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(54) **SUBSEA WELL PROTECTION ASSEMBLY**
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(73) Proprietor: **CSUB AS**
4836 Arendal (NO)

(72) Inventors:
• **BRATTEKÅS, Jon Inge**
4844 Arendal (NO)
• **BRATTEKÅS, Christian Suhrke**
4841 Arendal (NO)

• **BERG, Mathias V.**
4823 Nedenes (NO)

(74) Representative: **Bryn Aarflot AS**
Patent
Stortingsgata 8
0161 Oslo (NO)

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Description**Technical Field**

- 5 [0001] The present invention relates to the field of subsea protection structures of the type used in the oil and gas industry in connection with subsea hydrocarbon wells and associated subsea equipment.

Background Art

- 10 [0002] It is common to protect subsea equipment, such as wellheads of subsea hydrocarbon wells, from damage such as from fishing equipment or falling equipment. Subsea wells are typically protected with well protection structures. Where only one subsea well shall be protected, such as a satellite well, the protection structure is often referred to as a SWPS (single well protection structure). Although protecting only one single subsea wellhead, SWPS's are large and heavy.
- 15 [0003] While the most common well protection structures are made of steel framework, there are known some examples of well protection structures that are made of glass-reinforced polymers (GRP).
- [0004] One such example is disclosed on www.compositesworld.com, under the headline "*Subsea Wellhead And Pipeline Protection Covers*", from 2002. This protection structure comprises a dome-like cap structure that covers the wellhead, wherein the entire cap structure can be pivoted away about a hinge section at one bottom edge.
- 20 [0005] A similar structural solution is disclosed in GB2426266, wherein the entire cap structure can be pivoted away for access to the equipment inside.
- [0006] Furthermore, patent application publication NO20080901 discloses a protective structure for subsea installations, such as wellheads. The protective structure can be made as one unit. Alternatively, it may comprise a lower frame and a hatch that connects to the lower frame with a hinge arrangement. Moreover, the structure may be produced in
- 25 fiber reinforced plastic (FRP).
- [0007] To support well protection structures on the seabed, it is common to use suction anchors that are distributed about the position of the well. Other methods may include piling into the seabed.
- [0008] An object of the present invention may be to provide a well protection assembly that is cost-effective and reliable.
- [0009] Another object of the present invention may be to provide a well protection assembly that is easy and cost-effective to install and to use.
- 30 [0010] Yet another object of the present invention may be to provide a well protection assembly that is durable, and which needs less maintenance.
- [0011] A further object of the present invention may be to provide a well protection assembly that provides easy access to the wellhead.

Summary of invention

- [0012] According to the present invention, there is provided a subsea well protection assembly having a base structure configured to rest on the seabed, and a top structure extending upwards from the base structure. The top structure is
- 40 configured to cover a wellhead space. The wellhead space is configured to accommodate a wellhead of a subsea well. The base structure and/or the top structure is made of a fiber-reinforced composite material. The top structure comprises a top ring section with a rectangular shape defining four corners, wherein the top ring section comprises upwardly protruding wire deflection arrangements between the corners.
- [0013] Such wire deflection arrangements can typically be configured for deflecting trawl wires, as will be discussed in more detail further below.
- 45 [0014] The wire deflection arrangements can be upwardly protruding, curved ridges. In other embodiments, the wire deflection arrangements can have a more pointed shape, for instance two inclined surfaces that meet at an upper vertex or upper edge.
- [0015] The said corners can have a rounded shape and the curved shape of the wire deflection arrangements can then be flush with the rounded shape of the corners. In this way, when a wire is deflected off a wire deflection arrangement, the wire will be further deflected away from the well protection assembly, when entering the rounded shape of a corner.
- 50 [0016] The top structure can comprise a releasable top frame that is configured to land on the top ring section.
- [0017] The releasable top frame can comprise a top frame aperture and a hatch configured to open and close the top frame aperture.
- 55 [0018] Moreover, the releasable top frame can have wire deflection arrangements positioned between the corners when in position installed on the top structure.
- [0019] In some embodiments, four legs extend downwards from the top ring section, wherein side openings are confined between the top ring section, and the legs. The side openings can then comprise side opening edges, and the

side opening edges can comprise a curved profile.

[0020] Having side opening edges with a curved profile reduces the risk of a trawl door or other equipment getting stuck in the protection assembly.

[0021] In such embodiments, the side opening edges can be made of a plate-shaped material, and the curved profile can end in a profile end.

[0022] Advantageously, the profile end can point away from the outwardly facing direction of the side opening. In other words, the profile end of the plate-shaped material can point inwards, into the protection assembly.

[0023] In some embodiments, the base structure has a base structure ring that can comprise two downwardly extending walls forming a downwardly open channel, with the two downwardly extending channel walls configured to extend into the seabed. Such design provides a good landing structure for landing directly onto / into the seabed.

[0024] Furthermore, the top structure and the base structure can in some embodiments be two separate, dismountable parts. The base structure or a base structure ring can have a rectangular shape and comprise a landing guide element, wherein the landing guide element is configured to engage with the top structure during landing of the top structure on the base structure.

[0025] In some embodiments, the top structure and the base structure can together be one single unit.

[0026] In some embodiments, the base structure can comprise free lower ends of legs that extend down from the top ring section of the top structure. In other words, the base structure can have free ends of legs instead of a base structure formed as a base structure ring.

[0027] With the term free lower end is meant that the lower end of the leg is not attached to other legs with a connection located at this lower end. In other words, the legs extend freely downwards from the top portion and are self-supported.

[0028] For embodiments having a base structure ring, the base structure ring can have a plurality of landing guide elements that comprise an outer guiding face with an inclination in relation to the vertical. The top structure can then have inner guide walls configured to engage with the outer guiding faces upon landing of the top structure on the base structure.

[0029] The top structure can in some embodiments comprise a top ring section and four legs extending downwards from the top ring section, lower beams extending between lower portions of adjacent legs, and side openings that are confined between the top ring section, legs and the lower beams.

[0030] In such embodiments, at least one of the side openings can be downwardly open. That means that there is no beam between the legs that define that or those particular openings, or that such beams are interrupted (i.e. not continuous between the adjacent legs).

[0031] The top ring section can have ring interruption that makes the top ring section discontinuous.

[0032] One or more of the side openings can have a downwardly extending skirt at their upper part of their perimeter.

[0033] The subsea well protection assembly can advantageously have a plurality of legs that extend down from a top ring section, wherein the legs comprise a mid-portion that is thinner than the leg portion at the lower and upper ends of the leg.

[0034] There is also provided a subsea protection structure of a fiber-reinforced composite material, comprising a top portion and at least four legs extending down from the top portion, and side openings between adjacent legs. The legs and the top portion may also be moulded as one single piece, and the legs comprise an inwardly open channel.

[0035] With the term inwardly open channel, is meant that the legs have a channel shape, where the channel substantially has two side walls that extend from a bottom wall. In some embodiments, the channel-shape may have a cross section formed like a capital U letter, having a smooth, curved bottom. In other embodiments, the cross section of the channel may be more like the cross section of the letter V, or a cup, having somewhat sharper edges in the interface between the side walls and the bottom wall.

[0036] Advantageously, the channel has a vertical extension of at least half the vertical extension of the entire subsea protection structure.

[0037] Moreover, two legs or more comprise a free, lower end.

[0038] In some embodiments of the second aspect of the invention, the side openings can comprise a downwardly extending skirt at their upper part of their perimeter. This will prevent entanglement with trawl doors or other type of fishing equipment that are pulled along the seabed.

[0039] In embodiments involving a base structure ring, the base structure ring may involve a circular shape or a polygonal shape, typically as a rectangle or square. The base structure ring is a ring that is adapted to encircle the position of the wellhead.

[0040] Advantageously, the base structure ring can comprise a landing guide element at each corner of its rectangular shape.

[0041] In some embodiments, the downwardly extending wall can comprise corrugation. This will increase the structural stability of the downwardly extending wall, which is advantageous when inserting the wall into the seabed.

[0042] The top structure can in some embodiments further comprise a bridging beam configured to be releasably attached to the ring interruption so that the ring interruption is bridged. Such a releasable bridging beam can contribute

in retaining stability and integrity of the protection assembly when installed, and can permit elongated pieces of equipment, such as a tie-in jumper, to be lowered partially into the space protected by the protection assembly.

[0043] The top structure can in some embodiments comprise a top ring section with a top aperture, one or more hatches configured to close the top aperture and to open the top aperture when moved upwards, wherein the one or more hatches comprise a buoyancy element. Providing the hatches with a buoyancy element can make it possible to operate them with an ROV even if the hatches are of a considerable size.

Brief description of drawings

[0044] While various features of the invention have been discussed in general terms above, a more detailed and non-limiting example of embodiment will be presented in the following with reference to the drawings, in which

Fig. 1 is a perspective view of a well protection assembly according to the invention;
 Fig. 2 is a perspective view of another embodiment of a well protection assembly according to the invention;
 Fig. 3 is a top view of the well protection assembly shown in Fig. 1;
 Fig. 4 is a perspective view of a base structure shown in Fig. 1;
 Fig. 5 is an enlarged cross section side view of a corner portion of the base structure shown in Fig. 4;
 Fig. 6 is an enlarged cross section view of a locking arrangement configured to releasably attach the protective top structure to the base structure;
 Fig. 7 is a perspective view of the protective top structure shown in Fig. 1 in a separate state;
 Fig. 8 is a perspective view of a subsea protection structure according to the second aspect of the invention;
 Fig. 9 is an enlarged cross section side view of the lower end of one of the legs shown in Fig. 8;
 Fig. 10 is a perspective view of an alternative design of the well protection assembly;
 Fig. 11 is a side view of the well protection assembly depicted in Fig. 10;
 Fig. 12 is a perspective view of the assembly in Fig. 10, shown with the hatches open and with a ring interruption in the top ring section;
 Fig. 13 is a top view of an assembly, shown without the hatches;
 Fig. 14 is a side view seen along a diagonal line extending between two opposite corners of the base structure;
 Fig. 15 is a side view of the assembly shown in Fig. 11, shown with a trawl door that is about to be pulled over the assembly;
 Fig. 16 is another side view depicting the situation shown in Fig. 15;
 Fig. 17 is a perspective view of an embodiment similar to the embodiment shown in Fig. 10 to Fig. 16;
 Fig. 18 is a side view of an upper part of a top structure;
 Fig. 19a to Fig. 19c are cross section views of different curvatures of the edge of a side opening;
 Fig. 20 is a cross section view of a portion of the upper part of the top structure; and
 Fig. 21 is an enlarged section of Fig. 17, showing a side opening edge in better detail.

Detailed description of the invention

[0045] Fig. 1 depicts a single well protection assembly 1 according to the present invention. The assembly 1 comprises two main parts, namely a top structure 100 and a base structure 200.

[0046] As will be discussed in detail further below, the base structure 200 rests on the seabed and supports the top structure 100 when in the installed mode as shown in Fig. 1.

[0047] The top structure 100 has a horizontal upper face, which comprises two pivoting hatches 101. In Fig. 1, the hatches 101 are shown in an open position, exposing an open top aperture 103. When in this open position, substantially the entire upper horizontal face of the top structure 100 is open. When installed over a subsea well (not shown), the operator may access the well from above through the top aperture 103, for instance during well workover operations. The assembly 1 comprises a wellhead space 4, which is configured to accommodate a wellhead of a subsea well.

[0048] The top structure 100 comprises four legs 105 that extend downwards from the upper face with an inclined orientation.

[0049] On each of the four legs 105 there is provided a lifting interface 107, for use during lifting.

[0050] Encircling the top aperture 103 and located at the upper portion of the four legs 105, there is a top ring section 109. The hatches 101 are connected to the top ring section 109 with hinges.

[0051] The top ring section 109 has a substantially rectangular or square shape, however with rounded outer corners 109b. The corners 109b are located where the top ring section 109 interfaces with legs 105 that extend down from the

top ring section.

[0052] In addition to the top aperture 103, which may be closed with the hatches 101, the top structure 100 comprises four side openings 111. The side openings 111 are arranged between two adjacent legs 105. Upwardly, the side openings are confined by the top ring section 109. Downwardly, the side openings are confined by a lower beam 113. The lower beams 113 extend between the lower portion of the adjacent legs 105.

[0053] While three of the four side openings 111 are partly confined downwardly with such a lower beam 113, one of the four side openings 111 is not. Rather, as appears from Fig. 1 and Fig. 7, one of the side openings 111 are open in the downward direction. This is advantageous if the operator wants to remove the top structure 100 from or land the top structure 100 onto the base structure 200 shown in Fig. 4. This is because absence of the lower beam 113 makes the top structure 100 able not to interfere with the flowline 9 (cf. Fig. 4).

[0054] Fig. 2 depicts a perspective view of a single well protection assembly resembling the embodiment shown in Fig. 1. However, in the embodiment shown in Fig. 2, the top ring section 109 is not continuous about the top aperture 103. Instead, there is a ring interruption 115. The ring interruption facilitates connection of a pipeline to the wellhead equipment (such as a subsea tree).

[0055] Moreover, contrary to the embodiment shown in Fig. 1, in the embodiment shown in Fig. 2 the base structure 200 and the top structure 100 is one single unit.

[0056] Fig. 3 depicts the single well protection assembly 1 shown in Fig. 1 with a top view. As appears from Fig. 3, the top aperture 103, which in the shown state is closed with two hatches 101, has a substantially square shape.

[0057] The outer perimeter of the base structure 200 also has a generally square shape. Notably, however, the four corners of the base structure 200 have a rounded shape.

[0058] Fig. 4 depicts the base structure 200 installed on the seabed and surrounding the wellhead 3 of a subsea hydrocarbon well. The base structure 200 comprises a base structure ring 202. The base structure ring 202 exhibits a generally squared shape in the shown embodiment.

[0059] At each of the four corners, there is an upwardly extending landing guide element 201. The landing guide elements 201 are configured to engage with the top structure 100 when the top structure 100 is landed on the base structure 200. This engagement will align the top structure 100 to the position of the base structure 200, ensuring that these two main parts are correctly assembled.

[0060] In the shown embodiment, the landing guide elements 201 have a curved overall shape that somewhat follows the curved shape of the corner of the base structure 200. Furthermore, the landing guide elements 201 have an upper portion that has a smaller horizontal extension than their lower portion.

[0061] In the shown situation in Fig. 4, a remotely operated vehicle (ROV) 5 is operating a schematically shown subsea Xmas tree 7 arranged on the wellhead 3. A flowline 9 is connected the Xmas tree 7.

[0062] Fig. 5 shows an enlarged side view of a portion of the base structure 200. From this view, some aspects of the shape of the landing guide element 201 can be appreciated. The landing guide element 201 has an outer guiding face 203. Furthermore, it has an upper guiding face 205, and a rear guiding face 207.

[0063] The upper guiding face 205 constitutes the vertically upper part of the landing guide element 201.

[0064] The generally curved shape of the landing guide element 201 comprises two end faces 209, where the curved shape ends.

[0065] As can be seen from Fig. 5, the outer guiding face 203, the rear guiding face 207, and the end face 209 all exhibit an inclination with respect to the vertical. The upper guiding face 205 is in the shown embodiment substantially horizontal.

[0066] The lower ends of the legs 105 (cf. Fig. 1) comprise an inner guide wall 106, which is configured to engage with and slide against the outer guiding face 203 of the landing guide element 201 when the top structure 100 is landed on the base structure 200. As now will be appreciated by the skilled reader, the four inner guide walls 106, of which one is located at the lower portion of the respective four legs 105, together form a landing capturing area. When the top structure 100 lands on the base structure 200, the four landing guide elements 201 must be positioned within this capturing area, so that the outer guiding faces 203 will engage the inner guide walls 106.

[0067] Advantageously, since the landing guide elements 201 constitute the upper part of the base structure 200, they are the first part of the base structure 200 with which the top structure 100 engages when landing.

[0068] As discussed above, the base structure 200 has a generally rectangular shape or a square shape. Between each of the four base corners 211 there extends a base beam 213.

[0069] Advantageously, the rectangular shape of the base structure 200 is continuous. This contributes to the stability of the base structure.

[0070] As is perhaps shown best in Fig. 5, the base beams 213 has the shape of a channel 204 with two substantially vertically extending channel walls 215. The channel 204 is formed by the two channel walls 215 and an upper, substantially horizontal channel top face 217. The cross section through the channel thus has the general shape of the letter "U", being oriented upside-down.

[0071] The vertical extension of the channel 204 can typically be between 0,5 and 3 meters, advantageously about 1

meter. It may however also be smaller or larger, depending on application and seabed condition.

[0072] As appears from Fig. 4, the channel walls 215 of the base beams 213 can advantageously have corrugations 219.

[0073] In the shown embodiment, the corners of the rectangular shape of the base structure 200 also has channel walls 215 and the horizontal channel top face 217. In other words, the channel 204 extends along the entire rectangular shape of the base structure.

[0074] The landing guide elements 201 advantageously protrudes upwards from the horizontal top face 217.

[0075] In the enlarged side view of Fig. 5, the seabed 300 is schematically indicated with a generally horizontal line. When landing the base structure 200 on the seabed 300, the channel walls 215 will extend into the seabed 300. In this manner, the base structure 200 will be anchored to the seabed 300 and will provide support to the top structure 100.

[0076] In some embodiments, the base structure 200 can comprise means for establishing a negative pressure within the channel 204, i.e. in the space between the seabed 300, the two channel walls 215, and the channel top face 217. Such means can for instance comprise a fluid communication interface through the channel top face 217 equipped with a suction interface 218. The suction interface 218 can typically connect to an ROV-operated suction device, by means of which the operator can pump fluid out from the channel 204, thereby forcing the base structure 200 into the seabed 300.

[0077] In scenarios where the operator is not using suction for forcing the base structure into the seabed, an opening in the channel 204 may still be advantageous. If the operator lowers the base structure 200 into the seabed by gravity or by application of another downwardly directed force, it may be advantageous to let fluid out of the channel through an opening. Hence, the suction interface 218 will still be advantageous even if not used for the provision of a negative pressure in the channel.

[0078] Reference is now made to Fig. 1, Fig. 4 and Fig. 6, for discussion of locking the top structure 100 to the base structure 200 after landing. As can be seen in Fig. 4, the base structure 200 comprises a base locking part 221. In the shown embodiment, the base locking part 221 is arranged on the channel top face 217 and in contact with the outer guiding face 203 of the landing guide element 201.

[0079] When the top structure 100 is in a landed position, a top structure locking part 121 is aligned with the base locking part 221. In the shown embodiment, one top structure locking part 121 is provided at the lower portion of each leg 105.

[0080] Fig. 6 depicts an enlarged cross section side view of the base locking part 221 and the top structure locking part 121, in a locked state. The base locking part 221 and the top structure locking part 121 are part of a locking arrangement 20.

[0081] The base locking part 221 protrudes up from the channel top wall 217. Furthermore, the base locking part 221 has at least one aperture 223, through which a locking bolt 122 extends, when in the locked mode. As shown in Fig. 6, the top structure locking part 121 has two top apertures 123, through which the locking bolt 122 extends.

[0082] The locking arrangement 20 further comprises a bolt housing 125, in which the locking bolt 122 is supported. The bolt housing 125 is configured to let the locking bolt 122 slide axially between a locked and unlocked position. In Fig. 6, the locking bolt 122 is shown in the locked position. By sliding it leftwards in the situation shown in Fig. 6, it will be moved into the unlocked position, i.e. out of engagement with the top aperture 121 and the base aperture 221. Such movement of the locking bolt 122 can advantageously be performed with an ROV.

[0083] The well protection assembly 1 according to the present invention is produced in a composite material, such as GRP (glass-fiber reinforced polymers). In preferred embodiments, both the top structure 100 and the base structure 200 are produced in GRP.

[0084] Furthermore, the top structure 100 and/or the base structure 200 are preferably produced with vacuum infusion.

[0085] Fig. 7 depicts the top protection structure 100 in a separate state, i.e. not installed on the base structure 200. Due to the relatively low weight of the top structure 100, it is provided with top structure ballast elements 127. The top structure ballast elements 127 increase the weight of the top structure 100 and facilitate landing on the base structure. In the embodiment shown herein, the top structure ballast elements 127 are integrated in two oppositely arranged lower beams 113 of the top structure 100.

[0086] In Fig. 7 the location of the inner guide wall 106 is indicated. As discussed above, the inner guide walls 106 will engage with the landing guide elements 201 on the base structure 200 during landing.

[0087] The base structure 200 is correspondingly provided with base ballast elements (not shown). In this embodiment, the base ballast elements are integrated in the base beams 213. The base ballast elements contribute in anchoring the base structure 200 to the seabed 300. They also contribute in forcing the channel walls 215 into the seabed 300 during installation. Advantageously, the base ballast elements 227 comprise metal, such as steel. Moreover, the base ballast elements 227 are advantageously fully encapsulated within the GRP material of the base structure 200, such as with a lamination sheet.

[0088] Still referring to Fig. 7, the side openings 111 are at their upper part of their perimeter provided with a skirt 129. While the general shape of the top structure 100 has an inclined outer face, the skirts 129 are substantially vertical. Advantageously, the skirts 129 extend along an edge portion at the lower part of the top ring section 109, in the position above the side openings 111, and some distance down on the legs 105. The legs 105 constitute a lateral boundary of

the side openings 111, and the skirts 129 advantageously extend some distance down along this boundary or edge.

[0089] The skirts 129 will contribute in preventing foreign objects, such as trawl equipment, to get stuck in the well protection assembly 1.

[0090] Provision of the skirts 129 makes the relatively large size of the side openings 111 possible.

[0091] In embodiments where the well protection assembly 1 comprises the protective top structure 100 and the base structure 200 in two separate parts, one may choose to land the base structure 200 on the seabed before landing the protective top structure 100 onto the base structure. One may also however choose to land both the protective top structure 100 and the base structure 200 simultaneously, while being attached together.

[0092] While the example of embodiment presented above relates to a single well protection structure, it shall be appreciated that at least some of the claims may relate to a well protection structure configured to protect a plurality of adjacently arranged wellheads.

[0093] Fig. 8 depicts a subsea protection structure 500 made of a fiber-reinforced composite material, such as GRP. It has a top portion 501, which in the shown embodiment comprises a substantially flat and horizontal upper face 503.

[0094] Down from the top portion 501 there extend six legs 505. The legs 505 comprise a free, lower end 507. The free lower ends 507 are supported only by the legs themselves, i.e. they are not attached to adjacent legs by a horizontal beam or the like. This facilitates placement of the protection structure 500 over subsea equipment that is connected to pipeline, an umbilical or the like extending from the equipment.

[0095] At the lower ends 507 of the legs 505 there is a foot portion 509. In this embodiment, the foot portion 509 is configured to land on the seabed.

[0096] Between the adjacent legs 505 there are side openings 511. The side openings provide access to equipment that is protected by the subsea protection structure 500.

[0097] At the upper perimeter of the side openings, there are provided downwardly extending skirts 529. The downwardly extending skirts 529 prevents fishing equipment or other possible equipment to get stuck at the upper edge of the side openings 511.

[0098] As can be seen from Fig. 8, the legs 505 comprises an inwardly open channel 513. In the shown embodiment, the channel has the general shape of the letter "U". This shape of the legs 505 provides stiffness. Moreover, this shape makes it possible to remove the legs from the mould after a moulding process.

[0099] The legs 505 are thus made of a sheet material, that is shaped like a channel, having an inwardly facing inner face and an outwardly directed outer face.

[0100] The subsea protection structure 500 can be moulded in one piece, i.e. the top portion 501 and the legs 505 are moulded with the same mould in one run.

[0101] As also appears from the view of Fig. 8, the legs 505 are larger at their lower portion than they are at a position between their lower portion and the top portion 501. In other words, the U-shape of their horizontal cross section through the channel exhibits a larger "U" close to the foot portion than at the location closer to the top portion 501.

[0102] While the subsea protection structure 500 shown herein has six legs 505, it shall be appreciated that it may in other embodiments have a larger or smaller number of legs, for instance four legs 505.

[0103] Fig. 9 depicts a cross section side view of a lower end 507 of one leg 505, comprising the foot portion 509. The foot portion 509 comprises a substantially downwardly extending anchoring wall 515. The anchoring wall 515 is configured to extend down into the seabed when the protection structure 500 has landed.

[0104] Furthermore, the foot portion 509 comprises a substantially horizontal support wall 517.

[0105] The channel 513 is also indicated in the view shown in Fig. 9.

[0106] Fig. 10 to Fig. 16 depict an alternative embodiment of the subsea well protection assembly 1 according to the invention. Corresponding to the assembly discussed above with reference to Fig. 1 to Fig. 7, the assembly shown in Fig. 10 to Fig. 16 also has a base structure 200 with a base structure ring 202. Other subsea well protection assemblies could however comprise the features particular to the assembly shown in Fig. 10 to Fig. 16, without the shown type of base structure 200.

[0107] Fig. 10 and Fig. 11 depict the subsea well protection assembly 1 in a perspective view and a front view, respectively. As appears from the front view of Fig. 11, the sides of assembly 1 have a somewhat curved shape 105b, curving inwards between the upper and lower portions of the assembly.

[0108] As appears in particular from Fig. 11, the assembly 1 has quite large side openings 111 that will give access to equipment protected by the assembly. The side openings are in the shown embodiment without hatches and provide access such as to an ROV performing operation on the protected equipment. Typically, the vertical distance between the lower and upper boundary of the side openings 111, i.e. the vertical distance between the top ring section 109 and the lower beam 113, can be between 5 and 9 meters, for instance 7 meters. Furthermore, the horizontal distance between two legs 105 that define the side boundaries of a side opening can typically be between 7 and 12 meters, for instance 9 meters.

[0109] While the side view of Fig. 11 depicts the subsea well protection assembly 1 from a front side, the view of Fig. 14 depicts the assembly with another side view, seen from a direction rotated 45 degrees about the vertical, with respect

to the view of Fig. 11. From this view, looking directly towards a corner of the assembly 1, it can be appreciated that the legs 105 comprise a substantially straight edge or ridge 105a. The curved shape 105b seen in the view shown in Fig. 11 and the straight ridge 105a seen in the view shown in Fig. 14 is provided by providing the legs 105 with a mid-portion 105c, which is thinner than the leg portion at the lower and upper ends of the leg.

[0110] Reference is now made to Fig. 12 and Fig. 13. In Fig. 12, the hatches 101 are shown in an open position. In Fig. 13, the hatches have been removed for illustrational purpose.

[0111] The hatches can advantageously be provided with buoyancy elements 101a that makes it possible for an ROV to open and close the hatches. The top aperture 103, which is closable with the hatches 101, can typically have side dimensions of about 4×4 meters to 9×9 meters, typically about 7×7 meters. Such a large top aperture 103 results in large hatches 101 which will have a considerable mass.

[0112] Corresponding to the embodiment discussed above with reference to Fig. 2, the assembly shown in Fig. 10 to Fig. 16 also has a ring interruption 115. The ring interruption facilitates connection of a pipeline to the wellhead equipment (such as a subsea tree). Furthermore, the subsea well protection assembly 1 shown in Fig. 10 to Fig. 16 comprises a removable bridging beam 109a (Fig. 10). The bridging beam 109a is configured to be releasably connected in the ring interruption 115, so that it completes the top ring section 109.

[0113] The possibility to remove a part of the top ring section 109, i.e. by removing the bridging beam 109, is advantageous for instance if the operator wants to install a pipeline, jumper or other large, elongated equipment from above and into the wellhead space 4 inside the assembly 1. Once the equipment is installed, the bridging beam 109a can be re-installed to complete the top ring section 109. The longitudinal dimension of the bridging beam 109a can typically be between 3 and 8 meters, for instance about 5 meters. The dimension of the ring interruption 115 will be related to the dimension of the bridging beam 109a.

[0114] The releasable attachment of the bridging beam 109a to the top ring section 109 will not be discussed in detail herein, as the skilled person will appreciate that this can be performed in different ways. For instance, a solution where locking bolts extend through aligned through holes can be used for releasable attachment. Advantageously, the locking, releasing and movement of the bridging beam is ROV operable.

[0115] Reference is now made to Fig. 15 and Fig. 16. These views illustrate a situation on the seabed 300, where a schematically depicted trawl door 401 is about to collide with the subsea well protection structure 1. The trawl door 401 is pulled by a trawl wire 403 which is part of a not shown fishing trawl. The trawl wire 403 has already collided with the top ring section 109 of the assembly 1.

[0116] The top ring section 109 of the assembly 1 has a substantially rectangular shape with four corners. Between each corner, the top ring section 109 comprises a wire deflection arrangement 110. In the shown embodiment, the wire deflection arrangement is in the form of a curved ridge 110.

[0117] While the general upper face of the top ring section 109 is relatively flat, cf. side view of Fig. 11, the curved ridges 110 protrude upwards from this general shape. The side view shown in Fig. 16 illustrates the trawl wire 403 colliding with a mid-portion of the subsea well protection assembly 1, i.e. between two corners of the rectangular shape of the top ring section 109. The trawl wire 403 will slide against one of the curved ridges 110. When doing so, the trawl wire 403 will be deflected towards one of the sides, i.e. towards one of the corners. This is due to the curved shape of the curved ridge 110. This deflection is illustrated with the upper arrow in Fig. 16.

[0118] As a result of the trawl wire 403 being deflected towards one of the corners of the top ring section 109, the trawl door 401 itself will collide with the assembly 1 at a side portion. Thus, instead of colliding with the subsea well protection assembly 1 in the middle of the side opening 111, the trawl door 401 is made to collide with the leg 105. This will make the trawl door 401 slide against the leg 105 and then pass the assembly 1 without getting stuck or without harming equipment inside the assembly.

[0119] The curving of the upper profile of the curved ridges 110 can typically have a radius of between 3 and 8 meters, typically about 5 meters. This will depend on the size of the subsea well protection assembly 1 and the dimensions of the top ring section 109.

[0120] As appears perhaps best from the side view of Fig. 14, the curved upper face of the curved ridges 110 can advantageously be substantially flush with the curved faces of the corners 109b of the top ring section 109 (i.e. the location where a corner of the top ring section 109 interfaces with the upper portion of a leg 105).

[0121] Reference is now made to Fig. 17, which shows an alternative embodiment of the subsea well protection assembly 1 according to the invention. In this embodiment, the top structure 100 comprises a releasable top frame 130. The releasable top frame 130 is configured to be releasably fitted in the top ring section 109. Although the releasable top frame 130 depicts only parts of the hinges and not the hinged hatches, it comprises one or more hatches 101 (cf. Fig. 10) that are configured to open and close a top frame aperture 131.

[0122] The releasable top frame 130 is shown in a side view in Fig. 18.

[0123] In this embodiment, the releasable top frame 130 comprises the wire deflection arrangement, in the form of curved ridges 110 as discussed above.

[0124] With the releasable top frame 130, the operator has flexibility when needing access from above. The hatches

101 can be opened if that provides a sufficient access, while the entire releasable top frame 130 can be removed if a larger opening is needed.

[0125] As shown in Fig. 17 and Fig. 18, the bridging beam 109a can be integrated in the releasable top frame 130. Hence, if the operator shall land an elongated, horizontally extending member into the wellhead space 4, for instance a jumper, the bridging beam 109a can be removed by lifting off the releasable top frame 130.

[0126] The subsea well protection structure 1 discussed with reference to Fig. 1 and Fig. 7 (inter alia) has a side opening 111 with a vertically extending skirt 129. Contrary to this, the embodiment shown in Fig. 10 to Fig. 21 involves a side opening 111 having side opening edges 111a that have a curved profile. Advantageously, the entire side opening 111 is enclosed by side opening edges 111a that have the curved profile. In some embodiments though, only the upper horizontal side opening edge 111a and the side opening edges 111a on the sides of the side opening 111 have the curved profile.

[0127] Having the said curved profile reduces the risk of a trawl door 401 getting stuck at a side opening edge 111a or needing excessive pull in the trawl wire 403 before disengaging. As indicated in Fig. 17 and Fig. 18, also the bridging beam 109a has the curved profile, corresponding to the curved profile of the side opening edges 111a.

[0128] Fig. 19a, Fig. 19b, and Fig. 19c depict cross section views of various profiles of the side opening edge 111a. As shown, the curvature radius can be different for various embodiments. However, there are no sharp edges in which a trawl door or similar equipment will get stuck when colliding with the subsea well protection assembly 1. As appears from these drawings, the profiles can be assembled with e.g. two separate pieces that are joined together. It is, however, also possible to form the profiles in one single piece.

[0129] In some embodiments, the curved profile of the side opening edge 111a can be made separately and be installed in the side openings 111. Alternatively, the curved profiles can be made as an integrated part of the main body of the top structure 100.

[0130] Fig. 20 shows a profile of an edge portion of the releasable top frame 130. Also shown is a curved ridge 110.

[0131] Fig. 21 depicts such an edge portion in closer detail, corresponding to the view shown in Fig. 17.

[0132] The profiles of the side opening edge 111a can advantageously be made of a plate-shaped fiber-reinforced material, such as shown in Fig. 19a, Fig. 19b, Fig. 19c and Fig. 20. The curved shape of the profile can advantageously end in a profile end 111b. In the embodiments shown herein, such as Fig. 17 and Fig. 19a, Fig. 19b, Fig. 19c, and Fig. 20, the profile end 111b points inwards towards the wellhead space 4 of the subsea well protection assembly 1. Thus, the profile end 111b points away from possible equipment that could collide with the subsea well protection assembly 1, such as a trawl door. In other terms, the profile end 111b points away from the outwardly facing direction of the side openings 111.

[0133] Advantageously, the subsea well protection assembly 1 discussed with reference to Fig. 10 to Fig. 21 is made of a fiber-reinforced composite material. The releasable bridging beam 109a is advantageously made of the same material as the rest of the assembly. Also, in embodiments involving the releasable top frame 130, the releasable top frame 130 can also be made of a fiber-reinforced composite material. The scope of the invention is set out solely by the appended claims that follow.

Claims

1. A subsea well protection assembly (1), comprising a base structure (200) configured to rest on the seabed, and a top structure (100) extending upwards from the base structure (200), wherein the top structure is configured to cover a wellhead space (4), wherein the wellhead space (4) is configured to accommodate a wellhead (3) of a subsea well, wherein the base structure (200) and/or the top structure (100) is made of a fiber-reinforced composite material, wherein the top structure (100) comprises a top ring section (109) with a rectangular shape defining four corners (109b), wherein the top ring section comprises upwardly protruding wire deflection arrangements (110) between the corners.
2. The subsea well protection assembly (1) according to claim 1, **characterized in that** the wire deflection arrangements (110) are upwardly protruding, curved ridges.
3. The subsea well protection assembly (1) according to claim 1 or claim 2, **characterized in that** the corners (109b) have a rounded shape and that the curved shape of the wire deflection arrangements (110) is flush with the rounded shape of the corners (109b).
4. The subsea well protection assembly (1) according to one of the preceding claims, **characterized in that** the top structure (100) comprises a releasable top frame (130) configured to land on the top ring section (109).

5. The subsea well protection assembly according to claim 4, **characterized in that** the releasable top frame (130) comprises wire deflection arrangements (110) positioned between the corners (109b) when in position installed on the top structure (100).

6. The subsea well protection assembly (1) according to any one of the preceding claims, **characterized in that** the top structure (100) comprises

- four legs (105) extending downwards from the top ring section;
- side openings (111) confined between the top ring section (109), and the legs (105);
- wherein the side openings (111) comprise side opening edges (111a), and
- wherein the side opening edges (111a) comprise a curved profile.

7. The subsea well protection assembly (1) according to claim 6, **characterized in that** the side opening edges (111a) are made of a plate-shaped material, and that the curved profile ends in a profile end (111b).

8. The subsea well protection assembly (1) according to claim 7, **characterized in that** the profile end (111b) points away from the outwardly facing direction of the side opening (111).

9. The subsea well protection assembly (1) according to one of the preceding claims, **characterized in that** the base structure (200) comprises a base structure ring (202), and that the base structure ring (202) comprises two downwardly extending walls (215) forming a downwardly open channel (204), with the two downwardly extending channel walls (215) configured to extend into the seabed.

10. The subsea well protection assembly (1) according to one of the preceding claims, **characterized in that** the top structure (100) and the base structure (200) are two separate, dismountable parts, that the base structure (200) comprises a base structure ring (202) and that the base structure ring (202) exhibits a rectangular shape and comprises a landing guide element (201), wherein the landing guide element is configured to engage with the top structure during landing of the top structure on the base structure.

11. The subsea well protection assembly (1) according to claim 10, **characterized in that** the base structure ring (202) comprises a plurality of landing guide elements (201) and that these comprise an outer guiding face (203) with an inclination in relation to the vertical, and that the top structure (100) comprises inner guide walls (106) configured to engage with the outer guiding faces (203) upon landing of the top structure (100) on the base structure (200).

12. The subsea well protection assembly according to one of the claims 1 to 9, **characterized in that** the top structure (100) and the base structure (200) together is one single unit.

13. The subsea well protection assembly (1) according to any one of the preceding claims, wherein the top structure (100) comprises

- four legs (105) extending downwards from the top ring section (109);
- lower beams (113) extending between lower portions of adjacent legs (105);
- side openings (111) confined between the top ring section (109), legs (105) and the lower beams (113);

characterized in

- **that** at least one of the side openings (111) is downwardly open; or
- **that** the top ring section (109) comprises a ring interruption (115), making the top ring section discontinuous.

14. The subsea well protection assembly (1) according to claim 13, **characterized in that** one or more of the side openings (111) comprise a downwardly extending skirt (129) at their upper part of their perimeter.

Patentansprüche

1. Unterwasser-Bohrlochschutzbaugruppe (1), umfassend eine Grundstruktur (200), die konfiguriert ist, um auf dem Meeresboden zu liegen, und eine obere Struktur (100), die sich von der Grundstruktur (200) nach oben erstreckt,

wobei die obere Struktur konfiguriert ist, um einen Bohrlochkopfraum (4) abzudecken, wobei der Bohrlochkopfraum (4) konfiguriert ist, um einen Bohrlochkopf (3) eines Unterwasserbohrlochs aufzunehmen, wobei die Grundstruktur (200) und/oder die obere Struktur (100) aus einem faserverstärkten Verbundmaterial hergestellt ist, wobei die obere Struktur (100) einen oberen Ringabschnitt (109) mit einer rechteckigen Form, die vier Ecken (109b) definiert, umfasst, wobei der obere Ringabschnitt nach oben vorstehende Drahtumlenkanordnungen (110) zwischen den Ecken umfasst.

2. Unterwasser-Bohrlochschutzbaugruppe (1) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Drahtumlenkanordnungen (110) nach oben vorstehende, gekrümmte Rippen sind.

3. Unterwasser-Bohrlochschutzbaugruppe (1) nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die Ecken (109b) eine abgerundete Form aufweisen und dass die gekrümmte Form der Drahtumlenkanordnungen (110) mit der abgerundeten Form der Ecken (109b) bündig ist.

4. Unterwasser-Bohrlochschutzbaugruppe (1) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** die obere Struktur (100) einen lösbaren oberen Rahmen (130) umfasst, der konfiguriert ist, um auf dem oberen Ringabschnitt (109) zu landen.

5. Unterwasser-Bohrlochschutzbaugruppe nach Anspruch 4, **dadurch gekennzeichnet, dass** der lösbare obere Rahmen (130) Drahtumlenkanordnungen (110) umfasst, die zwischen den Ecken (109b) positioniert sind, wenn sie auf der oberen Struktur (100) in Position installiert sind.

6. Unterwasser-Bohrlochschutzbaugruppe (1) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** die obere Struktur (100) umfasst

- vier Schenkel (105), die sich von dem oberen Ringabschnitt nach unten erstrecken;
- Seitenöffnungen (111), die zwischen dem oberen Ringabschnitt (109) und den Schenkeln (105) eingeschlossen sind;
- wobei die Seitenöffnungen (111) Seitenöffnungskanten (111a) umfassen, und
- wobei die Seitenöffnungskanten (111a) ein gekrümmtes Profil umfassen.

7. Unterwasser-Bohrlochschutzbaugruppe (1) nach Anspruch 6, **dadurch gekennzeichnet, dass** die Seitenöffnungskanten (111a) aus einem plattenförmigen Material hergestellt sind und dass das gekrümmte Profilende in einem Profilende (111b) endet.

8. Unterwasser-Bohrlochschutzbaugruppe (1) nach Anspruch 7, **dadurch gekennzeichnet, dass** das Profilende (111b) von der nach außen gewandten Richtung der Seitenöffnung (111) weg zeigt.

9. Unterwasser-Bohrlochschutzbaugruppe (1) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** die Grundstruktur (200) einen Grundstrukturring (202) umfasst und dass der Grundstrukturring (202) zwei sich nach unten erstreckende Wände (215), die einen nach unten offenen Kanal (204) ausbilden, umfasst, wobei die zwei sich nach unten erstreckenden Kanalwände (215) konfiguriert sind, um sich in den Meeresboden zu erstrecken.

10. Unterwasser-Bohrlochschutzbaugruppe (1) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** die obere Struktur (100) und die Grundstruktur (200) zwei separate, zerlegbare Teile sind, dass die Grundstruktur (200) einen Grundstrukturring (202) umfasst und dass der Grundstrukturring (202) eine rechteckige Form vorweist und ein Landeführungselement (201) umfasst, wobei das Landeführungselement konfiguriert ist, um während einem Landen der oberen Struktur auf der Grundstruktur mit der oberen Struktur in Eingriff zu kommen.

11. Unterwasser-Bohrlochschutzbaugruppe (1) nach Anspruch 10, **dadurch gekennzeichnet, dass** der Grundstrukturring (202) eine Vielzahl von Landeführungselementen (201) umfasst und dass diese eine äußere Führungsfläche (203) mit einer Neigung in Bezug auf die Vertikale umfassen, und dass die obere Struktur (100) innere Führungswände (106) umfasst, die konfiguriert sind, um mit den äußeren Führungsflächen (203) bei dem Landen der oberen Struktur (100) auf der Grundstruktur (200) in Eingriff zu kommen.

12. Unterwasser-Bohrlochschutzbaugruppe nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet, dass** die

obere Struktur (100) und die Grundstruktur (200) zusammen eine einzige Einheit sind.

13. Unterwasser-Bohrlochschutzbaugruppe (1) nach einem der vorstehenden Ansprüche, wobei die obere Struktur (100) umfasst

- vier Schenkel (105), die sich von dem oberen Ringabschnitt (109) nach unten erstrecken;
- untere Träger (113), die sich zwischen unteren Partien von benachbarten Schenkeln (105) erstrecken;
- Seitenöffnungen (111), die zwischen dem oberen Ringabschnitt (109), Schenkeln (105) und den unteren Trägern (113) eingeschlossen sind;

dadurch gekennzeichnet

- **dass** mindestens eine der Seitenöffnungen (111) nach unten offen ist; oder
- **dass** der obere Ringabschnitt (109) eine Ringstörung (115) umfasst, wodurch der obere Ringabschnitt unterbrochen wird.

14. Unterwasser-Bohrlochschutzbaugruppe (1) nach Anspruch 13, **dadurch gekennzeichnet, dass** eine oder mehrere der Seitenöffnungen (111) eine sich nach unten erstreckende Schürze (129) an ihrem oberen Teil ihres Umfangs umfassen.

Revendications

1. Ensemble de protection de puits sous-marin (1), comprenant une structure de base (200) configurée pour reposer sur le fond marin, et une structure supérieure (100) s'étendant vers le haut à partir de la structure de base (200), dans lequel la structure supérieure est configurée pour couvrir un espace de tête de puits (4), dans lequel l'espace de tête de puits (4) est configuré pour recevoir une tête de puits (3) d'un puits sous-marin, dans lequel la structure de base (200) et/ou la structure supérieure (100) sont constituées d'un matériau composite renforcé par des fibres, dans lequel la structure supérieure (100) comprend une section annulaire supérieure (109) ayant une forme rectangulaire définissant quatre coins (109b), dans lequel la section annulaire supérieure comprend des agencements de déviation de fil (110) faisant saillie vers le haut entre les coins.

2. Ensemble de protection de puits sous-marin (1) selon la revendication 1, **caractérisé en ce que** les agencements de déviation de fil (110) sont des crêtes incurvées faisant saillie vers le haut.

3. Ensemble de protection de puits sous-marin (1) selon la revendication 1 ou la revendication 2, **caractérisé en ce que** les coins (109b) ont une forme arrondie et que la forme incurvée des agencements de déviation de fil (110) affleure la forme arrondie des coins (109b).

4. Ensemble de protection de puits sous-marin (1) selon l'une des revendications précédentes, **caractérisé en ce que** la structure supérieure (100) comprend un cadre supérieur libérable (130) configuré pour atterrir sur la section annulaire supérieure (109).

5. Ensemble de protection de puits sous-marin selon la revendication 4, **caractérisé en ce que** le cadre supérieur libérable (130) comprend des agencements de déviation de fil (110) positionnés entre les coins (109b) lorsqu'ils sont en position installée sur la structure supérieure (100).

6. Ensemble de protection de puits sous-marin (1) selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la structure supérieure (100) comprend

- quatre pattes (105) s'étendant vers le bas à partir de la section annulaire supérieure ;
- des ouvertures latérales (111) confinées entre la section annulaire supérieure (109), et les pattes (105) ; dans lequel les ouvertures latérales (111) comprennent des bords d'ouverture latérale (111a), et dans lequel les bords d'ouverture latérale (111a) comprennent un profil incurvé.

7. Ensemble de protection de puits sous-marin (1) selon la revendication 6, **caractérisé en ce que** les bords d'ouverture latérale (111a) sont constitués d'un matériau en forme de plaque, et que le profil incurvé se termine dans une extrémité de profil (111b).

8. Ensemble de protection de puits sous-marin (1) selon la revendication 7, **caractérisé en ce que** l'extrémité de profil

(111b) pointe à l'opposé de la direction tournée vers l'extérieur de l'ouverture latérale (111).

5 9. Ensemble de protection de puits sous-marin (1) selon l'une des revendications précédentes, **caractérisé en ce que** la structure de base (200) comprend un anneau de structure de base (202), et que l'anneau de structure de base (202) comprend deux parois s'étendant vers le bas (215) formant un canal ouvert vers le bas (204), les deux parois de canal s'étendant vers le bas (215) étant configurées pour s'étendre dans le fond marin.

10 10. Ensemble de protection de puits sous-marin (1) selon l'une des revendications précédentes, **caractérisé en ce que** la structure supérieure (100) et la structure de base (200) sont deux parties démontables distinctes, que la structure de base (200) comprend un anneau de structure de base (202) et que l'anneau de structure de base (202) présente une forme rectangulaire et comprend un élément de guidage d'atterrissage (201), dans lequel l'élément de guidage d'atterrissage est configuré pour venir en prise avec la structure supérieure pendant l'atterrissage de la structure supérieure sur la structure de base.

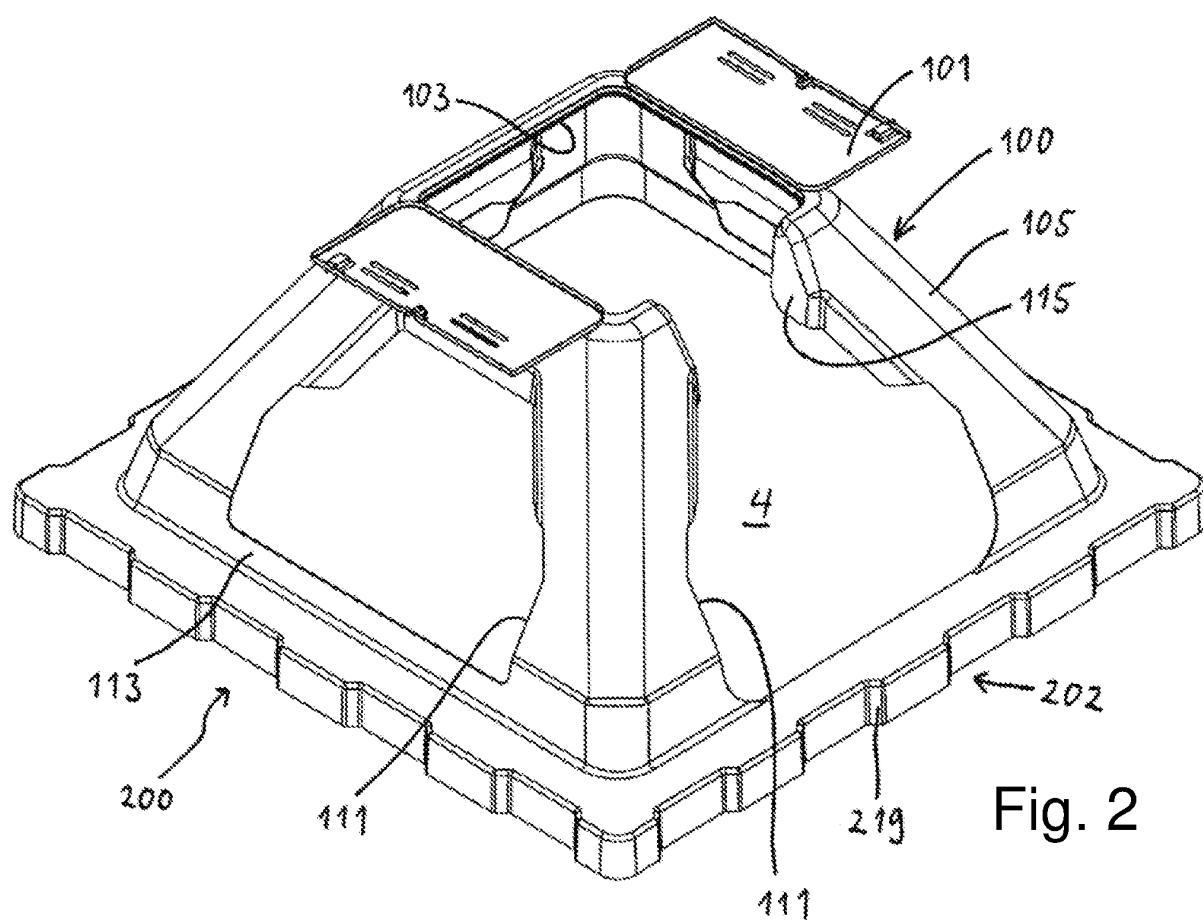
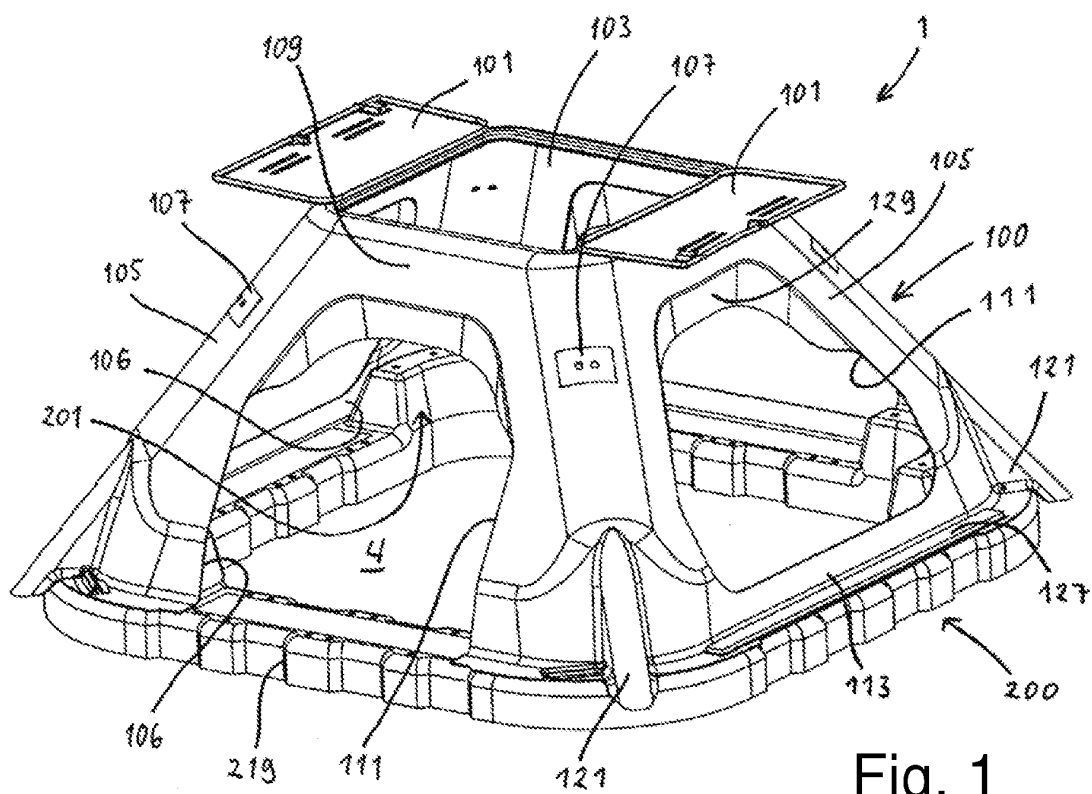
15 11. Ensemble de protection de puits sous-marin (1) selon la revendication 10, **caractérisé en ce que** l'anneau de structure de base (202) comprend une pluralité d'éléments de guidage d'atterrissage (201) et que ceux-ci comprennent une face de guidage externe (203) ayant une inclinaison par rapport à la verticale, et que la structure supérieure (100) comprend des parois de guidage internes (106) configurées pour venir en prise avec les faces de guidage externes (203) lors de l'atterrissage de la structure supérieure (100) sur la structure de base (200).

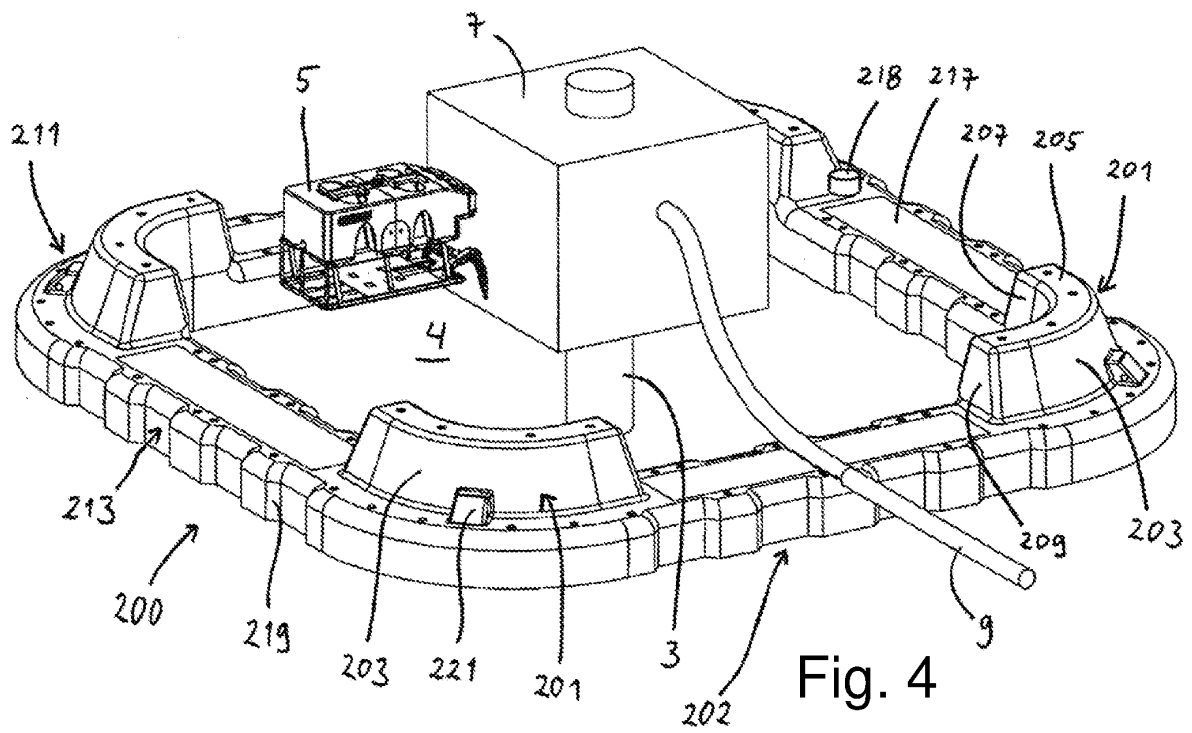
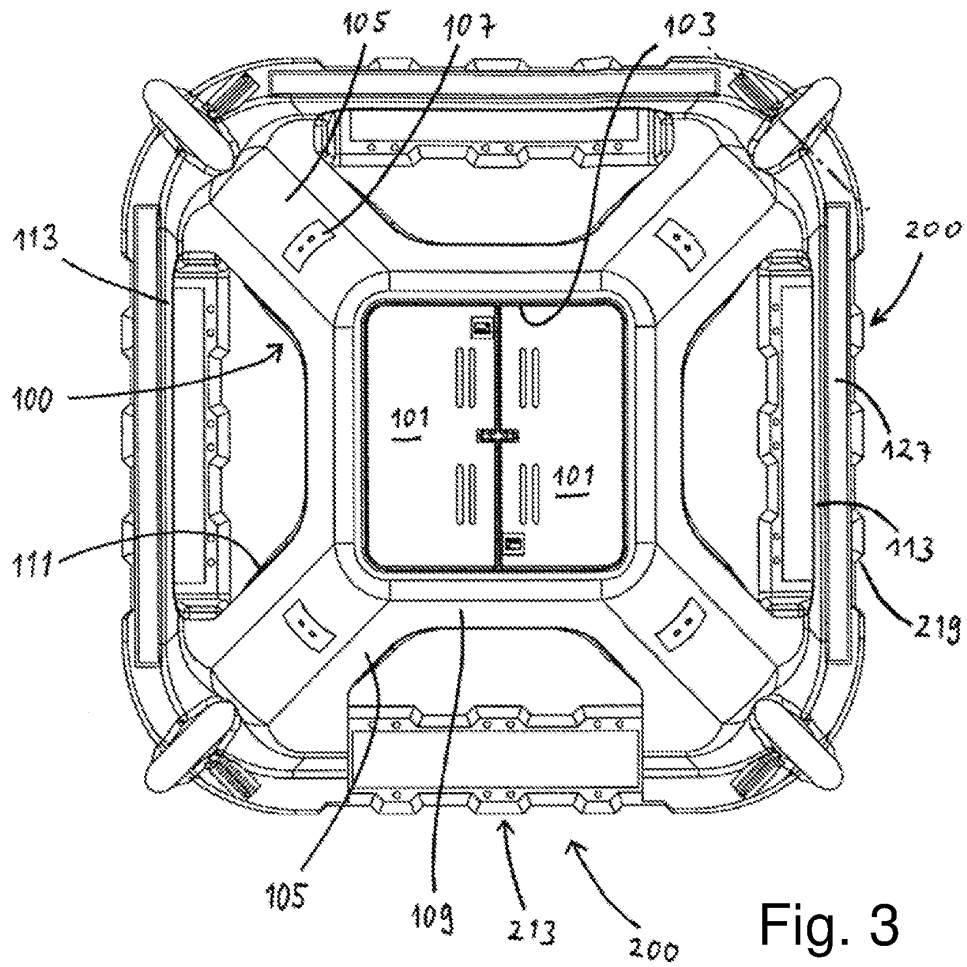
20 12. Ensemble de protection de puits sous-marin selon l'une des revendications 1 à 9, **caractérisé en ce que** la structure supérieure (100) et la structure de base (200) sont ensemble une seule unité.

25 13. Ensemble de protection de puits sous-marin (1) selon l'une quelconque des revendications précédentes, dans lequel la structure supérieure (100) comprend

- quatre pattes (105) s'étendant vers le bas à partir de la section annulaire supérieure (109) ;
 - des barres inférieures (113) s'étendant entre des parties inférieures de pattes adjacentes (105) ;
 - des ouvertures latérales (111) confinées entre la section annulaire supérieure (109), les pattes (105) et les barres inférieures (113) ;
- 30 **caractérisé en ce que**
- au moins une des ouvertures latérales (111) est ouverte vers le bas ; ou
 - la section annulaire supérieure (109) comprend une interruption annulaire (115), rendant la section annulaire supérieure discontinue.

35 14. Ensemble de protection de puits sous-marin (1) selon la revendication 13, **caractérisé en ce que** une ou plusieurs des ouvertures latérales (111) comprennent une jupe s'étendant vers le bas (129) au niveau de leur partie supérieure de leur périmètre.





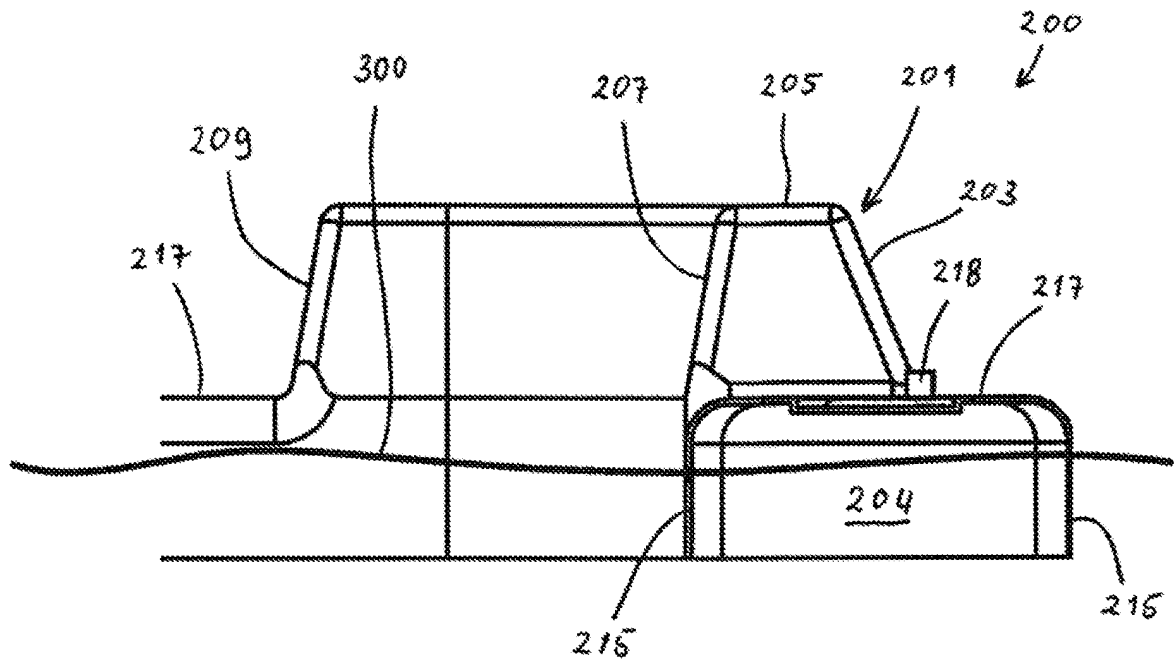


Fig. 5

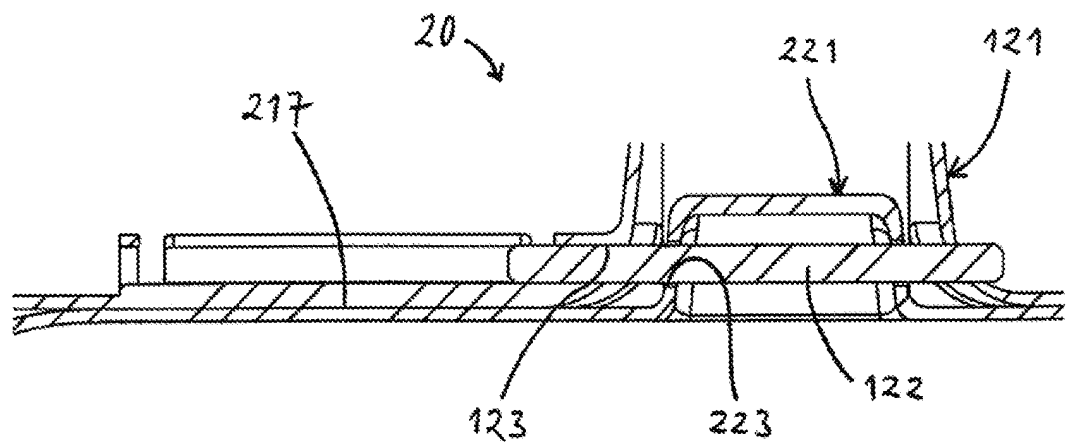
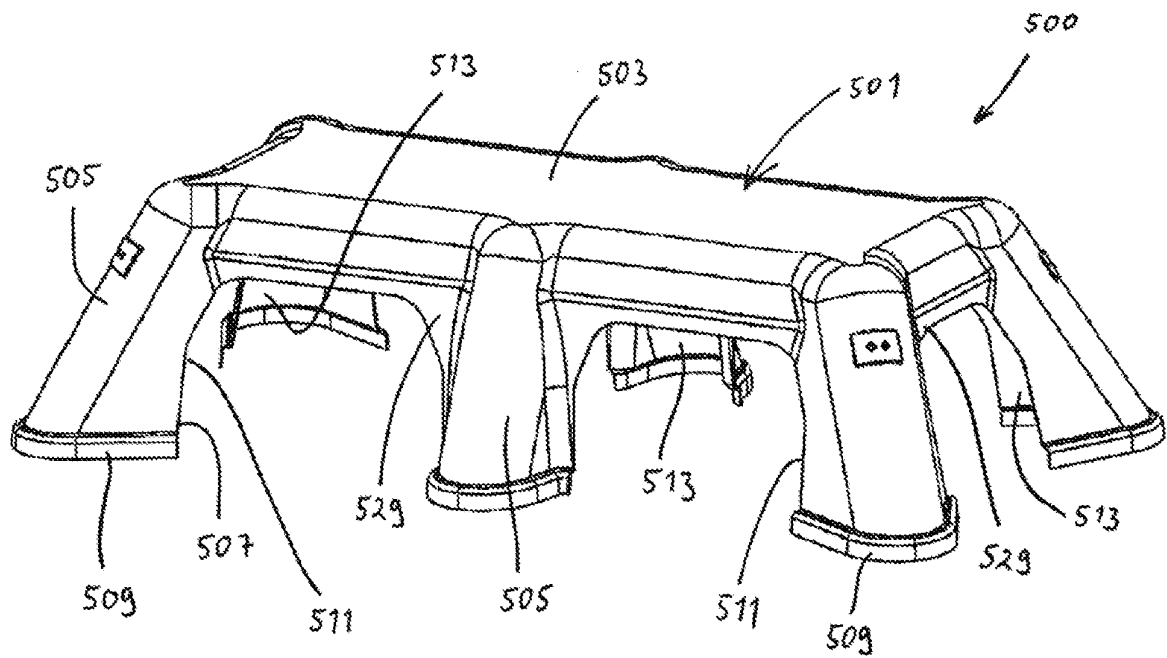
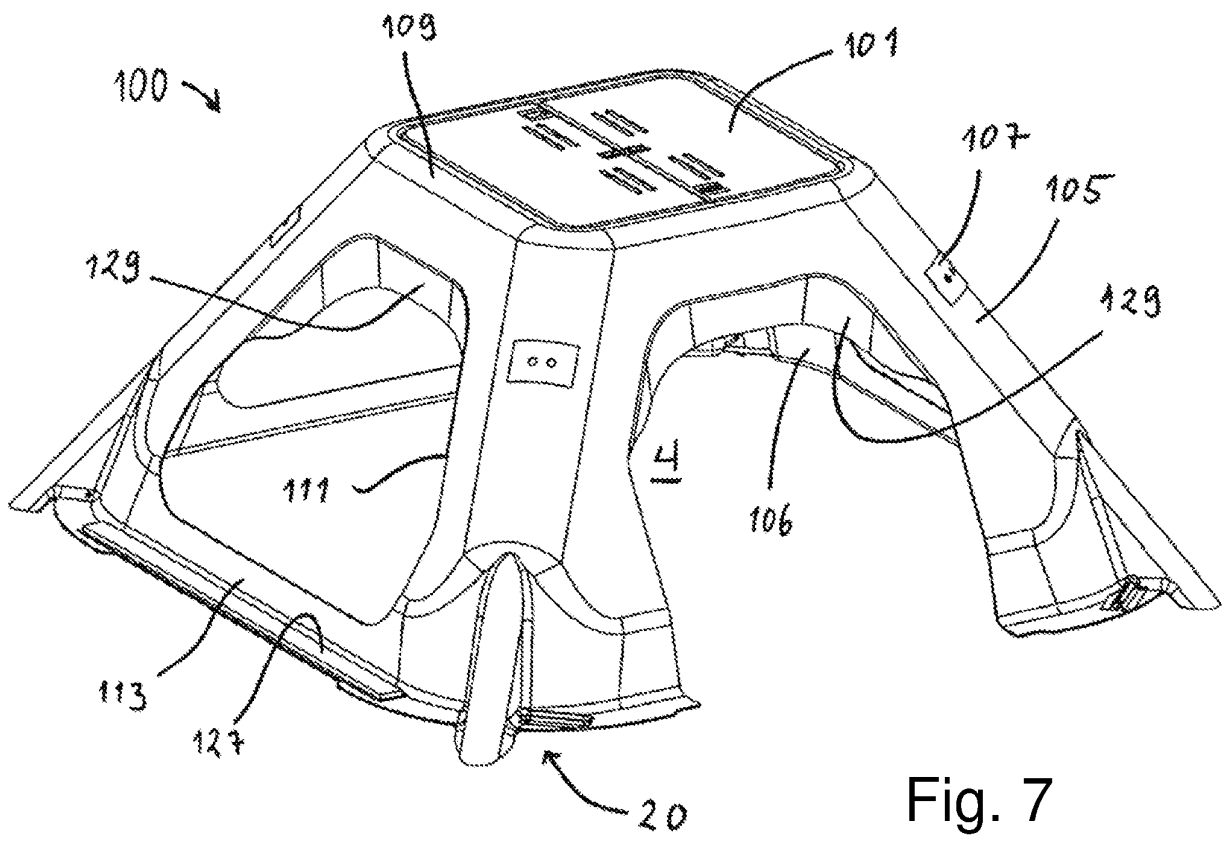


Fig. 6



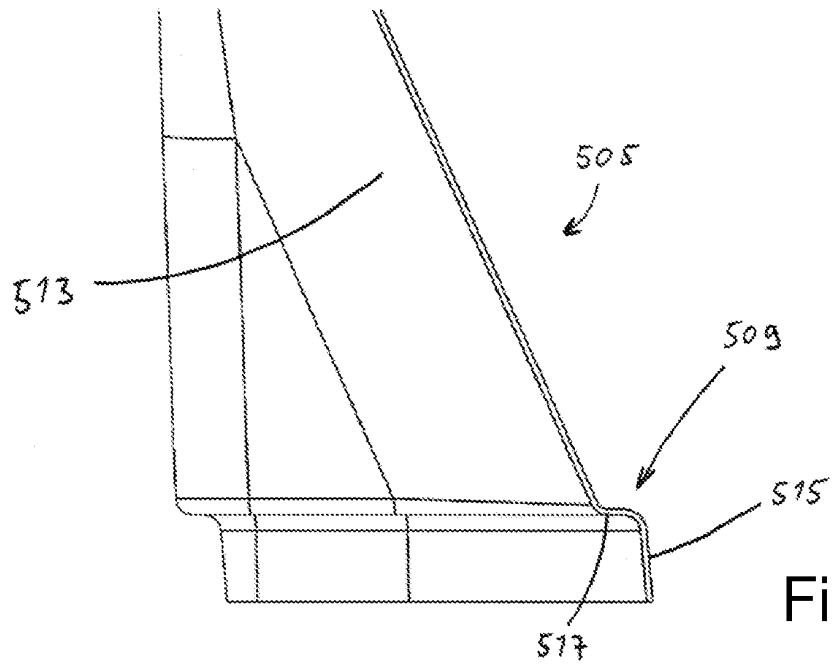


Fig. 9

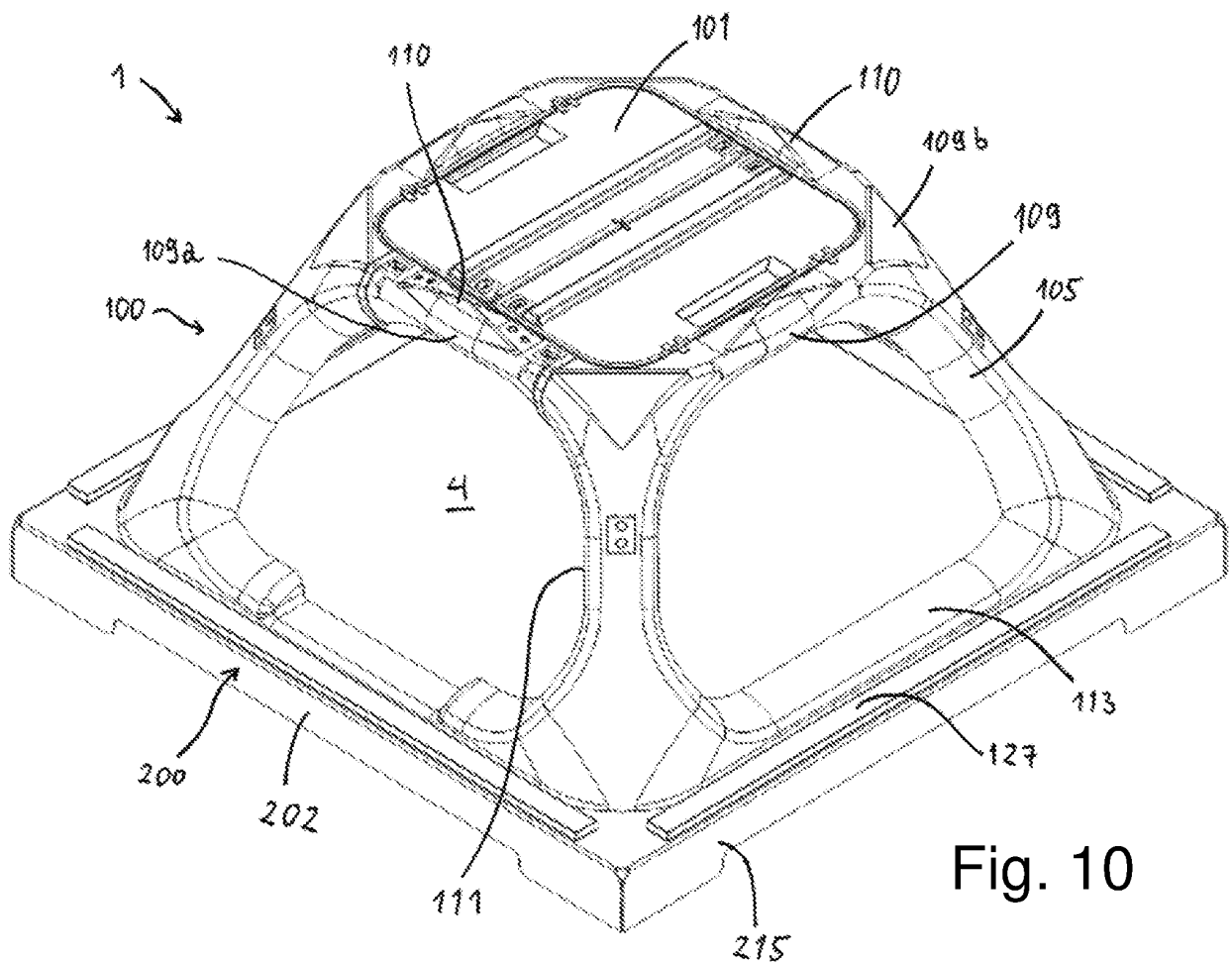


Fig. 10

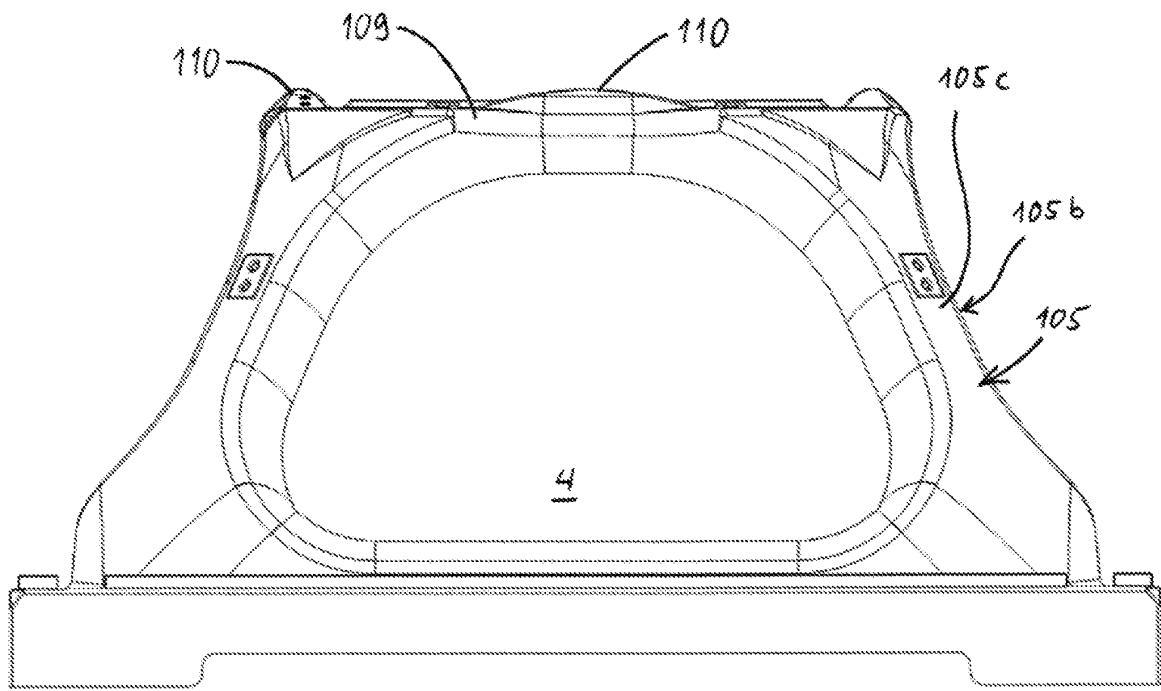


Fig. 11

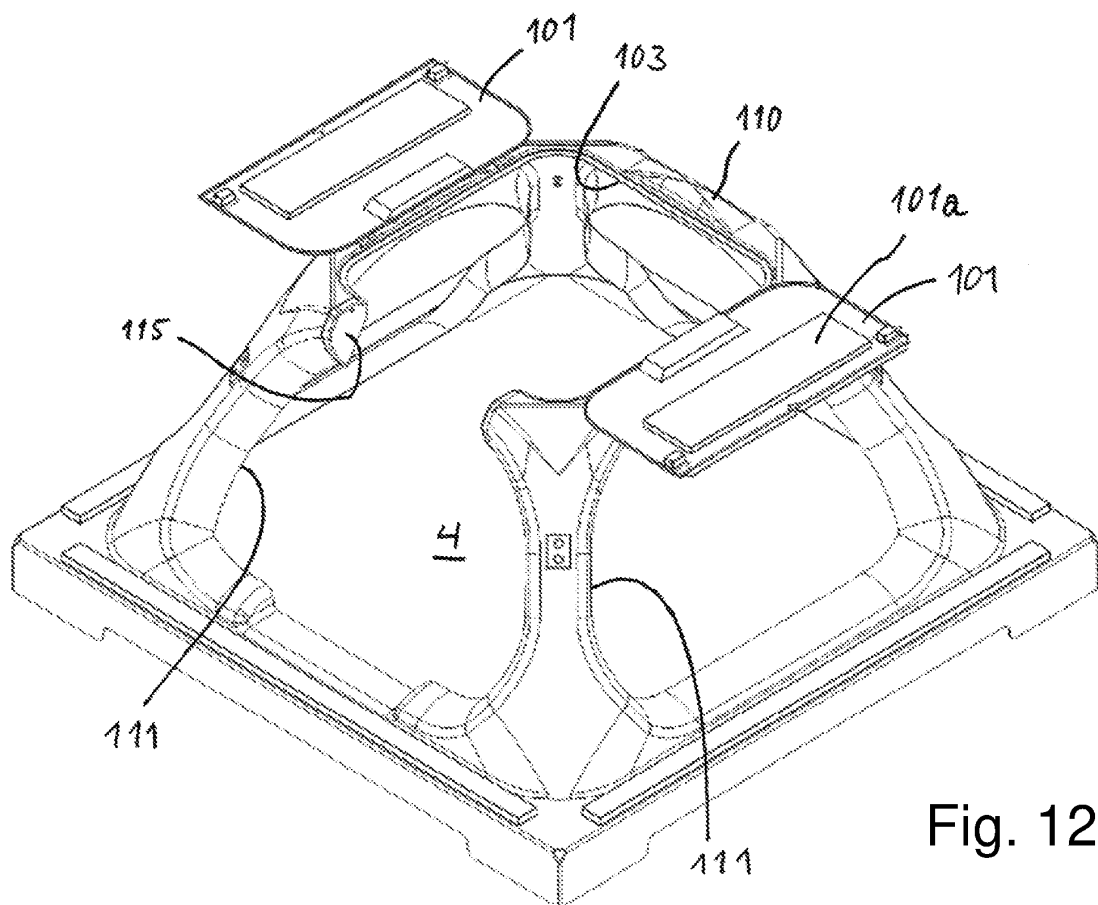


Fig. 12

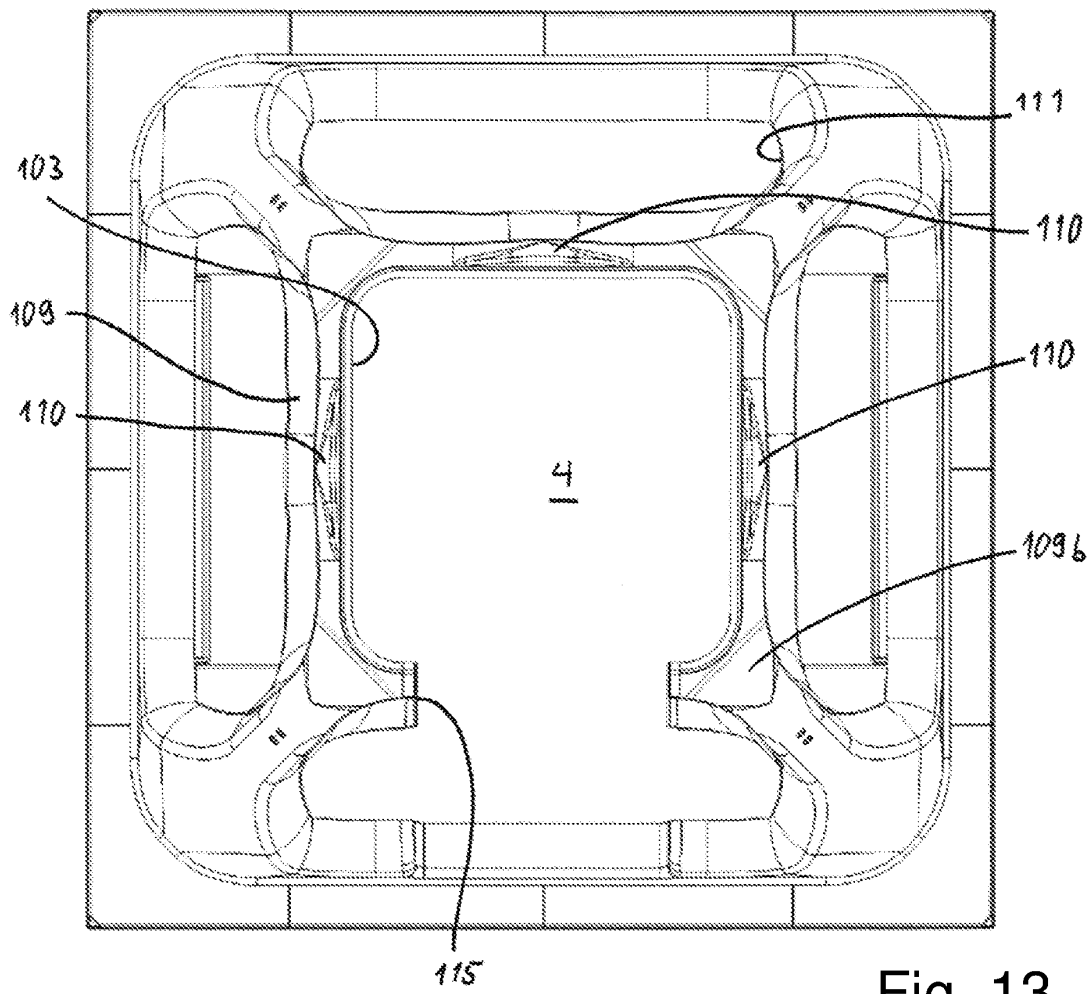


Fig. 13

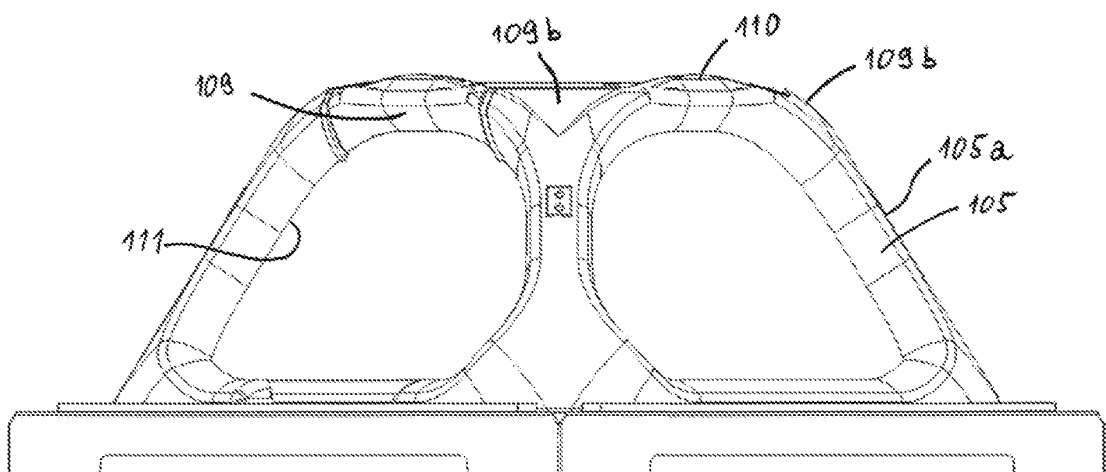


Fig. 14

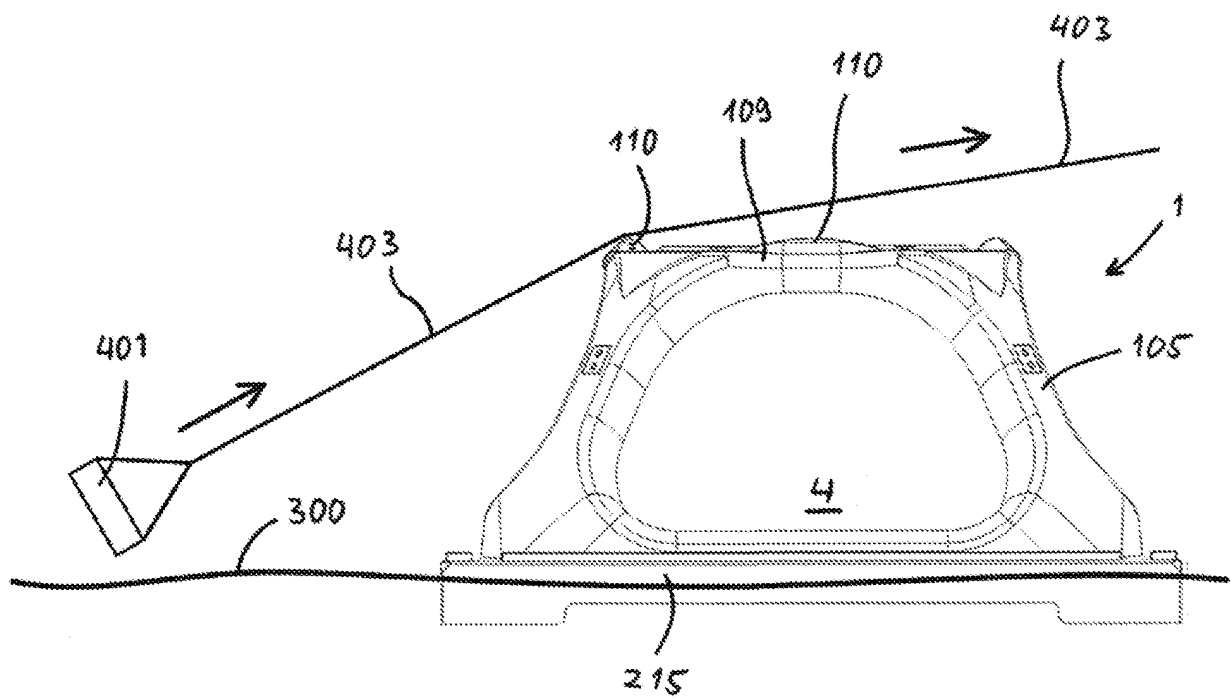


Fig. 15

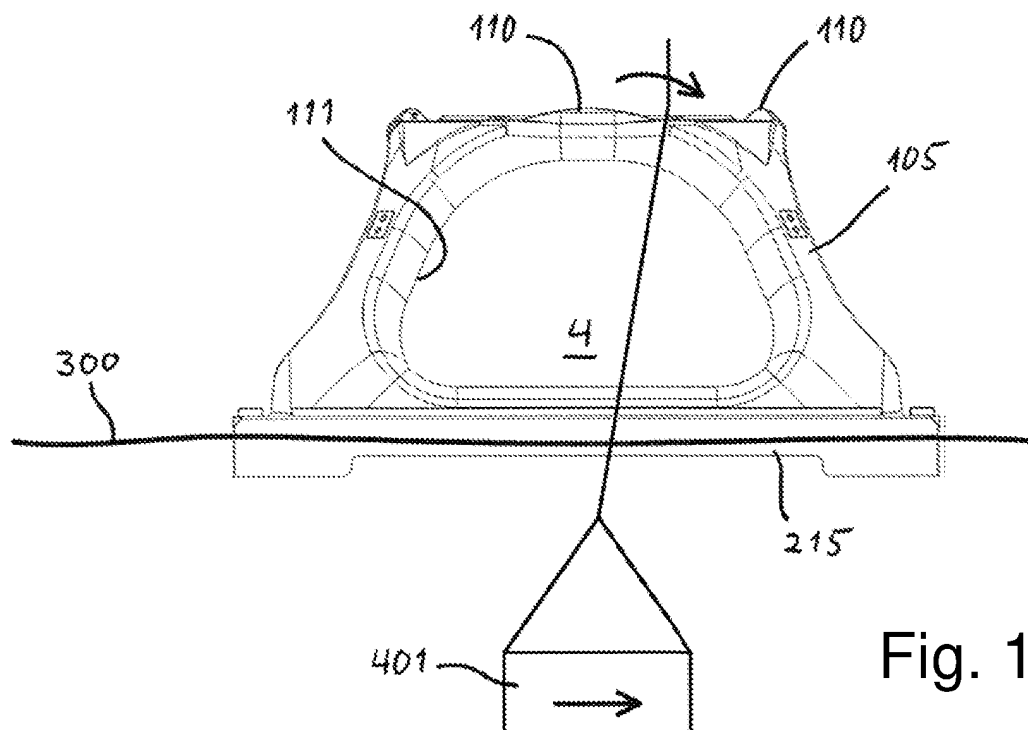
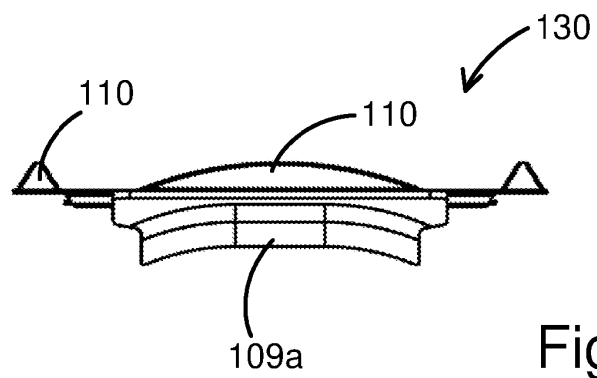
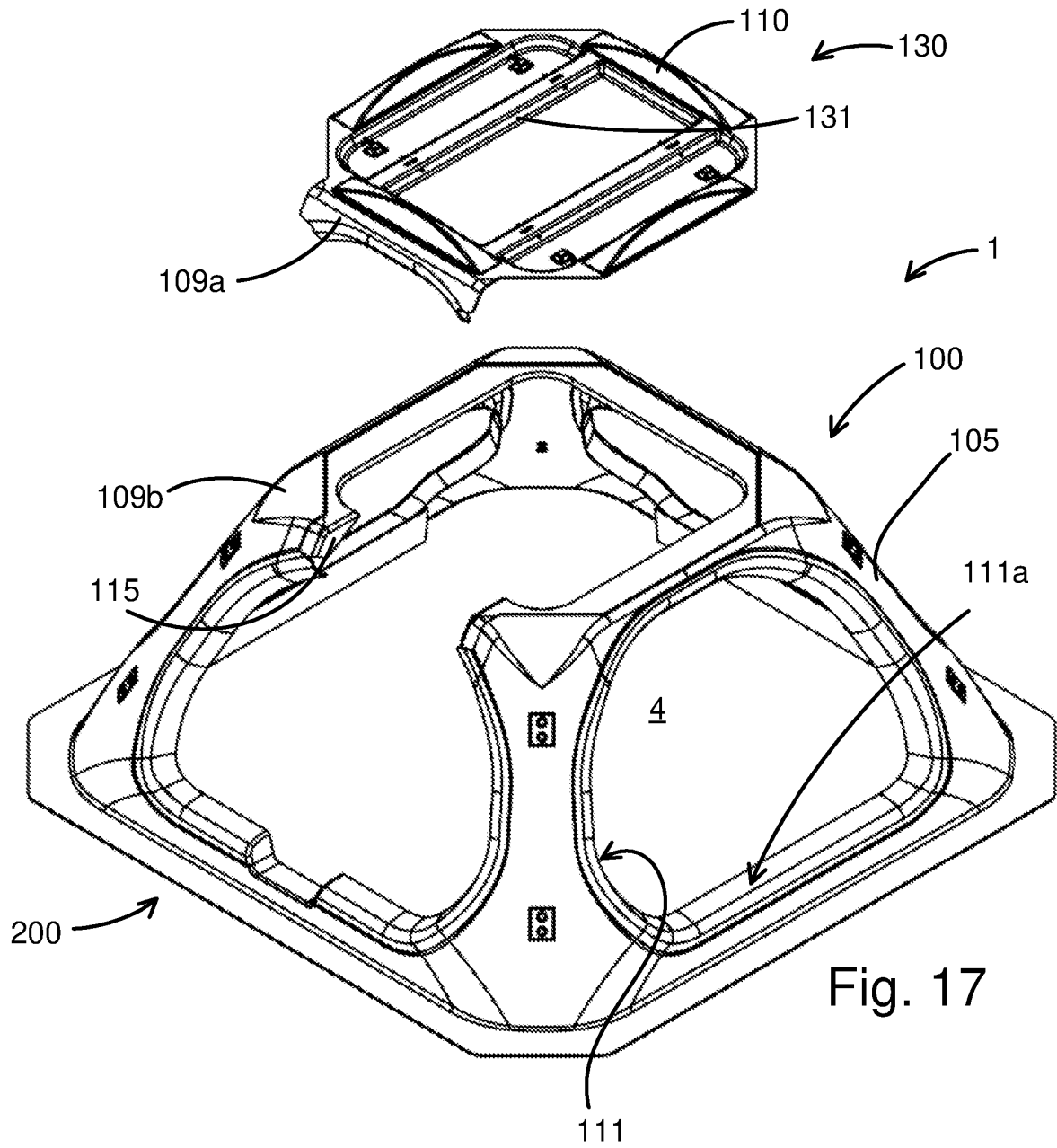


Fig. 16



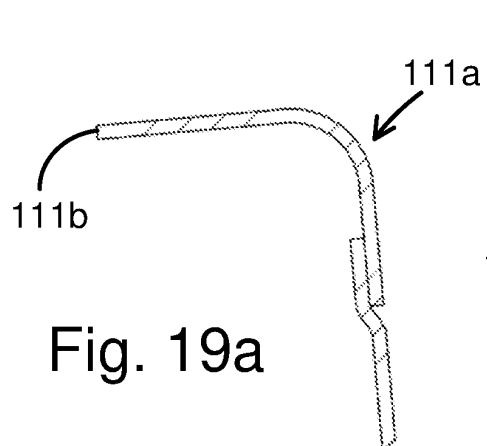


Fig. 19a

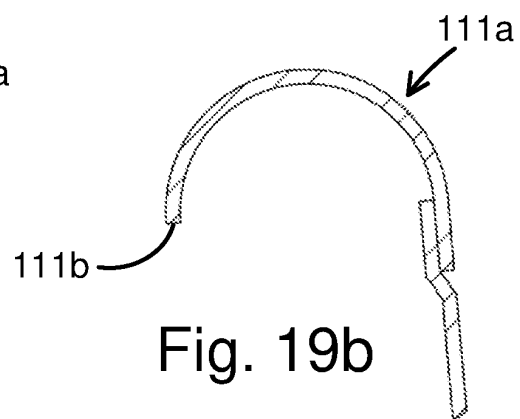


Fig. 19b

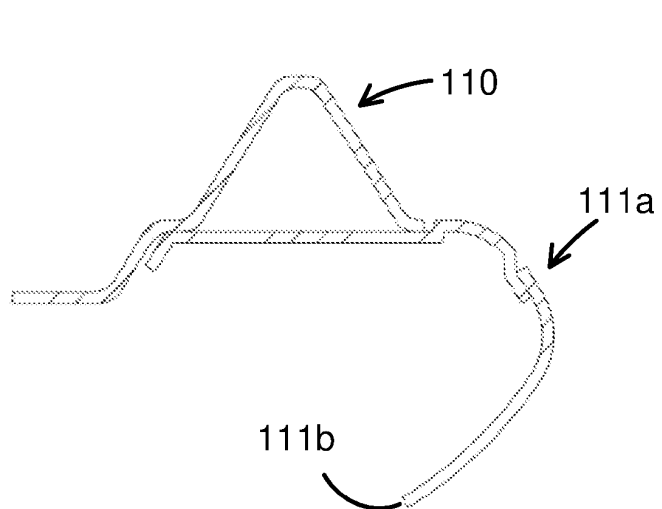


Fig. 20

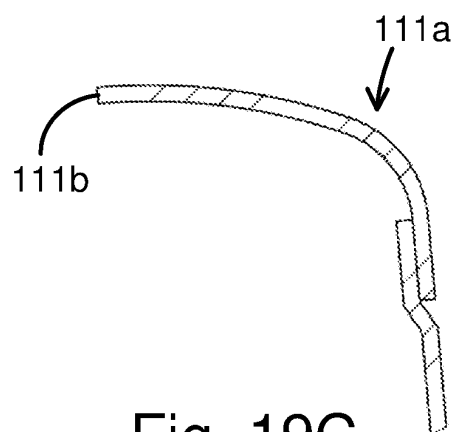


Fig. 19C

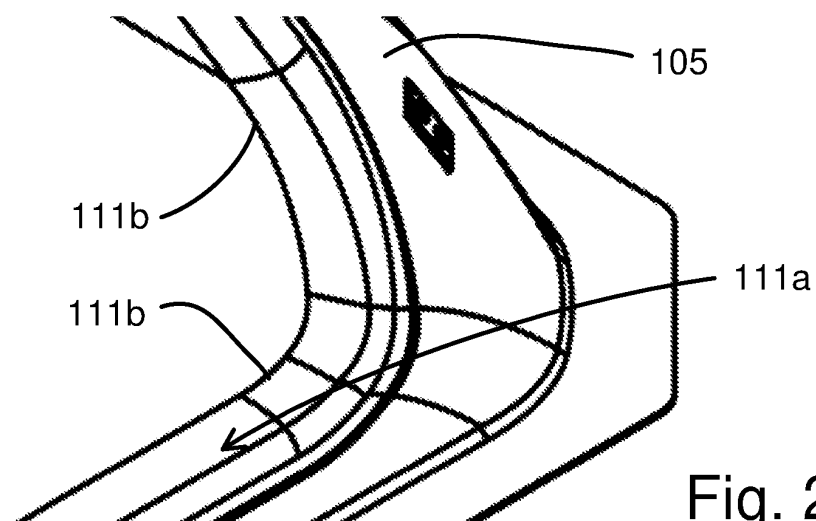


Fig. 21

REFERENCES CITED IN THE DESCRIPTION

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