (302) of the tubular part (2) through the expansion opening (6), and the first barrier compartment (7) is in fluid communication with the first zone (102) of the borehole through the first barrier opening (10), and the second barrier compartment (8) is in fluid communication with the second zone (103) of the borehole through a second barrier opening (11).

3. Annular barrier (1) according to claim 1 or 2, wherein the diaphragm is made from an elastically/plastically deformable material.

4. Annular barrier (1) according to claim 1 or 2, wherein the diaphragm is made from metal, alloy, plastic, elastomer or natural or synthetic rubber, or any combination thereof.

5. Annular barrier (1) according to any of the preceding claims, further comprising a connection part (12) connecting the expandable sleeve (3) to the tubular part (2).

6. Annular barrier (1) according to any of the preceding claims, further comprising a spacer (16) as a part of the connection part (12), a part of the expandable sleeve (3) and/or a separate part.

7. Annular barrier (1) according to any of the preceding claims, further comprising a spacer (16) in which the second barrier opening is arranged.

8. Annular barrier (1) according to any of the preceding claims, wherein at least one of the expansion pressure opening, the first barrier opening and/or the second barrier opening comprise a valve (19).

9. Annular barrier (1) according to claim 8, wherein the valve (19) is a one-way valve.

10. Annular barrier (1) according to any of the preceding claims, further comprising a restriction element (13) arranged on an outside of the expandable sleeve restricting the sleeve from expanding freely.

11. Annular barrier (1) according to any of the preceding claims, further comprising sealing elements (15) arranged on an outside of the expandable sleeve for sealing against the inside of the borehole.

12. Annular barrier (1) according to any of the preceding claims, wherein the diaphragm in an unexpanded state is substantially shaped as a hollow cylinder.

13. Annular barrier (1) according to any of the preceding claims, further comprising an anti-collapsing element (14) connected with the expandable sleeve (3) at predetermined positions along the sleeve.

14. Annular barrier system (500) comprising:

- a well tubular structure (300), and
- at least an annular barrier (1) according to any of the preceding claims arranged as part of the well tubular structure.

15. A method of placing an annular barrier (1) according to claim 1 in an annulus comprising the steps of:

- connecting the annular barrier with a well tubular structure (300),
- placing the unexpanded annual barrier in a desired position downhole, and
- expanding the sleeve by pressurised fluid from within the tubular part.

16. A method of using annular barriers according to claim 1 in an annulus to seal off an inflow control section, comprising the steps of:

- connecting two annular barriers with a well tubular structure (300) and in between them an inflow control section (600),
- placing the two annual barriers and the inflow control section in a desired position downhole,
- pressurising the tubular part (2) and expanding the annual barriers by pressurised expansion fluid from within the tubular part for providing a zone isolation between a first zone (102) and a second zone (103) of the borehole, the first zone having a first fluid pressure and the second zone having a second fluid pressure,
- stopping the pressurising of the tubular part
- activating the inflow control section for starting a production of fluid into the well tubular structure, and
- equalising the pressure between the first and/or second fluid pressure and the pressure within the space by letting fluid into the space.

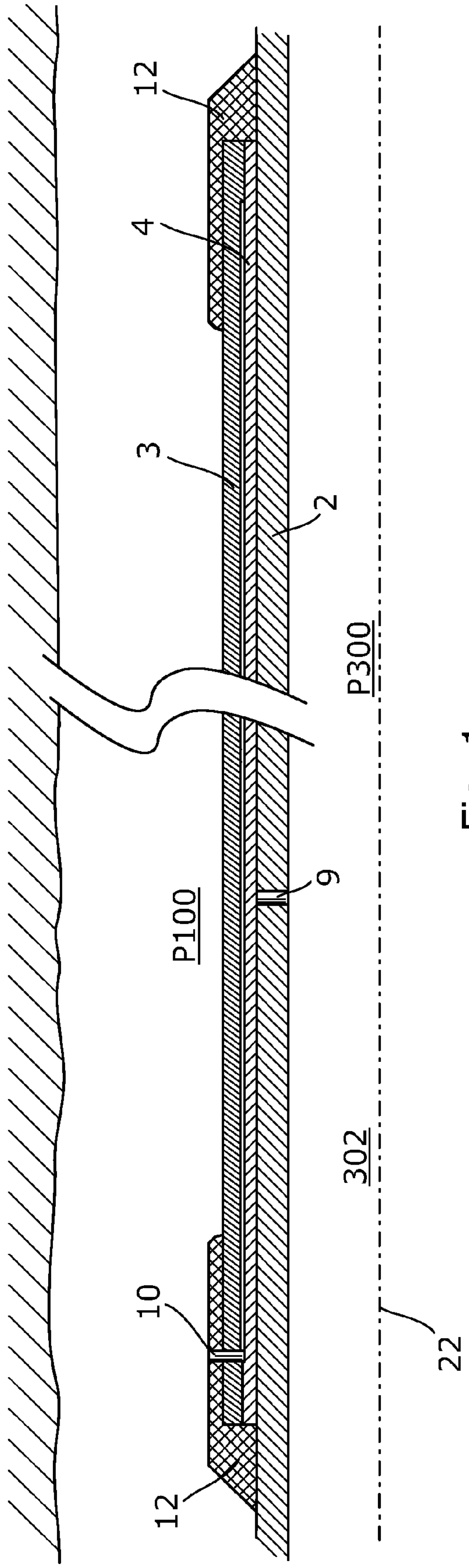

Fig. 1

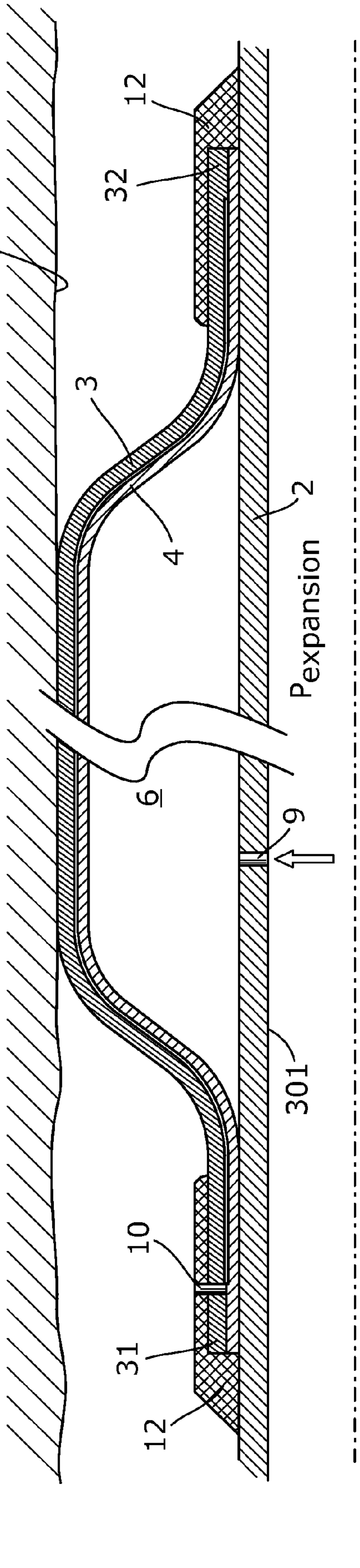

Fig. 2

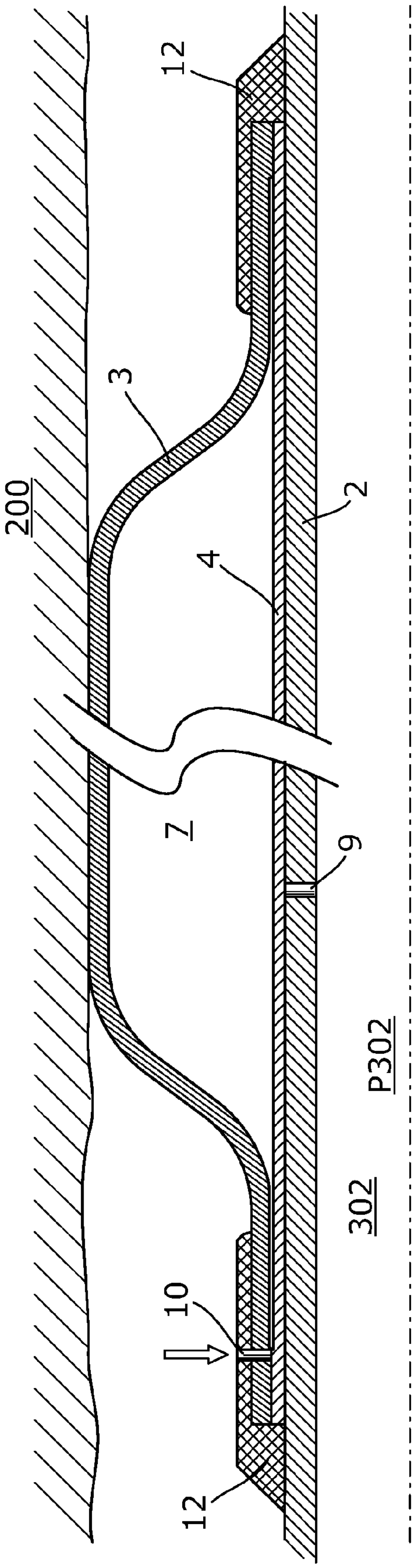

Fig. 3

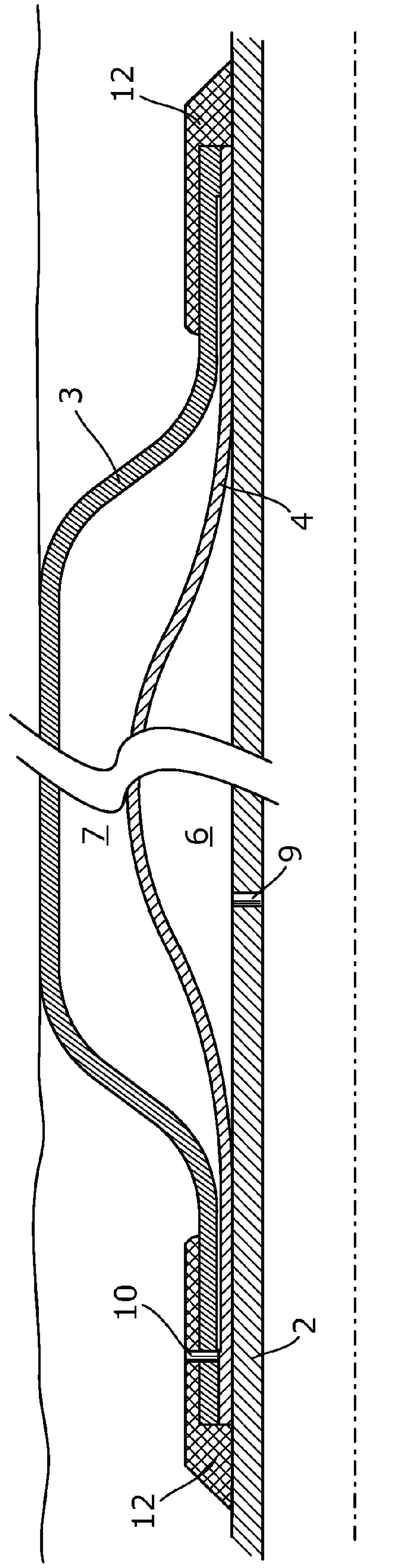

Fig. 4

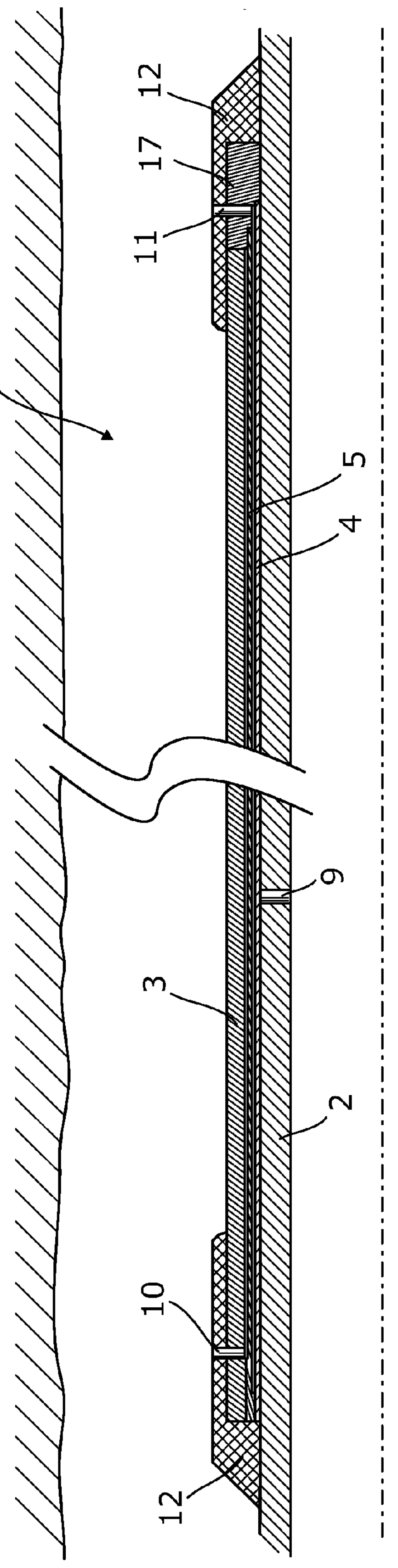

Fig. 5

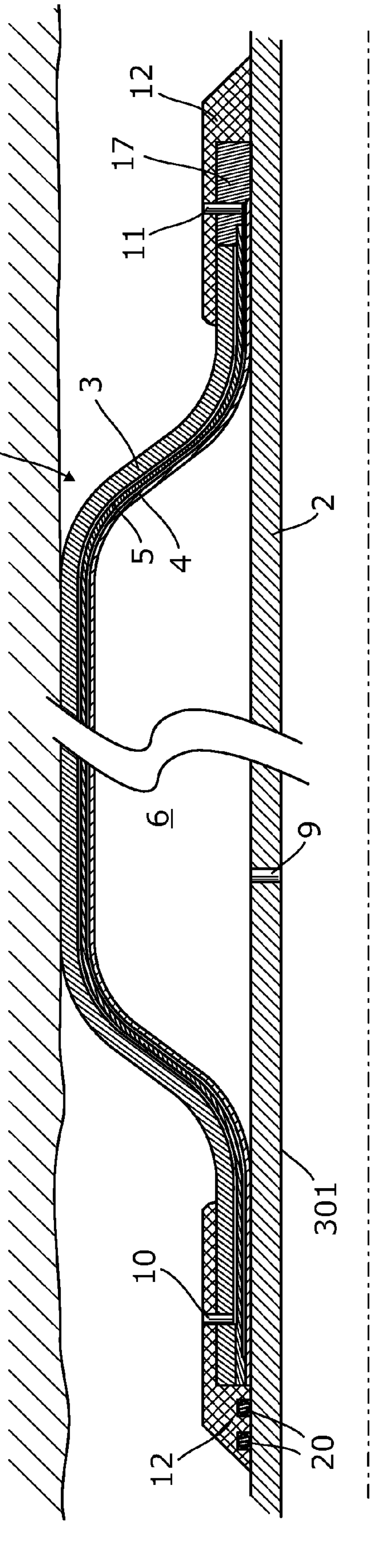

Fig. 6

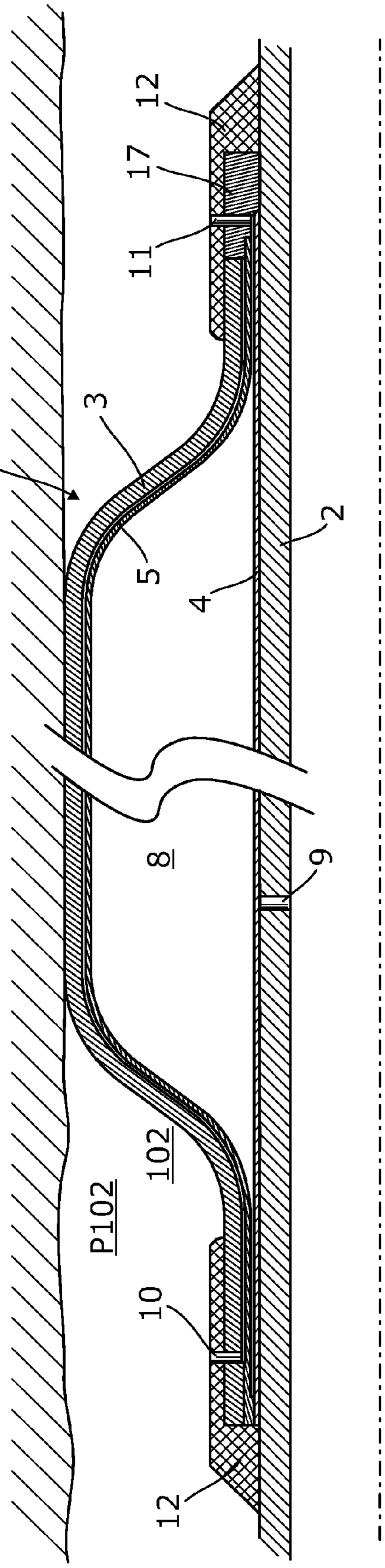

Fig. 7

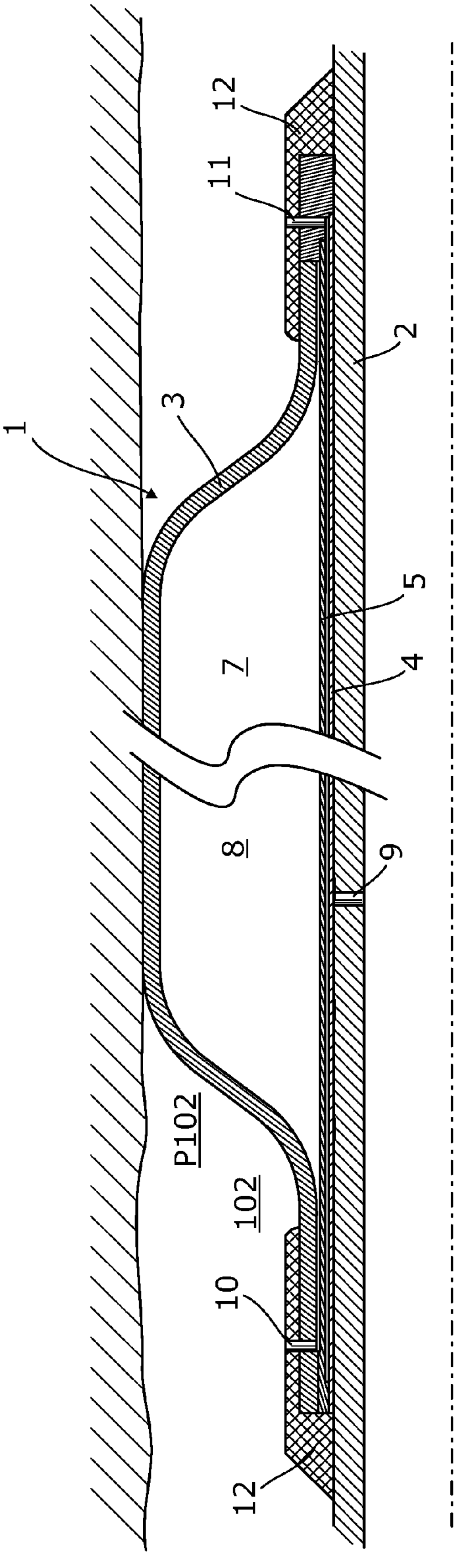

Fig. 8

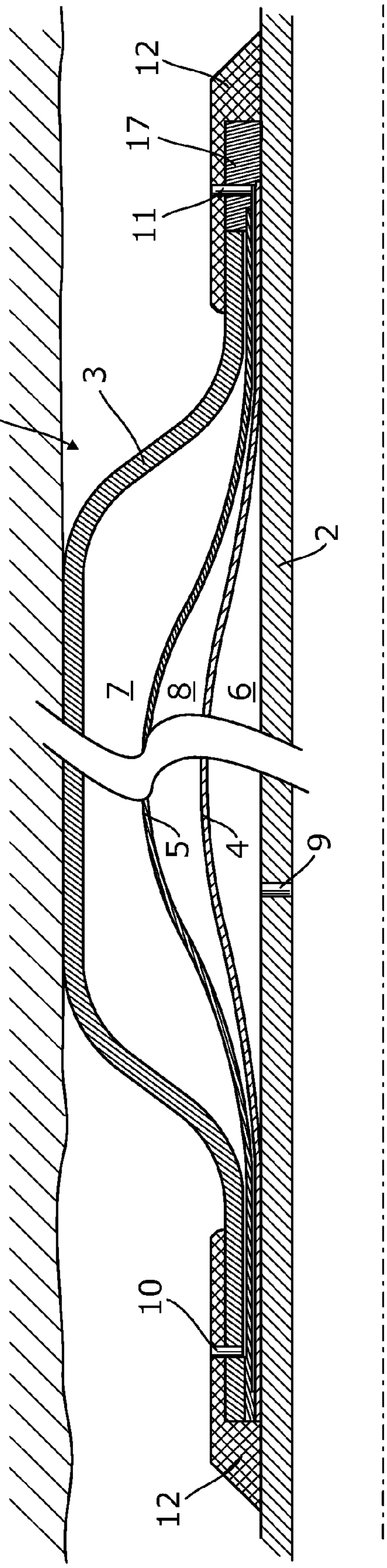

Fig. 9

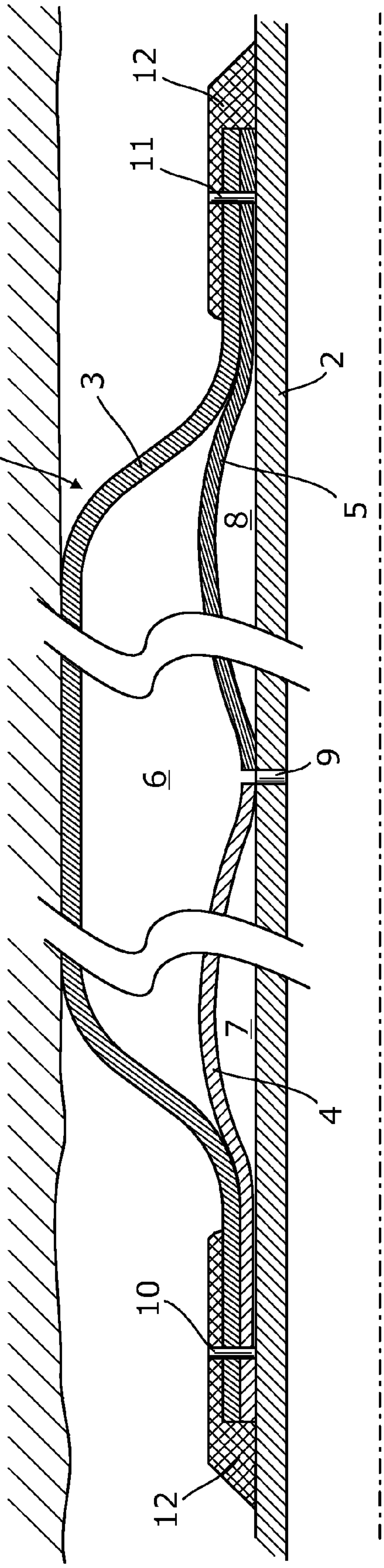

Fig. 10a

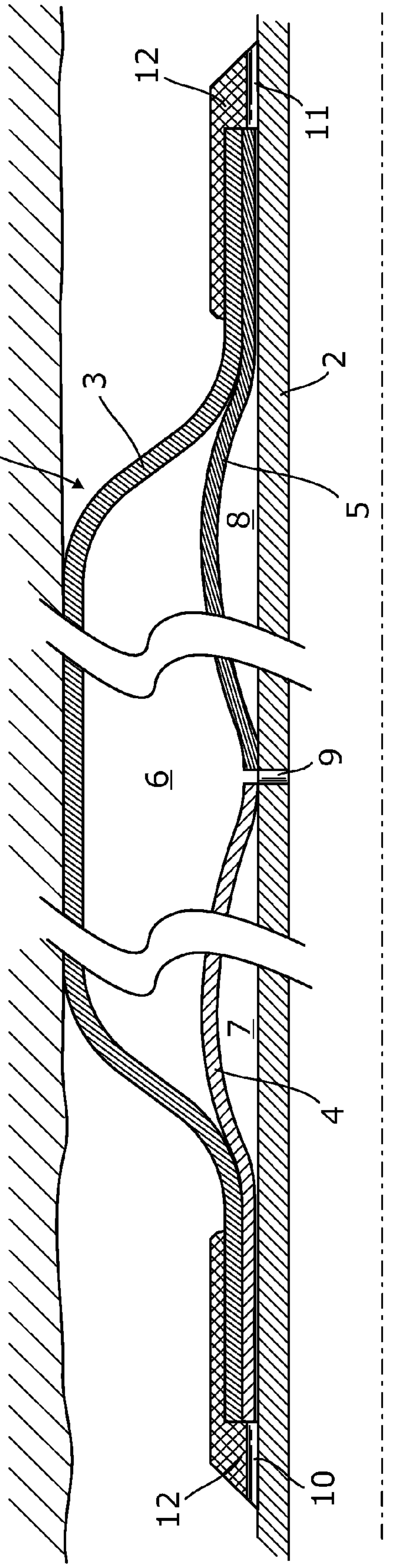

Fig. 10b

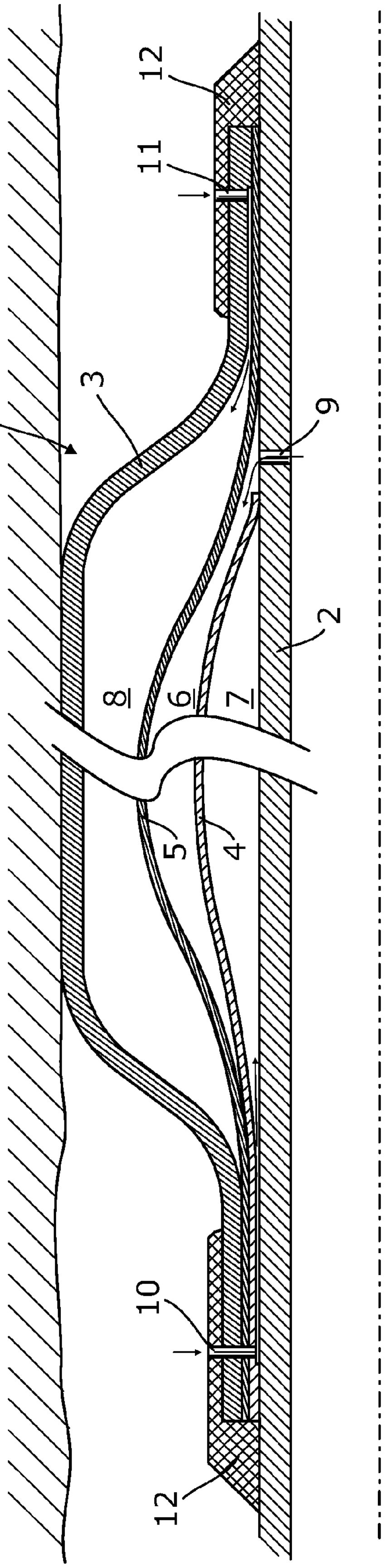

Fig. 11

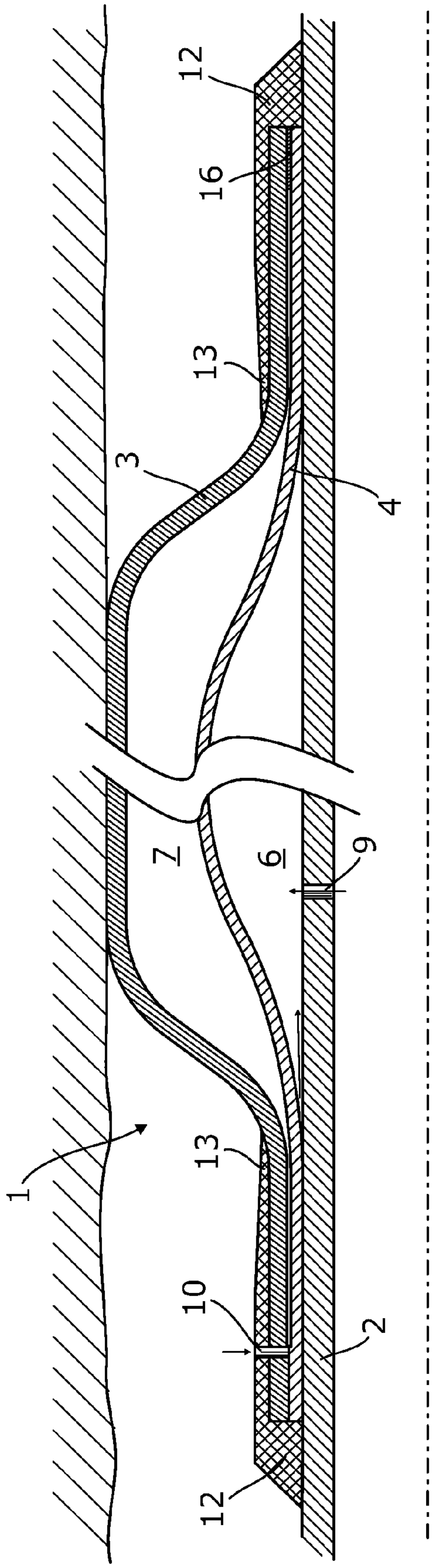

Fig. 12

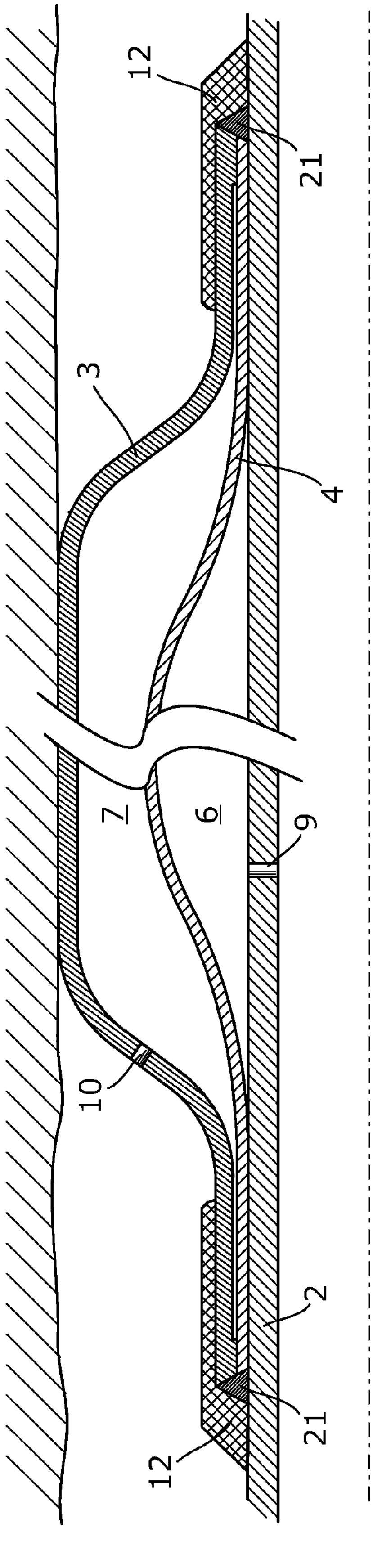

Fig. 13

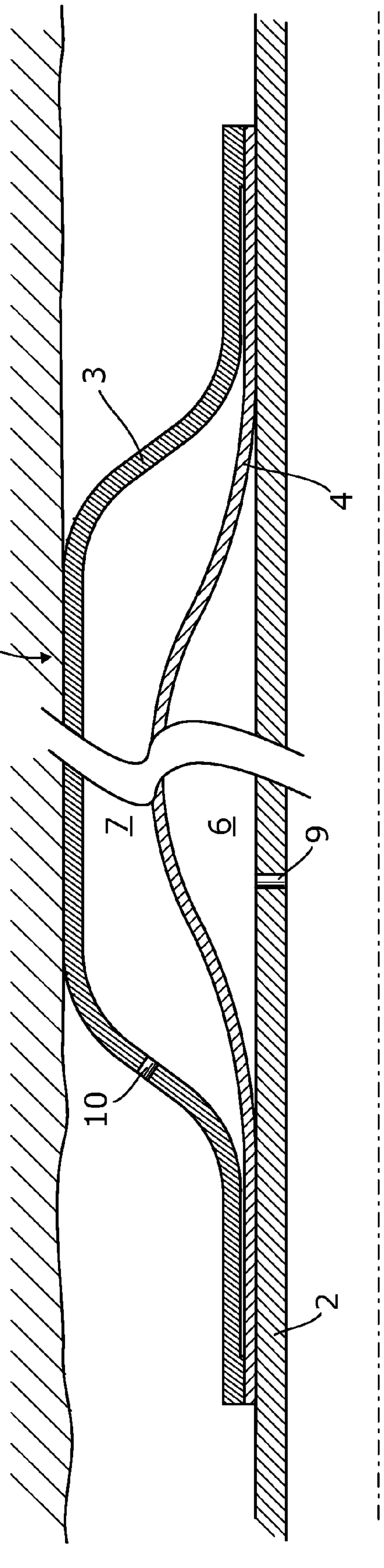

Fig. 14

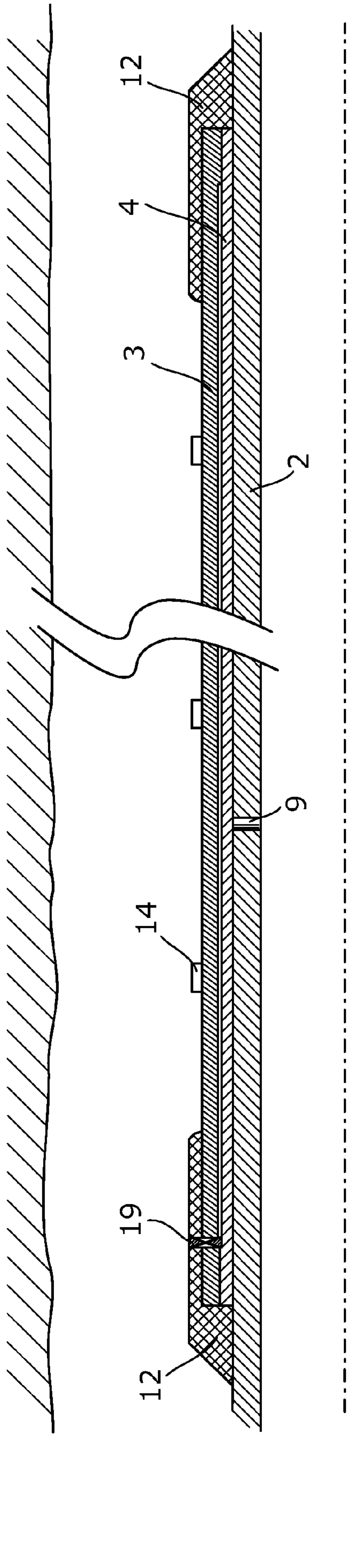

Fig. 15

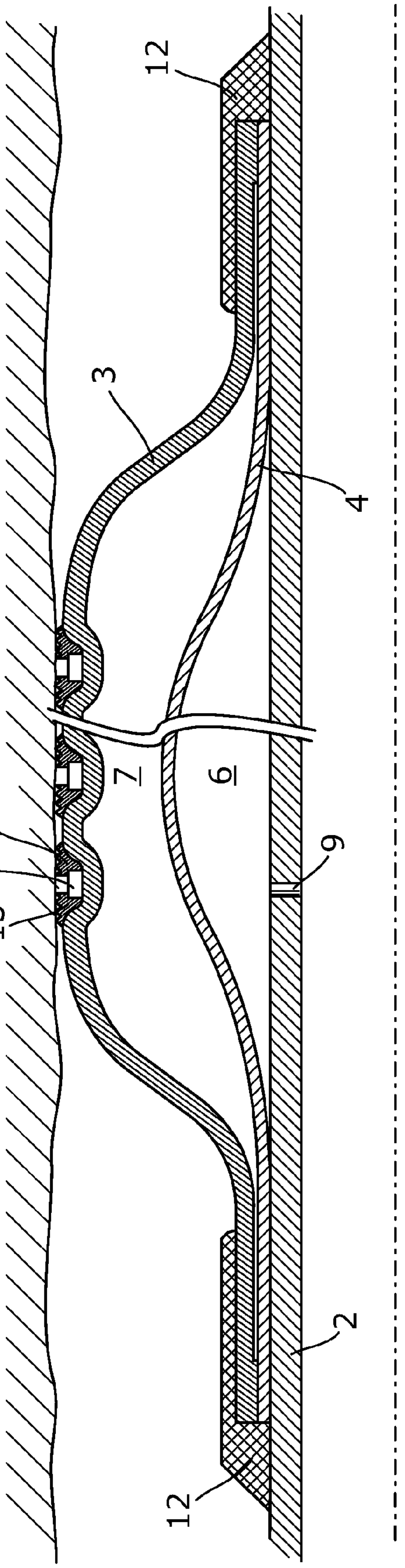

Fig. 16

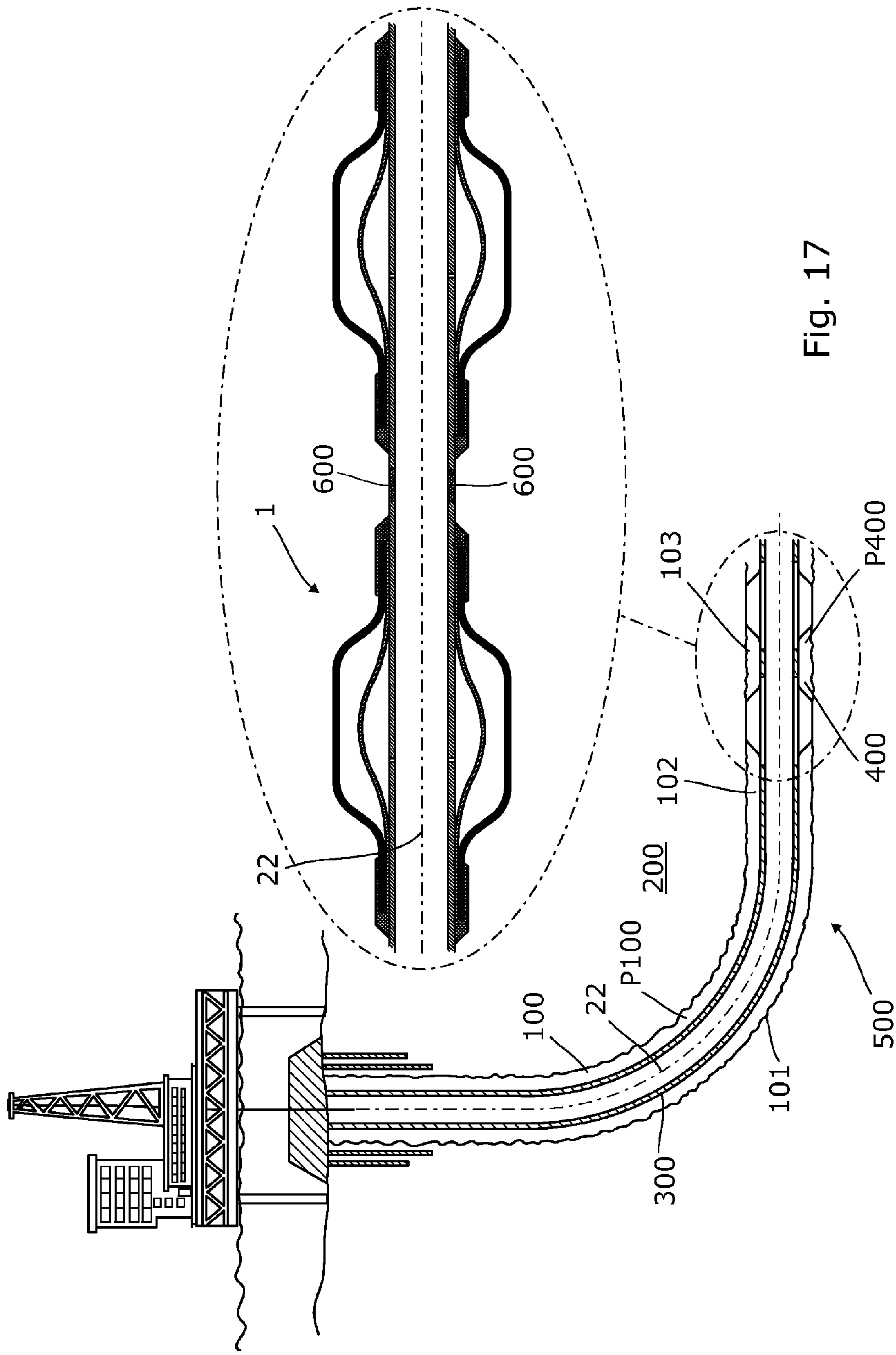

Fig. 17

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 11 15 2135

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2 959 226 A (BLOOD ROBERT H) 8 November 1960 (1960-11-08) * figure 2 * -----	1,3-16	INV. E21B33/127
X	US 2 859 828 A (WILLIAMS PHILIP S) 11 November 1958 (1958-11-11) * figure 5 * -----	1,3-16	
A	US 2 828 823 A (MOUNCE WHITMAN D) 1 April 1958 (1958-04-01) * figures 1,2 * -----	1-16	
			TECHNICAL FIELDS SEARCHED (IPC)
			E21B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	11 May 2011	Schouten, Adri

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

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

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 15 2135

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-05-2011

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2959226	A	08-11-1960	NONE	
US 2859828	A	11-11-1958	NONE	
US 2828823	A	01-04-1958	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82