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ABSTRACT

The present invention relates to an annular barrier (1) to be expanded in an annulus between a well tubular structure (3) and an inside wall (101) of a borehole (100) downhole for providing zone isolation between a first zone (102) and a second zone (103) of the borehole, the annular barrier having an axial extension (22), comprising a metal tubular part (2), the metal tubular part being a separate tubular part or a casing part for mounting a part of the well tubular structure, an expandable sleeve (3) surrounding the metal tubular part, each end (31,32) of the expandable sleeve being connected with the tubular part by means of a separate metal connection part (12), the expandable sleeve being made of metal and having a sleeve length and extending along the axial extension, an annular barrier space between the tubular part and the expandable sleeve, an expansion opening (9) in the tubular part through which fluid may enter the space (30) in order to expand the expandable metal sleeve, wherein each end of the expandable sleeve are fastened to the tubular part by means of the connection part without welding, the connection part being tubular and arranged concentrically to the tubular part, and the connection part having a length which is less than 50% of the sleeve length, the annular barrier further comprising a sealing element arranged on an outside of the expandable sleeve for sealing against the inside of the borehole, the sealing element being of a non-metallic material and having an uneven thickness along the axial extension, the sealing element covering at least 50% of the sleeve length.

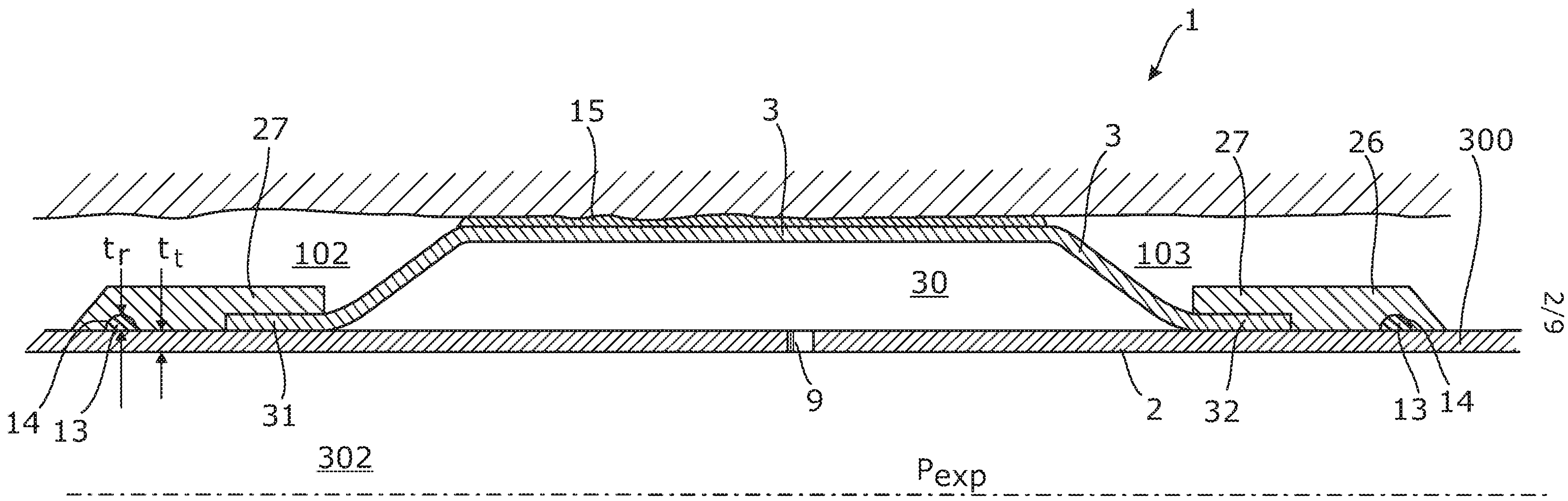

Fig. 2

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ANNULAR BARRIER

Field of the Invention

[0001] The present invention relates to an annular barrier to be expanded in an annulus between a well tubular structure and an inside wall of a borehole downhole for providing zone isolation between a first zone and a second zone of the borehole.

Background Art

[0002] In wellbores, annular barriers are used for different purposes, such as for providing a barrier to flow between an inner and an outer tubular structure or an inner tubular structure and the inner wall of the borehole. The annular barriers are mounted as part of the well tubular structure. An annular barrier has an inner wall 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 inner wall of the annular barrier.

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

[0004] When manufacturing annular barriers, it is very important that the quality of the annular barrier is very high, since once the annular barrier is in the well, it may be difficult to detect whether the annular barrier functions as intended or whether it e.g. ruptures due to material flaws or process error, and thus it is very important to be able to manufacture high quality annular barriers.

Summary of the Invention

[0005] It is an object of the present invention to wholly or at least partly overcome at least one of the above disadvantages and drawbacks of the prior art.

[0006] The present invention relates to an annular barrier to be expanded in an annulus between a well tubular structure and an inside wall of a borehole downhole for providing zone isolation between a first zone and a second zone of the borehole, the annular barrier having an axial extension, comprising:

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- a metal tubular part, the metal tubular part being a separate tubular part or a casing part for mounting a part of the well tubular structure,
- an expandable sleeve surrounding the metal tubular part, each end of the expandable sleeve being connected with the tubular part by means of a separate metal connection part, the expandable sleeve being made of metal and having a sleeve length and extending along the axial extension,
- an annular barrier space between the tubular part and the expandable sleeve,
- an expansion opening in the tubular part through which fluid may enter the space in order to expand the expandable metal sleeve,

wherein each end of the expandable sleeve are fastened to the tubular part by means of the connection part without welding, the connection part being tubular and arranged concentrically to the tubular part, and the connection part having a length which is less than 50% of the sleeve length, the annular barrier further comprising a sealing element arranged on an outside of the expandable sleeve for sealing against the inside of the borehole, the sealing element being of a non-metallic material and having an uneven thickness along the axial extension, the sealing element covering at least 50% of the sleeve length.

[0007] When using a welded connection as in known annular barriers, harm may be done to the material of the expandable sleeve, the connection part and/or the tubular part, and therefore by having the connection part squeezed or otherwise fitted onto the tubular part fastening the sleeve, in accordance with at least a preferred embodiment, the sleeve is not damaged. If the sleeve is damaged, it may rupture or fracture before it is fully expanded, and thus the expandable sleeve is not able to provide an isolation downhole. The connection part has a length which is at least 10% and less than 50% of the sleeve length, the connection part, in accordance with at least a preferred embodiment, thus being able to hold the expandable sleeve and the diaphragm fixed to the tubular part, also during expansion. Furthermore, in accordance with at least a preferred embodiment, by having a sealing element covering at least 50% of the length of the sleeve, it can be ensured that the seal is arranged between the expandable sleeve and the inner face of the borehole, even though the expandable sleeve is not expanded in an even manner.

[0008] Moreover, each end of the expandable sleeve may be fastened to the tubular part by means of crimping, glueing, pressing, heating and/or cooling.

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[0009] Also, the annular barrier may further comprise at least one sealing element arranged in at least one groove in a first part of the connection part and facing the tubular part.

[0010] Moreover, the connection part may have a second part overlapping one end of the expandable sleeve for pressing the end of the expandable sleeve towards the tubular part.

[0011] Furthermore, the sealing element may be corrugated.

Brief Description of the Drawings

[0012] Non-limiting embodiments of the present invention will now be described, by way of example only, with reference to the accompanying schematic drawings wherein:

[0013] Fig. 1 shows a cross-sectional view of a single sleeve annular barrier in its unexpanded position,

[0014] Fig. 2 shows a cross-sectional view of the annular barrier of Fig. 1 in its expanded position,

[0015] Fig. 3 shows a cross-sectional view of an annular barrier in its unexpanded position having sealing elements between the connection part and the tubular part,

[0016] Fig. 4 shows a cross-sectional view of the annular barrier of Fig. 3 in its expanded position,

[0017] Fig. 5 shows a cross-sectional view of a double sleeve annular barrier in its unexpanded position,

[0018] Fig. 6 shows a cross-sectional view of the annular barrier of Fig. 5 in its expanded position,

[0019] Fig. 7 shows a cross-sectional view of the annular barrier of Fig. 5 in its expanded position where the diaphragm sleeve has been deflated, resulting in an increase of the barrier compartment,

[0020] Fig. 8 shows a cross-sectional view of the annular barrier of Fig. 5 in its expanded position where the diaphragm sleeve is in an intermediate position, and

[0021] Fig. 9 shows a partly cross-sectional view of an annular barrier system.

[0022] 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

[0023] Annular barriers 1 are typically mounted into a well tubular structure 300, such as a production casing, before lowering the well tubular structure 300 into the borehole 100 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.

[0024] The annular barrier 1 of Fig. 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 annular barrier space 30 between the expandable sleeve 3 and the tubular part 2.

[0025] The tubular part 2, also referred to as a casing part, is connected with the casing parts or 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 of the well tubular structure.

[0026] The pressurised fluid used to expand the annular 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 Pexp is injected into an expandable space 30 until the expandable sleeve 3 abuts the

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inside wall 101 of the borehole, which is shown in Fig. 2. When the annular 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.

[0027] The annular barrier 1 further comprises two separate metal connection parts. One connection part partly overlaps a first end 31 of the expandable sleeve 3 and the other connection part 12 partly overlaps a second end 32 of the expandable sleeve 3. The connection part has a first part 26 and a second part 27, the first part 26 being firmly connected to the tubular part and the second part 27 overlapping the part of the expandable sleeve. As shown in Figs. 1-4, each end of the expandable sleeve is fastened to the tubular part by the separate connection part without welding.

[0028] Thus, the ends of the expandable sleeve are fastened by the connection part pressing the expandable sleeve end towards the tubular part. Each end of the expandable sleeve may thus be fastened to the tubular part by means of crimping, glueing, pressing, or heating and cooling. The heating and a subsequent cooling involve the step of first heating the material to increase the inner diameter of the connection part, and when the connection part is placed in its position opposite the sleeve, the connection part is cooled down resulting in a decrease of its diameter again. When using a welded connection in known annular barriers, harm may be done to the material of the expandable sleeve, the connection part and/or the tubular part, and therefore by having the connection part squeezed or otherwise fitted onto the tubular part fastening the sleeve, the sleeve is not damaged.

[0029] The connection part is tubular and arranged concentrically to the tubular part and the connection part has a length l_c which is more than 10% and less than 50% of the sleeve length, as shown in Fig. 1. When the connection part has a length which is at least 10% and less than 50% of the sleeve length, the connection part is able to hold the expandable sleeve and the diaphragm fixed to the tubular part, also during expansion.

[0030] Furthermore, the annular barrier comprises a sealing element 15 surrounding the expandable sleeve 3 and partly covering an outer face 41 of the expandable sleeve 3. Thus, the sealing element is fastened to the outer face of the expandable sleeve 3, e.g. by means of glueing, or just arranged around the expandable sleeve 3. While expanding the expandable sleeve 3, the sealing element is expanded also and the sealing element 15 is thus tightened around the expandable sleeve 3 as the expandable sleeve 3 expands. The sealing element 15 is prevented from falling off the annular barrier by the connection parts 12 when lowering the annular barrier into the borehole. By having a sealing element 15 covering at least 50% of the length of the sleeve, it is ensured that the seal is arranged between the expandable sleeve and the inner face of the borehole even though the expandable sleeve is not expanded in an even manner. The sealing element 15 is made of a non-metallic material, such as elastomers, rubber etc. The sealing element has an uneven thickness so as to be able to conform to the uneven surface of the inside wall 101 of the borehole 100. The sealing element is thus corrugated when seen in the cross-sectional view of Fig. 1, but may have another suitable uneven cross-sectional configuration in another embodiment.

[0031] In Fig. 1, the annular barrier further comprises two retainer rings 13 fastened to the metal tubular part 2 and increasing an outer diameter OD_t of the tubular part. Each of the first parts 26 of the connection part has a retainer groove 14 corresponding to the shape of the retainer ring 13. The retainer ring 13 engages the retainer groove when the connection part 12 is connected to the tubular part 2 for preventing the connection part 12 from moving in the axial extension when the expandable sleeve 3 is expanded. Thus, by having a retainer ring 13, the connection part 12 is prevented from moving in the axial extension 22 without using any weld. The retainer ring 13 is made of metal and is pressed or crimped onto the tubular part. Subsequently, the connection part is fastened to the tubular part so that the retainer ring 13 engages the retainer groove 14. The fastening of the tubular part around the retainer ring 13 may be performed by means of crimping, glueing, pressing, or heating and cooling as mentioned above.

[0032] The annular barrier 1 further comprises at least one sealing element 20 arranged in a sealing groove 28 in a first part 26 of the connection part, and the sealing element 20 is thus facing the tubular part, as shown in Figs. 3-4. The connection part 12 has the second part 27 overlapping one end 31 of the expandable sleeve for pressing the end of the expandable sleeve of the tubular part. The second part 27 of the connection part is firmly fastened to the tubular part, and in order to increase the sealing ability of the connection between the connection part and the tubular part, the sealing elements 20 are arranged there between in the sealing grooves 28.

[0033] The sealing groove 28 and the sealing element 20 are in Figs. 3-4 arranged closer to the second part of the connection part than the retainer groove 14.

[0034] As shown in Fig. 2, the retainer ring has a thickness t_r which is at least 50% of a thickness t_t of the tubular part.

[0035] The expandable sleeve length is 1-5 metres. A typical casing part has a length of 8 to 15 metres and preferably 10 metres to match standard equipment for assembling and inserting well tubular parts into boreholes. By having the expandable sleeve length of 1-5 metres, the annular barrier can be made so that two annular barriers and a fracturing opening or sleeve 600 (shown in Fig. 9) can be assembled to match the length of a typical casing part. Thus, the standard equipment on the rig can be used.

[0036] The outer diameter OD_t of the tubular part, as shown in Fig. 1, is between 0.10 metres and 0.25 metres so as to fit almost all boreholes in wells today. In order to be able to expand properly, the expandable sleeve has a sleeve thickness of 0.0025-0.014 m. The expandable sleeve is made of metal and needs to be thin enough not increase the overall diameter of the annular barrier and thick enough to able to withstand the high pressures from the borehole during the lifetime of the annular barrier without collapsing when a high borehole pressure occurs.

[0037] The annular barrier 1 furthermore has a first diaphragm 4 arranged in the annular barrier space 30 which divides the annular barrier space into a barrier compartment 7 and an expansion compartment 6 as shown in Figs. 5-8. 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. 5 is shown as a cross-section along a longitudinal extension of the expandable sleeve 3 or axial extension 22 of the annular barrier, and in its unexpanded and relaxed position, the line 22 is the centreline 22 of the annular barrier 1. The centreline indicates rotation symmetry around this line, i.e. the tubular part 2 in Fig. 1 is a hollow cylinder. In order to expand the expandable sleeve 3, pressurised fluid is injected into the 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. 6.

[0038] As shown in Figs. 5-8, each end of the expandable sleeve and the first diaphragm are fastened to the tubular part by means of a separate connection part without welding. Thus, the ends of both the expandable sleeve and the first diaphragm are fastened by the connection part pressing the sleeve end and the diaphragm end towards the tubular part. Each end of the expandable sleeve and the first diaphragm may thus be fastened to the tubular part by means of crimping, glueing, pressing, or heating and cooling as mentioned above. The heating and a subsequent cooling involve the step of first heating the material to increase the inner diameter of the connection part, and when the connection part is placed in its position opposite the sleeve and at least one diaphragm, the connection part is cooled down resulting in a decrease of its diameter again

[0039] When the pressure P_{exp} of the pressurised fluid is released in order to start production, the annular 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 annular barrier 1 is used to seal off a production zone 400 (shown in Fig. 9), 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 annular barrier increases, and the seal made by the annular barrier may become leaky. This is due to the fact that the pressure inside the annular barrier is no longer the expansion pressure P_{exp}, and that the pressure inside the well tubular structure P302 under normal operating conditions is typically much lower than the expansion pressure P_{exp}, and the pressure from the borehole P100 might then exceed the pressure P302 inside the well tubular structure. However, the annular barrier 1 of Figs. 5 and 6 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 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 102.

[0040] The first diaphragm 4 ensures that the first zone pressure P102 and thus the borehole is sealed from the inside 302 of the well tubular structure 300. When the annular 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 first zone pressure P102 and the pressure in the barrier compartment, causing the annular barrier to break its seal between the first zone 102 and second zone 103 of the borehole.

[0041] 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 annular barrier 1. Thus, the diaphragm is made of a material which is 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.

[0042] Fig. 7 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 and furthermore forcing the first diaphragm towards the tubular part 2. Fig. 8 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.

[0043] 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 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.

[0044] Furthermore, the expandable sleeve 3 has a wall thickness t_s which is smaller than a length L_s 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.

[0045] The annular barrier 1 may also have a valve arranged in the opening 9 placed in the tubular part between the two connection parts 12. Such a valve may be a one-way valve or a two-way valve.

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[0046] The annular barrier system 500 of the present invention may also expand the sleeve and thus the annular barrier by means of a drill pipe or a wireline tool.

[0047] The annular barriers 1 of the present invention may also be used when fracturing the formation in order to enable oil to run out of the formation at a higher rate. An annular barrier 1 is expanded on each side of the future production zone. Pressurised well fluid or water is injected through the fracturing opening or valve and in some cases thus through a production screen in order to crack and penetrate the formation. While the formation fractures, the pressurised fluid in the fracturing zone also flows into the expandable space of the annular barriers 1, reducing the risk of the fluid undermining the seal between the sleeve and the inside wall of the borehole, and also reducing the risk of the expandable sleeve collapsing inwards.

[0048] 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 in between the inner production tubing and an outer tubing in the borehole or between a tubing/casing and the inner wall of the borehole. A well may have several kinds of tubing/casing, and the annular barrier 1 of the present invention can be mounted for use in all of them.

[0049] 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.

[0050] The expandable tubular metal sleeve may be a cold-drawn or hot-drawn tubular structure.

[0051] The fluid used for expanding the expandable sleeve may be any kind of well fluid present in the borehole 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.

[0052] 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.

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CLAIMS

1. An annular barrier to be expanded in an annulus between a well tubular structure and an inside wall of a borehole downhole for providing zone isolation between a first zone and a second zone of the borehole, the annular barrier having an axial extension and comprising:

- a metal tubular part, the metal tubular part being a separate tubular part or a casing part for mounting a part of the well tubular structure,
- an expandable sleeve surrounding the metal tubular part, each end of the expandable sleeve being connected with the tubular part by means of a separate metal connection part, the expandable sleeve being made of metal and having a sleeve length and extending along the axial extension,
- an annular barrier space between the tubular part and the expandable sleeve,
- an expansion opening in the tubular part through which fluid may enter the space in order to expand the expandable metal sleeve,

wherein each end of the expandable sleeve are fastened to the tubular part by means of the connection part without welding, the connection part being tubular and arranged concentrically to the tubular part, and the connection part having a length which is less than 50% of the sleeve length, the annular barrier further comprising a sealing element arranged on an outside of the expandable sleeve for sealing against the inside of the borehole, the sealing element being of a non-metallic material and having an uneven thickness along the axial extension, the sealing element covering at least 50% of the sleeve length.

2. An annular barrier according to claim 1, wherein each end of the expandable sleeve is fastened to the tubular part by means of crimping, glueing, pressing, heating and/or cooling.

3. Annular barrier according to claim 1 or 2, further comprising at least one sealing element arranged in at least one groove in a first part of the connection part and facing the tubular part.

4. Annular barrier according to any one of claims 1 to 3, wherein the connection part has a second part overlapping one end of the expandable sleeve for pressing the end of the expandable sleeve towards the tubular part.

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5. Annular barrier according to any one of claims 1 to 4, further comprising the sealing element being corrugated.

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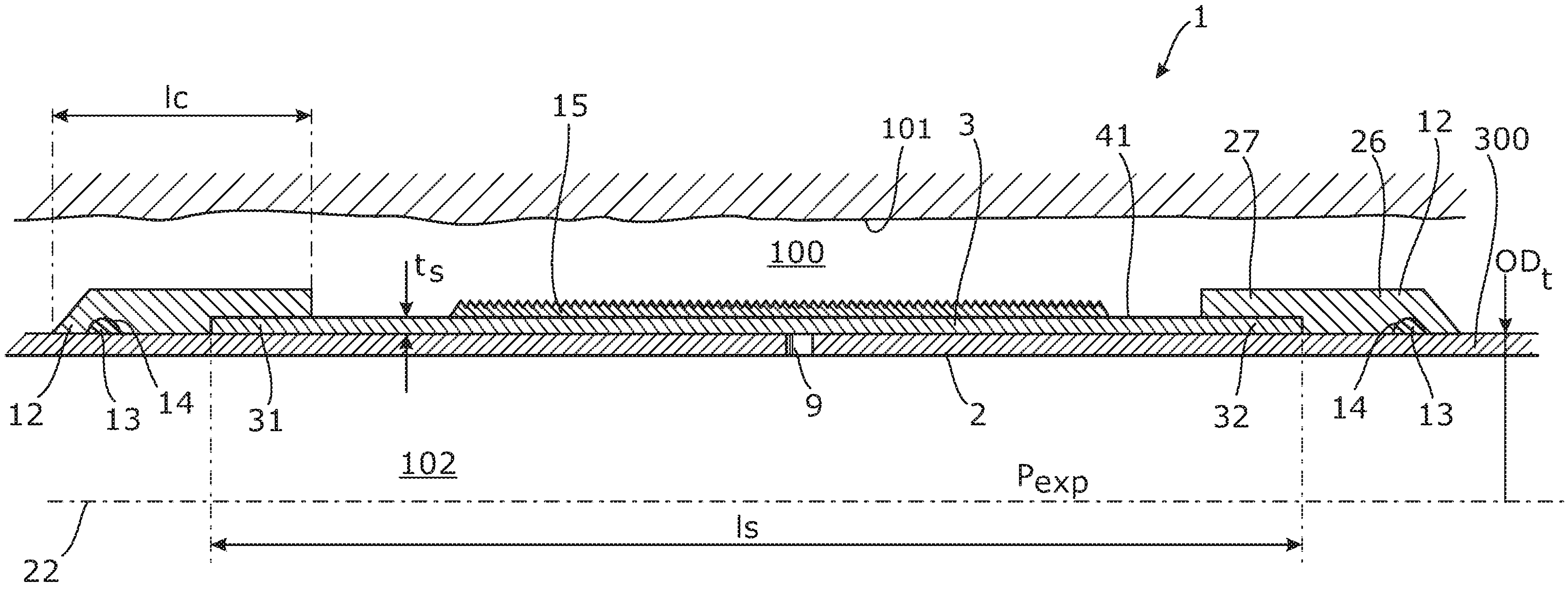
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Fig. 1

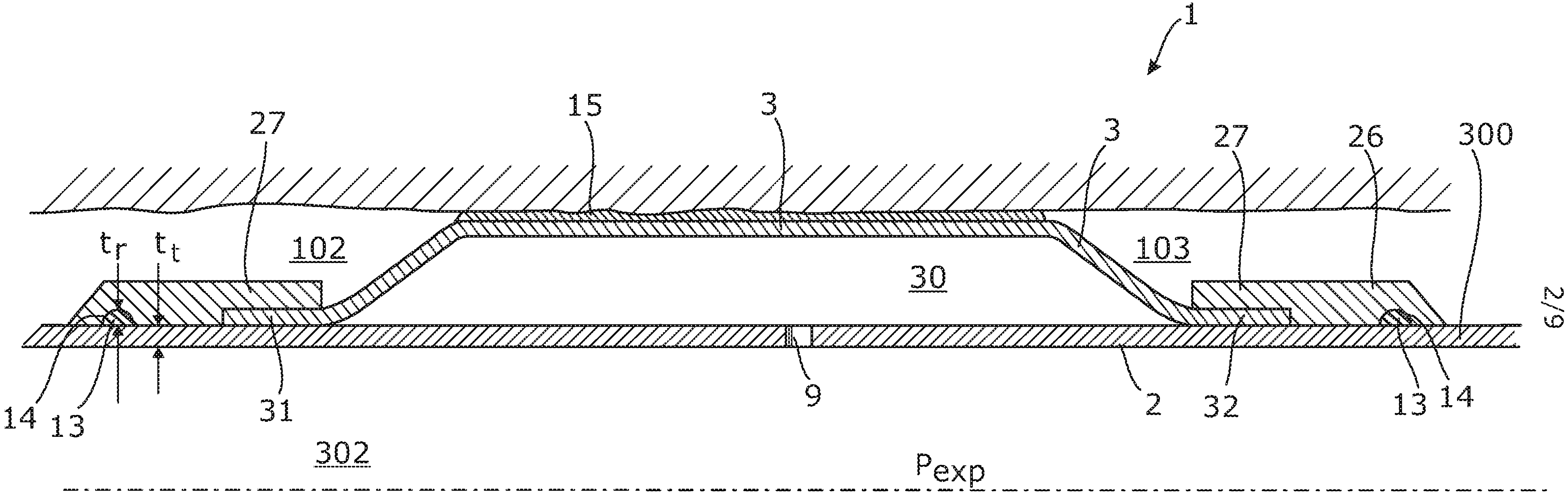

Fig. 2

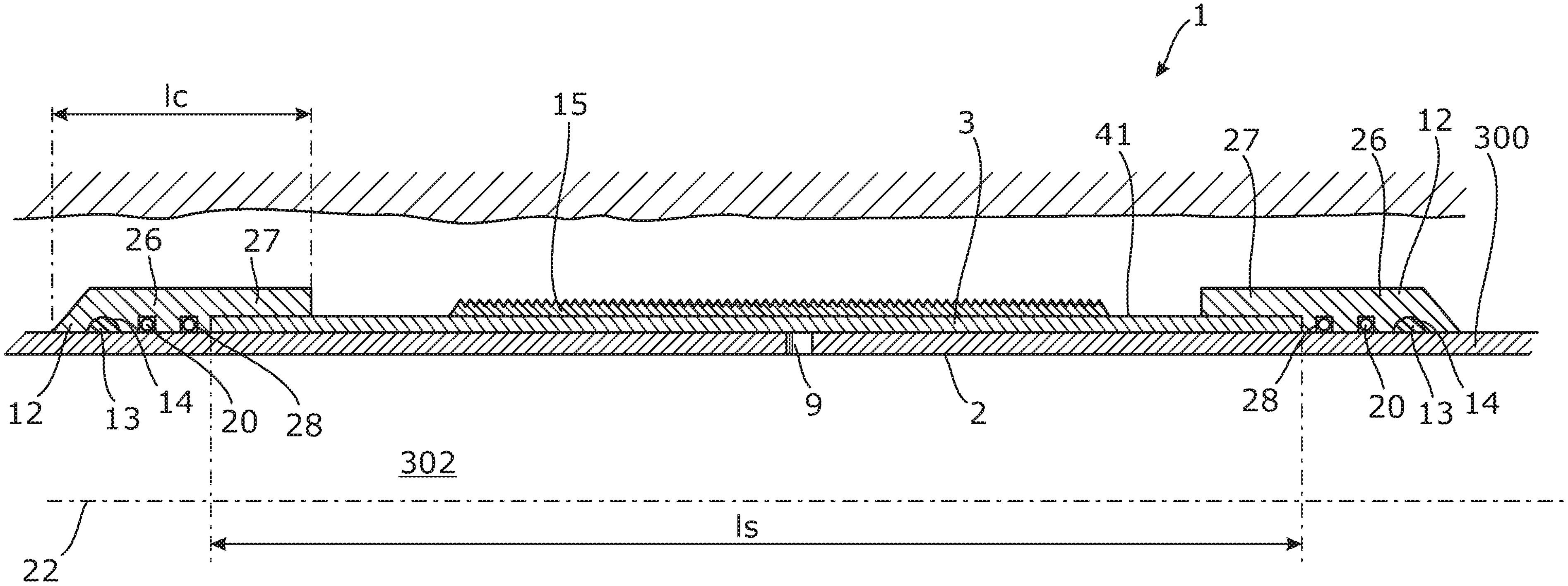

Fig. 3

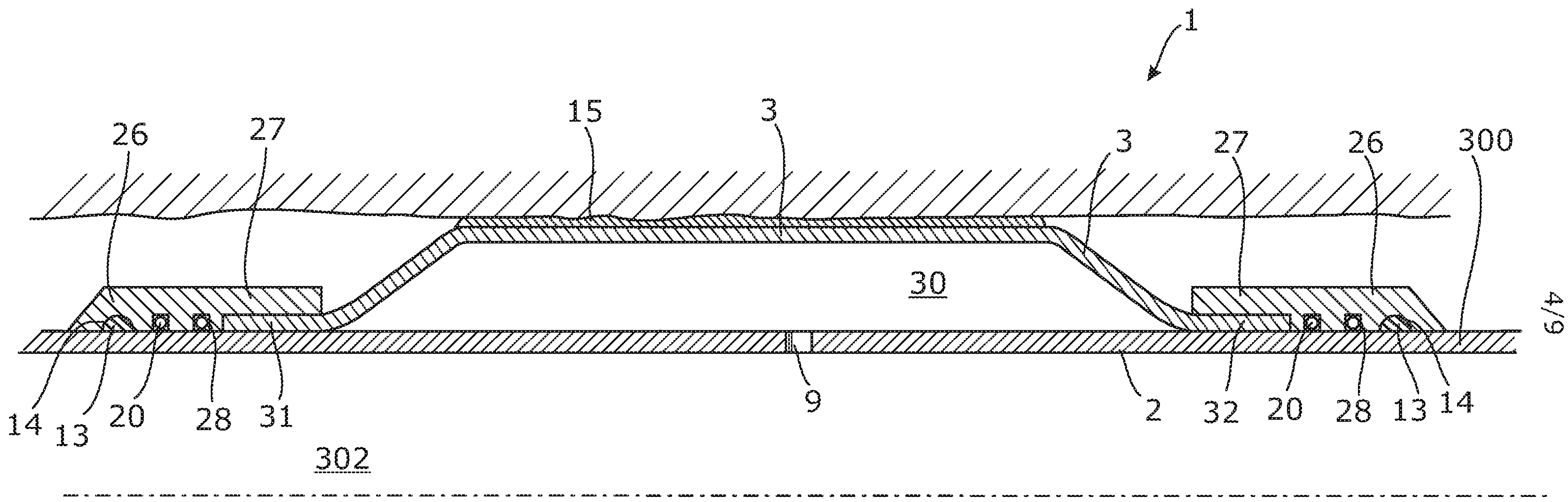

Fig. 4

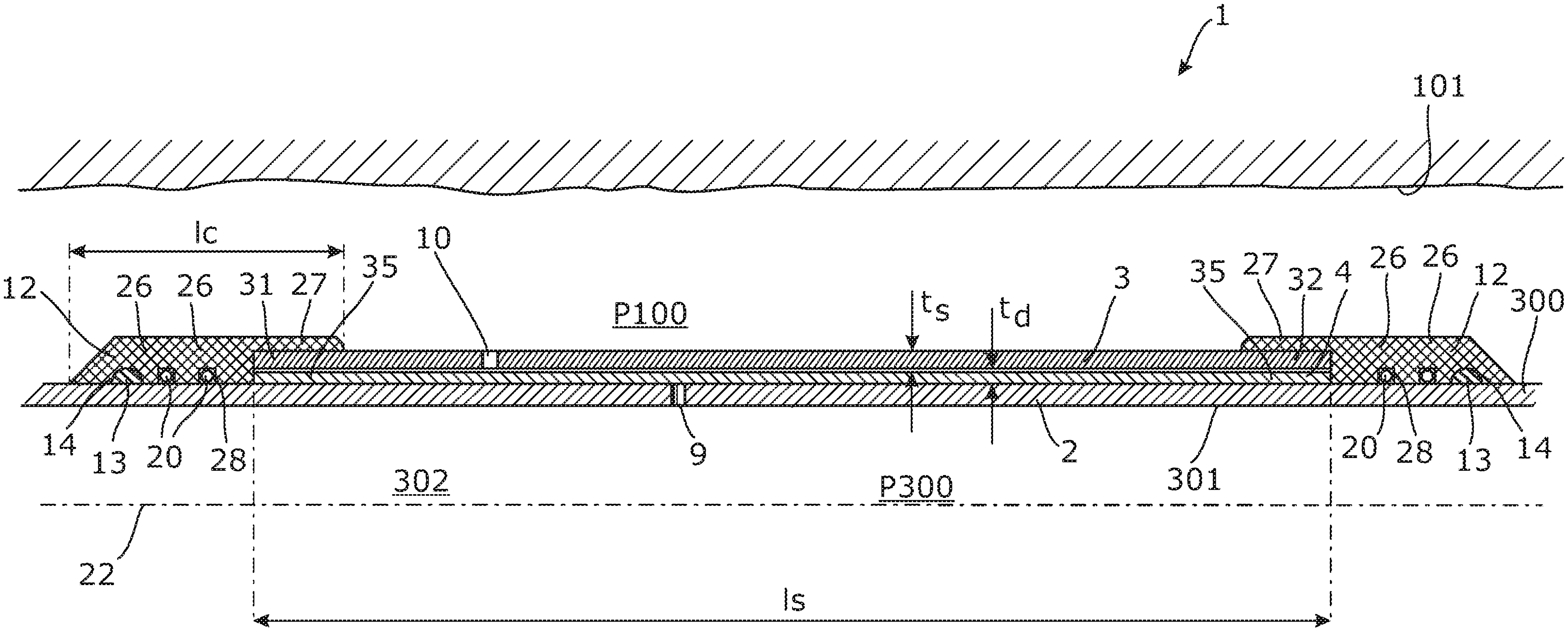
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Fig. 5

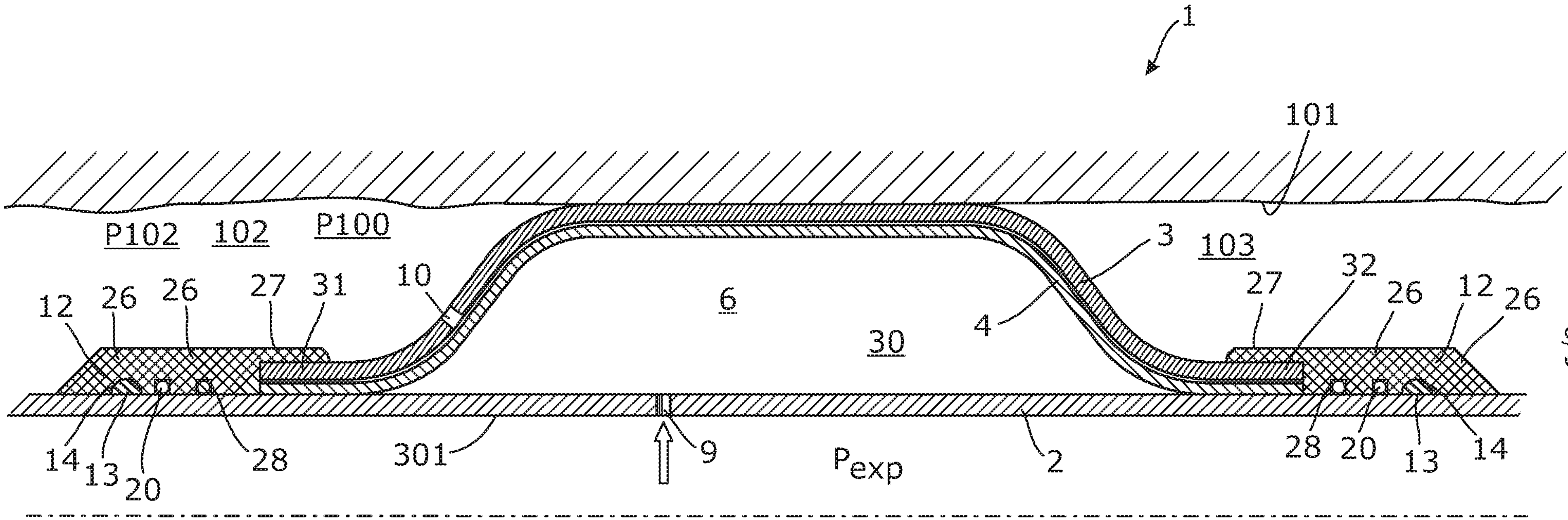

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Fig. 6

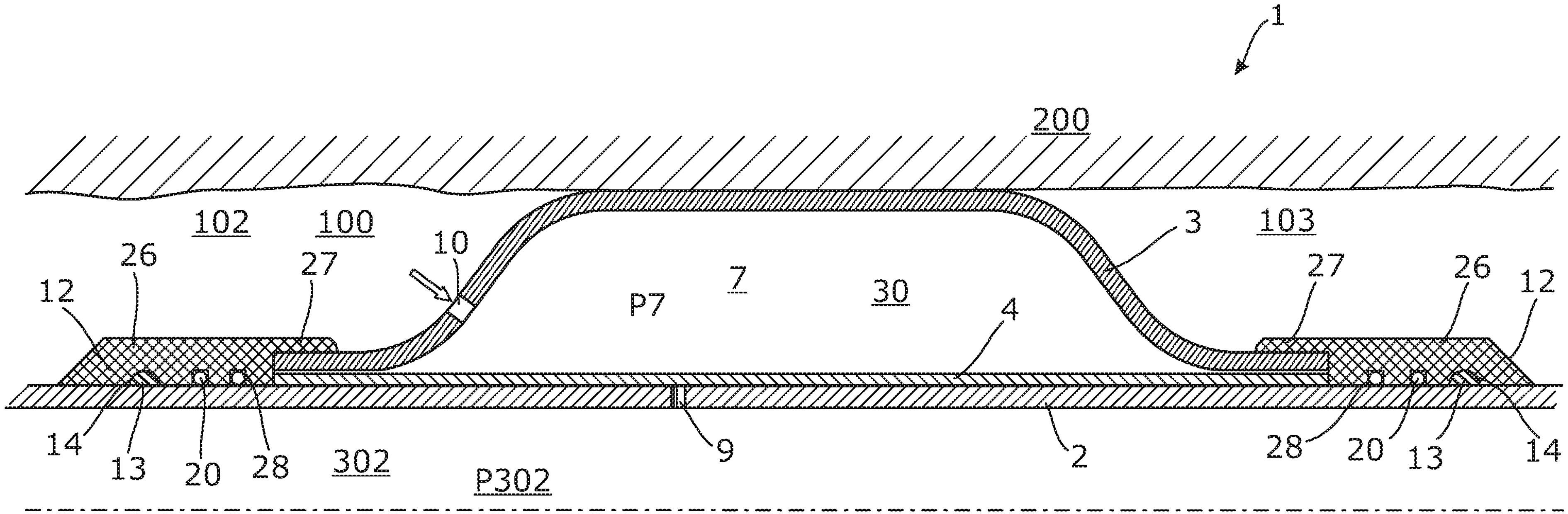
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Fig. 7

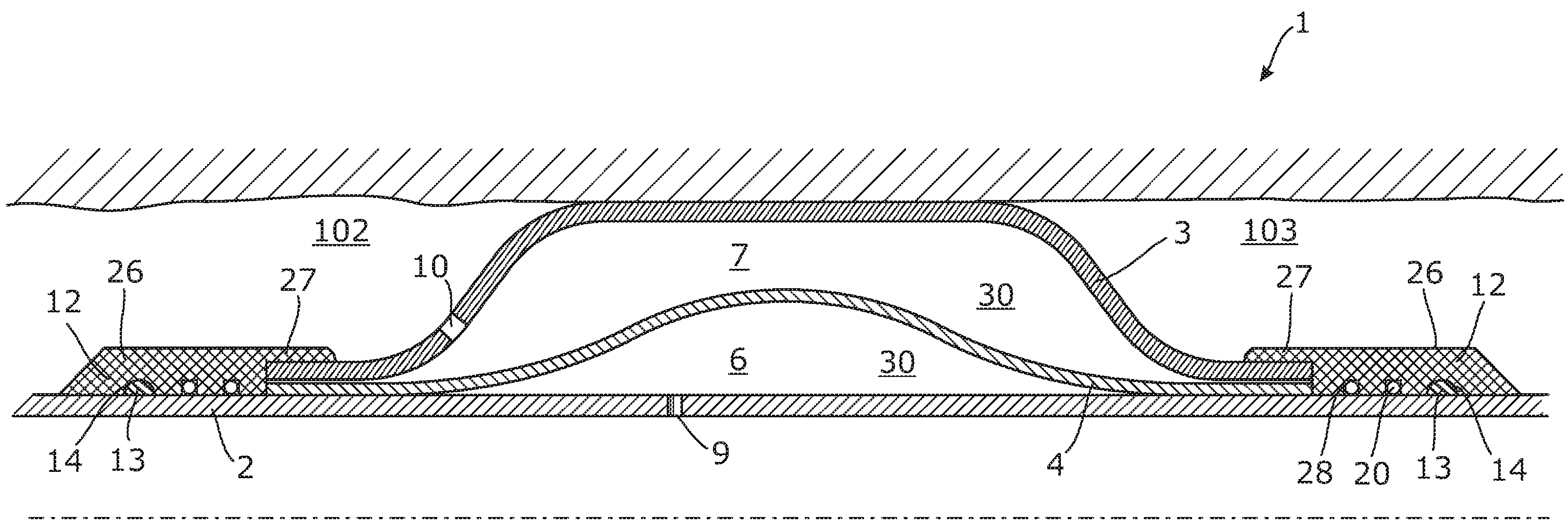

Fig. 8

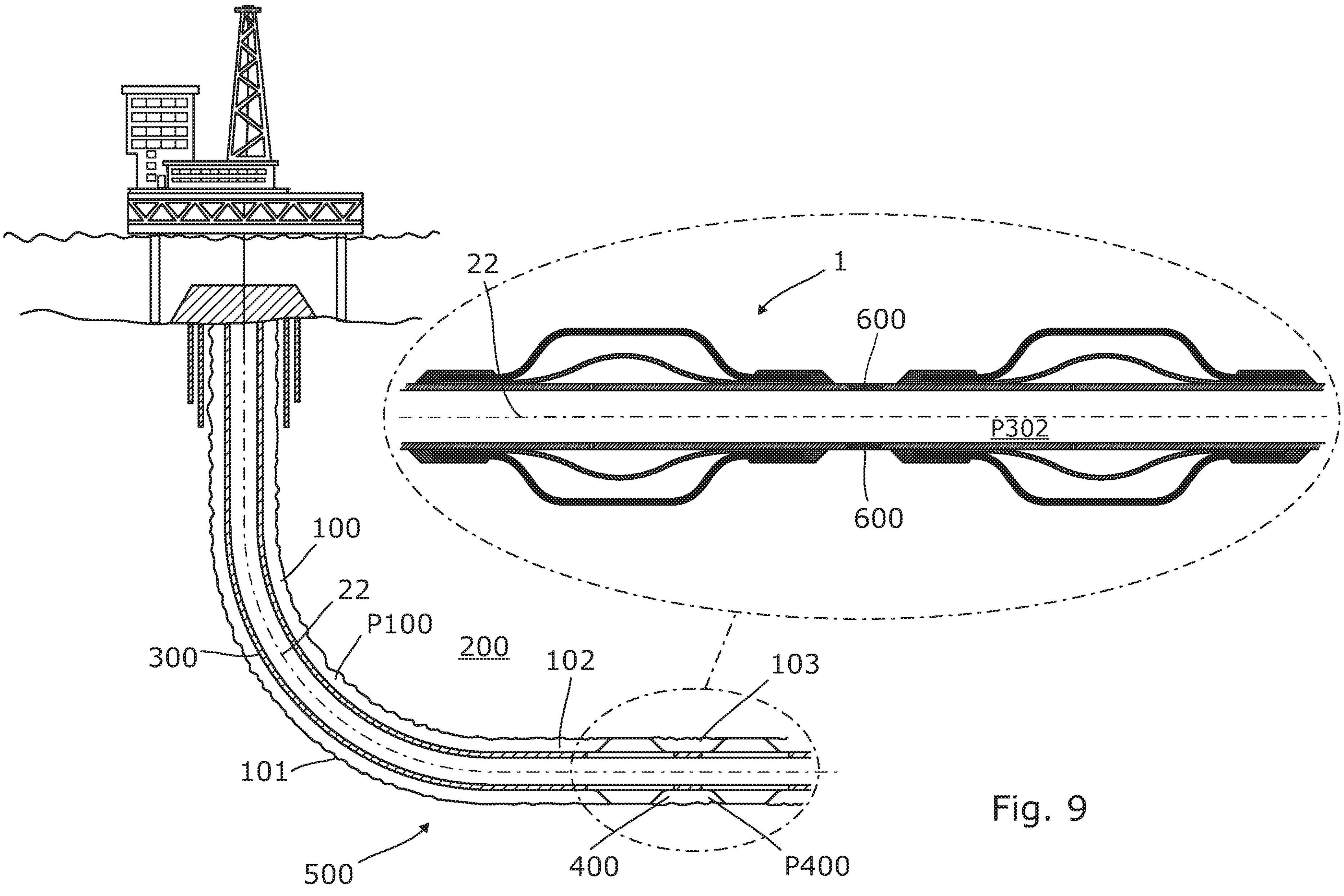

Fig. 9